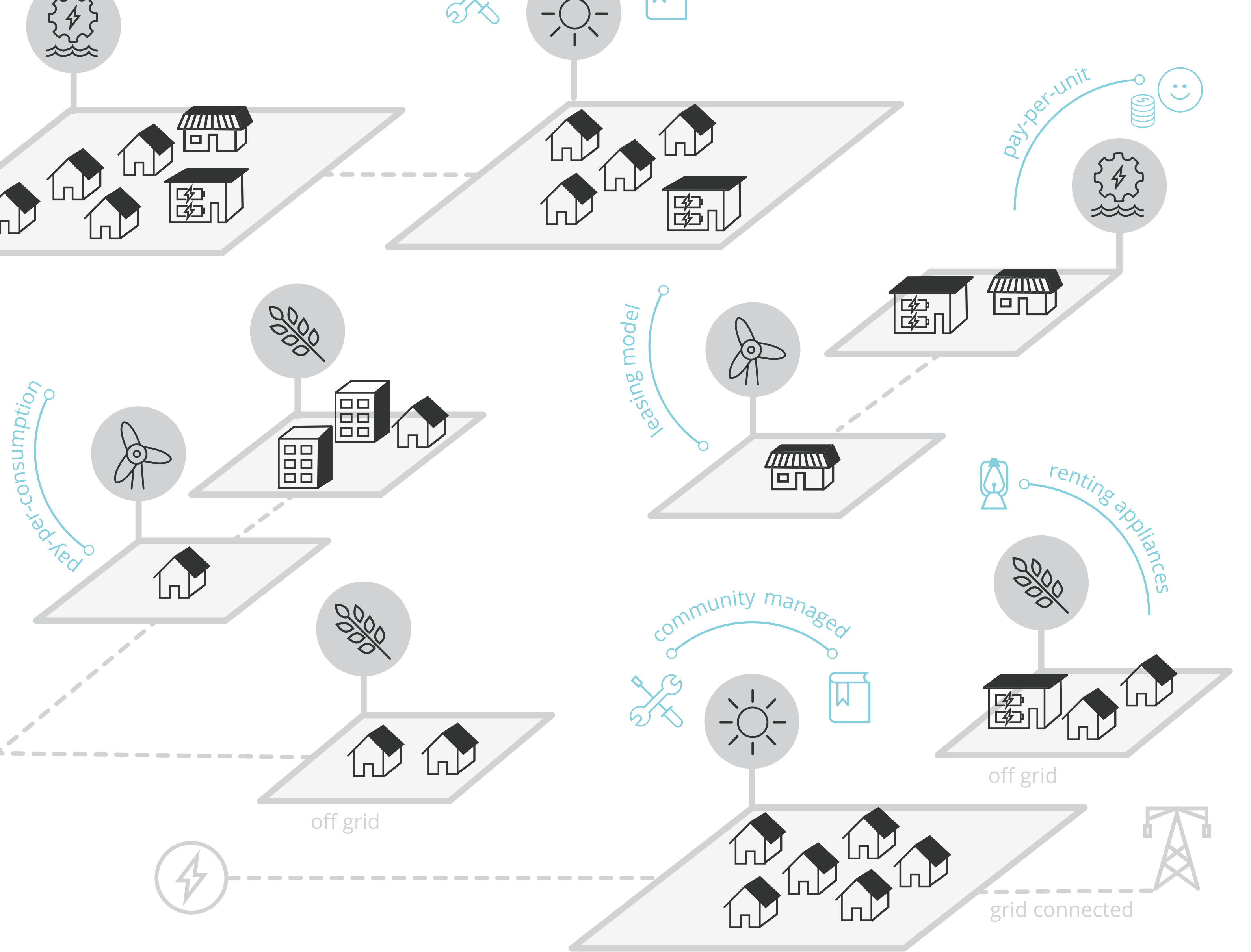

Designing Product-Service Systems applied to Distributed Renewable Energy in low-income and developing contexts: a strategic design toolkit

A Thesis Submitted for the Degree of Doctor of Philosophy
by
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EPSRC Engineering and Physical Sciences Research Council
LeNSes the Learning Network on Sustainable energy systems

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Abstract

Nowadays about 1.2 billion people in world lack modern access to electricity, with the majority of them living in rural areas in low-income and developing contexts.

This research addresses the issue of energy access by investigating the design of sustainable business models, and in particular by exploring the combination of Product-Service Systems (PSS) with Distributed Renewable Energy systems (DRE). The combination of PSS and DRE represents a new design approach to explore promising business models for energy access and to deliver clean and affordable solutions in low-income contexts.

The overall aim of this research is to explore the applications of PSS and DRE in low-income and developing contexts, thus defining characteristics of these models, their variables and critical factors. Additionally, this research aims at developing a support for companies, practitioners and other stakeholders for designing sustainable PSS applied to DRE, with a specific focus on the idea generation phase of new solutions.

The first part of this PhD resulted in the development of a classification system for PSS applied to DRE, in the identification of 15 Archetypal Models and in the collection of critical factors to successfully implement these models.

Then, these findings have been translated into three tools for designing PSSs applied to DRE: the Innovation Map, the Design Framework and Cards, the Energy System Map. These tools have been tested, refined and evaluated through a series of iterative applications in South Africa, Botswana, Kenya and the UK. Through the testing activities, which involved a wide range of companies, NGOs, practitioners and experts, the usefulness, usability and completeness of the tools were demonstrated.

This research concludes with reflections on the design process for different scenarios of applications and by highlighting further research activities for the field of PSS applied to DRE in low-income and developing contexts.

Keyworks: *Product-Service Systems, Distributed Renewable Energy, Design for the Base of the Pyramid, design tools, business model, energy access, sustainable energy, design for sustainability*

Declaration

I declare that this thesis was written by myself, Silvia Emili, that the work contained herein is my own except where explicitly stated otherwise in the text. I declare that this work has not been submitted for any other degree or professional qualification.

Silvia Emili

July 2017

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Publications arising from this PhD

Journal papers

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Conference papers

Emili S., Ceschin F., Harrison D. (2016). *Supporting SMEs in designing Product-Service Systems applied to Distributed Renewable Energy: Design Framework and Cards*. Proceedings of the Sustainable Energy for All by Design Conference 2016, Cape Town 28-30 September 2016. Poli.Design. ISBN 978-88-95651-23-1

Emili S., Ceschin F., Harrison D. (2016). *Design-supporting tools for visualising Product-Service Systems applied to Distributed Renewable Energy: the Energy System Map*. Proceedings of the Sustainable Energy for All by Design Conference 2016, Cape Town 28-30 September 2016. Poli.Design. ISBN 978-88-95651-23-1

Emili S., Ceschin F., Harrison D. (2016). *Supporting SMEs in designing sustainable business models for energy access for the BoP: a strategic design tool*. In: P. Lloyd & E. Bohemia, eds., *Proceedings of DRS2016: Design + Research + Society - Future-Focused Thinking*, Volume 4 ISSN 2398-3132. 27-30 June 2016, Brighton UK

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Book chapters/sections

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2.4 Environmental Impact of renewable energy

4.1 Sustainable Product-Service System applied to Distributed Renewable Energy: sustainability potential benefits

4.4 Sustainable PSS applied to DRE: a new classification system and 15 Archetypal Models

4.5 Sustainable PSS applied to DRE: critical factors

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Definition of terms

Base of the Pyramid (BoP): largely encompasses those four billion people living with less than $1500 per year. This research stretches the concept of BoP linking it with the one of *energy poverty*, including not only the four billion poor living at the BoP but also those with unreliable or limited energy access living in middle-income countries.

Critical factors: factors that influence a successful implementation of PSS+DRE in low-income and developing contexts, i.e. the characteristics that need to be considered in designing these solutions.

Dimensions: refers to variations of properties that give specificity and range to certain concepts. Dimensions are those variations used to describe characterising components of a certain model. In this thesis, the term is used to describe characteristics of DRE, PSS and PSS+DRE models.

Distributed Renewable Energy (DRE): small-scale electric power generation, based on renewable sources, located on the customer side of the network or provided with a local distribution network.

Energy access: the ability to obtain energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy, and safe for all required energy applications across households, productive engagements, and community facilities (SE4All, 2015).

Energy system: the energy generator, i.e. mini kit, individual system, charging station or mini grid.

Energy-using products: also referred as appliances, refer to equipment, powered by electricity that accomplish some function to deliver an energy service (light bulb, fan, refrigerator, radio, TV, mobile charger etc.).

Low-income and developing contexts: refers to territories and socio-geographical contexts in countries from the ODA list (based on the United Nations and World Bank). These include: Least Developed Countries (e.g. Bangladesh, Uganda), Low Income Countries (e.g. Kenya), Lower Middle Income Countries (e.g. Sri Lanka, Indonesia) and Upper Middle Income Countries (e.g. South Africa, Botswana).

Practitioners: the term is used to broadly include consultants, development practitioners (such as NGOs, international agencies), business-supporting organisations and designers. It refers to those who are involved in designing or supporting the implementation of energy solutions.

Product-Service Systems (PSS): type of value proposition where the business focus shifts from the traditional economic model of selling products or services, to providing an integrated combination of "system of products and services" that are able to fulfil customer satisfaction.

PSS+DRE: refers to the combination of PSS models and DRE systems. It is used interchangeably with *PSS applied to DRE*.

Small and Medium Enterprises (SME): includes medium-size companies (less than 250 employees), small firms (fewer than 50 employees), and micro-enterprises (less than 10 workers).

Support: term used in interchange with *design tool*

Sustainable development: defined as "development that meets the needs of the present without compromising future generations to meet their needs". It includes the three sustainability pillars: economic, socio-ethical and environmental.

Value proposition: the combination of products and services, it describes the offer provided to customers.

Variables: elements or features that characterise the PSS+DRE dimensions and that are subject to change.

Chapter 1

Introduction

"Energy is the golden thread that connects economic growth, increased social equity, and an environment that allows the world to thrive"
Ban Ki-moon, former UN Secretary-General

1. Introduction

This chapter provides an introduction to this research, by discussing the issue of energy access in low-income and developing contexts, introducing the topics of Distributed Renewable Energy, Product Service Systems and Base of the Pyramid. Also, in this chapter the author presents research aims, questions and objectives of this thesis. Finally, the structure of this thesis is presented.

1.1 A global challenge: the quest to Sustainable Energy for All

Nowadays about 1.2 billion people in world, about 15% of the global population, lack access to electricity, with the majority of them living in rural areas in low-income and developing contexts[1] (OECD/IEA, 2010). The absence or inadequacy of most basic energy services represent a major obstacle for socio-economic development (OECD/IEA, 2010), and it is shared knowledge that energy plays a key role in several aspects of sustainable development, from "*eradication of poverty through advancements in health, education, water supply and industrialization, to combating climate change"* (UN, 2016).

Growing concerns about population's rise, global energy supply's dependency from fossil fuels, and climate change are drawing global attention to urgently address these issues. Policy makers, investors, businesses and non-governmental organisations are urged to focus on closing the energy gap by applying solutions that are sustainable in the long term. In order to meet the ambitious target of universal energy access for 2030, radical changes need to be made to address these issues. Moreover, it has been predicted that without significant changes and improvements by 2030, the growth of global population will eventually result in an increment of people without modern energy access (IEG, 2015; OECD/IEA, 2014). Although significant barriers have been overcome in increasing energy access (Practical Action, 2016; UN, 2016), the need for a paradigm shift has emerged, "*to lead to a new era driven more by people than by the market, more decentralized than centralized, more democratic than monopolistic, more inclusive than exclusive*" (Colombo et al., 2014 - p. 6).

Another significant aspect to be pointed out is that energy choices driving climate change are expected to worsen the situation to a greater extent for low-income people living in developing countries (Kleinfeld & Sloan, 2012; IPCC, 2014). Energy choices have direct effects not only on greenhouses gas emissions, of which 65% can be attributed to energy supply and energy use (OECD/IEA, 2010), but also on deforestation, draughts and floods. The issue is that while low-income

[1] In this thesis the term "low-income and developing contexts" refers to territories and socio-geographical contexts in countries from the ODA list (based on the United Nations and World Bank). These include: Least Developed Countries (e.g. Bangladesh, Uganda), Low Income Countries (e.g. Kenya), Lower Middle Income Countries (e.g. Sri Lanka, Indonesia) and Upper Middle Income Countries (e.g. South Africa, Botswana). In order to simplify the terminology adopted in this research, the general term "low-income and developing contexts" is used.

and developing countries have contributed little to the greenhouses gas emissions, they have limited capacity to adapt to climate-related disasters, increasing poor people's vulnerability to hunger and poverty (Gaye, 2008). The challenge of limiting global warming to 1.5C agreed in the Paris Agreement in 2015 puts pressure on speeding up the race to sustainable energy scenarios, where projections expect renewable sources to provide 60% of global supply by 2040 (OECD/IEA, 2016).

1.1.1 Energy and sustainable development

The links between access to clean, modern and sustainable energy services and socio-economic development are clear (IEA & the World Bank, 2015). Lack of access to modern energy services has repercussions on several aspects of human development, from economic competitiveness to health and gender equality. The International Energy Agency (IEA) has developed an Energy Development Index (EDI) in order to understand the role that energy plays in human development. The EDI tracks electricity consumption (commercial and residential) per capita, the share of population with access to electricity and the share of modern fuels for residential energy use. On the other side, the HDI (Human Development Index) encompasses life expectancy index, education levels and income. As visible in Fig. 1.1, the trendline represent a curve where countries with the lowest access to modern energy, such as in Sub-Saharan Africa, also score low HDI.

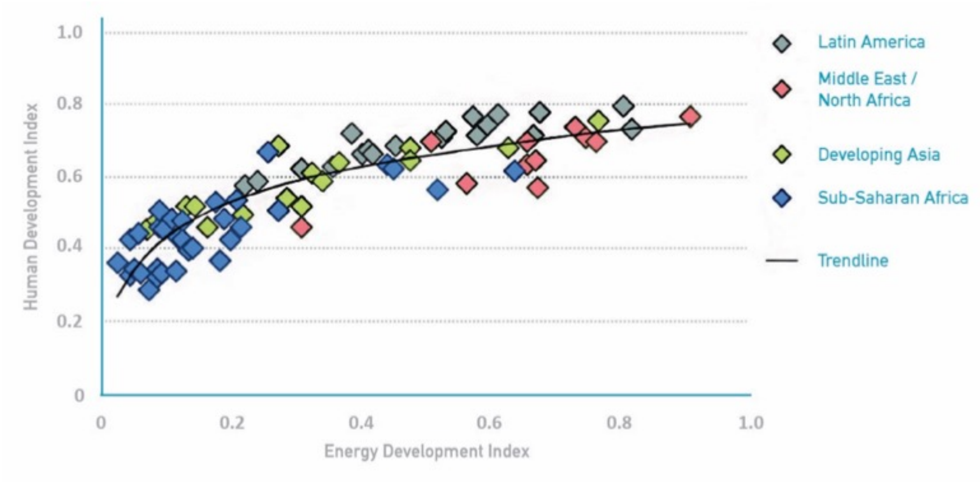


Figure 1.1 - Relationship between HDI and EDI (OECD/IEA, 2010)

The importance of energy in achieving sustainable development is further highlighted in the UN Sustainable Development Goals (SGD), particularly Goal n.7: Ensure access to affordable, reliable, sustainable and modern energy for all. The targets include ensuring universal access to modern, clean and affordable energy services, increasing the share of renewable energy, doubling the global rate of improvement in energy efficiency. Despite the creation of a specific SDG on energy, it is evident that other aspects of sustainable development are directly influenced by the accomplishments in targeting universal energy access. Several other targets, such as ending poverty

(Goal n. 1), ensuring access to clean water and sanitation (Goal n. 6), achieve gender equality (Goal n. 5) and promote inclusive economic growth (Goal n. 8), are linked to energy. The key implications for energy and development can be highlighted in the following points:

- Health: Energy is critical to provide quality health services, i.e. refrigeration of vaccines, sterilization services and the provision of life-saving interventions that would be impossible without adequate lighting and electricity (ESMAP, 2015; Zerriffi, 2011). Furthermore, kerosene and candles, which are the main means of lighting in energy-poor households, are major sources of indoor air pollution which causes chronic diseases and kills hundreds of thousands of people in Africa each year (OECD, 2016). The use of solid fuels for cooking is estimated to be responsible for over 4 million premature deaths (WHO, 2014). Other risks are related to accidental fires leading to burns and deaths (ESMAP, 2015).
- Economic development: energy is a crucial enabler for enhancing productivity and driving economic and social development (ESMAP, 2015; Bologna, 2014), allowing for example businesses to continue after dark and use machinery and appliances (Zerriffi, 2011). The use of energy for productive activities such as electric-powered farm equipment, water pumps, or irrigation have direct effects on costs, labor time consumed and productivity (Cabraal et al., 2005). Another aspect is related to expensive prices of fuels. In fact, people without modern energy access pay high amounts, around 20% of their income, for fuel-based lighting (Morris et al., 2007), and the price of kerosene is subject to changes connected with global oil prices.
- Education: electricity is fundamental for providing education in schools (UNESCO, 2011) but also is a key enabler to allow children to study at home after dark. The correlation between energy and education is supported also by evidences that electricity has direct effects on school attendance, literacy and education levels of both adults and children (Cabraal et al., 2005).
- Safety and community services: Energy for public spaces is considered another fundamental aspect of sustainable development and it includes uses of energy for street lighting, public buildings, schools etc. (ESMAP, 2015). Street lighting improves road security and safety, particularly for women, and especially for rural areas where mobility at night is often precluded (ESMAP, 2015).
- Gender equality: Energy poverty is also a gender issue. The lack of modern energy services contributes to discrepancies in gender equality as women are mostly responsible for household activities and they consume time in fuel collection and food preparation,

therefore limiting their ability to engage in income-generation activities and education. (Colombo et al., 2014; ENERGIA/UNDP, 2004).

- Communication services: a range of benefits for human development such as social connectivity and increase in communication services are linked with the use of mobile phone, IT services and financial services such as mobile money. Radio and communication also play a key role in development (Cabraal et al., 2005), for example in health services such as radio-telephone communications with hospitals. More people have now access to mobile phones than to energy, water or sanitation services (Nique & Arab, 2012) and this represent a key factor in developing energy infrastructure that enables lower-income customers to step up the energy ladder.

To conclude this section, the link between energy access and poverty alleviation has been discussed. Providing modern energy services and ensuring universal access represent key challenges for sustainable development.

1.1.2 The context of electrification: challenges and opportunities

The electricity access deficit in 2012 accounted 15% of the world population without access, most of these living in Sub-Saharan Africa and South Asia, with a major share of households located in rural areas (Fig. 1.2). For the majority of people living in rural contexts, basic electrification is provided by expensive and dangerous fuels such as kerosene and candles, which directly affect safety and health of those living at the Base of the Pyramid[2] (Zerriffi, 2011).

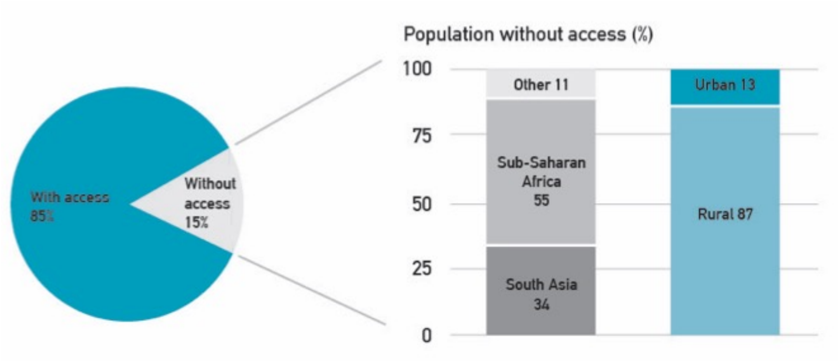


Figure 1.2 – Share of the global population without access to energy – (World Bank, 2015)

In order to understand the context of electrification it is necessary to define "energy access". Despite the shared understanding of the connection between poverty and energy and how these aspects are

[2] The concept of Base of the Pyramid, introduced by Prahalad and Hart (2002), largely encompasses those four billion people living with less than $1500 per year. BoP definition and characteristics are discussed in Section 2.3

linked, an agreed definition of what energy poverty means is missing (Colombo et al., 2014; OECD/IEA, 2014). A general definition proposed by ESMAP (2015) refers to energy poverty line as the minimum level of energy required to satisfy basic human needs. Although this may vary according to cultural preferences, climate conditions and economic development (Barnes et al. 2011), common aspects can be traced across definitions. For household access, energy access means a minimum level of electricity (Tier 1, see Table 1.1), safer and sustainable cooking fuels and stoves; for productive activities it relates to enabling economic activities such as agriculture, textile industries etc. For public services it means access to electricity in schools and health facilities as well as street lighting (OECD/IEA, 2014).

Differences may appear when defining modern energy access for rural or urban customers. For instance, the initial level of electricity consumption in rural areas is assumed to be 250 kWh per year, which may include the use of a few lights and mobile phone charging for about five hours a day. On the other hand, for an urban household it reaches 500 kWh per year and usually includes other energy-using products such as TV or cooling/heating systems.

In this research the widely shared approach developed by ESMAP and applied by UN Sustainable Energy for All initiative definition (SEforAll, 2013) is adopted. This definition of energy access is based on a multi-tier approach and it is defined as '*the ability to obtain energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy, and safe for all required energy applications across households, productive engagements, and community facilities*'.

In particular, it is useful to distinguish between six levels based on supply of electricity (ESMAP, 2015), Tier 0 being without access, Tier 1 and 2 very low power (between 3-50W), involving lighting and communication services; Tier 4 and 5 being up to 20kW allowing energy supply for productive uses.

Tackling energy access in low-income and developing contexts is a complex challenge. In rural areas, households are sparsely located far from the national grid, and lower income customers usually require low power capacity and have low ability to pay for these services (Terrado et al., 2008). At the same time, when grid extension is available, it often fails due to poorly-managed utilities, generation shortages, financing issues and political interference (Zerriffi, 2011). Even in those communities located close to the main grid or in electrified cities or urban slums, a large number of customers have inadequate services.

		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Capacity	Power		Very low power Min 3W	Low power Min 50W	Medium power Min 200W	High power Min 800W	Very high power Min 2kW
	Daily Capacity		Min 12Wh	Min 200Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
	Or Services		Lighting of 1000 lmhrs per day and phone charging	Lighting, air circulation, television and phone charging	Tier 2 + air cooling, refrigeration, water pumps, rice cookers	Tier 3 + washing mashines, ironing, toaster, microwave	Tier 3 + air conditioning, vacuum cleaner etc.
Duration	Hours per day		Min 4 h	Min 4 h	Min 8 h	Min 16 h	Min 23 h
	Hours per evening		Min 1 h	Min 2 h	Min 3 h	Min 4 h	Min 4 h
Typical supply technologies			Solar lantern, mini kit	Rechargeable battery, Solar Home System (SHS)	Medium SHS, fossil fuel-based generator, mini grid	Large SHS, fossil fuel-based generator, mini grid, central grid	Large fossil fuel-based generator, central grid

Table 1.1 – Definition of energy access according to levels of electricity supply (ESMAP 2015)

In order to provide alternative solutions to those living in energy poverty, in the past decade there has been a growing interest in Distributed Generation as promising alternative to the centralised grid. These solutions offer an opportunity to accelerate the transition towards universal and modern energy access (REN21, 2016).

1.1.3 The role of Distributed Renewable Energy in achieving universal access

Distributed Generation, defined as small-scale energy generation either located at the customer's point of use or within a local distribution network (Ackerman et al., 2001), is expected to play a key role in achieving universal access. In particular, Distributed Renewable Energy (DRE) generation, i.e. when renewable energy sources such as solar, wind, hydropower or biomass are involved in small-scale energy production, represent a promising approach to sustainable development. These types of models are leading a shift of the energy paradigm, away from the dominant model of energy monopolies that characterised the last century (Kammen, 2015). In this scenario, developing countries can leapfrog the old energy paradigm and move to a more sustainable, clean and reliable energy future (Tice & Skierka, 2014).

A global trend shows that investments and the introduction of supporting policies for DRE is continuously increasing in high-, low- and middle-income countries (IEA & The World Bank, 2015; REN21, 2016). According to a recent report by REN21, DRE systems are currently serving 100 million people worldwide, both in form of stand-alone systems and mini-grids. This market is expected to exponentially flourish due to a range of favourable conditions such as increasing of investments, maturation of innovative business models and support by dedicated policy measures and fiscal incentives (REN21, 2016). Moreover, many ventures lead the commercial success and rapid market penetration at the bottom of the energy ladder (Tier 1 and 2). According to The World Bank (2016), over 100 companies, formed in the last 10 years, are successfully providing small stand-alone systems such as solar kits or solar home systems (SHS) in low-income contexts and 14 millions of these products have been sold only in the past five years. The momentum for distributed energy and its role in achieving universal access is also supported by international organisations and initiatives such as the Lighting Africa (The World Bank), United Nations' Sustainable Energy for All, Access to Energy Initiative (World Business Council for Sustainable Development), the International Energy Agency and it is backed up by investments from multilateral development banks such as African Development Bank, Asia Development Bank, Inter-American Development Bank (Power for All, 2016; Berthélemy & Béguerie, 2016).

Despite the key role of DRE in reaching those 1.2 billion people without electricity, there is widespread understanding that grid expansion will still play a role in achieving universal energy access (Table 1.2). In fact, decentralised systems and grid expansion will play complementary roles, where DRE is going to reach those customers that are not feasible to be connected to the main grid due to financial, infrastructural and political barriers (Tenenbaum et al., 2014; World Bank, 2016) OECD/IEA, 2010)

	On-grid	Mini-grid	Isolated off-grid	Total
Africa	196	187	80	463
Sub-Saharan Africa	195	187	80	462
Developing Asia	173	206	88	468
China	1	1	0	2
India	85	112	48	245
Other Asia	87	94	40	221
Latin America	6	3	1	10
Developing countries*	379	399	171	949
World**	380	400	172	952

* Includes Middle East countries; ** Includes OECD and transition economies

Table 1.2 - Generation requirements for universal electricity access 2030 (TWh) from OECD/IEA, 2010

Although being promising, DRE models present some limitations and their implementation is not always straightforward. Besides technological barriers, such as limited capacity, low-voltage, seasonality due to renewable sources, DRE systems require adequate services such as installation and maintenance to avoid system failures (Schäfer et al. 2011; Terrado et al. 2008). Affordability is another barrier for low-income customers who have very limited purchasing power, while most DRE technologies still present high capital investments (Zerriffi, 2011). This also relates to local entrepreneurs who need access to capital if wanting to venture in the provision of energy services (Terrado et al., 2008; Iyer et al., 2010). Another barrier is related to the enabling environment, in fact

DRE require appropriate policy frameworks and regulations (Beck & Martinot 2004; Terrado et al. 2008).

In order to overcome these barriers, the DRE scenario *"will require a huge system transformation […] upon which business models will have to capitalize"* (SE4All, 2015). The academic literature on DRE and rural electrification is predominantly focused on country-based approaches, technology options, successful cases and policy implications, but approaches that embrace simultaneously these several factors are limited (Schillebeeckx et al., 2012). In fact, appropriate energy solutions are not only a matter of technology implementation, but even when DRE are well developed, often failures are related to the lack of services such as maintenance and repair, appropriate training or to financing issues. It has been argued that in order to scale-up energy access several challenges in innovating products, services and business models need to be addressed (Aron et al., 2009; Colombo et al., 2014; Wilson et al., 2009; Wilson et al., 2012). In fact, providing energy services in the BoP requires to understand users' needs and behaviours, how these influence the type of energy service and how these types of services can be provided considering a sustainable supply chain. This means considering the combination of products, services but also the actors involved and the existing infrastructures (Bellanca & Garside, 2013). As argued by Steward (2012), "the most significant emission reducing innovations in the decade to 2020 will draw on existing technologies. Therefore, innovation that embraces novelty which is non-technological in nature, such as business models and services will be of primary importance".

In low-income and developing contexts the transition towards sustainable and modern energy access may be achieved by integrating DRE technologies with business models that encompass environmental, social and economic benefits. In other words, it may be promising to look at designing sustainable business models.

"To reach the poorest and to effectively contribute to sustainable local development in the long term, standard business models need to be modified"

Wilson & Zarsky, 2009 – p.1

1.2 Sustainable energy business models

The design and implementation of business models for DRE systems has been considered by several authors (Bardouille, 2012; Barnes, 2005; Bellanca & Garside, 2013; Terrado et al., 2008; WBCSD, 2012; Wilson et al., 2012). It is a widely held view that business model innovation for energy solutions in low-income contexts should balance economic, environmental and social needs (Boons & Lüdeke-Freund, 2012). In other words, "the value proposition of a business model for sustainable development needs to be considered in terms of financial, environmental and social value" (Wilson et al., 2009).

For what has been said in the previous section, the need to adopt environmentally-friendly business models for energy represents an urgent need to sustainably meet the energy needs of 1.2 billion people. The implementation of DRE technologies requires to overcome several barriers such as affordability for lower-income people, provision of product-related services, appropriate system operation, while simultaneously ensuring financial sustainability. In addition, services such as consumer training, installation, maintenance and financing should be provided to ensure successful ventures (Terrado et al., 2008). In other words, integrating DRE products with appropriate services and simultaneously providing solutions that are socio and environmentally sustainable can be achieved by applying specific types of sustainable business models. With regards to the given case, it is promising to look at the model of Product-Service System (PSS), a concept originally developed for industrialised contexts (Mont, 2002).

1.2.1 Product-Service Systems (PSS)

In this framework, the concept of Product-Service Systems emerges as an appropriate business model with environmentally-beneficial implications. In a PSS, defined as "a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs" (Tukker & Tischner, 2006), the business focus shifts from just selling products to providing customer's satisfaction (e.g. from selling lighting systems to providing an agreed amount of lux). These types of value proposition, if properly designed, can provide a range of economic advantages, aligned with environmental benefits.

An example of PSS: Philips Pay-per-lux model*. The company offers lighting services instead of selling lights. Philips provides customers with energy-efficient lights and takes care of installation, maintenance and repair, optimising management and durability of products. The provider retains ownership of lights while customers pay a fixed agreed amount to have the desired result. (Ellen MacArthur Foundation case study, n.d.).*

Although PSS innovations were traditionally explored to be applied in industrialised contexts, many authors argue that these types of value propositions are suitable for Base of the Pyramid contexts (Castillo et al., 2012; Jagtap & Larsson, 2013; Moe & Boks, 2010; Schafer et al., 2011; UNEP, 2009). Several benefits emerge from the application of these models in low-income and developing countries, from enhanced affordability for lower-income customers, to strengthening of local economies, dissemination of skills and environmental benefits (UNEP, 2002).

The application of PSS models appears not only suitable for low-income markets but also appropriate to be combined with DRE systems in tackling the issue of energy access. The literature on PSS and PSS for BoP contexts presents exhaustive studies on the design, implementation and introduction of these models. However, the application of PSSs in the energy sector are limited to some studies that focus either on a specific technology (Friebe et al., 2013; Eldegwi et al., 2015; Lemaire, 2009; Müller et al., 2009) or on a selected context (Costa Junior & Diehl, 2013), and more in particular studies that look at the design and implementation of PSS and DRE models in BoP contexts are missing.

1.3 A new approach to Sustainable Energy for All: Product-Service Systems applied to Distributed Renewable Energy

The combination of PSS and DRE represents a new design approach to explore promising business models for energy access in the BoP (Vezzoli et al., 2015). As mentioned before, combining energy technologies and a comprehensive service package is required to successfully implement these solutions (Friebe et al., 2013; Schäfer et al., 2011; Terrado et al., 2008). It has been argued that *"a switch from 'providing technology' to 'providing Energy Product Service Systems' bears great chances for regional economic development"* (Schäfer et al., 2011 - p. 326).

An example of PSS applied to DRE in BoP contexts: *Off Grid Electric provides electricity services through solar mini kits in Tanzania. The service is tailored to users' needs and customers pay small daily fees according to the chosen package (e.g. use of two lights and a phone charger for a certain amount of hours a day). Off Grid Electric retains ownership of systems and appliances and trains a network of local dealers for installation and customer support. (Sources: Off Grid Electric case study, Appendix I)*

Several potential advantages arise from the combination of PSS and DRE systems (Friebe et al., 2013; Vezzoli et al., 2015; Müller et al., 2009). From an environmental perspective, these can lead to reduced impact compared to fossil-fuel based solutions and traditional product-based business models, combined with increased reliability, flexibility and efficiency. Economic advantages include increased affordability for lower-income customers, reduced investment costs and reduced operation costs in the long term. From a socio-ethical point of view, combining PSS and DRE can lead to increased energy independency and community self-sufficiency, while being tailored to customers' needs and enhancing dissemination of skills and competences.
The concepts of DRE and PSS have been researched extensively, nevertheless a comprehensive study that explores the combinations of these models in BoP contexts is missing.

1.4 Scope of this research: aims, objectives and research questions

1.4.1 Research aims

The overall aim of this research is to explore the applications of PSS and DRE in low-income and developing contexts, thus defining characteristics of these models, their variables and critical factors (see definitions in p. 109). Additionally, this research aims at developing a support for companies, practitioners and other stakeholders for designing sustainable PSS applied to DRE in BoP contexts, with a specific focus on the idea generation phase of new solutions.

1.4.2 Research questions

RQ1: What are the characteristics and applications of PSS and DRE in BoP contexts?

- 1.1 What are the characteristics of PSS applied to DRE?
- 1.2 How can these models be classified?
- 1.3 What are the applications of these models in BoP contexts?
- 1.4 What are the critical factors to successfully implement these models?

RQ2: How companies and practitioners might be supported in designing PSS applied to DRE for BoP contexts?

- 2.1 How can the identified critical factors and successful cases be translated to support the design of PSS applied to DRE?
- 2.2 What tools can be developed for designing these models?

1.4.3 Research objectives

A. To review literature on DRE systems, PSS, design approaches for the BoP and to explore the combination of these models, identifying their characteristics.
B. To develop a classification system for PSS applied to DRE.
C. To investigate the applications of PSS and DRE in low-income and developing contexts, identifying characteristics of these models.
D. To identify critical factors for designing PSS and DRE.
E. To review existing design approaches and tools for PSS, DRE and design for the BoP and to understand how these are applied by the research recipients (companies and practitioners).
F. To translate the outcomes of the primary studies (RQ1) into supports for companies, practitioners and designers.

G. To evaluate the outcomes of this research through a series of iterative testing activities, involving a wide range of stakeholders from different contexts and fields of expertise.
H. To discuss implications of this research for the field of PSS and DRE, providing guidelines for different types of recipients (e.g. SMEs, NGOs).

1.5 The LeNSes project and the EPRSC-funded project

This research has been framed within the EU-funded LeNSes project (Learning Network on Sustainable energy systems, October 2013 - October 2016). Then, the outputs of this research led to the EPSRC-funded project (Global Challenges Research Fund, October 2016 - February 2017) “Design and innovation tools to support SMEs in developing sustainable Product-Service Systems for energy access in African contexts”. The LeNSes project provided a supporting ground for this research to be carried out, offering a platform for engaging participants, disseminating results. The EPSRC-funded project, instead, has been granted on the research outputs of this PhD and enabled the researcher to further develop and evaluate the design tools. The following sections illustrate the activities related to both projects.

1.5.1 The LeNSes project

The LeNSes project (Edulink II, 2013-2016) has provided a framework for carrying out data collection, involving partners and engaging a wider range of stakeholders for the testing activities. The project is described as a “Multi-polar and open network for curricula and lifelong learning capacity development focused on locally-based Sustainable Energy System Design & Engineering (SES.DE)” (Vezzoli et al., 2015).
The project involved three European universities (Politecnico di Milano, Brunel University London and Delft University of Technology) and four African universities: Cape Peninsula University of Technology (Cape Town, SA), Makerere University (Kampala, Uganda), University of Botswana (Gaborone, Botswana) and University of Nairobi (Nairobi, Kenya). The main activities were structured to benefit capacity building and curriculum development in the field of SES.DE, by enabling African High Education Institutions teachers to deliver didactic curricular courses and lifelong learning modules. In particular, the main activities were:

- **Didactic curricular courses**: African partners in collaboration with European partners designed and developed curricular courses to be carried out in the African universities. In a first round, the courses have been implemented through an exchange modality: each African partner hosted a pilot course, while European partners collaborated in the implementation acting as a guest school. In a second round, courses have been integrated in African partners’ curricula, with a long distance support by European partners. The researcher was involved in the design and implementation of the pilot course held at University of Botswana between 16-27 March 2015.

- **Lifelong learning modules**: As a pilot case, each African partner in collaboration with a European university delivered a professional training module to local companies, consultancies and organisations. The researcher was involved in the design and implementation of the lifelong learning modules at Cape Peninsula University of Technology in February 2016 and at University of Nairobi in April 2016.
- **Open Learning E-Platform (OLEP)** The OLEP is intended as an open web platform that allows a decentralised and collaborative production and fruition of knowledge to support didactic and lifelong learning activities. The platform collects slides, video lessons, case studies, tools and learning resources developed within the LeNSes project. The researcher actively contributed in developing learning resources and uploading research outputs and tools to the OLEP.

The project offered the opportunity to engage with business-supporting organisations and with companies and practitioners operating in South Africa, Botswana and Kenya. These have been involved in testing and evaluating the design tools. A more detailed discussion of activities carried out within the LeNSes project is described in Chapter 3: Research methodology.

1.5.2 The EPSRC-funded project

The initial outcome of this research (i.e. the design tools) constituted the basis for the EPRSC-funded project 'Design and innovation tools to support SMEs in developing sustainable Product-Service Systems for energy access in African contexts'[3]. In fact, this project has been designed around the outcomes emerging from the first part of this PhD research and the author was appointed as RA for the project. The funding was granted to carry out further testing and refinements of tools, with the overall aim of improving the ability of companies in the energy sector to design and innovate DRE systems adopting a PSS approach. Focusing on the Kenyan and Botswanan contexts, the project aimed at:

1. Testing and refining the design tools in order to improve effectiveness, usefulness and usability, and maximise their potential adoption by a broad range of companies and practitioners.

[3] Principal investigator: Dr Fabrizio Ceschin; co-investigators: Prof David Harrison (Brunel University London), Dr Richie Moalosi and Cheddi Kiravu (University of Botswana), James Wafula (University of Nairobi).

2. Partnering with local research institutions (University of Botswana and University of Nairobi) to enable them to carry out similar research activities in future by strengthening their capability, and reinforce the basis for future collaborative activities.

3. Partnering with business-supporting institutions to enable the dissemination of project results to a wide group of beneficiaries.

The project, which has been carried out between November and February 2016, enabled the researcher to spend six weeks in Kenya and Botswana to carry out practical activities and those included evaluation and refinement of tools with companies and experts on policy, design, business and technology in the chosen context. In detail, the project plan was structured as following:

- *Initial workshop with companies*: companies were involved in a 3-days' workshop that aimed at introducing the PSS+DRE design approach and at applying the design tools.
- *Evaluation of tools with experts* in a second phase, experts of technologies, policies and regulations, business and design were involved in individual sessions/interviews to gather feedbacks about the design tools, their applications and suggested improvements.
- *Tools refinement:* a refined and final version of tools was prepared together with an guide for the use of the tools in different organisations and an online platform for dissemination.

A more detailed discussion of activities carried out within this project is described in Chapter 3: Research methodology.

1.6 Outline of this thesis

This thesis is structured around four main research phases: research clarification and methodology, exploratory phase, development evaluation and refinement phases and conclusion phase.

More in detail, the structure of the thesis is illustrated in Fig. 1.3, and each chapter is described below.

<u>Research clarification and methodology:</u>

Chapter 2 – Literature review

This chapter includes a review of existing literature around the three main topics of PSS, DRE and Design for the BoP. It provides an overview of the benefits and research needs for PSS applied to DRE in low-income and developing contexts. The chapter concludes by identifying unanswered gaps in the knowledge and by summarising research needs.

Chapter 3 – Research methodology

This chapter provides a framework for this research by reviewing selected methodologies and explaining the rationale behind choices in research methods and tools. The design of the research strategy is then presented, illustrating phases and outcomes of this research project.

Exploratory phase:

Chapter 4- Primary studies

The first part of this research aims at gaining in-depth knowledge about characteristics of PSS+DRE models and their applications in BoP contexts. These primary studies describe the activities undertaken to respond to RQ1. This chapter describes how PSS+DRE's characterising dimensions have been identified and it provides a classification system for these models. In a second phase, a case study collection of PSS applied to DRE in BoP contexts is presented, leading to the identification of PSS+DRE Archetypal Models. Then, a review of literature on PSS+DRE critical factors is discussed.

This chapter also contains an investigative study with renewable energy companies and practitioners, which aimed at gathering a general understanding about the target users of this investigation.

Development, evaluation and refinement phases:

Chapter 5 – PSS+DRE Innovation Map

This chapter describes the design and evaluation of the first tool: the PSS+DRE Innovation Map. This tool aims at classifying PSS applied to DRE models and it is a strategic design tool for positioning a company's offer, mapping competitors and designing new concepts. The tool is composed of the Map, a collection of PSS+DRE Archetypal models and case studies, a set of Concept Cards to design new models. The chapter illustrates how the tool has been developed, tested and refined through a series of iterations in Botswana, South Africa and Kenya.

Chapter 6 – PSS+DRE Design Framework and Cards

In this chapter the PSS+DRE Design Framework and Cards is presented as a second outcome of this research, built on the review of literature and on findings from the exploratory phase (primary studies). The tool is designed to support the idea generation and concept development of PSS+DRE models and it is composed of a Framework, a Design Canvas and a set of Cards with guidelines, critical factors and case studies. The chapter describes the development, evaluation and refinement of the tool through its several iterations in Botswana, South Africa, Kenya and UK.

Chapter 7 – PSS+DRE Visualisation system

A third outcome of this research is presented in this chapter, which discusses the design, development and evaluation of a Visualisation System for PSS+DRE. The Energy System Map is presented as a tool to visualise PSS+DRE models, defining actors involved, their interactions and flows of goods, services and money. The tool and its design implications are discussed and supported with the description of testing activities in Kenya and Botswana.

Conclusion phase:

Chapter 8 – Discussion

Building upon the results obtained in the several testing activities (of all design tools), this chapters aims at making some considerations in terms of flexibility and adaptability of tools. In particular, this chapter discussed how different users (e.g. NGOs, SMEs) can apply the tools in their organisations.

Chapter 9 – Conclusions

The thesis concludes by providing a summary of outcomes of this research, highlighting the contribution to knowledge and its limitations, and discussing further research activities.

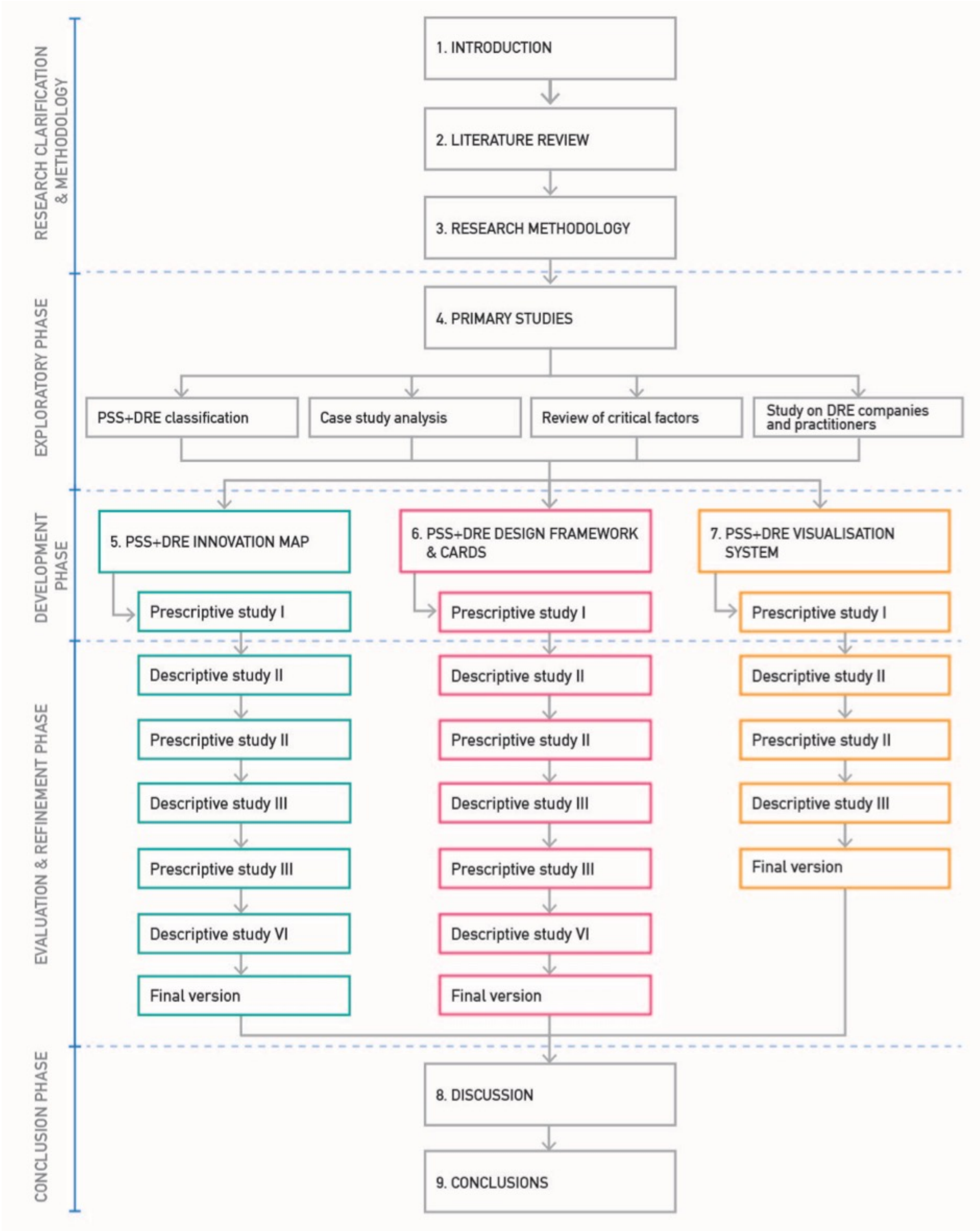


Figure 1.3 - Outline of this thesis and relative chapters

1.7 Chapter summary

This chapter provided an introduction to the topics investigated in this thesis. The problem of energy access for Base of the Pyramid contexts has been highlighted, illustrating how Distributed Renewable Energy models represent a promising approach to provide small-scale and locally produced clean electricity in rural areas and urban slums. In these contexts, the model of Product-Service Systems emerges as a promising type of sustainable business model to provide energy solutions for lower-income customers. The combination of PSS and DRE models in the BoP represents a novel approach that requires further investigation. This chapter highlighted the research aims and questions, providing a structure of how these will unfold in the thesis.

Chapter 2

Literature review

2: Literature review

The literature review is conducted around three main topics of investigation (Fig. 2.1): Product-Service Systems (PSS), Distributed Renewable Energies (DRE) and Design for the Base of the Pyramid (BoP). The chapter is structured as follows: first a review on *Distributed Renewable Energy* systems is presented, defining characteristics of these models, benefits and barriers, their classifications and methods and tools for designing DRE systems. Then, the concept of *Product-Service Systems* is introduced, outlining benefits and limitation of these models, discussing sustainability potential, reviewing their classification and design approaches for sustainable PSSs. The third section explores the concept of *design for the Base of the Pyramid* (BoP), discussing BoP definition, design approaches and the application of PSS models in BoP contexts. Lastly, the combination of PSS and DRE in BoP contexts is discussed, highlighting benefits, research needs and design implications.

The chapter concludes with a summary of findings and identified gaps in the literature.

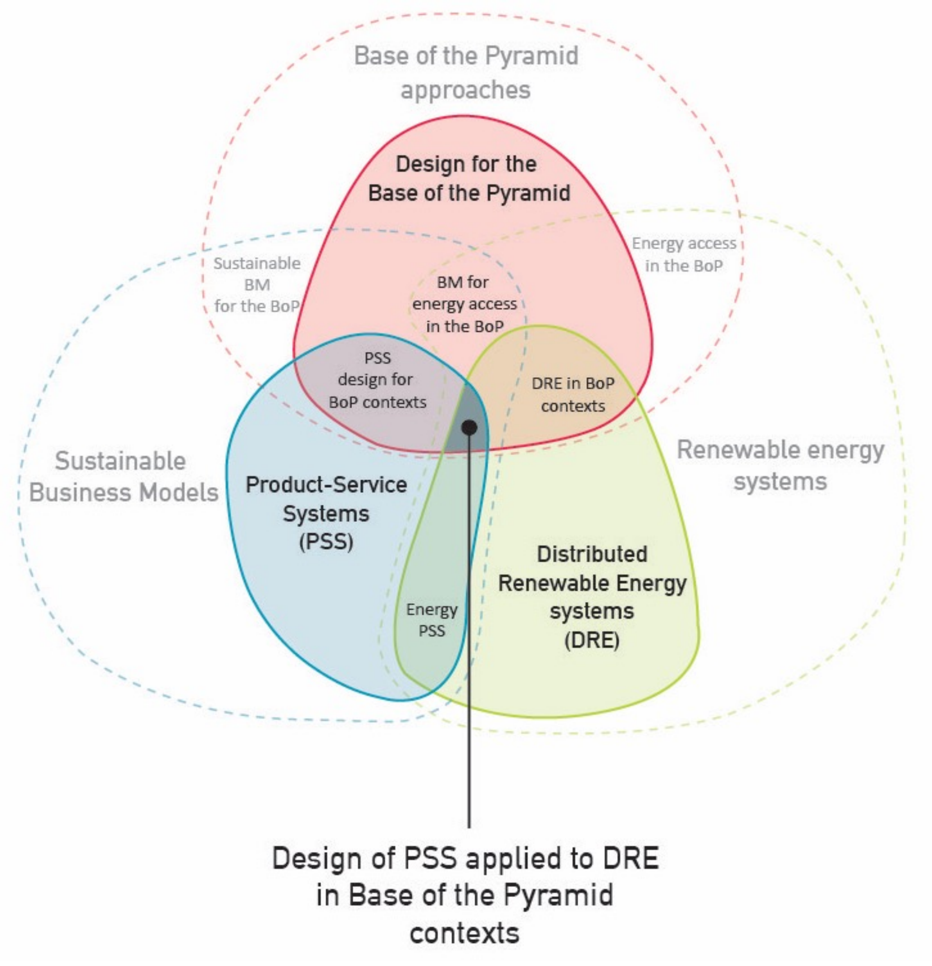


Figure 2.1 – Focus of the literature review

2.1 Distributed Renewable Energy (DRE) systems

The issue of energy access in low- and middle-income contexts represents a serious hindrance to economic and social development, especially for those living in rural areas (OECD/IEA, 2010). The approaches to provide energy in these contexts include different technologies, costs and services (Barnes, 2011) and include grid extension or distributed/off-grid systems. The estimates for 2030 (OECD/IEA, 2010; The World Bank, 2016) forecast that grid extension will still play a role in achieving universal energy access, but a major contribution will be played by decentralised options. In fact, distributed systems can meet the needs of rural communities in a more cost-effective way than grid extension, especially in African and South-East Asian contexts (OECD/IEA, 2010). Even countries that almost reached total electricity supply with an electrification rate of 90%, such as Argentina, Brazil, Chile and Mexico, are predicted to reach the remaining off grid communities with distributed options (Barnes, 2011).

This section discusses the benefits and implications of Distributed Renewable Energy in achieving universal energy access, presents definition and classification of DRE models and highlights business model approaches for designing DRE systems in low-income and developing contexts.

2.1.1 Distributed energy generation vs centralised energy generation

Traditional power generation is associated with large and centralised power plants that supply households, communities and productive activities located in a large area (Alanne & Saari, 2006).In low-income, developing and rural contexts the traditional energy generation model that supplies power through grid expansion is not considered sufficient to electrify those areas from an economic and organisational point of view (OECD/IEA, 2014; Myers, 2013; Zerriffi, 2011). The main issue related to traditional energy generation in low-income contexts derive from high investments needed for fossil fuels-based generation and from high costs in transmission and distribution grids that results in unaffordable electricity for people living in rural areas (Kaundinya et al., 2009). In addition to the geographical characteristics of these contexts and to the low ability to pay and low energy demand of customers, the lack of managerial and financial resources often results in generation shortages and low-quality power delivery (Zeriffi, 2011).

Distributed Generation, on the other side, implies the use of smaller units substituting larger ones (Alanne & Saari, 2006) and refers to electricity generated near the point of use or with a local distribution network (Ackerman et al., 2001). In the last decade there has been a renewed interest in Distributed Generation due to technological innovations and an economic and regulatory environment that favour the spread of this type of small-scale electricity generation (Pepermans et al., 2005; REN21, 2016). According to OECD/IEA (2002), the main factors influencing this trend towards distributed energy generation can be listed as: the availability of new technologies, the increasing need of reliable electricity generation, the liberalisation of energy markets, and a growing concern towards climate change. Several countries have implemented successful small scale distributed systems such as Brazil, Cambodia, South Africa, China, Bangladesh and India (Niez, 2010; Zerriffi, 2011) and Distributed Generation may play a key role in achieving 100% rural electrification by 2030 (Narula et al., 2012; OECD/IEA, 2010; The World Bank, 2016). As highlighted by the World Bank (2016), the future of energy supply in low-income and developing countries will be characterised by interplay between grid extension and distributed systems, and the latest will represent 70% of rural energy supply by 2030.

2.1.2 Distributed Renewable Energy: definition

Authors find no consensus on a shared definition of Distributed Generation. Some distinguish between decentralised and distributed systems (Mandelli & Mereu, 2014; Alanne & Saari, 2006; OECD/IEA 2002), where the first refer to units that have no interactions with each other (Fig. 2.2), while distributed can imply the exchange of energy among different units (Fig. 2.3). On the other hand, the term Distributed Generation can be viewed as synonymous of *decentralised*, *modular*, *localised* or *embedded* (Kaundinya et al., 2009; OECD/IEA, 2002; Rolland & Glania, 2011; Schäfer et al., 2011; Turkson & Wohlgemuth, 2001). Table 2.1 provides some of the definitions of Distributed Generation. In this thesis we refer to the more general definition provided by Ackerman et al. (2001) which defines Distributed Generation as *"electric power generation within distribution networks or on the customer's side of the network" (Ackermann et al., 2001 – p. 201).*

When renewable energy sources (such as the sun, wind, water, biomass and geothermal energy) are involved in the distributed generation of energy, we can refer to **Distributed Renewable Energy (DRE)** (REN21, 2014; Vezzoli et al., 2015). Building upon the definitions proposed in the literature, in this thesis *DRE models are defined as small-scale electric power generation, based on renewable sources, located on the customer side of the network or provided with a local distribution network. This definition includes both decentralised systems and systems that can be connected with each other to exchange energy units*.

Author	Definition
Ackermann et al., 2001; Pepermans et al., 2005	*"Electric power generation within distribution networks or on the customer side of the network."*
OECD/IEA 2002	*"Generating plant service a customer on-site or providing support to a distribution network, connected to the grid at distribution-level voltages. […]"*
Beck & Martinot, 2004	*"Generation of electricity at or near the point of end use, often in small quantities, rather than remotely in a large centralized power plants."*

Alanne & Saari, 2006	*"Small-scale (under 200 kWe) energy conversion units that are placed in the same location with an energy consumption point and that are used by a small number of people"*
Mandelli & Mereu (2014)	*"Small scale electricity production […] that can be installed close to the load demand […] near to the consumer […] and they can be fuelled by local resources."*
REN21 (2014)	*"the systems of production are relatively small and dispersed […] rather than relatively large and centralised and generation and distribution occur independently from a centralised network"*

Table 2.1 - Some definitions of Distributed Generation

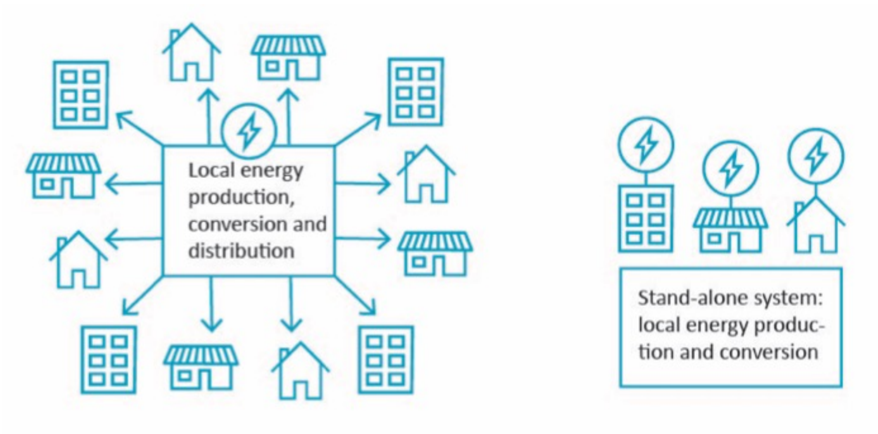


Figure 2.2 - Decentralised energy system, adapted from Alanne & Saari (2006)

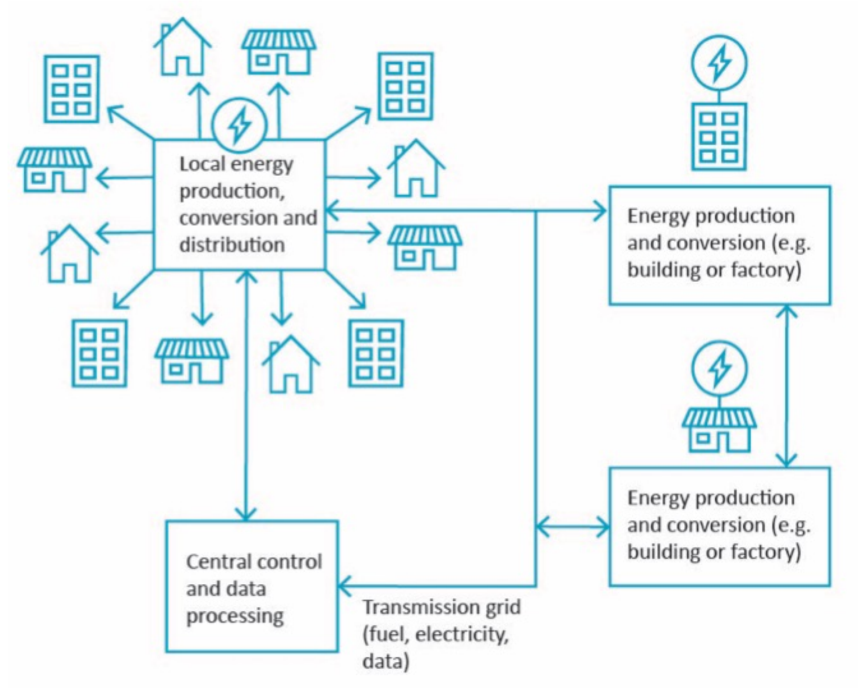


Figure 2.3 - Distributed energy system, adapted from Alanne & Saari (2006)

2.1.3 Classification of Distributed Generation

The literature on Distributed Generation lacks of a shared approach for categorising models, in fact *“no consensus has been reached […] for a classification of distributed generation”* (Mandelli & Mereu, 2014 – p. 79).

A very broad differentiation can classify DG models in stand-alone energy systems and grid-based systems.

- **Stand-alone energy systems**: off-grid systems serving an independent user (Rolland, 2011). Under this category we can find:
  - *Mini kits*: small systems with energy generator, battery and appliances such as lights and phone charger (Bardouille, 2012).
  - *Individual energy systems*: independent systems for individual users (such a household), productive activities, or larger user (e.g. school).
  - *Charging stations*: stand-alone systems with a generator component and a storage system for providing energy services such as charging or internet connection (Rolland, 2011).
- **Grid-based systems**: they are larger stand-alone systems that supply power at a local level, using local-wide distribution networks (Rolland, 2011). We can distinguish between:
  - *Isolated mini grids*: generator facilities that supply electricity to households, productive activities or other users.
  - *Connected mini grids*: generator systems that are connected, and exchange electricity with, the main grid.

In the several classifications proposed authors use different dimensions[4] to describe and classify DG models**.** The different approaches are discussed here and summarised in Table 2.2.

A first possible approach to classify DG models is to analyse them through a *technology lens*. Ackermann et al. (2001) classify models considering only the capacity of power produced (i.e. rating of DG, the highest power produced) and affirm that other dimensions such as ownership, environmental impact or technology used are not relevant to describe and classify these models. It proposes the following distinction: micro distributed generation (~1 W - 5kW); small distributed generation (5 kW - 5 MW); medium distributed generation (5 MW - 50 MW); and large distributed generation (50 MW – 300 MW). Pepermans et al. (2005) also consider this classification valid.

[4] The term ‘dimensions’ refers to variations of properties that give specificity and range to certain concepts (Glaser & Strauss, 2008). In other words, DRE dimensions are those variations used to describe characterising components of these models.

Another aspect of the technology lens is the type of connection used to deploy distributed energy. Several authors (Lemaire, 2011; Terrado et al., 2008; Zerriffi, 2011; Mandelli & Mereu, 2014) use the type of generation to classify models, i.e. whether the energy is produced through stand-alone systems or through grid-based system. Among these approaches, Bardouille (2012) classifies options in: household devices and systems, community-level mini utilities, and grid-based electrification.

The source used for energy production (solar, wind, biomass, hydro) is also included under the umbrella of technology choice. Zerriffi (2011) provides a classification of DG that also includes non-renewable energy sources.

Apart from the technical point of view, authors refer to the *value proposition and payment structure* as other dimensions to classify DG models. The value proposition is intended as the combination of products and services and it describes the offer provided to customers. The payment structure defines what customers pay for, e.g. pay to purchase, leasing or fee-for-service. Several authors (Friebe et al., 2013; Schultem et al., 2003; Chaurey & Kandpal, 2009; Palit & Chaurey, 2011; Terrado et al., 2008) focus on a single technology (e.g. solar stand-alone systems) and differentiate between sales models (cash and credit model – end-user or dealer-credit options) and service models (leasing, fee-for-service). In a report prepared by ISES (2001) a similar classification of "rural energy supply models" is presented, but taking into accounts all technology choices.

Another important dimensions considered in DG classification systems is the *capital financing*. This relates to how the capital is provided and determines how costs are recovered but also it influences the tariff structure and recovery of operating expenses (Zerriffi, 2011). Capital financing can be present in form of loans, subsidies, international donations or credit mechanism. Within this perspective, Hankins & Banks (2004) focus on solar system models in African contexts and describe consumer and company financing options when classifying models in commercially-led, multi-stakeholder programmatic model, utility model and grant-based model. On the other hand, Bardouille (2012) distinguishes according to the financial sustainability of a model and the types of subsidies involved, categorizing into commercial/enterprise-based, quasi-commercial and non-commercial models.

A key dimensions used for describing DG models is the *ownership of the energy system*, which is strictly related to the value proposition and that can be distinguished between user, service provider or community ownership. Anderson et al. (1999) describe the ownership dimensions considering only one specific type of technology, mini grids. Their classification includes community-led distributed generation, village energy committee, regional user organization and large-scale utility. Others (Rolland & Glania, 2011; Terrado et al., 2008) describe the possible models as micro-utility, private sector-based, community-based and hybrid models (often Private Public Partnerships).

What emerges in this latest classification is that some authors consider the nature of organization providing the energy solution, the *organizational form* (Zerriffi, 2011), to classify DG models. This dimensions refers to the type of energy provider and the network of stakeholders involved in providing the energy solution, e.g. a public entity (utility, government), a private enterprise (SMEs, local entrepreneurs), a cooperative or a Private Public Partnership (PPP) made up of different actors.

Related to the *organisational form*, is the *energy system operation* dimension. This describes the nature of the actor responsible of using and maintaining the energy system and can be, for example, the end-user, the provider, a community or a local entrepreneur.

The last dimension considered for classification purposes in the literature is the *target customer*. This refers to the type of end-user: a household or single individual, a productive activity (agriculture, industry or commercial activities) or a community (mix of households, productive activities, public entities). Mandelli & Mereu (2014) align target users with technology choice and distinguish between Distributed Generation (home based systems, community and SMEs based systems, centralized micro grids) and Decentralised Generation (Hybrid micro grid systems).

Drawing conclusions on the literature about Distributed Generation and DRE systems, several approaches have been adopted to classify and describe these models by considering multiple dimensions: energy system, value proposition/payment structure, capital financing, energy system ownership, organisational form, energy system operation and target customer. Among the reviewed methods, a joint classification which considers all identified dimensions is missing.

Authors	Classifications of DG models	Dimensions						
		Energy system: considers the type of generation (stand alone, grid based systems) and type of source involved (e.g. solar, wind, hydro, biomass)	*Value proposition/payment structure:* type of offered provided (combination of products and services) and payment type (e.g. credit, leasing model etc.)	*Capital financing:* indicates presence of subsidies and affects cost recovery and tariff structure (govern. subsidies, donations, private loans, MFI etc.)	*Energy system ownership:* who owns the system (provider, user, shared)	*Organisational form:* nature of the organisation providing energy solution - (private company, local entrepreneur, government, PPP, utility, community)	*Energy system operation:* who operates and manages the system (provider, user, entrepreneur).	*Target customer* : nature of end user (i.e. households, communities or productive activities)
Mandelli & Mereu (2014)	Distributed Generation (Home Based Systems, Community and SMEs Base Systems, Centralized Microgrids); Decentralized generation (Hybrid	x						x

	Microgrid Systems)							
Krithika & Palit (2013)	*Stand-alone systems*: fee for service, consumer finance, leasing. *Mini grids*: private sector, cooperative, community managed,	x	x		x	x	x	
Friebe et al. (2013) Chaurey & Kandpal (2010)	*Stand-alone systems (PV):* Sales models (cash model, credit model), service models (leasing, fee for service)		x		x		x	
Bardouille (2012)	Household level devices and systems, community-level mini-utilities, grid based electrification. Divided into commercial/enterprise-based, quasi-commercial, non-commercial	x		X		x		
Int. Solar Energy Society (ISES) (2011)	Cash and carry, instalments credit, finance leasing (hire purchase) fee for service		x		x	x	x	
Lemaire (2011)	Grid extension, stand-alone systems, distributed mini-grid systems	x						
Zerriffi (2011)	Distributed Rural Identification Models (DREM) rated according to the impact and the outcomes of the projects.	x	x	X		x	x	x
Palit & Chaurey (2011)	*Stand-alone systems*: consumer financing, fee for service, leasing model *Mini grid systems:* community-based model or utility model		x			x		
Rolland & Glania (2011)	*Mini grid systems*: micro-utility, private-sector based, community based, hybrid model				x	x		
Terrado et al. (2008)	*Stand-alone systems*: dealer	x	x		x	x	x	

	credit, fee for service, leasing model *Mini grid systems:* enterprise, community based or utility model							
Hankins & Banks (2004)	*Stand-alone systems (PV):* commercially-led, multi-stakeholder programmatic model, utility model, grant-based model		x	X		x	x	
Schultem et al. (2003)	*Stand-alone systems (PV):* cash sales model, credit model (dealer credit, end user credit, lease/hire purchase), fee for service model		x		x	x		
Ackerman et al. (2001)	Distinguish between ratings of Distributed Generation (micro, small, medium, large DG)	x						
Anderson et al. (1999)	Village Energy Committee, Regional User Organisation, Large Scale Utility				x		x	

Table 2.2 - Classifications of DG and respective dimensions used by authors

2.1.4 Benefits and limitations of DRE systems

The application of DRE systems to provide energy access in low-income and developing contexts presents several advantages in terms of environmental, economic and socio-ethical benefits (summarised in Table 2.4).

- **Environmental**. In terms of technological benefits, DRE generation presents reduced network losses and improves reliability of distribution (Ackermann et al., 2001; Lopes et al., 2007) while the use of renewable sources has beneficial impact on emissions' reduction and climate change mitigation (Kaundinya et al., 2009; OECD/IEA, 2002; Schillebeeckx et al., 2012; WBCSD, 2012). DRE systems present high flexibility in operations, size and expandability, resulting in a capacity to adapt to customers' demand (OECD/IEA, 2002).
- **Economic**. Several authors agree on the potential economic benefits of DRE models in supporting decentralised markets and contributing to local economic development by creating employment, developing new revenue sources for local communities and by introducing new capital and innovation (Chaurey et al., 2012; Colombo et al., 2014; Terrado

et al., 2008). Compared to grid-based systems, stand-alone systems are the most cost effective solution for customers located in remote locations (Bologna, 2014; Kaundinya et al., 2009; Lopes et al., 2007) and results in lower energy prices in the long term for both providers and customers (Lopes et al., 2007; OECD/IEA, 2014). Due to their small-scale architecture, DRE systems may also be more flexible and more resilient in adapting to local demand (Johannson et al., 2004; Kaundinya et al., 2009). In fact, due to their modular and network structure, DRE can adjust to increases in energy needs, in changes of technology and they are not affected by fuels price instability (e.g. diesel-powered generation).

- **Socio-ethical**: Some authors agree that DRE systems are the key alternative to provide energy supply in the short-medium term to those 1.4 billion people currently living off-grid (IEA, 2014; Narula et al., 2012; Zerriffi, 2011). DRE generation can encourage greater competition in the electricity scenario (OECD/IEA, 2002) allowing customers to choose the most suitable energy option. The democratisation of energy access through small-scale, easy-to-install and manage energy plants can also support communities' self-sufficiency (Chaurey et al., 2012).DRE systems can also enable customers to be independent energy producers, enabling the use of energy for income generation and productive uses which represents a key aspect of accessing modern energy services (Brew-Hammond, 2010).

Benefits of DRE
TECHNOLOGY / ENVIRONMENTAL
Reduction of network losses, improvement of reliability of distribution
Reduction of emissions due to renewable sources
Adaptability to customer demand
ECONOMIC
Support of local markets: job creation, new revenue structures
Cost effective alternative for isolated communities
Lower energy prices in the long term
Higher flexibility and resilience
SOCIO-ETHICAL
Encouragement of competition
Democratisation of resources and support of communities self-sufficiency

Enabling of users to be independent producers and to enhance productivity

Table 2.3 – Summary of benefits of DRE systems

Although considered promising under many aspects, DRE generation also presents some limitations (summarised in Table 2.4). Technological constraints are mostly related to the limited capacity and low voltage of DRE systems. The use of renewable energy sources can be affected by site specificity and seasonality of resources (Beck & Martinot, 2004; Terrado et al., 2008). The need for storing excess electricity produced and related battery costs are also limitations of off-grid systems (Kaundinya et al., 2009).

Economic barriers include high initial capital costs for end users and providers (Krithika & Palit, 2013), compared to non-renewable sources such as kerosene and diesel generators or energy through grid connection (OECD/IEA 2002; IEA, 2014). In addition, most lower-income customers tend to choose solutions with lower up-front investment costs due to availability of cash and lack of financing options (Colombo et al., 2014; Rolland, 2011). DRE systems require technical expertise to be managed, and often the lack of technical skills for installation and operation of renewable energy plants result in project failures (Palit & Chaurey, 2011).

From a socio-cultural perspective, the adoption of DRE systems is influenced by the awareness about technology options and their perceived benefits (Bardouille, 2012). The lack of confidence in some technologies, in some cases due to market distortion caused by low-quality products, can represent a barrier for the introduction of DRE (IFC, 2011). Another factor is related to cultural preferences and habits which influence people's willingness to pay and adopt a new energy technology (Bologna, 2014). In order to tackle these barriers, the implementation of DRE systems may require long-term capacity building, training of end users and effective demand-side management (Rolland, 2011). Some authors argue that technology is often not adapted to the specific local conditions and customer needs (Schäfer et al., 2011).

Another key aspect influencing the implementation of DRE is the need for an appropriate institutional and policy support (Kaundinya et al., 2009; Beck & Martinot, 2004; Terrado et al., 2008; REN21, 2016). For instance, DRE systems require specific regulatory frameworks that enable independent power production, feed-in tariffs, appropriate product and service quality standards (Terrado et al., 2008).

Considering these challenges, what emerges from the literature is that in order to successfully provide clean and affordable energy access, several aspects need to be considered. In fact, key additional services such as financing, capacity building, maintenance, installation, repair and disposal of products are required to provide "energy product service systems" (Schäfer et al., 2011; Terrado et al., 2008).

Barriers of DRE
TECHNOLOGY / ENVIRONMENTAL
Limited capacity and low voltage
Site specificity and seasonality of renewable sources
Need for storage excess electricity (for off-grid systems)
ECONOMIC
Higher capital costs for providers and customers
Need for skilled personnel, capacity building and local maintenance
SOCIO ETHICAL
Cultural barriers for adopting new technologies due to lack of awareness and cultural habits
Need for capacity building and training
POLICY
Need for appropriate policy and regulations

Table 2.4 – Summary of barriers for DRE

2.1.5 Business model innovation for DRE systems

A growing number of actors involved in the energy sector, from entrepreneurs, to SMEs to multinational corporations, is succeeding in profitably tapping the DRE market in low-income contexts (Bardouille, 2012). However, several challenges in innovating products, services and business models need to be addressed to scale-up energy access (Aron et al., 2009; Colombo et al., 2014; Wilson et al., 2009; Wilson et al., 2012).

As anticipated before, barriers to the implementation of DRE systems are not primarily technological, but they are mostly related to affordability, customer awareness and the need for additional services. In fact, services such as consumer training, installation, maintenance and financing should be provided to ensure successful ventures (Terrado et al., 2008). In other words, it can be affirmed that it is not only a matter of applying appropriate technologies, but that success factors are related to "embedding the introduction of technical systems in a range of services" (Schäfer et al., 2011). It has been argued that the penetration of DRE in low-income and developing contexts "requires innovative design and support for energy delivery models" (Wilson et al., 2012). For these reasons, the successful implementation of DRE can be tackled from a business model innovation perspective.

A business model "describes the rationale of how an organization creates, delivers and captures value" (Osterwalder & Pigneur, 2010) by addressing customers' needs and desires (Hannon, 2012).

In order to address poverty and energy access major opportunities lie in innovating business models that encapsulate products and services (WPCSD, 2012) and that provide environmental and social benefits aligned with economic sustainability (Wilson et al., 2009, Stubbs & Cocklin, 2008).

A successful implementation of DRE systems requires approaches in business model innovation that combines technologies, financial mechanisms and organisational structure (Wilson et al., 2012). These include type of energy system, governance and management, ownership structures, relationships with end users and financing options. However, challenges are not only related to the value chain (product design, manufacturing, marketing and distribution, finance, maintenance and after-sale service), but also to the enabling environment and the socio-cultural context influencing the delivery model (Barnes, 2005; Bellanca & Garside, 2013; WBCSD, 2012; Wilson et al., 2012).

Wilson et al. (2012) propose a definition of pro-poor business models for DRE by defining an energy deliver model "as combination of technology, finance and management required to supply energy to users". This includes the technology choice, the distribution of power and products to customers and it "needs to consider governance, management and ownership structures, and the chosen financing options and payment systems". In this perspective, business models for DRE systems need to be properly designed to deliver energy services to the poor, by including not only "processes and activities aimed at delivering energy services to end users" but also those "administrative and physical infrastructures" (e.g. supportive policies and access to capital financing, transport and IT infrastructures etc.) that influence the success implementation of the energy system (Leopold et al., 2015).

Several authors investigated challenges for business model innovation for energy interventions in low-income contexts (Bellanca & Garside, 2013; Bologna, 2014; Aron et al., 2009; Wilson et al., 2009; Wilson et al., 2012; Chaurey et al., 2012; Bardouille, 2012; Krithika & Palit, 2013; Schillebeeckx et al., 2012; Kolk & van den Buuse, 2012; Zerriffi, 2007). These studies highlight that is necessary to include multiple ingredients in the business model composition but also to define what factors are implicated for success (Krithika & Palit, 2013; Barnes, 2005). This means that the choice of appropriate business models needs to follow certain essential requirements, such as the choice of suitable technology, the estimation of energy demand, the design of electricity tariffs etc.

As previously discussed, the analysis of the literature about DRE highlighted several dimensions used to describe and classify these models. The multi-dimensions characterising DRE systems need to be considered for the design of appropriate business models. In fact, since it is not possible to suggest one single best approach for the choice of DRE business model (Krithika & Palit, 2013), one option is to group the identified requirements in clusters or elements. Building upon previous categorisations

(Biswas et al., 2001; Schillebeeckx et al., 2012; Zerriffi, 2007), we can summarise the following key aspects of DRE business models:

- Suitability of technology: this refers to the choice of the energy system and products, which should meet the energy needs of customers and should be chosen according to the availability of local resources and the characteristics of the chosen context. The product choice should be based on consumers data about energy consumption, income, current energy expenditure and willingness to pay (Terrado et al., 2008; Krithika & Palit, 2013).

- Economic sustainability: the business model should be financially viable and economically sustainable (Bologna, 2014; Barnes & Foley, 2004) and the issue of affordability must be tackled with specific support for customers and providers (Wilson et al., 2012). Capital financing, cost recovery through appropriate tariffs are influenced by a number of factors that should be considered in designing the solution. These can include the presence of subsidies, the involvement of financing institutions and government regulations (Zerriffi, 2011).

- Socio-cultural embeddedness: this relates to designing solutions that have a positive development impact and provide benefits for the society in terms of income generation, health and education (Krithika & Palit, 2013; Bellanca & Garside, 2013). Appropriate models consider user needs and how the energy solution affects their communities (Schillebeeckx et al., 2012) and ensure training, awareness and acceptance of energy solutions (Chaurey et al., 2012). Another key aspect for successful implementation of DRE is related to the involvement of communities and end-users planning and developing (Practical Action, 2016; Wilson et al. 2009; Chaurey et al., 2012; Krithika & Palit, 2013).

- Appropriate organisational form: pro-poor business models for DRE require an adequate cooperation among different stakeholders, as a "*mix of actors, public institutions, private companies and civil society forming innovative partnerships"* (Bologna, 2014). This means that ownership structures, management and administration of the delivery model should be clearly defined (Barnes & Foley, 2004; Wilson et al., 2012).

- Supporting policies and institutional framework: a favourable policy environment that includes regulatory systems, subsidies and import tariffs, must be considered (Bologna, 2014). Although an adequate policy framework is not directly influenced by the actors involved in the solution (Bellanca & Garside, 2013), this influences many aspects of the business model such as the technology choice, supporting activities, type of offer.

Despite considering socio-economic sustainability, the literature on business models for DRE does not exhaustively cover the environmental implications of choosing specific business models. Even if some authors state that environmental protection is key for DRE systems in the context of developing countries (Friebe et al., 2013) and that solutions must be monitored in terms of environmental impact (Bellanca & Garside, 2013), most studies imply that the choice of DRE system over fossil fuels-based solutions or centralised systems automatically presents environmental benefits.

In conclusion, the implementation of DRE requires the adoption of sustainable business solutions that simultaneously consider the multi-dimensional characteristics of DRE systems (i.e. value proposition, energy system, organisational structure etc.) while tackling economic, environmental and socio-ethical sustainability. For these reasons, it is promising to look at the model of Product-Service Systems, a specific type of value proposition that "is designed to be competitive, satisfy customer needs and have lower environmental impact than traditional business models" (Mont, 2002) (see Section 2.2).

2.1.6 Tools for DRE design and planning

The literature on Distributed Generation and DRE presents several attempts to provide methods and tools for designing successful projects. Most design methods are structured in form of guidelines, best practices and successful cases, especially by international organisations such as The World Bank, IEA (International Energy Agency), UNIDO (United Nations Industrial Development Organization), REEEP (Renewable Energy and Energy Efficiency Partnership), ARE (Alliance for Rural Electrification), Energy 4 Impact, Practical Action and more.

Schillebeeckx et al. (2012), in their review of academic papers from 1990 to 2011, address the lack of a framework that encloses all building blocks for designing energy projects. They affirm that the literature focuses singularly on the applications of different technologies, or the impacts of specific projects, on the institutional and regulatory factors or on the financial and business aspects.

In terms of methods for designing DRE systems, the types of guidelines and design recommendations can be grouped following Schillebeeckx et al.'s approach:

Technology: focus on design and use of specific DRE technologies, comparison of technologies and discussion on viability.

Institutional: focus on policy and governance, institutional factors, role of actors involved.

Viability: focus on financial viability, capital financing and investments, revenue structures.

User-centric: focus on users' needs, community involvement, competence building, local embedded-ness.

The review on tools for designing and planning DRE models has been carried out by categorising existing tools according to their main use or application, their strengths and weaknesses. A list of the reviewed tools is provided in Table 2.5.

Some toolkits, such as the *Energy Business Model Generator* (Gradl & Knobloch, 2011), consider several aspects of the energy provision and propose a business model composed by blocks (Fig. 2.4). The tool however does not provide information about technology options.

World Bank's *Renewable Energy Toolkit (REToolkit)*, on the other side, covers all aspects of renewable energy design: technology options, financial models, institutional frameworks, customers' requirements etc. (The World Bank, 2008). However, the REToolkit can be described as a manual of guidelines and best practices collected from The World Bank projects rather than a toolkit. Its main weakness relies in fact in the format, as it may be not useful in idea generation sessions.

UNIDO & REEEP developed an exhaustive manual that aims at training practitioners and policy makers on the development and implementation of DG systems with an overview of business models, technologies and implementation strategies. This toolkit however focuses mainly on regulations and policymaking for African contexts.

The most interesting approaches among DRE tools are the *Energy Delivery Model Tool* (Practical Action Consulting) and the *Energy Delivery Model Map and Canvas* (Wilson et al., 2012; Bellanca & Garside, 2013).

Figure 2.4 - Extract from the Energy Business Model Generator (Gradl & Knobloch, 2011)

The *Energy Delivery Model* tool (Fig. 2.5) is designed to provide preliminary analysis for planners and designers of new energy access projects, as well as to improve existing ones. The digital tool provides a step-by-step approach to identify stakeholders, energy systems, services and payment options and generate a map of the project. Its main strengths include: a comprehensive approach to multiple dimensions of DRE projects; the suggestion of optimal choices by automatically excluding non-appropriate options; the digital version enables users to review and modify the business model created. On another side, a digital tool may be not ideal for co-design and idea generation session especially when different types of stakeholders need to put their inputs in the process. Another weakness of the tool is related to the automatic selection of options which does not provide space for innovation or addition of new elements.

The *Energy Delivery Model Map* and *Delivery Model Canvas* (Fig. 2.6 and 2.7) combines a framework for "pro-poor energy delivery system" (Wilson et al., 2012) with the Business Model Canvas (Osterwalder & Pigneur, 2010). This tool represents the most comprehensive approach to integrate all dimensions of DRE models, including socio and environmental aspects of the business model. This framework provides users with questions and examples of variables that need to be considered for each design element. For example, the Key Stakeholders' block include: "Who are the key stakeholders? Which key activities do they perform?" and types of stakeholders listed are suppliers, government and local authorities etc. In their publication, Bellanca & Garside (2013) do not explain how the tool can be used in idea generation sessions and what other types of resources may be needed to complete the business model design. In fact, the framework does not include case studies, practical applications or examples of the listed dimensions. The authors however provide a list of existing tools that can be employed in various stages of the design process, such as stakeholder mapping tools, risk assessment and monitoring and evaluation processes.

In conclusion, most DRE literature provides tools and methods that are context specific or limited to one or few characterising dimensions (e.g. technology choice, capital financing). In addition, the majority of toolkits are structured in the form of manuals or guides and may not be suitable for idea generation sessions. On the other side, the most interesting approaches adopting a multi-dimensional perspective (Wilson et al., 2012; Bellanca & Garside, 2013) lack practical applications of the tools and do not include case studies or examples to guide the design process.

DRE design and planning					
Tool	**Author**	**Description – applications**	**Strengths**	**Weaknesses**	**Format**
Energy Delivery Model Tool	Practical Action Consulting, PISCES Project	A tool for preliminary analysis for planners and designers of new energy access	Step-by-step approach that suggests optimal choices;	Choices are limited to the ones provided, it does not open to innovation;	Digital

		projects, as well as to improve existing ones	comprehensive of multiple dimensions; generate map of the project	Digital version mat be difficult to be used in idea generation session	
Delivery Model Map and Delivery Model Canvas	Wilson et al. 2012; Bellanca & Garside, 2013	Combination of Delivery Model Map and Business Model Canvas approach, resulting in a canvas with key questions and examples for designing a sustainable DRE project	Very comprehensive of all dimensions and building blocks; includes sustainability aspects (socio-ethical and environmental)	Do not provide case studies or practical examples but it is limited to a list of factors and characteristics of the provided dimensions	Print
Business Model Canvas	Osterwalder & Pigneur, 2010	A canvas to describe, design and change a business model, composed by 'building blocks'	Intuitive and straightforward; great tool for idea generation sessions; can be applied to different contexts and types of businesses	Does not focus on the offer provided; too general to be applied to energy services; does not cover sustainability aspects	Print
REToolkit: a resource for renewable energy development	The World Bank, 2008	List of guidelines (report) for the implementation of DRE models	Highly detailed, covers all dimensions	Manual/book – difficult to be used in idea generation phases	Print
Energy Business Model generator	Gradl & Knobloch, 2011	List of guidelines for the implementation of DRE models	Highly detailed, includes case studies	Manual/book – difficult to be used in idea generation phases	Print
Toolkit for Implementing Household Energy Projects in Conservation Areas	Clough, Rai et al. 2012 (Energy 4 Impact/GVEP International)	General overview for technologies, approaches and business models for energy projects	Provides tips, guidelines, timeline and general information to set up an energy project	Manual/book – difficult to be used in idea generation phases	Print
Integrated business model toolkit	Schillebeeckx et al., 2012	Multi-dimension framework to design a user-centric business model for energy.	Consider all dimensions of DRE models; Include user-centric approach	The tool is composed by a list of questions for each dimension, it does not provide guidelines or examples	Print

Table 2.5 - List of reviewed tools for DRE design and planning

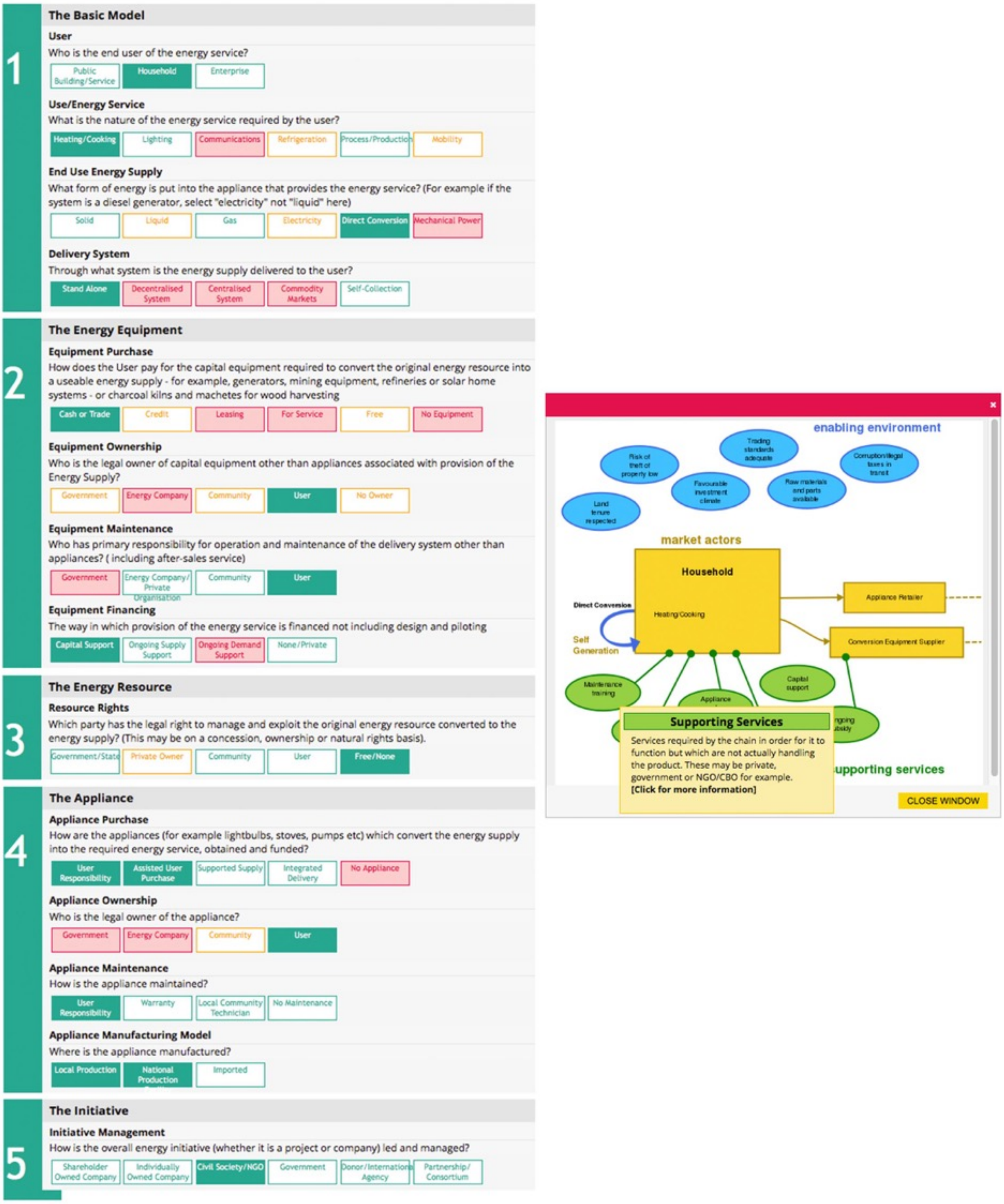


Figure 2.5 - Screenshot of the Energy Delivery Model Tool and the system map generated (Practical Action Consulting). Accessed: July 2017

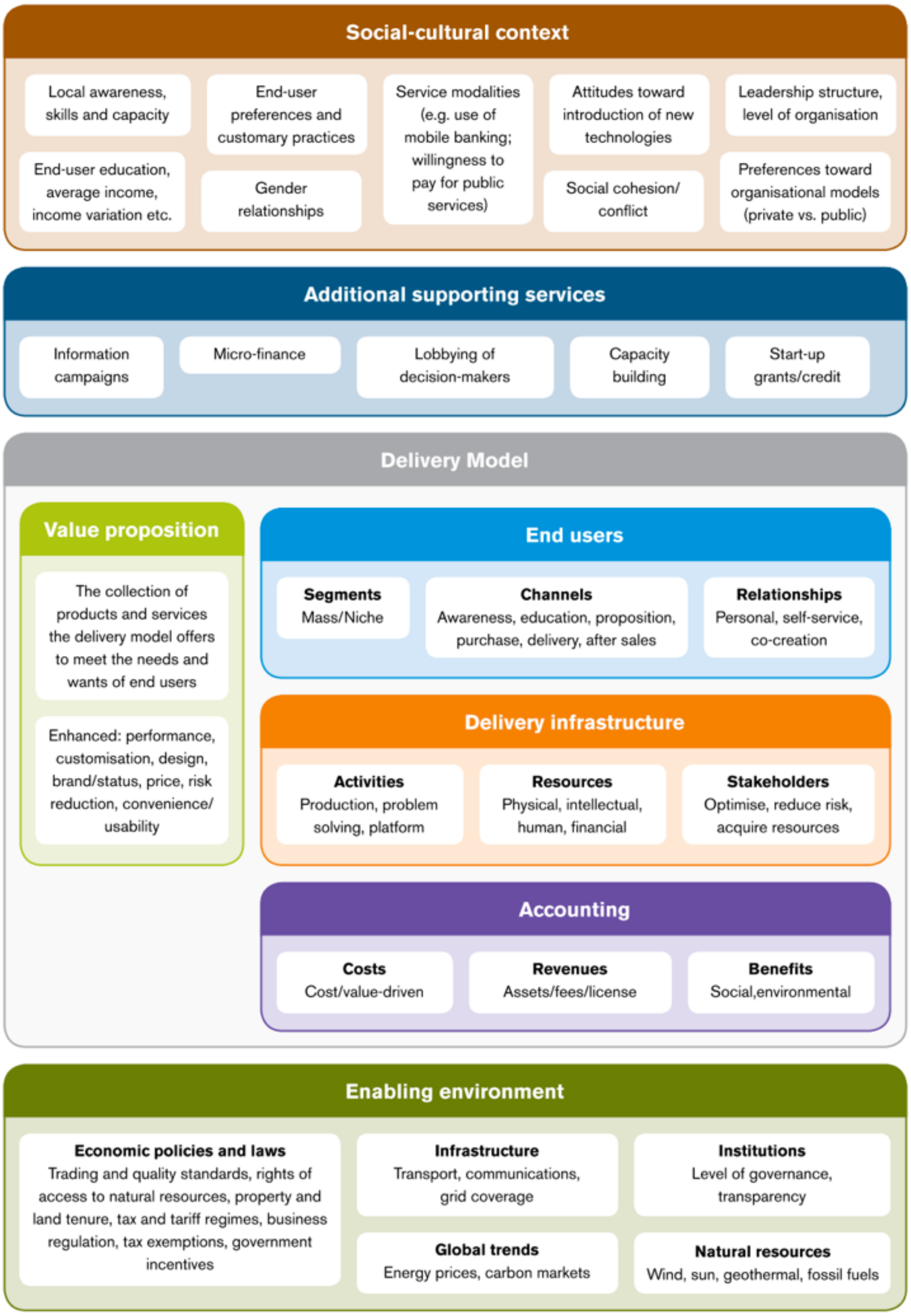


Figure 2.6 - Delivery Model Map, Wilson et al. 2012

Figure 2.7 – Delivery Model Canvas, Bellanca & Garside (2013)

2.2 Product-Service Systems (PSS)

The concept of Product-Service Systems (PSS) is introduced as a specific type of sustainable value propositions that integrate products, services, networks of players and supporting infrastructure (Goedkop et al., 1999). These specific business models are designed to focus on the functionality or satisfaction a consumer desires (Tukker & Tischner, 2006), simultaneously meeting economic, ecological and social needs (Boons & Lüdeke-Freund, 2013; Wilson et al., 2009).

This section presents an analysis of the literature about Product-Service Systems, illustrating benefits and barriers of these models, characteristics of sustainable PSSs and discussing their classification.

Lastly, this section reviews methods and tools to support the design of sustainable PSSs.

2.2.1 Product-Service Systems definition

The concept of Product-Service Systems finds several definitions in the literature (see Table 2.6). A PSS can be described as *"a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs"* (Tukker & Tischner, 2006 – p. 1552). It refers to specific type of value proposition where the business focus moves from the traditional economic model of selling products or services, to providing an integrated combination of "system of products and services" that are able to fulfil customer satisfaction. The emphasis is in delivering a performance/function rather than a product, e.g. providing mobility solutions rather than selling cars. Mont (2004 – p.71) proposes a definition of PSS: *"A product-service system is a system of products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models".*

Author	Year	Definition
Goedkoop et al.	1999	"A Product Service System (PS) system is a marketable set of products and services capable of jointly fulfilling a users' need. The product/service ratio can vary, either in terms of function fulfilment or economic value"
Mont	2004	"PSS should be defined as a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customers needs and have a lower environmental impact than traditional business"
Brandstotter et al.	2003	"A PSS consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs. Additionally PSS tries to reach the goals of sustainable development"
UNEP, Manzini & Vezzoli	2003	"PSS can be defined as an innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands"
Tukker	2004	"A PSS can be defined as consisting of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling

		specific customer needs"
Baines et al.	2007	"A PSS is an integrated product and service offering that delivers value in use. A PSS offers the opportunity to decouple economic success from material consumption and hence reduce the environmental impact of economic activity"
UNEP, Tischner et al.	2009	A PSS is a system of products and services (and infrastructure), to jointly cope with the needs and demands of customers in a more efficient way with better value for both businesses and customers, compared to only offering products [...]. PSS can decouple the creation of value from the consumption of materials and energy and thus significantly reduce the environmental impact in the life cycle of traditional product systems

Table 2.6 - Some definitions of PSS

According to this definition, the main elements characterising PSS models can be then described as:

- **Products**: the physical artefacts that can be "touched, stored and owned" (Roy, 2000).

- **Services**: it refers to any act or performance offered that is essentially intangible (Kotler, 1988). It includes services at the point of sale (customer assistance, financial services, training on product use, marketing etc.), services during the life cycle of the product (e.g. maintenance, upgrading, repair) and services at the end of the product's life, such as taking-back services and recycling.

- **Network of actors**: refers to the stakeholders involved in the creation and delivery of PSS and their interactions and partnerships.

- **Contract**: refers to the type of commitments, responsibilities and linkages between stakeholders, defining how the solution is provided to customers (Müller & Stark, 2008).

- **Infrastructures**: includes all physical and IT infrastructures involved in the PSS, such as communication systems, transportation, waste management services (Mont, 2004).

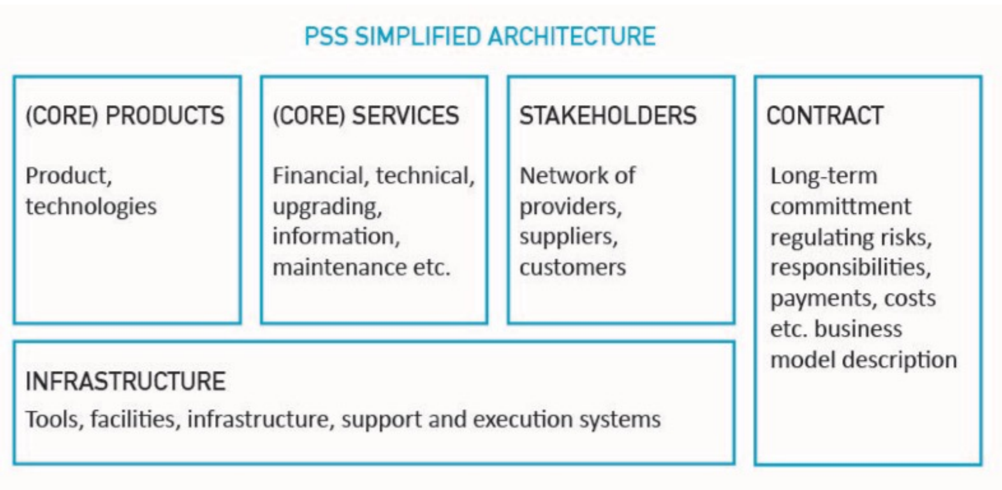


Figure 2.8 – PSS simplified architecture, adapted from Müller & Stark (2008), Mont (2004)

2.2.2 Traditional business models vs the functional economy

The PSS concept is inherently linked to the concept of *functional economy* (Table 2.7). A functional economy, opposed to traditional industrial economy, represents a promising mean to achieve sustainable development (Stahel, 1997). In this definition, *"a functional economy is one that* *optimizes the use (or function) of goods and services and thus the management of existing wealth (goods, knowledge, and nature). The economic objective of the functional economy is to create the highest possible use value for the longest possible time while consuming as few material resources and energy as possible"* (Stahel, 1997 – p. 91).

In a functional or service economy, the focus is on selling a performance, meaning that customers buy the "functioning of a product" and therefore the value shifts from the costs of producing products to the costs of providing the use of it (Stahel, 1994). On the contrary, in a traditional economy, the profit is directly linked to the sale of goods and producers are not always fully interested in reducing material and energy consumption during the product's use phase. In fact, in a functional economy profit is directly linked to the number of functional units delivered to customers (Stahel, 1994). Selling the use of products instead the products themselves and incentivising customers to return products to manufacturers are key elements of companies' success (Stahel, 1997). Several benefits for providers and customers emerge from shifting to a functional economy (see 2.2.5) and this represents a promising approach to move towards a more environmentally sustainable production/consumption system. However, it must be stressed that PSS innovations, which enclose the functional economy in their core, need to be properly designed to be more sustainable compared to traditional ones (Manzini & Vezzoli, 2003).

Traditional economy (sale of products)	Functional economy (sale of performance)
The object of the sale is a product	The object of the sale is a performance or a result
The ownership is transferred to customer	Ownership is retained by the provider (in most cases)
The payment is due at the transfer of property rights	Payment is due for the delivered performance
Income is generated at the point of sale	Income is generated over long-term provision of performance and services
The provider is responsible for manufacturing quality of products and does not have responsibilities over the life-cycle after the sale	The provider is responsible for quality and performance of products over their life-cycle
Products can be produced centrally and can be imported	Performance can only be produced locally

Table 2.7 - Traditional economy vs functional economy

2.2.3 Eco-efficient and sustainable PSS

As previously stated, PSS should be properly designed to provide an environmentally sustainable alternative to traditional business models. An *eco-efficient PSS* can be defined as a PSS "where the economic and competitive interest of the providers continuously seeks environmentally beneficial new solutions"[5] (Vezzoli et al. 2014). This means that stakeholders involved in providing the solution have an economic interest in optimizing resource and energy consumption in the production and delivery of the PSS. This includes products involved in the PSS offer, which should be properly designed to have a low environmental impact in all life-cycle phases (Vezzoli & Manzini, 2008). This aspect also relates to extending products life by upgrading, reusing and recycling materials (Mont, 2002).

When a PSS integrates economic, environmental and socio-ethical principles, it can be referred as *sustainable PSS*, meaning that the providers continuously seek solutions that are not only environmentally friendly but also aim at social wellbeing, equity and cohesion (Vezzoli et al., 2014).

2.2.4 PSS classification

Several authors agree on a unified PSS classification (Hockerts et al., 1993; Hockerts & Weaver, 2002; UNEP, 2002; Tukker & van Halen, 2003; Tukker, 2004; Vezzoli, 2007) that distinguished between three main categories: *Product-oriented*, *Use-oriented* and *Result-oriented* PSSs.

Within this classification, Tukker (2004) proposes eight different archetypal models of PSSs (Fig. 2.9):

- **Product-oriented PSS:** defined as value propositions where a company (or a partnership of companies/stakeholders) sells a product and provides additional services to guarantee its life cycle performance (Tukker, 2004). Examples of such services are maintenance, repair, upgrading, substitution, product take-back, etc. (UNEP, 2002). In this category, Tukker (2004) distinguished between *product-related services* and *advice and consultancy services*.
    - *Product related services*: the provider sells products and offers services that are needed during the use or end-of-life phases of the product (e.g. financing scheme, maintenance, upgrade etc.).
    - *Advice and consultancy services*: the provider sells products and offers advice or training about the use of the product sold.
- **Use-oriented PSS**: defined as value offers where a company (or a partnership of companies/stakeholders) provides access to products that enable customers to achieve particular results (Tukker, 2004). Customers do not own the product (the ownership is kept by the provider), and pay only for the time the product is actually used. Three main sub-categories can be found under this category (Tukker, 2004):
    - *Product lease*: customers pay a regular fee for unlimited and individual access to the product;

[5] This definition has been proposed by the LeNS project, Learning Network on Sustainability funded by the European Commission: Asia Link Programme-EuropAid (2007-2010).

  - *Product renting or sharing*: customers pay for using the product (e.g. by the hour) and different users can sequentially use the same product.
  - *Product pooling*: customers pay to use the product and there is a simultaneous use of the product by different customers.
- **Result-oriented PSS:** value propositions where a company (or a partnership of companies/stakeholders) offers a customized mix of services in order to provide a specific 'final result' (Tukker, 2004). Customers pay the company to get an agreed final result; they do not own the products and do not operate on them to achieve that result (ibid.). In this type of PSS we can distinguish (ibid.):
  - *Activity management/outsourcing*: part of an activity of a company is outsourced to a third party and customers agree on the quality indicators of the service provided (e.g. outsourcing of office cleaning activities);
  - *Pay per service unit:* customers pay for the output of the product (e.g. pay-per-wash in relation to washing machines) and they can either have personal access to the product, or they can share it among other customers;
  - *Functional result:* the provider delivers a result agreed with the customer (e.g. clean clothes), without directly referring to any predetermined product or technology involved. Contrary to the pay-per-service unit, in this case the provider operates on the product(s) involved.

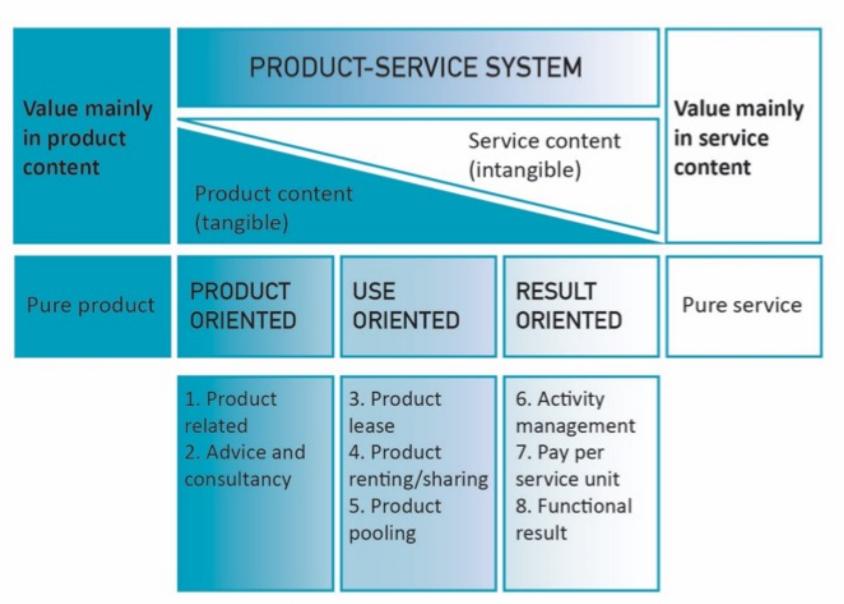


Figure 2.9 - PSS types (Tukker, 2004)

Similarly to the variety of definitions used by authors to describe PSS models, the literature also presents contrasting approaches in defining which dimensions are considered to characterise PSS offers. Gaiardelli et al. (2014) carried out an extensive literature review and analysis of the dimensions that describe PSS offerings. Their research identifies five main dimensions:

- The *value proposition* (or PSS offering) refers to the value offered to the customers, i.e. the specific mix of products and services for which the customer is willing to pay (Gaiardelli et al., 2014).
- The *product ownership* indicates whether the products involved in the PSS solution are owned by the provider, by the end user or shared by a number of users (Tukker, 2004). This dimension is strictly related to the value proposition and considered a key dimension of PSS models by several authors (Manzini & Vezzoli, 2003; Tukker, 2004; Markeset & Kumar, 2005; Aurich et al., 2010; Windahal & Lakemond, 2010).
- The *product operation* refers to who operates on the product/s involved in the PSS offer, i.e. the user or the provider. Also this dimension is strictly dependent on the value proposition.
- The *provider/customer relationship* dimension refers to the nature of interaction between those actors and ranges from transaction-based relationship (in product-oriented PSSs) to creating and maintaining a stronger relationship (in use and result-oriented PSSs) (Frambach et al. 1997). In general, the nature of provider/customer relationship presents a continuum ranging from transactional to relational (Penttinen & Palmer, 2007). However, the intensity of the relationship can differ from case to case and some product-oriented PSS may also present a more intense provider/customer relationship than other PSS types (Gaiardelli et al., 2014).
- Another important dimension is the *environmental sustainability potential*. In relation to this, several authors (e.g. Manzini & Vezzoli, 2003; Tukker, 2004; Tukker & Tischner, 2006; Tukker, 2015) agree that the environmental sustainability potential is higher for use-oriented PSSs, followed by result-oriented PSSs and product-oriented PSSs[6].

The previously described classification proposed by Tukker (2004) is widely adopted by scholars and it appears to be general enough to be adapted to various domains. However, regarding specific applications such as the combination of PSS and DRE models, this classification appears to be not suitable to describe the complexity of these models. This matter is addressed in Section 2.4.

6. Tukker (2004) and Tukker and Tischner (2006) have analysed the environmental impact of several PSSs and argue that, on average, the highest environmental benefit can potentially come from result-oriented PSSs (up to 90% reduction, or factor 10, compared to traditional business models based on selling products), followed by use-oriented PSSs (up to 50% reduction, or factor 2, except for leasing which can provide a reduction of up to 20%) and product-oriented PSSs (up to 20% reduction). These data have been confirmed by a literature review done by Tukker (2015). However, it is important to highlight that the sustainability performance of PSSs should be considered case by case. PSSs in fact have to be specifically designed, developed and delivered, in order to generate a lower environmental impact than the competing product orienting models (UNEP, 2002).

2.2.5 Benefits and barriers of PSS models

PSS models might provide benefits for customers, providers and for the society as a whole (Mont, 2002). Benefits can be grouped in categories: economic, environmental and socio-ethical benefits.

Economic benefits:

Adopting a PSS model can provide the possibility to find new strategic market opportunities for companies (Wise & Baumgartner, 1999; Goedkoop et al., 1999; Manzini et al., 2001; Mont, 2002). This means that PSSs can potentially increase a company's competitiveness in the value chain (Gebauer & Friedli, 2005; Tukker & Tischner, 2004). For example, manufacturing companies can add value to their products by providing services and thus differentiating the offer from traditional sales-based ones (Mont, 2002). Competitiveness is also enhanced because PSS offers are more difficult to copy (UNEP, 2002; Mont, 2002). In addition, PSSs can support strategic competition by building up barriers to entry for potential new competitors (Gebauer & Friedli, 2005; Oliva & Kallenberg, 2003).

PSS-oriented solutions enable companies to establish a longer and stronger relationship with customers (UNEP, 2002; Mont, 2004; Correa et al., 2007; Tukker & Tischner, 2006). In fact, the interaction with customers lasts for the whole period of the contract, which may result in higher customer's loyalty and satisfaction (Mont, 2004).

PSSs provide economic benefits from the customer's perspective. PSSs can increase value through a more tailored offer that suits customers better in terms of payment schemes and services offered (Mont, 2002; Cook et al., 2006; Baines et al., 2007; Aurich et al., 2010). The service component of a PSS solution facilitates the customisation according to specific customer's needs (Cook et al., 2006), thus resulting in added value for customers, especially in mature markets. PSS models release customers from the responsibilities of ownership, especially related to repair, maintenance and product disposal (Mont, 2002). Another economic benefit for customers is related to obtaining the 'desired satisfaction' without having to make a large upfront investment (Mont, 2004).

Lastly, PSSs present higher flexibility compared to traditional business models, being able to better respond to changing of customers' needs and markets (Mont, 2002; UNEP, 2002).

Environmental benefits:

Environmental sustainability of PSS models has been supported by a number of authors (Roy, 2000; Mont, 2002; Manzini & Vezzoli, 2003; Tukker, 2004; Tukker & Tischner, 2006; Baines et al., 2007; Vezzoli et al., 2014) and these type of value proposition, if properly designed, can have a "lower environmental impact than traditional business models" (Mont, 2002).

According to Roy (2000), the key of sustainability in a PSS relies in providing users with a *function* or *result* instead of having to buy and own products. Because customers pay per unit of function or performance delivered and not per unit of product sold, PSS models can decouple economic value from material and energy consumption (White et al., 1999; Stahel, 2000; Heiskanen & Jalas, 2000;

Wong, 2001; Zaring et al., 2001; UNEP 2002). This means that providers are economically interested in using eco efficient products, generating less material and energy waste in delivering the performance/result. As anticipated in the previous section, eco-efficient PSSs couple environmental and economic interests (Vezzoli, 2007). The benefits emerging from the applications of these models have an impact during and at the end of the product's life (UNEP, 2002). During the products' life, the provider is interested in using fewer resources to deliver customer's satisfaction. This can be achieved by using more efficient and advanced technologies, by reducing energy and material consumption and by extending materials' life (Vezzoli, 2007). If the ownership is retained by the PSS providers, they are economically interested in extending the product life span (Vezzoli, 2007, Mont, 2004). This means providing maintenance, repair and upgrade of products.

At the end of the products' life, PSS providers are economically interested in reusing or refurbishing products, thus facilitating remanufacturing and recycling.

As highlighter before, the environmental sustainability of PSSs varies from case to case and these models must be properly designed to provide the afore-mentioned benefits.

Socio-ethical benefits:

PSSs can provide several benefits for customers and for the society at a whole. For customers, PSSs may represent an opportunity to have access to products without high upfront investments. This is particularly relevant as it can increase opportunities in lower-income and developing contexts (UNEP, 2002). Another aspect is related to the customisation of the solution, which can provide a higher value for customers (Tukker & Tischner, 2006).

For the society at a whole, PSS can increase job opportunities and local employment. In fact, a functional economy is more labour-intensive (Mont, 2002). PSS solutions can also have a positive impact on local economies, by strengthening the involvement of local rather than global stakeholders (UNEP, 2002). This is related to the fact that while products can be produced and consumed in different geographical locations, services are more focused on the context of use, being created and consumed in the same place (Tukker et al., 2006).

Despite the potential several benefits, PSS solutions have not been widely implemented (Ceschin, 2013). These models present some implementation and adoption barriers for both providers and customers. Other issues are related to necessary changes at institutional and regulatory level.

Barriers for companies:

For companies adopting a PSS model require complex changes in the organisation and culture (UNEP, 2002; Ceschin, 2013). Providing PSS solutions demands a whole change in organisational skills, company's mindset and competences. For example, company's staff may need specific training (Mont, 2004) and the organisation may need to be restructured to be able to design and deliver a PSS solution (Baines et al., 2007). Another barrier is related to the uncertainty of cash flows, which requires product-based businesses to plan long-term investments (Mont, 2002). In fact, companies may often struggle in understanding savings emerging from service-based solutions in terms of economic and environmental terms (UNEP, 2002, Ceschin, 2013).

Barriers for customers:

These types of value propositions require important shifts in terms of customers' habits and behaviours. Among barriers related to customer's adoption of PSS solutions there is the necessary shift in product ownership (for use and result-oriented PSSs) (Ceschin, 2013; Goedkoop et al., 1999; UNEP, 2002; Manzini et al., 2001; Mont, 2002) which requires customers to adopt new habits, often without understanding the economic benefits of ownerless solutions (Ceschin, 2013). In fact, often customers are not aware of cost related to the life cycle of products (White et al., 1999) and they may perceive PSS solutions to be more expensive or not convenient compared to traditional sales of products.

Context-related barriers:

Other factors influence the implementation and diffusion of PSSs and these are related to the enabling environment. From a regulatory perspective, PSS require appropriate and supportive policies but the current regulatory framework often do not facilitate the diffusion of sustainable business models with appropriate policies on environmental innovations (Mont & Lindhqvist, 2003; Ceschin & Vezzoli, 2010; Ceschin, 2013). Other barriers are related to the necessary infrastructures for implementing PSSs, such as remanufacturing or recycling schemes, which may be unavailable in determined contexts (UNEP, 2002).

2.2.6 PSS design approaches

A new design approach that moves from product to system thinking is required to design PSS solutions (Manzini & Vezzoli, 2003). The design of PSSs has been investigated by several authors.

A number of methodologies can be found in the literature, most of them have been developed within EU-funded projects.[7]

Most methods are usually organised in main phases: preparatory phase or strategic analysis, exploring opportunities, PSS concepts design and PSS engineering. The MEPSS methodology, in particular, provides support through a step-by-step approach in a modular structure (Van Halen et al., 2005). The MEPSS divides the PSS development into five stages: strategic analysis, exploring opportunities, PSS idea development, PSS concept design, development and implementation of PSS

[7] ProSecCo (Product-Service Co-design, 2002-2004), INNOPSE (Innovation Studio and Exemplary Developments for Product Service Engineering, 2002-2005), HiCs (Highly Customerized Solutions, 2001-2004) (Manzini et al., 2004), MEPSS (Methodology for Product Service System development, 2002-2005) (Van Halen et al., 2005); SusProNet (Sustainable Product Development Network, 2002-2005).

project. A list of tools is identified for the developing of each stage, from the SWOT analysis, to scenario building and system map (Van Halen et al., 2005).

The Methodology for System Design for Sustainability (Vezzoli et al., 2009), developed from the MEPSS method, follows a similar structure (Fig 2.10):

1. *Strategic analysis*: aims at gathering information needed to generate sustainable ideas and scenarios.

2. *Exploring opportunities*: aims at producing a set of promising scenarios/ideas.

3. *System concept design*: aims at developing one or several sustainable concepts.

4. *System design (and engineering):* aims at detailing the selected concept.

5. *Communication*: aims at producing the material for external communication of the solution.

Figure 2.10 - The MSDS, from Vezzoli et al. (2009)

Another approach for PSS design is proposed by UNEP (2009) in the Design for Sustainability (D4S) program. In particular, addressing companies that want to introduce a PSS business model, the approach is structured in five steps with relative suggested tools (Table 2.8).

Steps	Tools
1. Exploring opportunities: identification of the existing reference system	- Drawing a system map/blueprint - Sustainability SWOT - Checklist for analysing existing reference system – Sustainability

2. PSS idea generation and selection of the most promising concepts	- Sustainability guidelines level 1 - Format of PSS concept integration - PSS sustainability screening tool - Portfolio diagram sustainability and feasibility
3. Detailing selected PSS concepts or PSS design	- Sustainability guidelines 2 - Extended system map of the new system /blueprint - Extended description of the new system - First advertisement for the new system
4. Evaluation of the detailed concepts and testing	- Three sustainability radars for the three sustainability dimensions with six criteria each
5. Planning implementation	- List of specifications for PSS implementation - Business plan for new PSS

Table 2.8 - D4S methods and tools

Recent reviews of PSS methodologies (Vasantha et al., 2012; Tukker, 2015) highlight the research needs in the field of PSS design. In particular, while methodologies and tools for eco-efficient and sustainable PSSs are mature (Ceschin, 2014), some gaps still exist for other aspects of PSS design. These include methods to facilitate co-designing, to support the implementation and evaluation phase of PSSs, to assess customer's needs and satisfaction, to understand differences of PSS types in the design process (Vasantha et al., 2012; Tukker, 2015; Ceschin, 2014).

2.2.6.1 Tools for PSS design

The PSS literature includes a number of design tools developed to support the design, co-design, engineering and communication of PSSs. Generally speaking, these tools can be categorised as follows (Ceschin, 2012; Ceschin, 2014): tools to support strategic analysis (e.g. sustainability SWOT, UNEP, 2009); tools to support the idea generation; tools for steering process towards sustainable PSS design (e.g. SDO Toolkit, Vezzoli & Tischner); tools for visualising PSSs (e.g. Product-service blueprint, Geum & Park, 2011); tools to support co-design processes (e.g. Interaction Table, Van Halen et al., 2005).

Some of the most common tools used for PSS design and concept development are reviewed here and they are listed in Table 2.9.

Verkuijl et al. (2006) list as main tools for PSS design those developed within the Highly Customerised Solutions project (HiCS) (Manzini et al., 2004). In particular, the Design Plan set of tools include the stakeholder system map, the motivation matrix, the interaction storyboard, the solution element.

The *stakeholders system map* (Fig. 2.11), developed by Jégou et al. (2004), visualises actors involved in a PSS solution, their interactions and flows of goods, services and information. This tool can be applied in several phases of the design process, as it is a visualisation of the solution but also a map of how the system works.

Another tool, the *motivation matrix* illustrates the contribution each stakeholder makes to the solution, from the point of view of the stakeholders' interests. On the other hand, the solution element tool uses a matrix to point out the elements of the system and who is responsible to design and deliver the specific solution, i.e. their contribution to the system.

The *interaction storyboard* is used to show the interactions between stakeholders along a horizontal timeline (storyboard). This tool simplifies interaction between users and providers during the solution's delivery.

Another example is provided by the *Sustainability Design Orienting toolkit* (SDO), developed within the MEPSS methodology (Vezzoli & Tischner, n.d.). The tool supports users in setting up sustainability priorities, analysing best practices and design new solutions following sustainable design-orienting guidelines. The main elements of the tool are a set of guidelines organised according to sustainability criteria and dimensions (Fig. 2.12). These guidelines can be used to assess the current situation and steer the design process towards a sustainable solution. The main weakness of this tool is the digital format, which may result difficult to be used in co-designing and idea generation session.

Regarding PSS visualisation tools, Ceschin et al. (2014) classify them into four main categories: tools that focus on what is offered to the customers (e.g. offering diagram, van Halen et al., 2005); tools aimed at detailing the stakeholders involved (e.g. stakeholders system map, Jégou et al., 2004; interaction map, Morelli, 2006); tools for visualising how the solution is engineered (e.g. interaction table, van Halen et al., 2005; product-service blueprint, Geum & Park, 2011); tools that focus on why the solution should be implemented (e.g. sustainability diagram, Ceschin & Vezzoli, 2007).

PSS tools					
Tool	**Author**	**Focus - applications**	**Strengths**	**Weaknesses**	**Format**
Stakeholder System Map	Jégou et al., 2004	A tool for designing and visualising PSS. It shows the actors, their interactions and flows of goods, services and information.	Highly customizable; can be applied in several stages of the design process	Requires some basic design skills (software)	Digital
Sustainability SWOT	UNEP (2009)	Analysis of the current and future situation, identifying strengths and weaknesses from an environmental, economic and socio-cultural perspective	Analysis of the current situation from different perspectives.	-	Print/digital
Stakeholders motivation matrix	Jégou et al. (2004)	Matrix indicating the contribution made by each actor in the system, their benefits	Co-design and visualisation tool; can be used with easy-to-use software	Requires some basic design skills (software)	Digital/print

		and conflicts			
Interaction table storyboard	Sangiorgi (2005), Jégou et al. (2004)	A tool that support a progressive design process of the user interaction with the production and delivery of the offer. Derives from the service blueprint	Visualise in a timeline all complex interactions between user and providers; can be detailed over different phases of the design process	Requires some basic design skills (software)	Digital
Product-service blueprint	Geum & Park (2011)	Visualise the processes constituting the service and their interactions, separating front-office with back-office	Cover all characteristics of PSS; allows the design of complex interactions; can be detailed over different phases of the design process	Focus more on the service than on the product; does not distinguish different types of PSS	Digital
PSS solution elements	Jégou et al. (2004)	A tool to describe all elements (material and non-material) involved in the PSS and who is responsible for designing and providing them	Visualise elements usually with icons and pictograms; simplifies roles of actors within the system	Requires some basic design skills (software)	Digital/print
PSS Business Model Ontology	Gaiardelli & Resta (2010); Resta, 2012	Adaptation of Business Model Canvas for the PSS field	Includes main 'elements' of the business model and visualises their relationships	General and abstract	Print
Sustainability Design-Orienting (SDO) toolkit	Vezzoli & Tischner (MEPSS project)	Tool for orientating the design process towards sustainable PSS solutions, using checklist, orienting guidelines and visualizing through radar diagrams the improvements in relation to an existing reference system.	Step-by-step approach for analysing existing models and designing new PSS solutions focusing on sustainability dimensions.	Digital version may be difficult to be used in idea-generation and co-designing session	Digital

Table 2.9 - PSS tools reviewed for this research

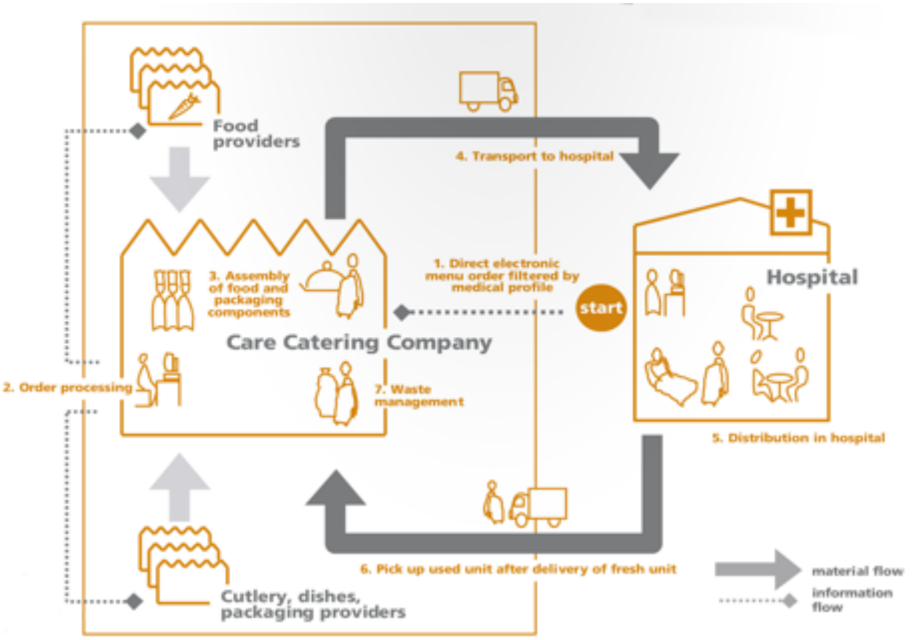


Figure 2.11 - Stakeholders System Map (Jégou et al., 2004)

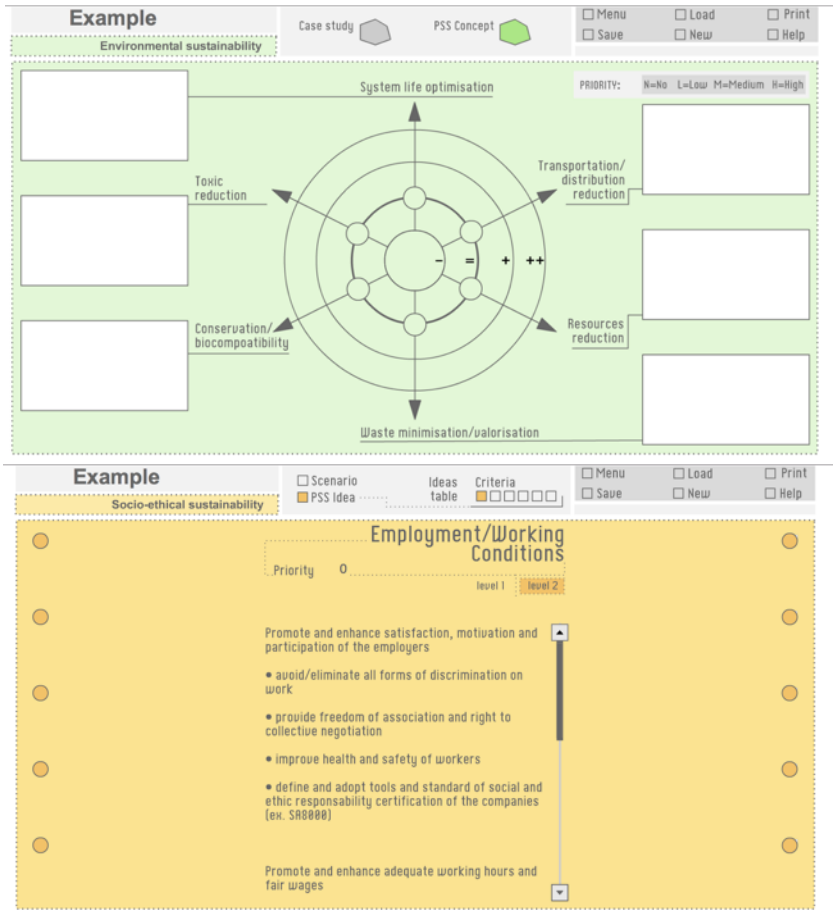


Figure 2.12 – SDO diagram and guidelines (Vezzoli & Tischner). Screenshot from: www.sdo-lens.polimi.it (accessed July 2017)

In conclusion, some considerations can be made. The review of tools and methodologies highlighted that PSS literature is quite mature and it provides an extensive range of approaches. Available tools cover different phases of the design process, from the strategic analysis to the ideation and visualisation phase. These approaches are flexible enough to be adapted to various disciplines, and they have been applied in several contexts of use, from car-sharing cases (Geum & Park, 2011) to food-delivery systems (Jégou et al., 2004). However, they appear to be too generic for specific applications, such as the DRE field. In fact, due to the complexity of DRE models and to the specific requirements of BoP contexts, existing PSS tools do not seem appropriate for this discipline.

2.3 Design for the Base of the Pyramid

This section of the literature review explores the concept of Base of the Pyramid (BoP), focusing on the implications for designing solutions for these contexts. The aim of this review is to gather approaches, guidelines and methods to design solutions for low-income and developing contexts, by adopting a business model innovation perspective and in particular by looking at the applications of PSSs in these markets. This section is structured as following: first the concept of Base of the Pyramid is introduced, then the author summarises the approaches for business model innovation in BoP, highlighting design implications. Then the applications of PSSs in these markets are discussed, concluding with reviewing the studies about designing these solutions.

2.3.1 BoP definition

The concept of Base of the Pyramid finds popularity in the literature since Prahalad & Hart introduced the term in 2002. The defined “world economic pyramid” (Fig. 2.13) can be divided in three parts: at the top it represents the middle and upper-income people mostly from developed countries and few from low-income and developing ones. In the middle, those who earn between $1.500-$20.000 per year are represented, which means poorer customers from developed countries and middle-income ones from the developing world. At the base of the pyramid lie 4 billion people whose annual income is less than $1.500.

Besides this first categorisation, the definition of BoP has changed in the past decade especially in consideration to income levels (Kolk et al., 2014). As London & Hart (2011) argue, the label for BoP has been developed considering the Purchasing Power Parity (PPP), which provides a standardised comparison of prices among countries by taking into consideration the price of a basket of same commercial goods and services. The PPP value ranges from $1 to $4 per day and from $1500 to $3000 per annum, providing a very broad variation within the socio-economic segment considered (London & Hart, 2011). Some authors set the extreme poverty line at $1 per day (e.g. in the UN Millennium Development Goals) but others, such as the World Bank, uses $2 per day for poverty measurement (Karnani, 2011).

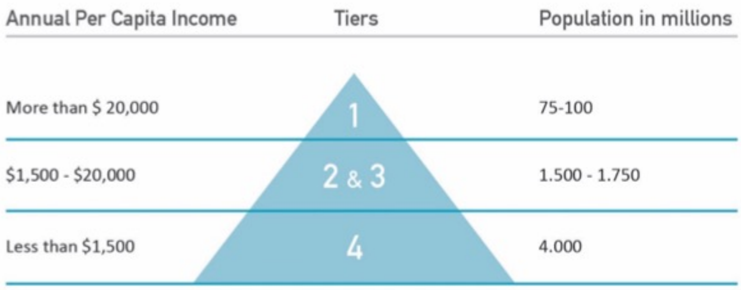


Figure 2.13 - The world economic pyramid, from Prahalad & Hart (2002)

In order to define the BoP market, the literature offers different characteristics of this socio-economic segment, one of them being the definition of poverty which includes a more complicated set of dimensions that the mere income per day. Jagtap et al. (2014) uses Karnani's (2011) definition of poverty as *"the lack of income and assets needed to attain basic necessities, such as food, shelter, clothing and fuel […] but also the lack of access to basic services that directly affect the material welfare of the poor, such as public health, education, safe drinking water, sanitation, infrastructure and security (Jagtap et al., 2014 – p. 529)*. This implies that business strategies should recognise different segments and factors involved within the BoP umbrella term and adapt them accordingly (London, 2007).

Most of the literature align the concept of BoP with the one of informal economy (Hammond et al., 2007). London & Hart (2011) provide a definition of BoP as that socio-economic segment that "primarily lives and operates their local enterprise in the informal economy". Or, more in general, reaching the Base of the Pyramid means reaching a market where people live in rural villages or urban slums, are mostly uneducated and do not use formal credit, communication and distribution channels (Prahalad & Hart, 2002).

Although BoP customers are mostly concentrated in emerging economies (Khalid et al., 2015), the literature refers to very diverse definitions that identify BoP with rural communities, slums dwellers, population of specific countries or even a simplified the "Poor", resulting in very different targets, approaches and initiatives (Kolk et al., 2014).

For the purpose of this thesis, it is important to insert the concept of BoP in relationship to the classification of low-income and developing countries. The definition of "poor" countries and relative classification provided by the World Bank, which is one of the most diffused (Sumner, 2010), divides countries according to the Gross National Income in: low-income, lower middle-income, upper middle-income and high-income. However, many countries such as China, India, Indonesia or Nigeria that shifted to the middle-income category in recent years, still have large parts of the population living with less than $1500 per year (Sumner, 2010). This means that about one billion BoP people live in middle-income countries. For this reason, this research stretches the concept of BoP linking it with the one of "*energy poverty*" (see Section 1.1) and including not only the 4 billion poor living at the BoP but also those with unreliable or limited energy access living in middle-income countries.

2.3.2 Innovation for the BoP

After a decade of research, London & Hart (2011) reviewed the approaches for "*finding* a fortune *at* the BoP" and affirmed that companies and ventures currently succeeding in operating in BoP markets are adopting a different approach, by "*creating* a fortune *with* the BoP". The authors affirm that the next-generation business strategies can be framed as "business with the four million" emphasizing the importance of co-creation of business models with their final customers. In other words, while at first researchers focused on the BoP as an untapped market to be exploited, the second wave of research on BoP contexts values the importance of involving these customers in creating their own *fortune*.

In reviewing literature about BoP approaches, Kolk et al. (2014) provide an analysis of projects and studies on the topic that classify BoP business models according to the position of the Poor in the value network (consumers or entrepreneurs) and the mode of engagement (recipients of existing products or co-inventors). Several authors argue that new and properly designed business models and products need to be combined in order to tackle poverty alleviation (Jun et al., 2013; London & Hart, 2004; Simanis & Hart, 2009). The role of the Poor *as customers* or *as producers or entrepreneurs* becomes crucial and strategies that involve BoP as consumers and that have a primary aim of earning profits may not be sustainable or alleviate poverty (Jagtap & Larsson, 2013: Karnani, 2009). Others consider them as entrepreneurs or producers (Karnani, 2009), or some researchers reported the involvement of customers as co-designers of BoP initiatives (London, 2007; Simanis & Hart, 2009).

As Halme et al. (2012) affirm, most literature on business model innovation and BoP is primarily focused on successful cases and examples, on how these model relate with many constraints (Anderson & Markides, 2007; Prahalad, 2006) but "research on business solutions for poverty alleviation is still in its infancy" and the need to look at how innovation processes take place in designing inclusive business models has to lead future research.

Several issues for business models and design in the BoP need to be overcome (Jagtap & Kandachar, 2010; Jagtap et al., 2014; Moe & Boks, 2010; UNDP, 2008; Hammond et al., 2007) and these can be summarised as:

<u>Market information</u>: the lack or limited information about users' needs, preferences and their capabilities in performing business activities (UNDP, 2008).

<u>Regulatory environment and governance:</u> an inappropriate or ineffective regulatory framework with lack of enforcement result to be inadequate to support business innovation (UNDP, 2008). Slow

bureaucracy and corruption at different levels also influences economic activities and hinder business growth (Moe & Boks, 2010; Jagtap & Larsson, 2013).

Physical infrastructure: infrastructure of BoP contexts can be missing or inadequate and might not be reliable for the provision of products and services. Transportation, telecommunications networks, electricity and water systems are just some of the example that affect business development (UNDP, 2008). Poor distribution channels also result in high prices for targeting these contexts (Karnani, 2005).

Knowledge and educational skills: literacy levels and the lack of skills may prevent BoP customers to understand the benefits of products and services, or to use them effectively. The lack of knowledge influences also the opportunity for them to start their own ventures or participate in business activities (UNDP, 2008; Jagtap & Larsson, 2013).

Access to finance: the lack of access to credit services, banking and insurances may limit or exclude access to products and services and results in low purchasing power of customers.

In order to overcome these challenges, the role of strategic design and business innovation for the BoP seems to be crucially relevant.

2.3.3 Design approaches for the BoP

Over the past decade researchers have been exploring the role of design for the Base of the Pyramid (dos Santos et al., 2009; Jagtap & Kandachar, 2010; Jagtap et al., 2014; Sethia, 2005; UNEP, 2009). As argued before, traditional business models and companies' approaches need to be transformed and adapted to approach the BoP and in this scenario design can play a key role to foster sustainable innovation (dos Santos et al., 2009).

Designers should understand their vital role for businesses working for the BoP market, recognising the importance of design approaches for creating appropriate business solutions (Sethia 2005). Designers can apply their capabilities as creative thinkers that can understand users' needs, facilitate communication and provide innovative solutions (Moe & Boks, 2010).

Designers who focus on BoP require not only specific approaches but also appropriate skills (dos Santos et al., 2009): to tap into users' specific – and often tacit - needs, to apply innovative approaches and business processes, to envision long-term strategies, to enable communication between consumers and companies.

Most authors affirm that design for the BoP requires different approaches in respect to design for industrialised countries (UNEP, 2008; Jagtap et al., 2014) and while some focused on the product or service design implications, others have highlighted the need to adopt a systemic perspective in order to successfully meet BoP customers.

Anderson & Markides (2007) affirm that strategic innovation in BoP contexts should follow the 4As: Affordability, by making products and services inexpensive for the poor; Acceptability, by offering solutions that are adapted to the unique needs and cultural background of the BoP; Availability, i.e. overcoming distribution and supply chain issues; Awareness, by communicating benefits of products and services and address the lack of familiarity with technology.

A similar approach is proposed by Castillo et al. (2012) who cluster four areas of design requirements, extracted from literature review and practice-based research. They group the requirements into:

- *Desirability:* projects addressing BoP markets need to show a deep understanding of the customers' context. A user-centred approach and co-creation methods are supported by several authors (Smith, 2007; Kandachar & Halme, 2008; Hart, 2008; Kandachar, et al., 2009; and IDEO, 2009), where end-users help designers to frame the problem and find appropriate solutions.
- *Feasibility:* Technological and organization requirement need to be addressed taking into consideration the previously analysed context of use. Moreover, technologies developed for developed countries need to be adapted to be suitable for the BoP market (Kandachar & Halme, 2008).
- *Viability:* the financial sustainability of the project must be taken into consideration and any solution must consider, among others, customers' willingness and ability to pay (Smith, 2007), income generation capacity and distribution systems (Larsen & Flensborg, 2011).
- *Sustainability*: designing for about 4 billion people must take into consideration the environmental and social impacts of any project for the BoP, considering each stage from design to implementation (Castillo et al., 2012). On this matter, UNEP (2009) propose an extensive guide on Design for Sustainability for developing economies.

In reviewing approaches for designing solutions at the BoP, Castillo et al. (2012) analyses the four methodologies: Design for Sustainability (D4S) (UNEP, 2009), Human Centred Design toolkit (HCD) (IDEO, 2009), BoP protocol (Simanis & Hart, 2008), and Market Creation Toolbox (BIDD, 2011).

Design for Sustainability (D4S) (UNEP, 2009) is a collection of tools and methods for product design, redesign and development and for PSS creation with a focus on sustainability requirements This include a section on renewable energy technologies and in particular on innovation tools for sustainable product design in developing countries. Several tools are suggested for the design process: sustainability SWOT, life cycle assessment, sustainability radar, system map, blueprint etc.

Human Centered Design toolkit (HCD) (IDEO, 2009) is a step-by-step guide to create e develop appropriate solutions for BoP customers. Main tools suggested in this guide aim at understanding user context (interviews, self-documentation, in context immersion, participatory co-design). For the design phase, the HCD toolkit suggests the use of personas, brainstorming, prototyping and innovation pipeline. The toolkit does not cover in specific sustainability requirements.

The *BoP Protocol* (Simanis & Hart, 2008) is an approach developed through guidelines for enterprises to focus on business co-creation with BoP customers. This guide covers tools for user research and co-design (participatory workshops, role playing, group field visits), however it does not provide specific tools for the design process, limiting the suggestions to brainstorming and prototyping techniques. Another toolkit, the *Market Creation Toolbox* (Larsen & Flensborg, 2011) aims at evaluating, implementing and prototyping business models in developing markets with a focus on understanding end-users. Some tools are suggested for the design phase of solutions: scenarios, prototyping, concept assessment. The toolkit does not include a sustainability perspective and it appears to be useful for evaluating concepts in a more advanced stage of the design process rather than supporting the idea generation of new solutions.

2.3.4 PSS in BoP contexts

Moving from product design approaches and business innovation, design research started to focus on the applications of specific types of sustainable business models, Product-Service Systems, in BoP contexts. These studies highlight how a PSS approach may overcome those identified challenges for business and design in low-income and developing contexts, and simultaneously meet sustainability requirements.

***An example of PSS in BoP contexts**: Pésinet's monitoring service for children in Mali.*
The PSS aims at reducing child mortality and improving health conditions in the region of Coura, Mali. Pésinet offers monitoring services using ICTs and mobile phones: mothers subscribe to the service paying a monthly fee, which includes weekly check-ups, medicines and doctors' consultations. A local representative weights the children twice a week and send the information via SMS to the local doctor. If necessary, the doctor schedules a visit for the child to receive treatment. The PSS involves a partnership between women from the community, local hospitals and mobile companies to provide the ICT platform (Jagtap & Larsson, 2013).

The United Nations Environment Programme (UNEP) explored the concept of PSS and its potentials in emerging contexts by arguing that *"Product-Service Systems (system innovation) may act as business opportunities to facilitate the process of socio-economic development of emerging context – by jumping over or bypassing the stage characterised by individual consumption/ownership of mass-produced goods – towards more advanced service-economy 'satisfaction-based' and low resource intensive"* (UNEP, 2002; UNEP, 2009).

Authors who explored the applications of PSS models to BoP contexts (UNEP, 2002; Moe & Boks, 2010; Schafer et al., 2011; Jagtap & Larsson, 2013; Castillo et al., 2012; Vezzoli et al., 2014) argue that these value propositions can provide eco-efficient solutions and at the same time tackle social and equity issues. Several reasons can be pointed out. PSS are focused on the context of use by establishing longer and stronger relationships with the users, involving local stakeholders and communities and thus strengthening local economies (UNEP, 2002). This can lead to the development of network enterprises and enhanced partnerships (Vezzoli et al., 2014). By being more labour and relationship intensive and shifting towards a "service economy", PSS models enable job creation and dissemination of skills (UNEP, 2002) while the provision of services such as training of product use, monitoring and after-sale services may allow unfamiliar technologies and products to penetrate these markets (Schafer et al., 2011).

PSS models can tackle the issue of affordability and low purchasing power of BoP customers. In fact, PSS models often do not require to pay the full price of a product but instead users pay to get access to it (e.g. renting models) or they pay per unit of performance delivered, therefore allowing lower-income customers to get access to otherwise unaffordable products (Tukker et al., 2006).

Other benefits that emerges from the application of PSS models in BoP markets are related to environmental sustainability aspect. Considering the links between poverty and sustainability (Jagtap et al., 2014), business strategies for the BoP need to bring environmental benefits. PSSs are appropriate because, if properly designed, they aim at reducing resources and waste, considered key factors for businesses in BoP contexts (Schafer et al., 2011). In fact, by "leapfrogging the stage of individual consumption/ownership of goods in favour of a low-tech, low resource intensive service economy" (Castillo et al., 2012) PSS solutions can trigger more sustainable behaviour in consumption and production patterns.

2.3.4.1 PSS design for BoP contexts

The literature exploring PSS and BoP provide a range of approaches, strategies and methodologies for designing these types of value propositions and support businesses and designers in overcoming the challenges for innovating in these contexts.

Jagtap and Larsson (2013), building on previous guidelines from UNDP (2008), identify a set of strategies for PSS design at the BoP:

- *Adapt products and processes*: this strategy includes redesign of products, adapting technologies to specific BoP requirements and innovating business models to provide these products.

- *Invest in removing market constraints*: this relates to capacity building, awareness and education.
- *Leverage the strengths of the poor*: this refers to including customers and communities in designing the PSS and performing business activities, using local networks of stakeholders, cooperatives etc.
- *Combine resource and capabilities*: includes collaborating and building partnerships with several actors such as local businesses, NGOs and local governments.
- *Engage in policy dialogue with governments*: this refers to the inclusion of relevant governments in discussions for appropriate regulation and policy support.

Another interesting approach discussing the design of PSS for BoP contexts is proposed by Shafer et al. (2011). In this research, they identify nine design principles that belong to identified areas of design, manufacturing, services, sales, distribution, awareness and familiarity (see Table 2.10). These principles should be adopted as guidance for the design process.

Principles for PSS design for BoP contexts
1- PSSs should search for partnerships and promotion devices to promote product awareness, product benefits, and ease consumer reluctance to adopt new technologies.
2. PSSs should explore adaptive distribution and access methods to address lack of infrastructure in sprawling rural markets, increase efficiency, and remedy customer transportation issues.
3. PSSs should disseminate prices and service schedules via public outlets to aid consumers with finance planning and to encourage consumer turnout.
4. PSSs should organize and facilitate manufacturing and sales networks of individuals or small businesses that are self- motivated in order to stimulate growth, and promote economic viability.
5. Services should be designed to make up for lack of expertise, and technological unfamiliarity in the market population.
6. The product/service mix should be designed with the cultural practices and traditions of the emerging market in mind.
7. PSSs should seek additional functionality and services that are easily integrated with existing product/service mixes to efficiently expand into new demographics.
8. PSSs should blend local practices and knowledge with modern advanced methods and technology to create viable system networks.
9. Mobile outlets should be explored as an adaptable platform that can satisfy a variety of functions, and effectively cover large areas at a fraction of the cost of traditional sales networks and with increased efficiency.

Table 2.10 - Principles for PSS design for BoP contexts, Schafer et al. (2011)

The afore-mentioned approaches mainly provide guidelines for designing PSS in BoP contexts. On the other hand, Moe & Boks (2011) explore methodologies and design tools for the design of PSS at the BoP, by combining main elements from PSS and BoP literature. This result in including some of the

PSS tools (stakeholder mapping or network analysis, value creation and focus on customers) and BoP strategies (stakeholders' involvement and co-design, avoiding business as usual). This study aimed at providing a methodological framework for PSS design in BoP contexts that stretches along five main steps for guiding designers:

1. preparation phase: definition of goals, strategies, partners and time frames.

2. contextualisation: use of qualitative research methods to understand the context, user needs and habits, and explore opportunities for innovation. Tools for this phase include interviews, storytelling, in-context immersion, SWOT analysis, Mindmaps, Personas etc.

3. concept development: design and development of concepts as well as prototyping, testing and evaluating solutions. Tools include group sketching, brainstorming, storyboards, scenario building etc.

4. implementation: selection of the most promising idea and development of the business model. Tools for this phase are blueprint, use cases, feasibility assessment, price mapping, resource flow etc.

5. managing: analyses post-consumption aspects from a sustainability perspective, by monitoring how the solution will be implemented.

The design implication for PSS in emerging economies has been discussed also by Pardo (2012) and Rapitsenyane (2014), with a particular focus on supporting SMEs in adopting PSS solutions respectively in the contexts of Colombia and Botswana.

As discussed above, the literature on design approaches for the BoP, and in particular for PSS design, presents several approaches to design solution for these contexts (see Table 2.11). However, this research area still requires efforts to develop an appropriate set of tools and methods (Moe & Boks, 2010). In particular, design approaches and tools for the BoP are general enough to be applied for different fields but do not include any specific approach for energy access or DRE. While some examples of the methodologies in practice are provided for specific sectors such as healthcare (Jagtap & Larsson, 2013; Schafer et al., 2011) or ICT (Moe & Boks, 2010), applications in the energy sector are missing. In conclusion, the literature on PSS and BoP do not exhaustively provide appropriate design approaches and tools for specific applications (i.e. energy). Therefore, new tools and methods should be developed.

Design approaches for the BoP

Tool	Author	Context of use / phase	Strengths	Weaknesses	Format
Design for Sustainability (D4S)	UNEP, 2009	A collection of tools for product design, redesign and development and for PSS creation with a focus on sustainability requirements	Includes tools for addressing sustainability requirements	Does not include tools or methods for gathering information on users/context and does not cover co-creation	Print

Human Centred Design Toolkit	IDEO, 2009	A step-by-step guide to create e develop appropriate solutions for BoP customers including co-design	Guides in all phase of the design process	Does not consider sustainability requirements	Print
BoP Protocol	Hart, 2008	An approach developed through guidelines for enterprises to focus on business co-creation with BoP customers	Focus on co-creation	Does not provide specific tools for the process or a methodology; does not include sustainability requirements	Print
Market Creation Toolbox	Larsen & Flensborg, 2011	A toolkit to evaluate, implement and prototype business models in developing markets with a focus on understanding end-users	Useful to evaluate and implement design concepts; strong focus on understanding end-users	Useful for advanced phases of the design process, not for ideation phase; does not include sustainability requirements	Print
Methodological framework for the BoP	Castillo et al. (2012)	Comprehensive methodology of 5 steps with relative tools for designing products and services and PSS	Includes sustainability perspectives; list of tools for each design phase	Does not provide suggestions or examples of the tools in use	Print

Table 2.11 - BoP toolkits reviewed for this research

Figure 2.14 - Some toolkits for designing for the BoP (image prepared by the author)

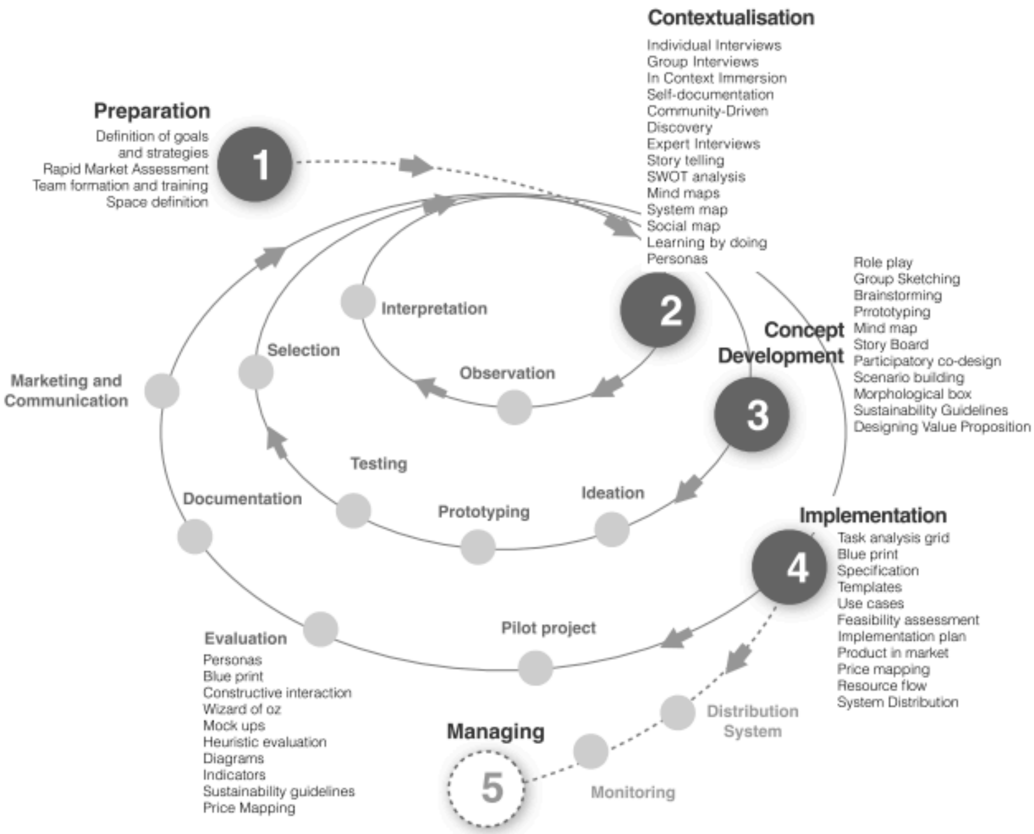


Figure 2.15 - Castillo et al. (2012) methodological framework and tools for the BoP (p. 12)

2.4 Design of Product-Service Systems applied to Distributed Renewable Energy in Base of the Pyramid contexts

The literature discussed so far presents extensive research on PSS, DRE and on design approaches for the BoP. The combination of these different models represents a promising approach for tackling the issue of sustainable development and universal energy access. Yet few studies explore the applications of PSS, DRE and their design implications. In this section we introduce the concept of energy PSSs, then the author discusses the specific applications of PSS and DRE systems and the benefits emerging from applying these models in BoP contexts. The section concludes with design implications for this discipline.

2.4.1 Energy Product-Service Systems

Since its inception, the PSS literature has explored different fields of applications, from the automotive industry to bike sharing systems, chemical management services, ICT technology etc. Recent studies have explored the applications of PSS models in the energy sector (Hamwi et al., 2016; Hannon, 2012; Hellström et al., 2015; Helms, 2016; Overholm, 2015) and particularly looking at the integration of these sustainable business models for ESCos (Energy Service Companies) in industrialised contexts (Hannon, 2012; Hamwi et al., 2016; COWI, 2008).

The choice of this specific type of business model for energy has been justified with its sustainability implications and its contribution to sustainable development (Hannon, 2012). Hannon argues that the adoption of a PSS approach for energy service companies could facilitate the transition to sustainable energy systems. In sustaining this argument, COWI (2008) presents a case study where the application of result-oriented PSSs in energy provision is proposed as a model with lower environmental impact due to the fact that the provider optimizes the energy production and consumption by choosing the most appropriate and energy-efficient technology to deliver the final result. Other examples are provided by Overholm (2015) with ventures adopting PSS models in solar PV in western economies such as the US and highlighting the sustainability benefits for customers compared to product-based business models. The application of PSSs and energy systems has been also discussed by Hamwi et al. (2016), who identify promising models for the household energy sector with the aim of reducing consumption and changing customer behaviour.

Energy PSS models appears as viable options for addressing sustainability issues such as climate change, energy security and affordability (Hannon et al., 2015), but despite these recent studies, the applications of PSSs in the energy sector and in particular looking at decentralised and distributed energy systems has been only partially investigated.

2.4.2 PSS applied to DRE in BoP contexts

In BoP markets, the importance of combining energy technologies and a comprehensive service package is required to successfully implement these solutions (Friebe et al., 2013; Schäfer et al., 2011; Terrado et al., 2008). Several studies examine the benefits of PSS models in reaching low-income and BoP customers, however few authors (Costa Junior & Diehl, 2013; Eldegwi et al., 2015; Friebe et al., 2013; Lemaire, 2009; Müller et al., 2009) have explored the combination of PSS, DRE in BoP contexts . As argued in section 2.1.5, DRE models require appropriate business models and PSSs can represent a promising approach for sustainable energy access in the BoP. In other words, *"a switch from 'providing technology' to 'providing Energy Product Service Systems' bears great chances for regional economic development"* (Schäfer et al., 2011 – p. 326).

The application of PSS models to DRE systems looks like a promising approach to deliver sustainable energy solutions in low and middle-contexts due to several potential benefits:

- ***Economic***. Most benefits of adopting DRE systems are associated with lower transmission costs for remote regions and lower energy prices in the long term (with benefits for both providers and consumers) (Lopes et al., 2007). Due to the small-scale architecture, these systems can result in great flexibility and economic resilience (Johansson et al., 2004), allowing providers to better adapt to changes in the market and in customer needs. The adoption of a PSS model increase accessibility for those customers who cannot afford the full price of DRE technologies. In fact, PSS offers do not require payment for the full value of the equipment, thus can enable low-income consumers to get access to modern electricity services without high initial costs (Friebe et al., 2013). Also, PSS models can provide great benefits in product-related services such as maintenance, after-sale services and user training and can affect the economic and technical performance of the products involved (Tukker, 2004).

- ***Environmental.*** From an environmental point of view, the use of locally available and renewable energy sources, such as the sun, wind, water, biomass and geothermal energy, results in a reduced environmental impact compared to the various processes of extraction, transformation and distribution of fossil fuels (Schillebeeckx et al., 2012). Moreover, local electricity production and distribution increase reliability and reduce failures compared to bulk electricity transmission (Lopes et al., 2007). The benefits are not only related to the choice of DRE technologies. A PSS approach can provide additional benefits because energy providers would be economically interested in optimising material and energy consumption (see also Section 2.2.4). In the case of solar technologies, for instance, the responsibility of producers concern optimising the energy production of the PV panels, the functionality of their installation and they will be responsible for about 20-year period of product life-cycle (Överholm, 2015). By retaining ownership and responsibilities of products involved in the solution, providers ensure lower environmental impact than traditional business models (Mont, 2002; Tukker, 2004, Tukker & Tischner, 2006; Friebe et al., 2013).

  Lastly, training on product use and maintenance services avoid product failures and early disposal, considered essential aspects of successful implementation of energy solutions (IEA-PVPS, 2003; Krause and Nordström, 2004).
- ***Socio-ethical.*** One of the main benefits of DRE systems is that they enable a democratisation of energy access, thus enhancing community self-sufficiency and self-governance (Chaurey et al., 2012). DRE systems are in fact relatively easy to install and manage by small economic entities such as a single individuals and/or local communities, enabling them to be no longer only consumers but also producers of the energy. Combining a PSS approach offer additional advantages because a PSS offers can be tailored to the particular (cultural and ethical) needs of customers. Also, since PSSs are labour and relationship intensive solutions, they can lead to an increase in local employment and dissemination of competences and, eventually, to strengthening the role of local economy (UNEP, 2002; Tukker et al., 2006; Bologna, 2014).

Example of PSS applied to DRE in BoP contexts:

Sunlabob provides energy service through a renting model: the company leases the charging station and energy-using products (lanterns) to a village committee who in turns rents the products to the individual households. The committee is in charge of setting prices, collecting rents and performing basic maintenance. Sunlabob retains ownership, maintenance responsibilities and offers training services. End-users can rent the recharged lantern for a small fee and it will last for 15 hours of light, while the committee pays monthly fees to lease the charging station (Gaillard & Schroeter, n.d.).

Figure 2.16 - The village committee receive training (credit: Sunlabob, retrieved from http://nexus-scu.org/energymap/sunlabob/, accessed in July 2017)

Earlier studies have focused on the applications of a specific technology, such as solar home systems, in low-income and developing countries (Eldegwi et al., 2015; Friebe et al., 2013; Müller et al., 2009) or they focused on a specific context, e.g. Brazil (Costa Junior & Diehl, 2013).

Müller et al. (2009) are the first authors to explore the applications of PSS and DRE, defined as "*microenergy systems*" (Philipp & Schafer, 2009), with a practical application for solar home systems in Tanzania. The relevance of a PSS approach is stressed to tackle the high capital costs of technologies, the need for installation, maintenance and payment structures. While Müller et al. (2009) focuses on the design and implementation of a PSS case study for the chosen context, Friebe et al. (2013) looks at exploring the different types of PSS models for solar home systems in low-income markets and at discussing policy implications.

Apart from these explorations of PSS in providing sustainable energy access in BoP contexts, research that encompasses different DRE technologies, a cross-country study and that considers design implications for these models is missing.

The main contribution to the discipline of PSS applied to DRE in BoP contexts arises from the LeNSes project (Learning Network for Sustainable energy systems - Edulink II Programme 2013-2016. See Introduction).

The LeNSes research hypothesis states that *"the Sustainable PSS offer model applied to Distributed Renewable Energy (DRE) is a win-win approach to diffuse them (DRE) in low and middle- income (all) contexts, because it reduces/cuts both the initial investment cost of hardware purchasing and the life-cycle costs of maintenance, repair, upgrade, etc. while improving local skills and rising local employment, resulting in a key leverage for a sustainable development process aiming at democratizing the access to resources, goods and services"* (Vezzoli et al., 2015).

2.4.3 Design implications for PSS applied to DRE in BoP contexts

Due to the limited and recent research on PSS applied to DRE for BoP contexts, designing these models appears as a novel discipline that require specific approaches, methods and tools.

In exploring the concept of *microenergy system,* Groh & van der Straeten (2015) stress the need to adopt a systemic perspective on designing decentralised energy solutions in developing countries. In their research, they refer to *"a broader understanding of the respective technical artefact in interrelation with its natural conditions, social context, economical system, organizational structures, and political framework".* In this context, a new role for design and new research approaches emerge. The combination of different perspectives from manufacturer, to end-users and policy perspectives (Groh & van der Straeten, 2015) needs to be taken into consideration.

The need to define design methods, tools and approaches for PSS applied to DRE emerged also within the research conducted in the LeNSes project. A definition of *System Design for Sustainable Energy for All* that encompasses PSS, DRE and BoP concepts has been proposed:

"System Design for Sustainable Energy for All (SD4SE4A), promotes a 'stakeholder configuration' approach, which means designing the interactions of the stakeholders in a particular satisfaction-system, combined with a 'system sustainability & energy for all' approach, which for economic and competitive reasons continuously seeks both socio-ethical and environmentally beneficial solutions that are powered by DREs for all" (Bacchetti et al., 2016; Vezzoli et al., 2014).

Several aspects should be considered for developing design research in the field of PSS applied to DRE in BoP contexts. This implies developing knowledge and expertise on "financing schemes, capacity building, life cycle analysis, robust design, recycling and upscaling of technical systems as well as methods of analysing users' needs […] for embedding technical solutions into service systems" (Schäfer et al., 2011).

From a design perspective, the combination of DRE, PSS and BoP design approaches requires to adopt transdisciplinary approaches and integrate the expertise of practitioners in academic research,

but it also demands an holistic and systemic perspective that encompasses the various elements to ensure successful projects (Schillebeeckx at el., 2012; Schäfer et al., 2011).
In synthesis, the design of PSS applied to DRE for BoP markets emerges as a novel and complex discipline that require further investigation for adopting appropriate design methods, approaches and tools.

2.5 Summary and conclusions of the literature review

This chapter provided a review of the current literature on the topics of DRE, PSS and design for the BoP. The combination of these models is then discussed, highlighting the need for further research in this field. In conclusion, some considerations can be made and these are summarised according to the topics: DRE (point 1), PSS (point 2), BoP (point 3) and the combination of these models, PSS+DRE in BoP (point 4 and 5).

1. A multi-dimensional approach to classify DRE system is missing

Distributed Renewable Energy has been introduced as an appropriate approach to tackle energy access in low-income and developing contexts. The DRE literature lacks a unified definition of the term and consequently a shared approach to classify DRE models. In fact, several dimensions are used by authors to describe and classify these models: *energy system, value proposition / payment structure, capital financing, ownership, organisational form, energy system operation* and *target customer.*
The most comprehensive attempts to cover design and implementation of successful DRE systems are provided by Zerriffi (2011) and Krithika & Palit (2013), who adopt a multi-dimensional approach and provide cross-country case studies to support their arguments. However, an inclusive approach that simultaneously includes all dimensions is missing.

1.2 DRE systems require appropriate business models to be successfully implemented

Barriers for DRE implementation are not primarily technological, but they are related to several factors which go beyond the technological aspect. These include the need to provide additional services, to implement suitable payment structures, to adopt an appropriate stakeholders' configuration etc. In other words, a successful implementation and diffusion of DRE models requires appropriate business models. The literature on DRE business models provides different perspectives which consider the multi-dimensional characteristics of DRE. However, these approaches do not cover environmental implications. Despite considering socio-economic sustainability, the literature on business models for DRE does not exhaustively cover the environmental aspects of choosing specific business models.

1.3 Tools and methods for designing DRE are limited

The review on approaches for designing business models for DRE discusses that the multi-dimensional characteristics of DRE systems (i.e. value proposition, organisational structure etc.) need to be considered. However, DRE literature mainly provides tools and methods that are context specific or limited to one or few dimensions (e.g. technology, capital financing). Although some interesting approaches (Wilson et al., 2012; Bellanca & Garside, 2013) adopt a multi-dimensional perspective, these lack of practical applications and do not include case studies or example on how to apply design guidelines. In addition, the majority of toolkits are structured in the form of manuals or guides and may not be suitable for supporting the generation of concepts.

2. PSS literature is mature, but lacks methods and tools for specific applications

Product-Service Systems have been introduced as sustainable business models that, if properly designed, satisfy customers' needs while seeking a positive environmental impact. PSS literature provides a widely accepted classification for these models, which appears to be general enough to be applied to various domains.

The review of tools and methodologies for designing sustainable PSSs highlighted that PSS literature is quite mature and it provides an extensive range of approaches. Available tools cover different phases of the design process, from the strategic analysis to the ideation and visualisation phase. These approaches appear to be too generic for specific applications, such as the DRE field. In fact, considering the complexity of DRE systems and the several dimensions that need to be considered, PSS tools are not appropriate.

3. Design approaches for the BoP are limited

The third section of this literature explores design approaches for the BoP. Particular attention has been placed on PSS approaches for BoP contexts and on design requirements for solutions in these contexts. However, this research area still requires efforts to develop an appropriate set of tools and methods. Design approaches and tools for PSS in the BoP are general enough to be applied for different fields but do not include any specific approach for energy access or DRE. In conclusion, new tools and methods should be developed to design energy PSS in the BoP.

4. The combination of PSS+DRE in BoP contexts presents limited academic research

The applications of PSS and DRE in BoP markets is presented as a promising approach to tackle energy poverty and sustainable development. Recent studies have partially explored these models, mainly focusing on specific technologies or selected contexts of application. A cross-country and cross-technology approach is missing. Further research is necessary to explore the practical applications of PSS and DRE and how these models can be described, classified and consequently designed.

4.1 Characteristics of PSS+DRE have not been explored

Both DRE and PSS literature consider several dimensions to describe these models, however their combination requires a novel approach. In fact, the dimensions used to describe PSSs (e.g. value proposition, product ownership) are too generic to be applied to DRE systems and do not exhaustively cover all their characteristics. In order to describe PSS+DRE models it is necessary to define their characterising dimensions.

4.2 A classification system for PSS+DRE is required

While DRE literature does not agree on a shared classification for these models, academic research on PSS proposes a widely adopted classification which is generic and, because of this reason, applicable to various domains. However, as previously discussed, combining PSS and DRE requires the identification of characterising dimensions of PSS+DRE, therefore the PSS classification does not appear to be appropriate to exhaustively cover DRE characteristics. Thus, a new classification system for PSS+DRE is necessary.

4.3 Applications of PSS+DRE in BoP contexts have not been exhaustively explored

Another gap in the knowledge is related to the practical applications and examples of PSS+DRE in BoP contexts. Further research should explore the applications of these models, spanning from various technologies to different contexts of implementation. The aim is to define their characteristics and their successful factors.

4.4 Critical factors of PSS+DRE in BoP contexts have not been identified

A more thorough investigation needs to examine what critical factors influence a successful implementation of PSS+DRE in low-income and developing contexts. In other words, it is necessary to explore which characteristics influence the success or failure of specific models, what factors need to be considered, which practical examples can be used to support the designing of these models.

5. Appropriate methods and tools are needed to support the design of PSS applied to DRE in BoP contexts

The literature on methods and tools for DRE, PSS and design for the BoP highlighted a shortcoming of tools that encompasses characteristics of all these models altogether. In fact, due to the complexity of DRE models and to the specific requirements of BoP contexts, existing PSS tools do not seem appropriate. Specific tools and methods for designing PSS+DRE models in BoP contexts are required.

The following chapter describes the methodology adopted in this research and how this PhD intends to cover the identified gaps in the knowledge.

Chapter 3

Research methodology

3. Research methodology

This chapter presents a roadmap for this research, providing the researcher's philosophical stance and explaining the rationale behind selected research strategy, methodology and methods adopted in this PhD.

3.1 Introduction: elements of a research design

Research, in its most general meaning, can be defined as "*systematic enquiry whose goal is communicable knowledge*" (Archer, 1995). This chapter describes how the *enquiry* seeks to find answers to the research questions, in a *systematic* way because it has been carried out according to a specific plan or methodology. The aim of this enquiry is to discuss how findings and *knowledge* are *communicated* to the design research field.

According to Crotty (1998), the research process is composed by four main elements:

- *Methods*: the techniques or procedures used to gather and analyse data related to some research question and hypothesis.
- *Methodology*: the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes.
- *Theoretical perspective*: the philosophical stance informing the methodology and thus providing a context for the process and grounding its logic and criteria.
- *Epistemology*: the theory of knowledge embedded in the theoretical perspective and thereby in the methodology.

These elements are interconnected with each other (Fig. 3.1): the epistemological stance informs how the researcher approaches the world with a set of ideas and provides a philosophical approach for the research, which is then carried out adopting a specific methodology and data collection (Denzin & Lincoln, 2003).

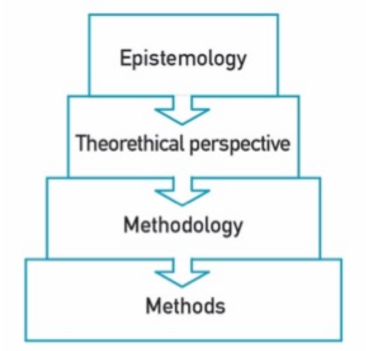


Figure 3.1 - Four elements of the design process, Crotty (1998)

This chapter discusses the elements of the research applied in this PhD by reviewing approaches and providing justification behind the choices of methodologies and methods adopted.
In order to define a research methodology for this PhD, the main elements of the research process identified by Crotty (1998) have been analysed to detail different strategies and approaches (Fig. 3.2). The chapter is structured as follows: first the research paradigm (epistemology and theoretical perspective) is discussed; then the research approach and purpose are considered, providing a basis for the research strategy chosen for this investigation. In Section 3.6 a methodological framework is chosen to structure the phases of this enquiry, followed by a discussion of methods applied. The phases of this research are then described according to the different research outputs (i.e. the three developed design tools: PSS+DRE Innovation Map, PSS+DRE Design Framework and Cards, and PSS+DRE Visualisation System).

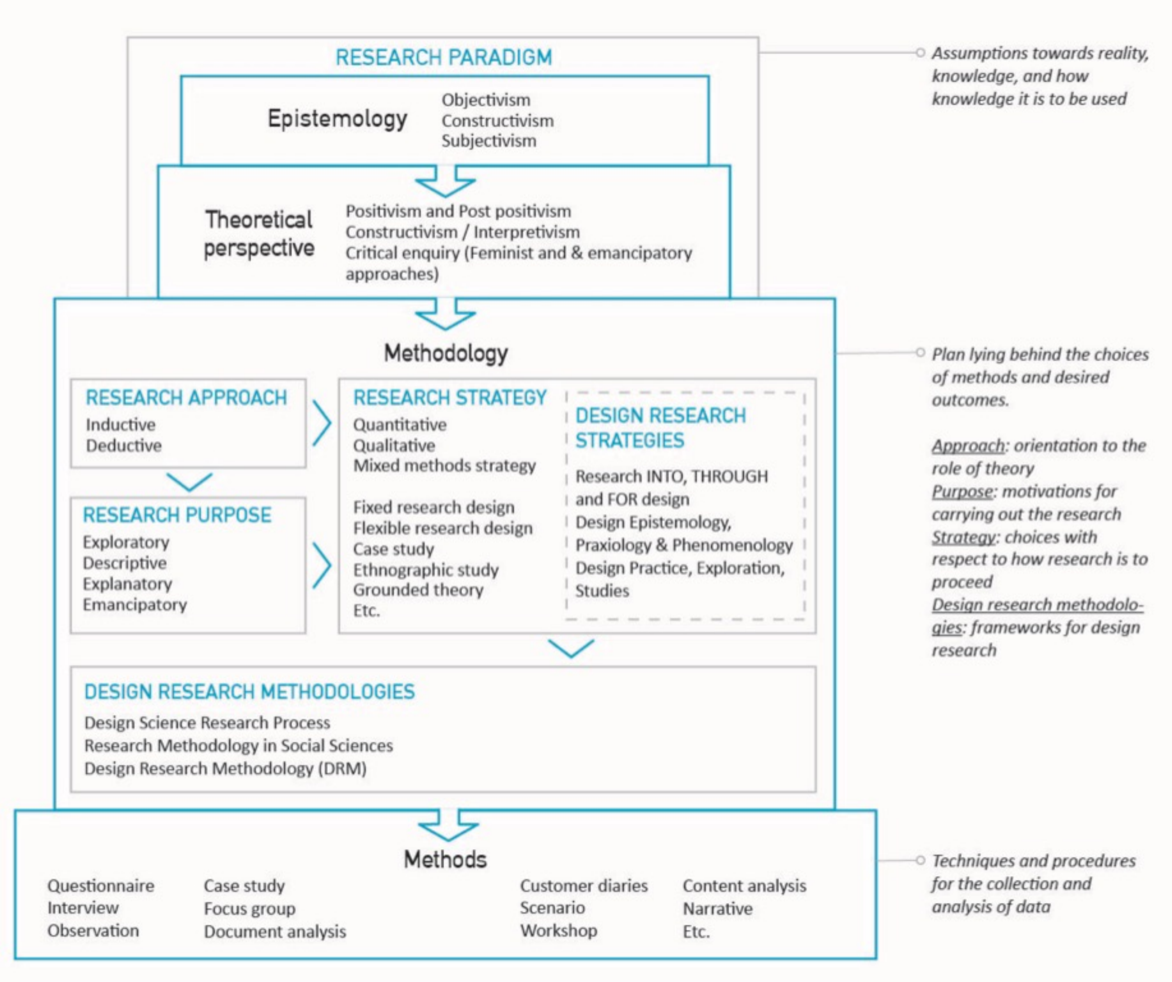


Figure 3.2 - Elements of the design process, adapted from Crotty (1998), Robson (2002), Denzin & Lincoln (2003), Creswell (2009)

3.2 Research paradigm

The research paradigm reflects the epistemology and theoretical perspective, i.e. the assumptions adopted towards truth, reality and knowledge. A description of the research paradigm provides information on how knowledge emerging from the research is to be used. In particular, the epistemological stance influences the research in terms of *what it means to know,* and provides a philosophical base for the research (Gray, 2004). This philosophical worldview is basically "a set of beliefs that guide action" (Guba, 1990 p. 17). To describe the same concept, other authors have referred to paradigms (Lincoln & Guba 2000), epistemologies and ontologies (Crotty, 1998).

In Crotty's words, "epistemology is concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate" (Crotty, 1998). Three epistemological stances can be distinguished (Table 3.1): objectivism, constructivism and subjectivism. In *objectivist* epistemology, an object carries an inherent meaning and researchers seek to "discover the objective truth" (Crotty, 1998). This means that the researcher does not influence the phenomenon he or she is investigating on. On the other side, *constructionism* refuses the existence of an objective truth and holds that meaning is deeply influenced by humans' interactions with reality. In this epistemological stance meaning is not discovered but the researcher is part of the phenomenon under discussion and therefore different people can interpret the same phenomenon each in one's own way. *Subjectivism* holds that meaning is not constructed by the interaction with an object (such as constructivism), but it is "imposed on the object by the subject" (Crotty, 1998).

Among most diffused theoretical perspectives there is positivism, interpretivism and other stances such as critical enquiry, postmodernism and feminism (Gray, 2014). Positivism's core argument is that the inquiry should be based on scientific observation and it is usually linked with quantitative research strategies. On the other side, interpretivism is often linked with constructivism and qualitative research and it is based on the assumption that the social world is inherently different than the natural world, hence it requires a different logic of research. Critical enquiry offers another perspective, affirming that "what a person knows is determined by their social position" (Gray, 2014) and that certain groups in society are privileged over others, adopting uncritical stances towards the phenomenon they explore. In adopting a critical enquiry perspective, the researcher aims at not just interpreting the world but also to change it.

RESEARCH PARADIGM		
Epistemology		**Theoretical perspective**
Objectivism	An objective reality exists independently of consciousness	Positivism / Post-positivism
Constructivism	Reality is constructed by the subject's interactions with the world	Constructivism / Interpretivism
Subjectivism	Reality is imposed by the subject on the world	Critical enquiry Feminism Postmodernism Neo-Marxism etc.

Table 3.1 - Epistemological stances and theoretical perspectives, adapted from Robson (2002) and Gray (2004)

This research follows a constructionist epistemological position and an interpretivist theoretical perspective. This paradigm is the most appropriate as the focus is on a complex reality that requires multiple qualitative methods to acquire understanding of the world. In fact, this PhD explores the links between Product-Service Systems (PSS) and Distributed Renewable Energy (DRE), looking at their applications in Base of the Pyramid (Bop) contexts. As discussed in the previous chapters, providing energy services in low-income and developing contexts requires the interplay of multiple factors, i.e. business models, customers, stakeholders, enabling environment etc. The focus of this research represents a complex reality where different elements appear under scrutiny: the stakeholders involved in providing these solutions, the types of PSSs, the different technologies involved, the contexts of implementation etc. In addition, this research aims at translating the acquired knowledge on PSS and DRE in a support for practitioners, therefore it involves the researcher 'constructing meaning' through the understanding of processes. According to Feast & Melles (2010), a constructionist position in design research involves gaining "knowledge through making and reflecting upon the making of artifacts, and through using and reflecting upon the use of those artifacts". This is particularly relevant for this research, which aims at building knowledge through the development and testing of design tools (artifacts). A constructionist stance is also relevant in the choice of research strategy and methods adopted (see 3.5 and 3.6.2) and it is especially dominant in the iterative process of tools development and testing.

3.3 Research approach

Having defined the research paradigm, it is important to define the approach on how theory is to be used in the research process. Research approaches can be classified as inductive or deductive. Inductive research provides theory as an outcome (Bryman 2012), meaning that observations and findings are used to draw conclusions and build theory. An inductive approach is used mostly in qualitative researches where the emphasis is on building theory. With an inductive approach data collection and analysis set the basis for the identification of patterns, relationships and the formulation of theories (Gray, 2014). On the other hand, a deductive approach starts with theory to formulate hypothesis, which are then empirically tested to be confirmed or refused. However this process may not necessarily follow a linear or clear sequence (Bryman, 2016). In fact, the revision of theory, which should conclude a deductive study, may involve an inductive phase where the researcher discusses the implication of his or her findings against the initial reference model.

The purpose of an enquiry may also be considered *complementary*, meaning that both inductive and deductive methods can be applied in a research strategy and should be seen more as 'tendencies' rather than distinctive approaches (Bryman, 2016; Gray, 2014).

In this research, a combination of both research approaches is adopted. This choice is justified by the different types of research questions addressed in this investigation (see Section 1.4). In order to answer RQ 1 (What are the characteristics and applications of PSS+DRE in BoP contexts?), the process followed an inductive approach that aimed at building a theory on PSS applied to DRE models. Data have been collected to discover PSS+DRE applications in BoP contexts, their characteristics and their critical factors. These data have been analysed and used to build a classification system of PSS+DRE models, to describe their archetypal models, to develop a design framework and to collect guidelines for designing these models. In other words, the knowledge acquired in the first phase of this research has been used to develop theory on PSS+DRE in BoP contexts. In a second phase, RQ 2 (How companies and practitioners might be supported in designing PSS+DRE in the BoP?) aimed at translating the developed theory in supporting tools for practitioners. Some hypotheses were made about how these tools can support companies and practitioners in designing PSS+DRE models. These hypotheses were then tested through a series of empirical experiments. This phase of the research has been driven by a deductive reasoning, which aimed at evaluating the design tools in terms of usability, effectiveness and usefulness. The relationships between Research Questions and approach chosen are illustrated in Fig. 3.3.

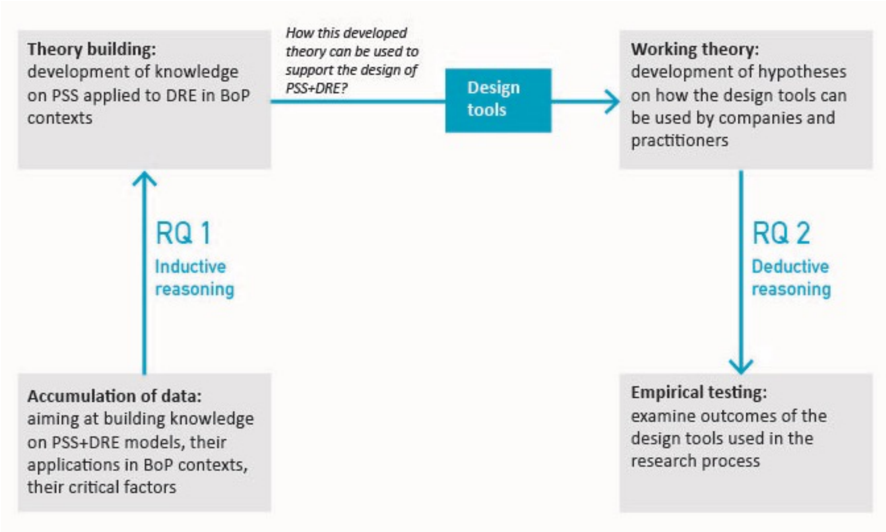


Figure 3.3 - Combination of inductive and deductive approaches in this research, based on Gray (2014)

3.4 Research purpose

The research purpose clarifies what the research is intended to find out and shapes the type of outcome the researcher wants to provide. Three types of research purposes can be outlined (Robson, 2002): exploratory – adopted for little understood phenomenon to find out what is happening, generate ideas and hypothesis for future research; descriptive – carried out to extend existing knowledge regarding a specific phenomenon, situations or people and portray a more accurate description; explanatory – to investigate the relationships among elements within a researched phenomenon. Table 3.2 summarises these different approaches.

In this PhD, the research purpose can be defined as exploratory. This is related to the topic of investigation, Product-Service Systems applied to Distributed Renewable Energy in BoP contexts. As previously highlighted in the literature review chapter, few studies have explored the combination of these models and a there is lack of knowledge about what models have been applied, what are their characteristics and how can they be successfully designed. Exploratory research applies best when there has been little or none previous investigation (Robson, 2011) and it is often linked with qualitative research strategies. The purpose of this research is therefore to *explore* the applications of Product-Service Systems (PSS) to Distributed Renewable Energy (DRE in Base of the Pyramid (BoP) contexts, to identify their characteristics and critical factors and translate those for supporting companies and practitioners in designing these models.

Exploratory	- To find out what is happening, particularly in little understood situations - To seek new insights - To ask questions - To assess phenomena in a new light - To generate ideas and hypotheses for future research - Almost exclusively of flexible design

Descriptive	- To portray an accurate profile or persons, events or situations - Requires extensive previous knowledge of the situation to be researched or described - May be of flexible and/or fixed design
Explanatory	- Seek an explanation of a situation or a problem, traditionally but not necessarily in the form of casual relationship - To explain patterns relating to the phenomenon being researched - To identify relationships between aspects of the phenomenon - May be of flexible and/or fixed design

Table 3.2 - Classification of the purpose of enquiry, from Robson (2002)

3.5 Research strategy

The research strategy can be defined as the "type or model that provides specific directions for the procedures in a research design" (Creswell, 2009). A popular distinction among research strategies is to classify the type of enquiry in qualitative or quantitative (Creswell, 2013; Bryman, 2016).

A qualitative enquiry "is a situated activity that locates the observer in the world. Qualitative research consists of a set of interpretive, material practices that make the world visible" (Creswell 2013). Qualitative research appears to be the most appropriate research type when the issue is complex, when the researcher aims at explaining mechanisms and links and with the overall objective of developing theories and concepts or hypothesis are developed and refined in the process of research (Flick, 2007). Qualitative strategy is in fact usually associated with inductive processes and usually implies the use of multiple methods to gather a deep understanding of the phenomenon under enquiry (Creswell 2013). On the other hand, quantitative research usually focuses on testing existing theory and it can be defined as "a strategy that emphasises quantification in the collection and analysis of data" (Bryman, 2012).

In the book *Real World Research*, Robson (2002) distinguishes between fixed and flexible research strategies, associating the first with quantitative data collection and descriptive studies and the latter with qualitative investigations. The main difference between the two is whether the research design is pre-determined before the data collection stage (Robson, 2002). A fixed design research strategy focuses on outcomes while a flexible design is more appropriate where the focus is on processes and the research has an exploratory purpose.

Case study	Development of detailed, intensive knowledge about a single case or a number of related cases. An empirical enquiry that investigates a contemporary phenomenon with its real-life context using multiple sources of evidence.

Ethnography	Seek to capture, interpret and explain how a group, organisation or community lives, experiences and makes sense. Explores the nature of a social phenomenon by making reports of events and often uses participant observation.
Grounded theory	Aims at generating theory from data collected during the study. Particularly useful in new, applied areas where there is lack of theory. Theory emerges from empirical data, with a systematic and inductive approach.
Action research	Aims at investing complex, real-life problems and it is characterised by iterative and reflective process and by a close collaboration between researcher and practitioners. It is usually carried out through participatory processes.

Table 3.3 - Traditional research strategies, compiled from Robson (2002), Gray (2014), Yin (1994)

Some of the traditional research strategies have been reviewed for this PhD (Table 3.3). Case study research is suitable for exploratory studies where detailed data is collected through different methods (Creswell, 1994). Case studies can also be considered a research method. An example is when a grounded theory strategy is adopted and case studies are used as a method to build theory. In this PhD, this approach is applied (see 3.6.2).

Grounded Theory is an approach for developing theory that is "grounded in data systematically gathered and analysed" (Strauss & Corbin, 1994). In other words, researchers develop theory from the data they collect through an inductive approach. Grounded theory characterises the first part of this research, which aims at building theory on PSS+DRE models (see 3.6.5).

Another strategy is Action Research, which “involves close collaboration between researcher and practitioners” (Gray, 2014) and it mostly applies to the investigation of complex social phenomena.

Qualitative and quantitative research should not be seen as polar opposites (Creswell, 2009), instead different strategies can be chosen within one research design (Gray, 2014). This approach is defined as *mixed methods research* strategy (Bryman, 2016; Creswell, 2009) or *multiple designs* (Robson, 2002). The aim of integrating two strategies can be justified to provide support to each other, to solve the problem of generalizability, to discuss and validate findings, or to provide a more general picture of the issue under study (Bryman, 1992; Creswell, 2009).

The research for this PhD can be defined primarily a qualitative investigation. However a mixed methods strategy has been adopted in some phases of the research, in particular in the second part of the research. As discussed in Section 3.3, in order to answer the different research questions, different approaches have been chosen. Creswell (2009) distinguishes between:

- *sequential strategy*, which involves a first phase of qualitative data collection and analysis, followed by a second phase of quantitative data collection and analysis that builds on the results of the first phase;

- *concurrent strategy*, where the researcher collects both quantitative and qualitative data concurrently and then compares the two databases to determine if there's convergence, differences or combination.

Similarly, Gray (2014), building on previous work from Rossman & Wilson (1985), differentiates between three different school of thought regarding mixed methods research strategies (Fig. 3.4).
This research falls under the pragmatist approach, or concurrent strategy, which integrates both qualitative and quantitative methods within a single study and making use of the strengths of both. Several reasons can be listed to justify the mix of strategies: to gain broader perspectives on the problem researched; to assess the different research questions; to arrive to a more comprehensive and complete account of the enquiry; and to enhance credibility and integrity of findings.

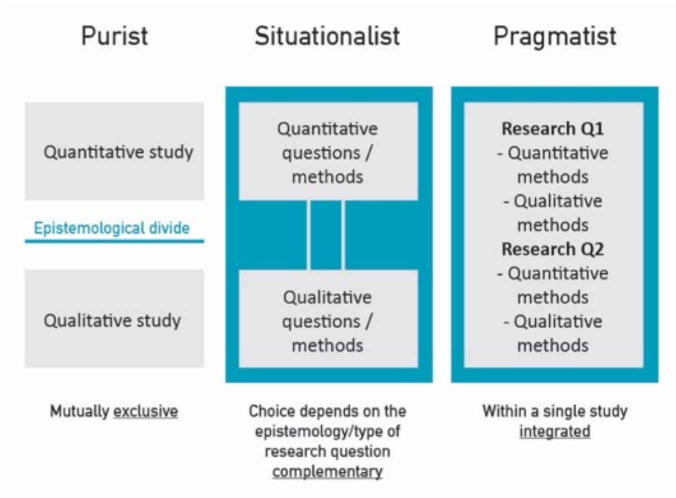


Figure 3.4 - Mixed methods research strategy, Gray (2014) adapted from Rossman & Wilson (1985)

Table 3.5 illustrates how the different approaches and strategies are combined in this research and provides a general research process that illustrates the activities undertaken to answer the Research Questions. In order to answer RQ 1 a qualitative strategy has been applied, adopting an inductive approach. The activities carried out to meet the objectives of RQ 1 are: reviewing literature about models of PSS applied to DRE in order to identify their characterising dimensions; identification of critical factors for PSS+DRE models; collection of applied examples (i.e. case studies) of PSS+DRE in BoP contexts; development of a classification system for PSS+DRE and its population with case studies, leading to the identification of archetypal models.
The knowledge produced in the first phase has been used to carry out a second stage of the research, aimed at answering RQ 2. Here the dimensions of PSS+DRE, the identified critical factors have been translated in tools for designing PSS applied to DRE. This results in the Sustainable Energy for All Design toolkit: the Innovation Map, the Design Framework and Cards and the Visualisation System. This part of the research adopted a mixed methods concurrent strategy which aimed at testing and

evaluating the tools by using simultaneously quantitative and qualitative data collections (see Section 3.6.3 for details about the methods selected).

3.5.1 Design research strategies

The above described research strategies have been adopted from the field of social sciences and have been used to frame this research in a general way. However, it is worth to review some approaches from the design field which can be used to better provide a framework for this research.
A popular approach is provided by Frayling (1993), who distinguishes between research *into* (art and) design, research *through* (art and) design and research *for* (art and) design. Research *into* design includes historical research, aesthetic or perceptual research, involving pure theoretical investigations. Research *through* (art and) design consists of both developing new artefacts or methods and understanding the process of design. Design becomes the vehicle for research and for communicating results. For example, this is the case of action research, where research reports communicate about the design process itself. Lastly, research *for* design where "the product is an artefact – where the thinking is embodied in the artefact" meaning that the "artefact" communicates new knowledge, for example a tool produced for designers to use it.
Cross (1999) propose a design research taxonomy that divides in:

- *design epistemology:* it concerns people, i.e. it studies ways of practicing and learning about design;
- *design praxeology:* it concerns processes, i.e. it studies methodologies, tactics and strategies of design in order to develop techniques to aid the designer;
- *design phenomenology:* it concerns products, i.e. it studies forms and characteristics of design artefacts.

Another popular framework for design research is proposed by Fallman (2008), who focuses in particular on interaction design, positioning it in between three extreme areas: *design practice* (design & industry), *design studies* (design & academia) and *design exploration* (design & society). Design practice is aligned with commercial and industry design activities and the researcher works with explicit research questions in mind. Design studies concern the academic discipline and aims at contributing to the body of knowledge, typically about design theory, methodology or history. Design exploration adopts a critical and subversive approach, integrating the 'what if?' question within the design process and aims at testing ideas and provoking the foundations of design.
In light of these reviewed design strategies, this PhD can be framed as follows (Table 3.4): it involves a research *for* design because it concerns the creation of design tools as artefacts that embodies the knowledge produced on PSS applied to DRE. This strategy is particularly adopted in the second part of the research (see Table 3.5). Simultaneously, this research investigates on the process of idea

generation with the design tools, in other world it can be defined as research *through* design. The artefacts (tools) can be considered instruments of the design enquiry (Keyson & Bruns, 2009) and they have been developed through the several interactions with users (companies and practitioners). Considering Cross (1999) classification, this research falls under the *design praxeology* category because it involves the development of tools and methods that aim at supporting the design process of PSS applied to DRE. Lastly, this PhD can be defined as a mix of *design practice* and *design studies,* because it focuses on the development of tools to support industry and practitioners but also at contributing to the academic knowledge about PSS and DRE and their design methodology. While the first part of the research can be clearly categorised as design studies, the second part of tools development and testing combines design practice with design studies, focusing both on the practical applications of the outcomes of this enquiry, i.e. the design tools, and enriching the design methodology for the selected discipline.

Reviewed design research strategies		Strategies adopted in this PhD
Frayling (1993)	Research into design Research through design Research for design	Research for design Research through design
Cross (1999)	Design epistemology Design praxeology Design phenomenology	Design praxeology
Fallman (2008)	Design practice Design studies Design exploration	Design practice + design studies

Table 3.4 - Design strategies reviewed and adopted in this research

Research question		Research objectives	Research approach	Reseach purpose	Research strategy	Activities
RQ1	**What are the characteristics and applications of PSS applied to DRE in BoP contexts?** 1.1 What are the characteristics of PSS applied to DRE? 1.2 How can these models be classified? 1.3 What are the applications of these models in BoP contexts? 1.4 What are the critical factors to successfully implement these models?	A To review literature on DRE systems, PSS, design approaches for the BoP and to explore the combination of these models, identifying their characteristics. B To develop a classification system for PSS+DRE models. C To investigate the applications of PSS and DRE in BoP contexts, identifying characteristics of these models. D To identify critical factors for designing PSS and DRE	Inductive	Exploratory	Flexible design: grounded theory Qualitative **Design strategies:** -Research *for* design - Design studies	Review of models A Case study research C Identification of dimensions of PSS+DRE A Development of a classification system of PSS+DRE and identification of archetypal models B Review of critical factors for the identified dimensions of PSS+DRE D
RQ2	**How companies and practitioners might be supported in designing PSS applied DRE for BoP contexts?** 2.1 How can the identified critical factors and successful cases be translated to support the design of PSS+DRE? 2.2 What tools can be developed for designing these models?	E To review existing design approaches and tools for PSS, DRE and design for the BoP and to understand how these are applied by the research recipients (companies and practitioners) F To translate the outcomes of the primary studies in supports for companies, practitioners and designers. G To evaluate the outcomes of this research through a series of iterative testing activities, involving a wide range of stakeholders from different contexts and fields of expertise. H To discuss implications of this research for the field of PSS and DRE, providing guidelines for different types of recipients (e.g. SMEs, NGOs).	Deductive	Exploratory	Flexible design Mixed methods concurrent strategy: qualitative + quantitative **Design strategies:** - Research *for* and *through* design - Design praxeology - Design studies + practice	Review of tools and approaches for PSS, DRE and design for the BoP. Study on DRE companies and practitioners. E Development of Innovation Map, Design Framework & Cards, Visualisation System F Design tools → Test → Refine G Discussions and conclusions H

Table 3.5 - Relationships between research questions, approach, purpose and strategies for this research

3.6 Research methodology

Due to the complexity of this research and the number of strategies adopted and activities planned, a design research methodology framework needed to be adopted in order to provide a formal structure to the investigation.

A number of methodologies from social sciences and design have been reviewed in order to adopt an appropriate methodology for this research, including: Design Science Research Process (Peffers et al., 2006), the Design Cycle (Takeda et al., 1990), Research Methodology in Social Sciences (Robson, 2003) and the Design Research Methodology (DRM) proposed by Blessing and Chakrabarti (2009).

The latter methodology, DRM, is widely accepted and it has been adopted by various design researchers (Ahmed, 2000; Dong, 2004; Cardoso, 2005; Gupta, 2007, Cifter, 2011; Nickpour, 2012; Wang, 2015) and was found to be the most suitable model for this research. The reason behind this choice is that DRM adapts well to this type of research, which focuses on the development of a *design support* and it provides a systematic approach that helps in clarifying objectives and outputs of each stage. Moreover, the DRM helped in reflecting on the process of design and its several iterations, providing a focus for each stage and developing an effective plan for the evaluation activities.

DRM consists of four main stages (Fig. 3.5): Research Clarification, Descriptive Study I (DS-I), Prescriptive Study (PS) and Descriptive Study II (DS-II) (Blessing et al. 1995; Blessing & Chakrabarti, 2009).

Research Clarification

The main objectives of this stage are the identification of research goals, questions and hypotheses and the formulation of an overall research plan. In particular, this phase aims at developing a picture of the existing situation, i.e. the area of investigation also referred as *Initial Reference Model* which "is the reference against which the intended improvements are benchmarked" (Blessing & Chakrabarti, 2009). The Research Clarification stage should provide a clear focus for the other stages: it identifies criteria for carrying out the DS-I, for developing the support in PS; it provides guidelines for evaluating the support in DS-II, according to the research goals. The research plan resulting from this stage includes the definition of research approach, type and methods, the expected contributions and a time schedule for the project.

Descriptive Study I (DS-I)

This stage aims at gaining a deeper understanding of the phenomenon under investigation. The objectives of DS-I are: to gain a better understanding of the existing situation; to provide the basis for the PS stage and how the support will be developed; to provide insights on how the support will be evaluated in DS-II. Depending on the research questions, the DS-I may be limited to a detailed literature review or also involve empirical studies (Comprehensive DS-I).

Prescriptive Study I (PS-I)

In this stage, the researcher intends to develop a *design support* to be used to address a specific need or problem of the existing situation described in RC and DS-I. It is important to have defined by this stage the view of the researcher about the role of the support, how this is going to be evaluated and how it is going to influence the Initial Reference Model. The objectives of this stage are: to use the results of DS-I to develop an *Intended Support;* to describe how the support is intended to be used; to develop a plan for its evaluation in DS-II.

Descriptive Study II (DS-II)

This stage is focused on the evaluation of the support. Blessing & Chakrabarti (2009) distinguish between two different types of evaluation: the *Application Evaluation,* which aims at testing the usability and applicability of the design support, i.e. whether the intended user understand how to apply the developed support; the *Success Evaluation* aims at identifying whether the support has the expected impact, i.e. its usefulness. This stage involves empirical studies and aims at evaluating whether the introduction of the support improves the existing situation (Initial Reference Model).

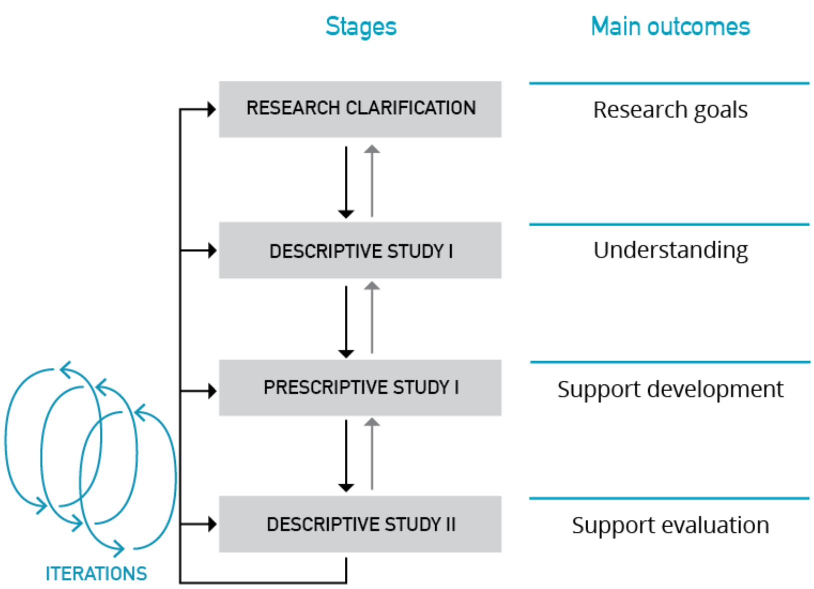


Figure 3.5 - DRM main stages, adapted from Blessing & Chackrabarti (2009)

3.6.1 Design Research Methodology applied for this research

The DRM has been adopted for this research to provide a framework for distinguishing outcomes and activities of each study and to provide a structure for the several iterations of tools' development and testing. Similarly to most design and research processes, the methodology of this PhD does not follow a rigid and linear path, but instead its main stages have been expanded to adapt to the several iterations and variations of the research (Fig. 3.6). The different stages of the tools' design and testing have followed a series of Prescriptive (support[8] development) and Descriptive (support evaluation) studies.

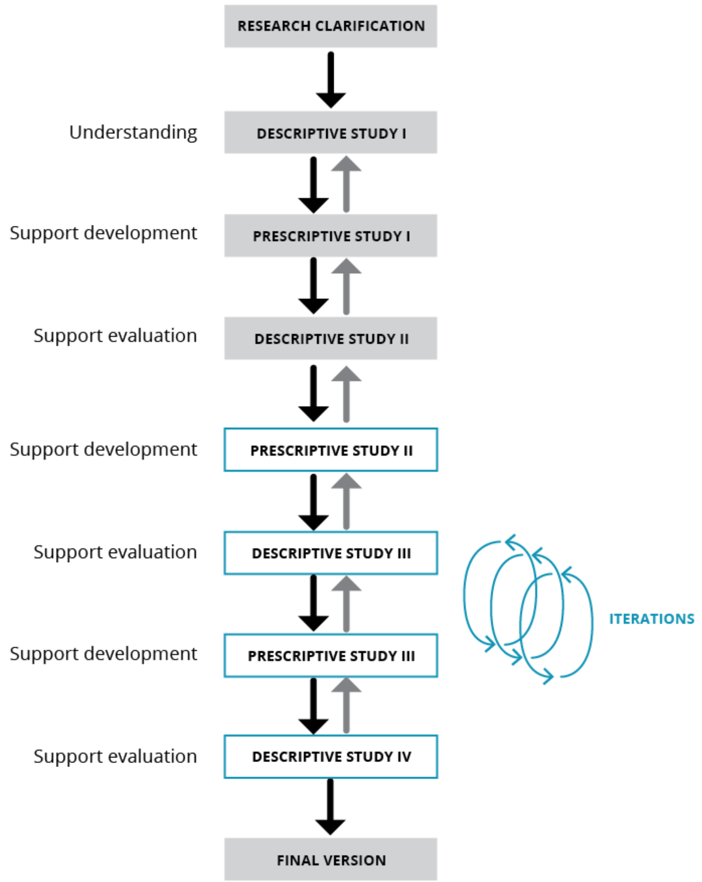


Figure 3.6 - DRM adapted for this research

3.6.1.1 Iterations and variations

Iterations can occur between different stages or within one stage (Blessing & Chakrabarti, 2009). An example of in-between-stages iteration took place while developing the support in PS-I. During the tools development, it became clear that additional information was needed to cover certain aspects of the context in which the supports should be implemented. On one side, a review of design tools for PSS and DRE design was necessary to benchmark the developed support. In addition, a study on the recipients of this research was carried out to investigate about knowledge and capabilities of companies involved in the renewable energy sector. This study was necessary to understand how companies designed their business model, who was involved in the process and what tools they used in the design process. These translated respectively in a literature review of tools and in semi-structure interviews and questionnaires with SMEs. So, while the first version of the support was developed and tested, these complementary primary studies took place to provide a better

[8] In this thesis the term *support* refers to the design tools and it is used interchangeably.

understanding of the support in use and to better plan its evaluation. These activities are described in Chapter 4 - Primary studies.

On the other side, an example of iteration within one stage can be found in PS-III where the Design Framework & Cards version 1.0 have been developed and evaluated within one stage. Once the new version of the tool was designed, an empirical study with designers at Brunel University was organised to evaluate the tool's usability and ease of use. This iteration was necessary to improve some aspects of the tool and to prepare a refined version (1.1) that would be used with companies and practitioners. These activities are described in Chapter 6.

Phases and organisation of this research

In order to simplify the organisation and readability of this thesis, the order of different DRM studies is not used as primary structure. Instead, the thesis is arranged according to the main outputs of the research (Primary Studies, PSS+DRE Innovation Map, PSS+DRE Design Framework and Cards, PSS+DRE Visualisation System). As anticipated in the Introduction, the thesis is structured as follows:

- Chapter 4 will describe the Descriptive Study-I, i.e. the primary studies undertaken and how these have been used for the tools' development;
- Chapter 5 will focus on the Innovation Map tool and its relative development and refinement stages;
- Chapter 6 is about the Design Framework and Cards;
- Chapter 7 describes the development and testing of the Visualisation System.

Fig. 3.7 shows the different stages and corresponding outcomes while Fig. 3.8 presents the same information organised according the corresponding tool.

The methods used in each study are briefly explained in the following sections. However, a detailed description including sampling, validity and reliability of each study is provided in the dedicated chapter.

Research Question	Stages	Activities	Research methods	Outcomes
	RESEARCH CLARIFICATION	Review on PSS, DRE, BoP design approaches	Literature review	- Description of the actual situation - Gaps in the knowledge - Description of the desired situation - Research goals - Research methodology
Research Question 1	DESCRIPTIVE STUDY I	PSS+DRE dimensions and classification system	Theory-building approach	UNDERSTANDING - Identification of PSS+DRE dimensions - Collection of PSS+DRE cases - Development of a classification system for PSS+DRE and identification of Archetypal Models - Collection of critical factors for designing PSS+DRE models - Understanding about the research target users: DRE companies and practitioners
		Research of examples of PSS applied to DRE in BoP contexts	Case studies collection	
		Review of PSS+DRE critical factors	Literature review	
		Study on DRE companies and practitioners	Semi-structured interviews and questionnaires	
Research Question 2	PRESCRIPTIVE STUDY I	Development of Innovation Map 0.1		SUPPORT Design of supporting tools to understand PSS+DRE offers, mapping companies and competitors, generating new concepts, detailing and visualising solutions.
		Development of Design Framework & Cards 0.1		
		Development of visualisation system 0.1 and 1.0		
	DESCRIPTIVE STUDY II	Pilot testing with design students. Evaluation with companies, practitioners and experts in Botswana and South Africa.	Workshop Observation Questionnaires	EVALUATION Evaluation of the tools in terms of ease of use, usefuleness. Evaluation of the Innovation Map in terms of completeness.
		Pilot testing with design students, energy experts and designers in Botswana and South Africa.	Workshop Observation Questionnaires	
		Evaluation with companies and practitioners in Kenya. Evaluation with designers in UK.	Workshop Observation Questionnaires	
	PRESCRIPTIVE STUDY II	Development of Innovation Map 1.0		SUPPORT Improvement and additional features of tools.
		Development of Design Framework & Cards 0.2		
		Development of visualisation system 1.0		
	DESCRIPTIVE STUDY III	Evaluation with companies and practitioners in South Africa and Kenya.	Workshop Observation Questionnaires	EVALUATION Evaluation of the tools in terms of ease of use, usefuleness and completeness.
		Evaluation with companies and practitioners in South Africa and Kenya.	Workshop Observation Questionnaires	
		Evaluation with companies and practitioners in Kenya and Botswana.	Workshop Observation Questionnaires	
	PRESCRIPTIVE STUDY III	Development of Innovation Map 1.1		SUPPORT Improvements on the current design of tools following feedbacks on usability and format.
		Development of Design Framework & Cards 1.0 Evaluation with designers in UK. Development of Design Framework & Cards 1.1	Workshop Questionnaires	EVALUATION Evaluation of the Design Framework & Cards in terms of usability, appearance, ease of use.
	DESCRIPTIVE STUDY IV	Evaluation with companies and practitioners in Kenya and Botswana. Evaluation with companies and experts in Kenya and Botswana.	Workshop Observation Questionnaires Interviews	EVALUATION Evaluation of the tools in terms of ease of use, usefulness. Evaluation of the Design Framework & Cards in terms of completeness and usefulness.
	FINAL VERSION	Innovatio Map 2.0		SUPPORT Improvements and final digital and print version of the tools
		Design Framework and Cards 2.0		
		Visualisation system 2.0		

Fig. 3.7 - Research Methodology: stages, activities, methods and outcomes

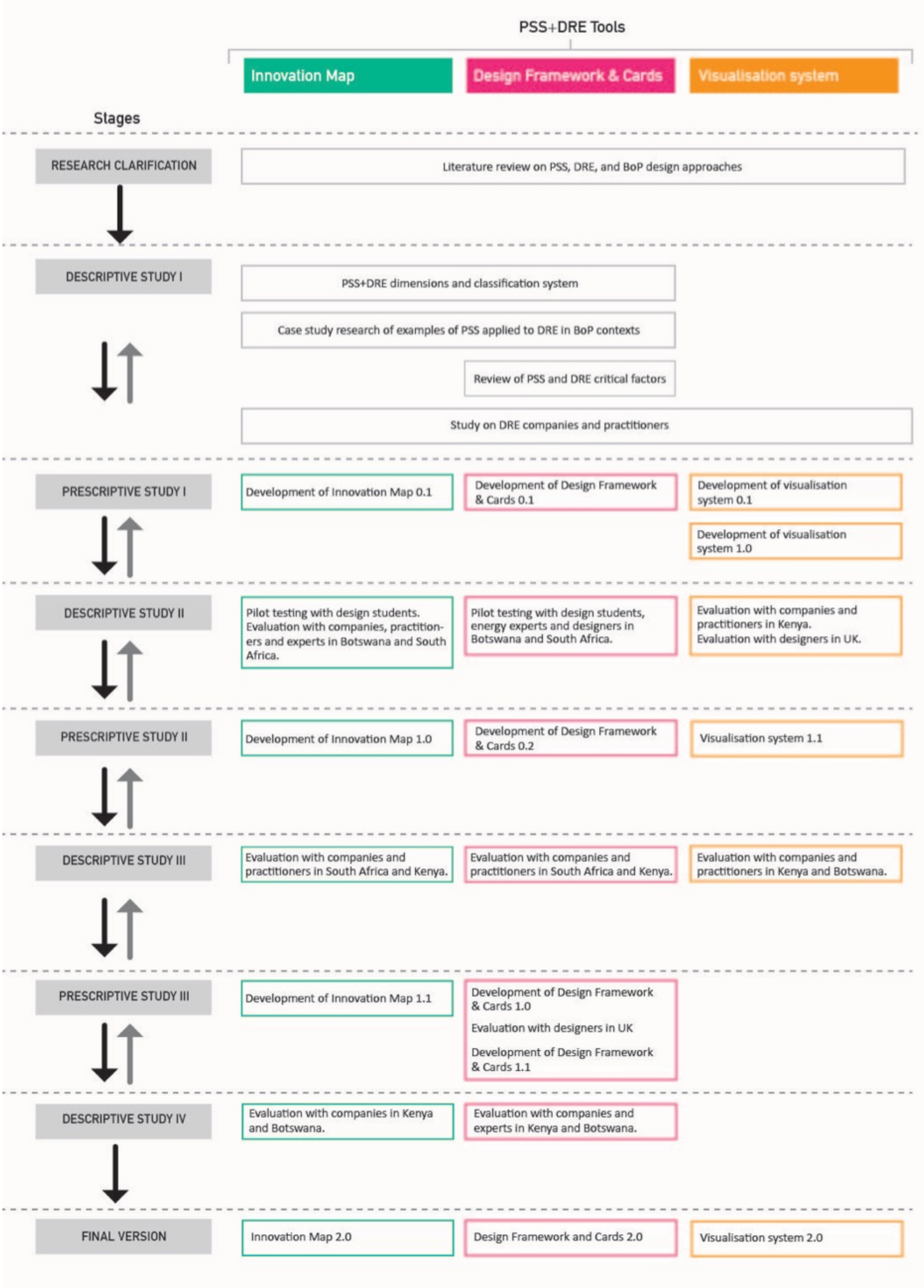


Figure 3.8 – Tools' development: description of stages and activities

3.6.2 Research methods

As described in Section 3.5, this PhD is characterised by a mixed methods concurrent strategy and a combination of deductive and inductive processes which translates in the use of different qualitative and quantitative methods (Table 3.6).

Quantitative	- Pre-determined - Instrument-based questions - Performance data, attitude data, observational data and census data - Statistical analysis - Statistical interpretation
Qualitative	- Emerging methods - Open-ended questions - Interview data, observation data, document data, audio-visual data - Text and image analysis - Themes, patterns, interpretation
Mixed methods	- Both pre-determined and emerging methods - Both open- and closed-ended questions - Multiple forms of data drawing on all possibilities - Statistical and text analysis - Across database interpretation

Table 3.6 - Research methods: quantitative, qualitative and mixed methods, Creswell (2009)

The combination of multiple methods can be aligned with the different stages and approaches of this research. In a first phase, an inductive approach characterises the investigation and a primarily qualitative strategy is adopted: primary data is collected and used to form a set of theories and models, in this case exploring models of PSS+DRE, defining variables and critical factors for these models. The data collected through multiple methods have been used to build a new classification system of PSS+DRE (then evolved in the Innovation Map) and a Design Framework for PSS+DRE and a collection of critical factors and guidelines (then organised in the Cards). The methods used in this phase are literature review, case study research, semi-structure interviews and questionnaires.

In a second phase, the research adopts a deductive approach, in order to test the generated theory through experimentation with companies and practitioners. This stage is characterised by a concurrent strategy where both qualitative (workshops, observation, interviews) and quantitative (questionnaires, content analysis) data collection are employed. In particular, the use of different data collection techniques is justified by a methodological triangulation (Gray, 2014), used to help balance weaknesses in each data collection method. Mixing qualitative and quantitative can be combined to measure different elements of a phenomenon (Gray, 2014). In this case, the adoption of different data collection methods has been used for testing the applications of the design tools. For example, questionnaires have been employed to capture quantitative data and rating of tools' easiness of use and usefulness; interviews have been used to understand the tool's completeness and usefulness.

A description and justification of methods used in this research is presented below, following the order on how they have been implemented in the PhD. Details about how these methods have been implemented in specific studies are discussed in the corresponding chapters.

Case study

In this research, the case study has been used as a method to build knowledge on PSS+DRE models. In particular, the case study analysis aimed at answering the question "what are the applications of PSS and DRE in BoP contexts?" and at integrating the literature review about critical factors for designing PSS+DRE models. The purpose was to collect and analyse examples of PSS applied to DRE and to gain understanding on what models have been used and what characteristics they present. For these reasons, the *exploratory case study* (Yin, 2009) appeared as an appropriate method for this phase of the research.

The selection of cases followed a *theoretical sampling strategy* (Eisenhardt, 1989) based on the dimensions characterising PSS+DRE. Case selection and analysis was in fact carried out simultaneously to a literature review on PSS+DRE dimensions and critical factors, and aimed at integrating the emerging theory. Source of evidence in the case study collection included: documentation such as company reports, websites, academic studies about the same case, news and articles about the case. The use of triangulation of sources represents a major strength in case study research (Yin, 2009), a minimum of three sources have been used for each collected case.

Cases were then analysed and clustered following the cross-case synthesis (Yin, 2009), resulting in a catalogue of cases described according to the identified dimensions. This study is discussed in Section 4.3.

Workshop

The main method used for the application of the design tools in a real context has been the workshop, principally in the form of idea-generation sessions. Workshops have been used to test different aspects of the design tools: the ease of use and clarity, the usefulness (e.g. understand models of PSS+DRE, mapping companies' offers, generate new concepts of PSS+DRE etc.). In other words, workshops have been used to evaluate the applications of the design tools. The use of this method in design research has been established by various studies (for example Davis, 2010; Clatworthy, 2011; Lockton, 2012; Wang, 2015).

Workshops are context-specific research methods where the researcher not only "describe, understand and explain" (Robson, 1993) but also facilitate a group of participants in working together on a specific problem/topic. One advantage lies in having a diverse mix of participants working together to produce specific concepts and allowing them to build on each other' ideas resulting in a wider range of approaches and concepts. On the other side, the group may affect how participants behave in the study, i.e. leading to production-blocking or social loafing. In order to limit this, participants have been organised in groups of maximum of four people, according to their chosen topic of interest.

Another limitation of the workshop as a method is the ecological validity: due to the 'artificial setting', the ideas generated may not be applied outside of the context where they were generated. In order to tackle this constraint, companies and practitioners were encouraged to generate concepts they could implement in their organisations. In some of the workshops participants were mixed together according to the topic of interest of their choice (e.g. solar power), and generated ideas for 'fictional' concepts, for example a new business model of a not-existing company. However, in other cases, participants worked on their own briefs and developed concepts and ideas that could be practically implemented in their companies.

In this research, workshops have been used with different procedures according to the scope of the specific study and the type of participants involved.

The author facilitated the workshop sessions by introducing the topic, in some cases with an exhaustive introductory presentation on PSS, DRE, sustainable development etc. (such as in the short courses with companies in South Africa, Kenya and Botswana), in other cases with a shorter presentation on the topic and procedures to use the tools (e.g. the workshop at Brunel, some workshops in Kenya).

During the practical session the author acted as an external observer, providing clarification on how to use the tools when necessary, but without intervening during the process.

Workshops had different time schedules according to the specific study and to the constraints deriving from participants' involvement, budget available and other organisational factors. Sessions lasted in some cases a minimum of 3 hours and in others a maximum of 2 weeks (e.g. course at University of Botswana). A list of workshops carried out in this PhD research is presented in Table 3.7.

Workshop	Study	Location	Duration	Participants
W1	DS-II	University of Botswana	2 weeks	39, design students
W2	DS-II	University of Botswana	4 hours	4, DRE and PSS experts
W3	DS-II	Cape Town, South Africa	4 hours	3, design consultants
W4	DS-III	Cape Peninsula University of Technology, South Africa	4 days	12, mix of companies and practitioners
W5	DS-III	University of Nairobi, Kenya	4 days	12, mix of companies and practitioners

W6	PS-III	Brunel University London	2 hours	12, designers
W7	DS-IV	University of Nairobi, Kenya	3 days	2, NGO and company
W8	DS-IV	Kenyatta University, Kenya	4 hours	8, consultants and DRE students
W9	DS-IV	University of Botswana	3 days	2, companies

Table 3.7 - List of workshops carried out for this research

Questionnaire

Questionnaire have been employed in DS-I and in the evaluation sessions of the tools. In particular, the self-administered questionnaire is a type of questionnaire that the respondent answers without the aid of the researcher and it can be used to collect qualitative and quantitative data, similarly to semi-structure interviews (Bryman, 2016). The main advantages of this method are:

- it is quick to administer and allows the collection of data in large quantities at the same time;
- without an interviewer present it does not affect the answers that people may give;
- it can be generally more convenient for respondents because they can complete it with the time needed and reflect on the questions.

On the other side, disadvantages for this specific method are: the inability for respondent to elaborate on open-ended questions since there is no interviewer to probe respondents and the risk of missing data if questions are not answered.

Open-ended questions have been used to allow respondents to answer in their own words, because they allow tapping in the respondent's level of knowledge and understanding of a specific matter (Bryman, 2016). Closed-ended questions have been used to provide quantitative data, facilitate the comparability of answers and reduce the variability of answers.

Questionnaires with different purposes have been used in this PhD:

1. <u>Questionnaire on DRE companies' business model design (DS-I)</u>
   The questionnaire has been structured with open-ended questions and aimed at gathering information on the design of business model for DRE companies. The questionnaire has been completed by companies and practitioners, some in person and some through the online version. Questionnaires have been employed in Botswana, South Africa and Kenya and online. The same questions have been used in semi-structured interviews as complementary method in the same study. These activities are described in Section 4.6.
2. <u>Questionnaire for tools' evaluation</u>

Most part of the evaluation of tools' usability, completeness, ease of use and usefulness has been carried out through questionnaires. Companies and practitioners who were involved in the workshops were asked to provide feedback through open- and closed-ended questions at the end of the session. This method allowed the researcher to collect a wide amount of quantitative data through closed-ended questions (e.g. ranking the applications of a specific tool) and to gather qualitative comments and suggestions for improvements through open-ended questions. The same questionnaire has been used with participants from Botswana, South Africa and Kenya in order to ensure external validity of responses. For each tools' Descriptive Studies the results are discussed in the relative section, while a sample of the questionnaires is provided in Appendix III.

Interview

Semi-structured interviews have been used with experts and practitioners to validate the completeness and applications of the Innovation Map and Design Framework and Cards.

In this PhD, semi-structured interviews have been used primarily with the aim of gathering qualitative data, although quantitative elements are also present. In particular, in order to validate the design tools and to enhance reliability and validity, interviews were designed to gather quantitative feedback on specific topics.

Three studies involved interviews as a data collection method:

1. <u>Semi-structured interviews on DRE companies' business model design (DS-I)</u>

   In this case the interview method is used together with questionnaires in the same study. The aim was to gather information regarding DRE companies' business model design. Interviews were chosen as a preferred method to get a deeper understanding of the context where the tools may be used, starting with companies operating in the context of Botswana. Questionnaires where later used to expand and confirm the acquired knowledge for other contexts (South Africa, Kenya, and online). This study is described in Chapter 4.
2. <u>Semi-structured interviews with companies and experts in Botswana (Innovation Map DS-II)</u>

   The use of interviews for evaluating the Innovation Map tool was chosen as primarily quantitative method: the aim was to provide specific answers in terms of tool's completeness and its possible applications. In this case both companies and experts were involved.
3. <u>Semi-structured interviews with experts in Kenya and Botswana (Design Framework and Cards DS-IV)</u>

   Similarly to the Innovation Map DS-II, semi-structured interviews were used to validate the completeness and the applications of the Design Framework and Cards. This round of interviews was carried out with experts and practitioners in Kenya and Botswana. Sessions have been recorded and transcribed.

Observation

Observation has been used as a method to integrate the data collection from questionnaires. One of the techniques of observation research is non-participant or unstructured observation, which "aims at recording in as much details as possible the behaviour of participants" while "the observer does not participate in the setting" (Bryman, 2016). This method has been used during workshops with the aim of taking notes about participants using the tools, paying attention at misuse, misunderstanding or other problems encountered during the process. In fact, observation can be applied to report an event that has been evaluated with other methods, such as questionnaires or interviews, to provide a deeper analysis of problems encountered, omissions or wrong interpretation in the answers (Bryman, 2016).

During the workshop sessions the author has acted as non-participant observer by taking notes of participants' conversations, behaviours and issues encountered during the idea generation with the tools. This method was better implemented in the latest stages of the research (workshops in Kenya and Botswana as part of the EPSRC-project / DS-IV) where the number of participants was limited.

Content analysis

This method seeks to "analyse documents and texts to quantify content in terms of predetermined categories in a systematic and replicable manner" (Bryman, 2016). This technique has been used to evaluate the outputs of the tools in use, in particular the ideas and concepts generated. For example, the hypothesis formulated to evaluate the effectiveness of the Design Framework and Cards stated that the tool would support the generation of ideas and that would help detail concepts. In order to validate this hypothesis, the filled design canvases used in workshops by companies have been analysed in order to evaluate the concepts generated (qualitative analysis) and the amount of ideas produced (quantitative analysis).

The analysis of material produced during the workshops however presents some limitations. In fact, it is possible that not all ideas discussed are written down on post-its, or that more complex concepts are documented in a simplified way. For these reasons, the mere analysis of content produced during the workshop may provide a limited view. As argued before, the adoption of mixed methods (i.e. content analysis in association with observation and questionnaires), was necessary to triangulate results among different methods and to provide a comprehensive understanding of the effectiveness and usefulness of tools.

3.6.3 Sampling

The sampling strategy varied for the different studies of this research. In the tools' evaluation a *purposive sampling* strategy was mostly adopted. This method involves the researcher in selecting participants who represent the population being studied (Robson, 2002), in this case companies and practitioners working in the renewable energy sector. This strategy has been adopted for evaluations with experts and companies during the Innovation Map DS-II, for all the activities related to the EPSRC-funded project where the author had complete autonomy in organizing workshops and testing activities. For the evaluation with designers at Brunel University (Design Framework and Cards PS-III), a number of design researchers and master students have been selected initially following a purposive strategy but also involving *convenience sampling* to reach a certain number of participants.

For the workshops with companies organised within the LeNSes project, participants have been selected using the *snowball sampling*, which involves identifying a number of subjects (the partners in the project) who in turn identify other participants (local companies and practitioners). This method has been preferred because the partner organisations, such as KEREA (Kenya Renewable Energy Association), had already access to a database of local companies and practitioners. In some cases (e.g. W5, W7, W8), the author provided guidelines for local partners about the types of participants to be involved in the study, i.e. SMEs and practitioners working on business models and energy access, and assisted local partners in the recruiting process. A list of suggested companies, compiled after an internet search on key players in the selected context, was prepared to support the recruitment of participants.

Sample sizes varied according to the different studies and their purposes. Due to the primary qualitative aspect of this research, the main criterion adopted was to involve people with expertise and knowledge of the sector under investigation (DRE, PSS, energy access, strategic design, business model design). In addition, the availability of participants to attend the workshops played a key factor in shaping activities and accommodating companies' resources. As result, some workshops were organised over 3-4 half days of activities, leaving participants able to attend their business engagements after the workshop. In the pilot workshops in Botswana (DS-II), where the first version of the tools was tested, a higher number of participants (39 design students) allowed the researcher to gather quantitative data. In this case the sampling strategy aimed at recruiting more participants, regardless of their knowledge or expertise, in order to provide a feedback on usability and clarity of the tools.

Another sampling strategy was adopted for the selection of cases in the case study analysis in DS-I. The *maximum variation sampling* (Miles & Huberman, 1994), which involves the researcher selecting a diverse range of cases with the aim of identifying common patterns, aimed at describing the widest amount of PSS+DRE models from a variety of contexts.

A summary of sampling strategies adopted in this research is provided in Table 3.8, while details for each case are described in the respective study.

Study	Research method	Sampling strategy	Sample sizes and criteria
DS-I	Review of critical factors	Theoretical sampling	-
DS-I	Case study research	Theoretical sampling and maximum variation strategy	58 case studies
DS-I	Interviews and questionnaires with DRE companies	Purposive sampling: participants were chosen based on their expertise in the energy, PSS and design sector.	Theoretical saturation: 18 companies and practitioners
DS-II	Testing Innovation Map: interviews and questionnaires in Botswana and South Africa	Purposive sampling: participants were chosen based on their knowledge and expertise in the energy sector	Theoretical saturation: 21 participants
DS-II	Testing tools: workshops in Botswana and South Africa	Snowball sampling: participants (design students) were involved by local partners. Purposive sampling: experts and practitioners were chosen based on their knowledge and expertise.	W1: 39 design students W2: 4 experts W3: 3 designers
DS-III	Testing tools: workshops in South Africa and Kenya	Snowball sampling: participants were involved by local partners, based on guidelines from the author	W4: 12 companies and practitioners W5: 11 companies and practitioners
PS-III	Testing Design Framework & Cards: workshop at Brunel University	Purposive and convenience sampling: participants were chosen based on their skills and expertise in design and considering their availability for the study.	W6: 12 designers
DS-IV	Testing tools: workshops in Kenya and Botswana	Purposive sampling: participants were chosen based on their expertise in the energy sector.	W7: 1 company, 1 NGO W8: 2 companies W9: 8 students and practitioners
DS-IV	Interviews with experts	Purposive sampling: participants were chosen based on their knowledge and expertise in the energy, PSS and design sector.	Theoretical saturation and availability of participants: 12 experts

Table 3.8 - Summary of sampling strategies and sizes adopted in this research

3.6.4 Research Clarification

The outcomes of the Research Clarification stage are the definition of a research approach, type and methods and the planning of expected contributions within a specific timeframe. This stage of the PhD was completed after the first literature review (Chapter 2), which led to the identification of gaps in the knowledge and research questions. Chapter 3 discusses the strategy and methodology for this research, here the Research Clarification can be summarised as follows:

- Research aims, questions and objectives are discussed in Section 1.4.

- In this PhD, a combination of inductive and deductive approaches is adopted (Section 3.3). A first stage of inductive approach aims at answering RQ1, by building theory on PSS+DRE models. In a second stage, the testing of design tools is characterised by a deductive approach.
- The purpose of this research is exploratory (Section 3.4): this PhD aims at exploring the applications of PSS+DRE in BoP contexts, at identifying their characteristics and critical factors, at translating these for supporting companies and practitioners in the design process.
- This research is predominantly qualitative and it adopts several strategies (Section 3.5): in a first phase, a grounded theory approach is used to build knowledge on PSS+DRE models in BoP contexts. In a second phase, a mixed methods concurrent strategy is used to answer RQ2.
- A number of different methods (Section 3.6.2) are adopted in this PhD: case study, questionnaire, interview, workshop, observation, content analysis.
- The timeframe to carry out the research was set to be concluded by end of 2016 (three years).

3.6.5 Descriptive Study I (DS-I) (Chapter 4)

The Descriptive Study I (DS-I) encompasses different primary studies that aimed at gathering a sufficient understanding of the topic, in line with the exploratory purpose of this research. The starting point of this stage is based on the research questions rather than hypothesis, because the area to research is still unexplored. The type of DS-I can be described as *comprehensive*, i.e. it involves a literature review as well as empirical studies. This phase of the research is characterised by the grounded theory approach, with the aim of building knowledge on PSS+DRE and at answering RQ1. The main activities undertaken in the DS-I are described below.

3.6.5.1 Identification of dimensions of PSS+DRE and development of a classification system for PSS+DRE models

The first literature review on PSS and DRE identified dimensions characterising PSS and DRE models. The review also explored how PSS and DRE have been respectively classified (see Sections 2.1.4 and 2.2.5). The literature showed that the multi-dimensional characteristics of DRE systems needs to be considered when classifying these models in combination with PSSs. The first phase of this research aimed at identifying characterising dimensions of PSS+DRE models, building from the reviewed PSS and DRE literature. This study adopted an "analytical conceptual research" approach (Meredith, 1993; Wacker, 1998), which focuses on building new insights through logically developing relationships between defined concepts (in this particular case the PSS and the DRE concepts). The literature from different backgrounds (PSS and DRE) has been integrated by suggesting relationships between variables based on these existing findings. Having identified PSS+DRE dimensions, these have been used to develop a new classification system for these models. The classification system is presented as a first outcome of this research.

3.6.5.2 Case study analysis

The goal of this step was to collect and analyse cases of PSS models applied to DRE, in order to gain an understanding of the range and characteristics of existing models. As qualitative strategy, a case study approach is considered appropriate for studying new topic areas (Strauss and Corbin, 1990) and especially for understanding complex phenomenon (Merriam, 1998). In this research, the case study analysis has been used to answer the questions: *What are the applications of PSS+DRE models in BoP contexts?* and consequently *What are the critical factors to successfully implement these models?*

In order to enhance validity and reliability of the data collected, the research used a triangulation approach (Yin, 1994): multiple methods for collecting data were used to verify that all sources converged on the facts of a case. Secondary sources have been used for data collection, such as scientific papers, existing reports made by other researchers or international organisations (such as the World Bank), company's website, online articles. For each case a minimum of three sources were collected.

Following the maximum variation strategy, the aim was to sample for heterogeneity and select cases that maximise diversity. In particular, cases were selected in order to cover, as much as possible, all the possible differences in the characterising dimensions (e.g. different types of technologies and energy sources, different types of target customers). All cases selected have been implemented in low- or middle-income contexts. The amount of collected cases followed the principle of saturation - the point at which there are no new ideas and insights emerging from the data. A final number of 56 cases were collected, while each case was described detailing the dimensions previously identified in the literature review.

The collected cases were then positioned on the classification system and clustered in groups of similar cases. This activity led to the identification of Archetypal Models of PSS+DRE. Each model was then described in terms of offers provided, payment structure and energy system.

This study is described in Chapter 4, while a collection of cases and sources are provided in Appendix I.

3.6.5.3 Review on PSS+DRE critical factors

Having identified dimensions of PSS+DRE, it was necessary to gain a deeper understanding of their variables and critical factors. A second literature review of PSS+DRE dimensions was carried out in order to extract critical factors that influences the successful implementation of these models.

This stage of the research was framed in the grounded theory strategy, where data collection, in this case arising from literature review, is used to build theory. In a second stage, the critical factors emerging from the review led to the development of the design support (PSS+DRE Design Framework and Cards, Chapter 6).

The literature can also be used to match between data collected through other methods, in this research, case study analysis. In this research the literature helped in confirming some critical factors found in the case studies.

In summary, the review of PSS+DRE critical factors have been used to build theory on PSS+DRE models and was later translated in a design tool: the Design Framework visualises the PSS+DRE dimensions and variables (see section 6.1.1), while the Cards collect the critical factors and successful aspects (Section 6.1.2).

3.6.5.4 Study on the target users of this research: DRE companies and practitioners

During the development of the support (PS-I), it appeared to be necessary to acquire additional information regarding the context of the support in use, i.e. concerning the recipients of the research (SMEs, practitioners). This study aimed at gathering information on who is involved in the design of business models of renewable energy SMEs, what tools are used in the process and what knowledge on PSS these companies may have. The results were used to better detail the recipients of the tools and to consequently adapt the tools for them to use.

Within the DS-I, different methods can be used and adapted to the iterations and research context (Blessing & Chakrabarti, 2009). The study started with interviews to obtain a detailed understanding of the topic (Botswana) and then continued with questionnaires to verify the findings apply to other contexts (Kenya, South Africa and online questionnaires). The aim was to gather a wider range of responses from different types of companies operating in different contexts and therefore to ensure generalizability of findings. This study is described in Chapter 4.

3.6.6 PSS+DRE Innovation Map: stages (Chapter 5)

A first outcome of this research is the Innovation Map. The tool's development and evaluation has followed several iterations, which are introduce below and exhaustively described in Chapter 5.

Innovation Map PS-I

The first version of the Innovation Map (0.1) has been developed from the primary studies. The classification system of PSS applied to DRE is used as a strategic design tool for positioning companies' offers, mapping competitors in a specific context and new business exploring opportunities.

Innovation Map DS-II

A first iteration of testing and evaluation of the support took place in Botswana and South Africa between March and May 2015. This phase aimed at evaluating the tool under different aspects:

- the completeness and inclusion of all possible archetypal models;
- the clarity and ease of use;
- its usefulness as a strategic design tool.

For this reason, different types of participants were selected form the testing activities: DRE companies, energy experts and academics, design practitioners.

This phase also included a pilot study with design students at University of Botswana.

The methods used in this phase are semi-structured interviews with companies and experts, workshops, observation and content analysis.

Innovation Map PS-II

Building from the first evaluation activities and from the data collected in Botswana, a new version of the tool has been designed, the Innovation Map 1.0. In this version, new features are introduced to apply the tool in idea generation session.

Innovation Map DS-III

This version of the tool has been applied in workshops with companies and practitioners in South Africa and Kenya. The testing activities took place between February and April 2016 as part of the lifelong-learning courses organised within the LeNSes project. A four-days' workshop has been organised in Cape Town with the collaboration of Cape Peninsula University of Technology and TU Delft and involved 11 participants amongst DRE companies and practitioners. A second workshop was organised in Nairobi in collaboration with University of Nairobi and involved 12 participants. Methods for data collection included questionnaires, observation and content analysis.

Innovation Map PS-III

In this iteration some minor changes are introduced, developing the Innovation Map version 1.1.

Innovation Map DS-IV

Version 1.1 has been applied in a round of evaluation with companies and practitioners in Kenya and Botswana as part of the EPSRC-funded project. The activities took place in November 2016, when the researcher organised two workshops respectively at University of Nairobi and University of Botswana. These workshops aimed at using the tool for a 'real-life' brief that each company chose and at collecting qualitative feedbacks. For this purpose, a smaller number of participants was involved, one NGO and one company in Kenya and two companies in Botswana.

In this stage two other brief workshops were organised in Nairobi: one was carried out at University of Nairobi with one company and included an introduction to the tool and a brief idea generation session. Another one took place at Kenyatta University, where the researcher was invited from the Chendaria Business Incubator Centre to facilitate a session with 12 participants, mainly MSc students in renewable energy, some consultants and some affiliates of the centre. In both these two additional workshops data was collected with questionnaires.

Innovation Map's final version

Building on the outcomes of DS-IV, the final version (2.0) of Innovation Map has been designed in both printed and digital version.

3.6.7 PSS+DRE Design Framework and Cards: stages (Chapter 6)

The second outcome of this research is the Design Framework and Cards tool. The development and evaluation of the tool has undergone several iterations which are anticipated below and described in detail in Chapter 6.

Design Framework and Cards PS-I

A first version (0.1) the Design Framework and Cards has been developed building on the primary studies of DS-I (case study research, literature review). Once the PSS+DRE models have been identified and their characterising dimensions determined, the DS-I focused on collecting key factors, best practices and success elements of PSS applied to DRE.

In the Prescriptive Stage, the theory built with the primary studies has been used to develop the support. The Design Framework has been built considering the building blocks of a PSS applied to DRE offer; all collected critical factors have been transformed in guidelines and organised in topics (e.g. "training services") that could support companies and practitioners in the design process. These guidelines have been organised in the form of cards, grouped according to the design dimension (e.g. customer). This process is exhaustively documented in Section 6.1.2.

Design Framework and Cards DS-II

A first version of the tool has been evaluated with pilot testing in Botswana and South Africa between March and May 2015. The first study engaged design students at the University of Botswana, who attended a course organised as part of the LeNSes project. As part of the two-week course, students used the Design Framework and Cards for generating concepts of PSS applied to DRE for the specific context of Botswana. This pilot study aimed at testing usability and ease of use of the tool and to gather suggestions for improvements.

The tool has been then applied in two other short workshops. One was organised at the University of Botswana with four academics with experience in PSS and DRE and aimed at applying the tool for a real-life project the participants were working on. A second workshop took place in Cape Town, where the researcher organised a short session with a strategic design agency.

Design Framework and Cards PS-II

A second version (0.2) of the tool was developed building on the feedback collected in Botswana and Kenya.

Design Framework and Cards DS-III

The tool has been then evaluated in practice through two sessions organised in South Africa and Kenya between February and April 2016. This study coincides with the Innovation Map DS-III and it involved companies and practitioners working in the DRE sector who attended the 3-days workshops. The tool has been used in idea generation session and data have been collected through questionnaires, observation and content analysis.

Design Framework and Cards PS-III

A new version of the Design Framework and Cards was then developed, bringing changes mainly in terms of layout and appearance. Within the PS, the tool needed to be evaluated in terms of usability and consistency before proceeding to further applications (Blessing & Chakrabarti, 2009). For this reason, this stage involves an evaluation phase to test the tool from a purely design perspective. A workshop with designers has been organised at Brunel University London in May 2016 and it involved 12 designers. The purpose of this study was not to evaluate the applications of the tool but instead to gather feedbacks and suggestions on the tool as a design artefact. Data has been collected through questionnaires.

After this short iteration, a new version of the Design Framework (1.1) has been designed.

Design Framework and Cards DS-IV

This stage focused on evaluating the tool in use with companies and on collecting qualitative data on the completeness and usefulness of the tool with experts in Kenya and Botswana. These activities were carried out as part of the EPSRC-funded project and, in line with the Innovation Map DS-IV, two workshops were organised in Nairobi and Gaborone. The workshops aimed at collecting data from the selected companies who worked on real-life briefs and questionnaires and group discussions were used to collect feedbacks.

Additionally, the Design Framework and Cards were used in two short workshops in Nairobi where the tool has been used for a brief idea generation session and feedbacks have been collected with questionnaires.

A second phase of this study involved experts in DRE business, technology, design and policy who participated in semi-structured interviews. This study aimed at evaluating in detail the content of the tool and in particular the completeness of the Design Framework and the usefulness/appropriateness of guidelines in the Cards. The sessions were structured with an introduction phase, a general discussion on the tool and how it is to be used, followed by semi-structured questions. In some cases, the interview has been coupled with a questionnaire as some participants preferred to provide feedbacks in later stage. This study is discussed in Section 6.6.2 and a sample of the questions is provided in Appendix III.

Design Framework and Cards' final version

A final version (2.0) of the tool, both in digital and printed form has been designed.

3.6.8 PSS+DRE Visualisation System: stages (Chapter 7)

Chapter 7 focuses on a third outcome of this research, a Visualisation System for PSS applied to DRE models.

Visualisation System PS-I

The first version (0.1) of the Visualisation System has been developed on the outcomes of the DS-I: the identification of PSS+DRE characterizing dimensions and variables and the literature review on design tools for PSS and DRE. The Visualisation System is based on the adaptation of an existing tool, the System Map (Jegou et al., 2004), integrated with elements emerging from the PSS+DRE literature. The first purpose to develop a Visualisation System for PSS applied to DRE emerged from the need of clarifying archetypal models (see DS-I) and to provide a visual representation of these models. Later, it became clear that this Visualisation System could be used to support companies and practitioners in the design process. For these reasons, the Visualisation System has been adapted to be used as a design tool, the *Energy System Map*, in workshop sessions.

Visualisation System DS-II

This version of the tool has been applied in workshops with companies and practitioners in Kenya, in combination with the Innovation Map and Design Framework and Cards DS-III. During the testing activities, participants provided feedbacks through questionnaires. Other data was collected through observation.

In a second phase, an evaluation of some aspects of the tool has been undertook during the workshop with designers at Brunel University London. Here the aim of the study was to rank the clearness of icons used in the Visualisation System.

Visualisation System PS-II

A second version of the tool has been developed according to the data collected in DS-II.

Visualisation System DS-III

During the workshops organised as part of the EPSRC project, the Visualisation System 1.0 has been applied by companies in two workshops, at University of Nairobi and University of Botswana. Similarly to the DS-I, data have been collected through questionnaires.

Visualisation System's final version

The latest version of the Visualisation System has been developed in digital and printed version.

3.7 Chapter summary

The chapter described the rationale, strategy, methodology and methods of this PhD.

This research follows a constructivist epistemological position and an interpretivist theoretical perspective.

While this research can be defined as exploratory in nature, different approaches and strategies characterise the research process. An inductive approach is adopted in the first phase of the PhD, which aimed at answering RQ 1 and at building a theory on PSS applied to DRE models. A deductive stance distinguishes the second part of the research, whose purpose is to test the constructed theory and hypotheses built in the first stage. Here, in order to answer RQ 2, the design tools are tested through empirical evaluation.

Several research strategies from social science and design have been reviewed in order to define a strategy for this PhD. This research is predominantly qualitative and adopts a flexible design strategy, however it is characterised by a mixed method concurrent strategy which integrates both quantitative and qualitative data collection methods within a single study. Several methods have been adopted in different stages of the research: workshops, questionnaires (qualitative and quantitative), semi-structured interviews, observation and content analysis.

The methodological framework chosen for this PhD is the Design Research Methodology proposed by Blessing and Chakrabarti (2009), structured in four main stages, Research Clarification, Descriptive Study-I, Prescriptive Study I and Descriptive Study II. The DRM has been adapted to the several iterations present in this research and each stage has been described according to the main outputs of this PhD: Descriptive Study I – Primary Studies (Chapter 4), PSS+DRE Innovation Map (Chapter 5), PSS+DRE Design Framework and Cards (Chapter 6), PSS+DRE Visualisation System (Chapter 7). A timeline of the tools development is presented in Fig. 3.9.

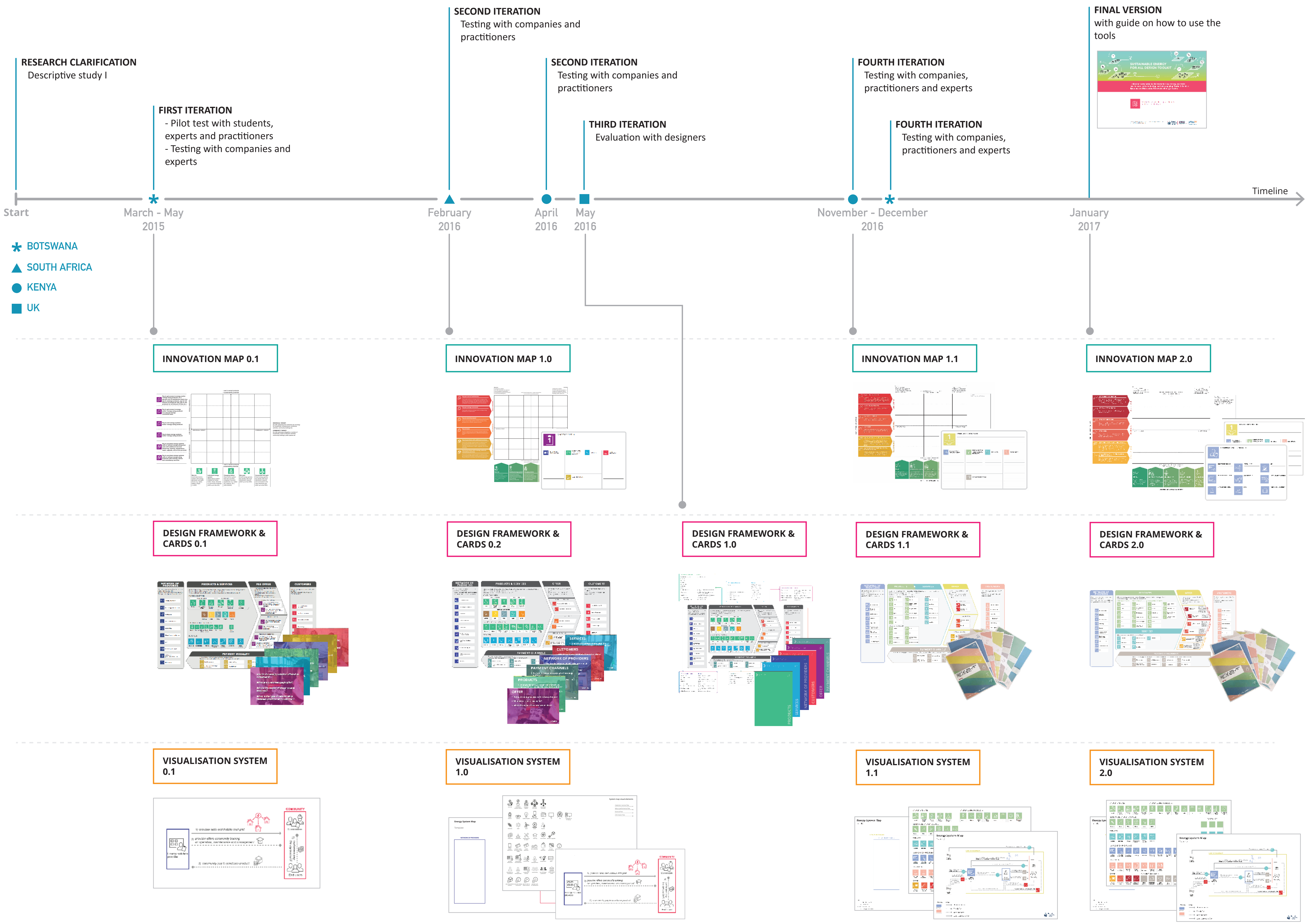


Fig. 3.9 - Tools' development timeline

Chapter 4

Primary studies

4: Primary studies

This chapter describes the activities undertaken as part of the Descriptive Study I (DS-I), which firstly aims at answering RQ1: what are the characteristics of PSS+DRE? How can these models be classified? What are the applications of these models in BoP contexts? What are the critical factors to successfully implement these models? Additionally, this chapter includes a study that was carried out during the development of the tool (Prescriptive Study I). This aimed at gathering additional information about the target user of the support (i.e. DRE companies and practitioners).

The activities described in this chapter are summarised below:

- *Identification of PSS+DRE characterising dimensions* (Section 4.1) *and development of a classification system for PSS applied to DRE* (Section 4.2): a theory-building approach was used to identify dimensions of PSS+DRE models and to build a new multi-dimensional classification system.
- *Case study analysis* (Section 4.3): a collection of case studies on PSS+DRE models in BoP contexts was used to explore the range and characteristics of existing models and to complement the literature review. The positioning of case studies on the newly-developed classification system led to the identification of Archetypal Models of PSS applied to DRE.
- *Review on PSS+DRE characterising dimensions and critical factors* (Section 4.4): a review of the literature was used to build theory on PSS applied to DRE.
- *Study on the target users of this research: DRE companies and practitioners* (Section 4.5): interviews and questionnaires were adopted to gather information about the recipients of this research.

The chapter concludes with a summary of findings and discusses how these will be used for the development of the design support in the following research phases.

4.1 PSS+DRE characterising dimensions

As described in Chapter 2, the literature review on DRE highlighted the lack of an inclusive approach to describe and classify DRE systems. In fact, several dimensions are adopted by authors to characterise DRE models: *energy system, value proposition/payment structure, capital financing, ownership, organisational form, energy system operation* and *target customer* (Table 4.1). Despite some attempts to adopt a multi-dimensional approach and to use cross-country case studies (Zerriffi, 2011; Krithika & Palit, 2013), an inclusive approach that includes all DRE dimensions is missing.

On the other hand, the literature on PSS reflects that a generic but widely accepted classification is used by most authors, which distinguishes between three main types of PSS models (Product-, Use- and Result-oriented) and eight archetypal models (Tukker, 2004). Gaiardelli et al. (2014) identified the main dimensions used to describe PSS models: *value proposition, product ownership, product operation, provider/customer relationship, environmental sustainability potential* (Table 4.1).

The literature on PSS applied to DRE presents limited investigations on these models and their characteristics. Studies focus on specific technologies or contexts of application, lacking a comprehensive approach to describe, classify and consequently design these solutions.

The following section illustrates how PSS+DRE characterising dimensions[9] have been defined and it describes how the literature review has been carried out to identify variables[10] of these dimensions and critical factors[11] to implement PSS applied to DRE.

The identification of PSS+DRE characterising dimensions was carried out using a theory-building approach. In particular, an *analytical conceptual research* approach was adopted (Meredith, 1993; Wacker, 1998). This approach focuses on building new insights through logically developing relationships between defined concepts, in this case the PSS and the DRE concepts. It involves integrating research, often from a diverse background of literatures, and suggesting relationships between variables based on these existing findings.

The starting point was the comparison between DRE and PSS dimensions (Table 17). As discussed in Chapter 2, PSS dimensions can be applied to various domains but appear to be inappropriate for describing specific applications of these models. In fact, the type of products included in the solution (e.g. energy system), the nature of stakeholders involved (e.g. private enterprise, NGO) or the type of target customer are not listed as characterising dimensions of PSS models.

DRE dimensions	PSS dimensions
1.Energy system	-
2. Value proposition / payment structure	2. Value proposition / payment structure
3. Capital financing	-
4. Energy system ownership	4. Product ownership
5. Organisational form	-
6. Energy system operation	6. Product operation
7. Target customer	-
-	8. Provider / customer relationship

[9] The term 'dimensions' refers to variations of properties that give specificity and range to certain concepts (Glaser & Strauss, 2008). In this case, PSS+DRE characterising dimensions refers to those variations used to describe characterising components of these models.

[10] The term 'variables' refers to elements or features that characterise the PSS+DRE dimensions and that are subject to change.

[11] The term 'critical factors' refers those factors that influence a successful implementation of PSS+DRE in low-income and developing contexts.

-	9. Environmental sustainability potential

Table 4.1 - Dimensions characterising DRE and PSS models, identified through literature review

Some differences between PSS and DRE dimensions can be also pointed out. The DRE's dimension #4 refers to the ownership of the energy system, while the PSS ownership considers all products involved in the PSS solution. Similarly, DRE's dimension #6 refers to who operates the energy system (e.g. a local entrepreneur, the customer or the community), while in PSS models it refers to who operates on the products involved in the solution (i.e. the customer or the provider).

The combination of PSS and DRE dimensions led to the identification of nine characterising **dimensions of PSS+DRE** (Table 4.2 and Fig. 4.1) (Emili et al., 2016): *1# energy system, 2# value proposition/payment structure, 3# capital financing, 4# ownership (of the energy system and energy-using products), 5# organisational form, 6# energy system operation, 7# target customer, 8# provider/customer relationship* and *9# environmental sustainability potential*.

In reference to these, some clarifications can be made. Dimension #6 refers only to the energy system operation. This can be explained by the fact that end users always operate on the energy-using products or appliances.

PSS+DRE Dimension	Description	Details
1. Energy system	Defines the connection type (stand-alone, grid-based systems) and renewable source involved (solar, wind, biomass etc.)	Stand-alone system: mini grid, individual energy system, charging station Grid-based system: isolated mini grid, connected mini grid Energy sources: solar, hydro, biomass, wind, human power
2. Value proposition / payment structure	Represents the value offered to the customer, i.e. the combination of product and services for which the customer is willing to pay and the payment structure.	Product-oriented PSS: - Pay-to-purchase with advice, training and consultancy services - Pay-to-purchase with additional services Use-oriented PSS: - Pay-to-lease - Pay-to-share/rent/pool Result-oriented PSS: - Pay-per-energy consumed - Pay-per-unit of satisfaction
3. Capital financing	Indicates how capital is provided for the energy solution and determines cost recovering and tariff structure	Fully-subsidised, quasi-commercial, commercially-led
4. Ownership (of the energy system and energy-using products)	Refers to who owns the energy system and products involved in the offer, i.e. the provider, the end user or a number of users.	Customer or provider
5. Organisational form	Indicates the nature of the organisation providing the energy solution	Public sector-based, utility, NGO, community, PPP/hybrid, private sector-based
6. Energy system operation	Defines who operates the energy system.	Customer or provider

7. Target customer	Indicates the type of end-user (e.g. household, community, public building)	Individual or community
8. Provider / customer relationship	Refers to the nature and intensity of interaction between the two actors and varies from transaction-based (product-oriented PSSs) to relationship-based (result-oriented PSSs) according to the responsibilities and activities performed on the product (Penttinen & Palmer, 2007; Gaiardelli et al., 2014).	Transaction-based or relationship-based
9. Environmental sustainability potential	Refers to the PSS environmental impact, which can potentially be lower than traditional product-based business models. It generally goes from high sustainability potential in result-oriented PSSs, to low sustainability potential in product-oriented PSSs (Tukker & Tischner, 2006).	Low, medium or high environmental sustainability potential

Table 4.2 - Dimensions characterising PSS+DRE models

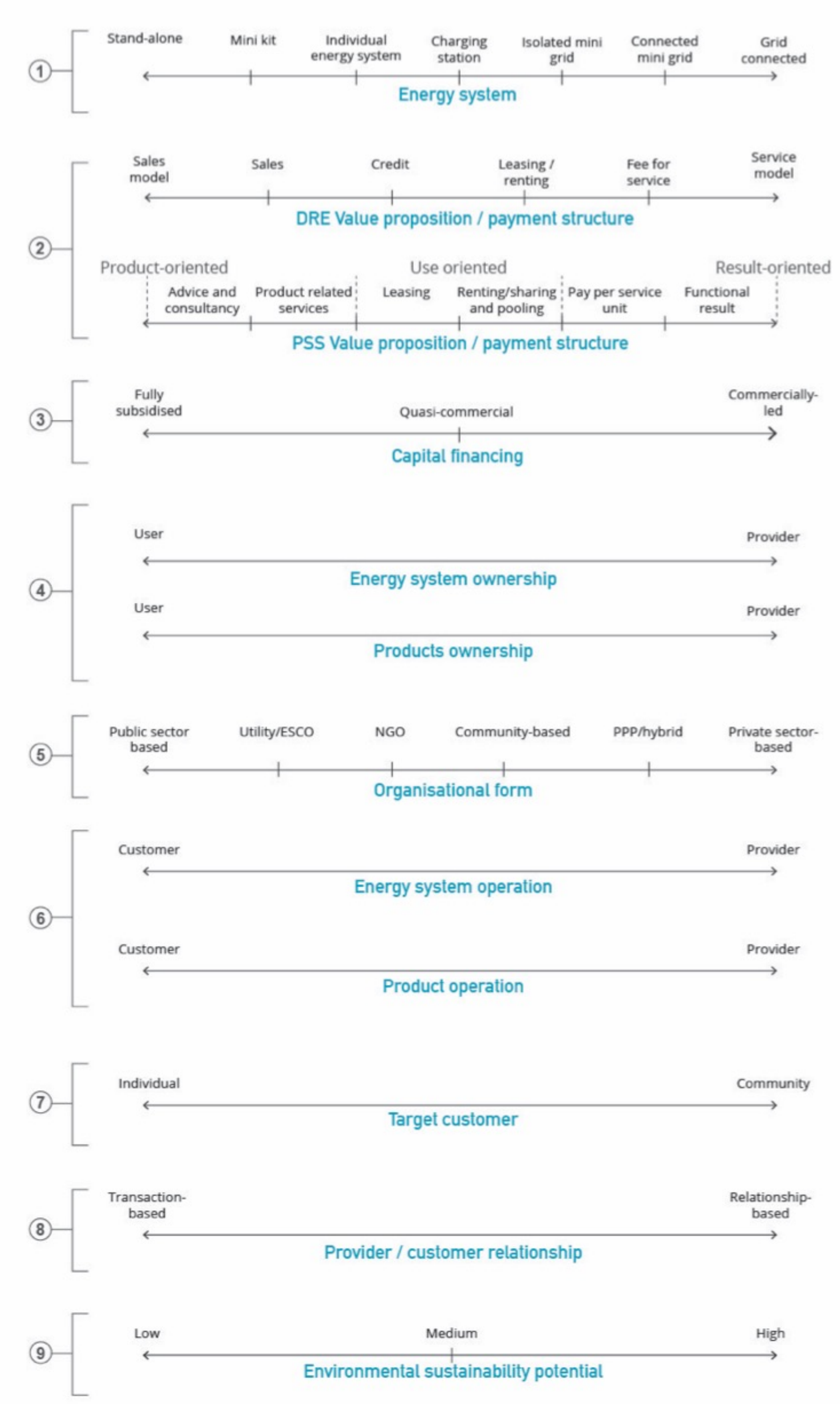


Figure 4.1 - PSS+DRE dimensions illustrated

Having identified the main dimensions characterising PSS+DRE models, the following step was to review the literature for each of these dimensions in order to identify their variables and critical factors. In line with the aim of building theory on PSS applied to DRE, this phase of the research presents main features of grounded theory. In particular, simultaneous collection and analysis of data has been carried out, identifying PSS+DRE variables through literature review and case study analysis. In this case the literature has been used as "data" to develop theory (Glaser, 1992) and consequently has been compared with the dimensions and critical factors emerging from the case study analysis (Section 4.2).

The following section describes how the review of literature has been carried out and how the data collected has been categorised.

4.2 A classification system for PSS+DRE models

A theory-building approach was used to develop the first version of the classification system and archetypal models. As anticipated in Section 3.6.4, the analytical conceptual research approach (Meredith, 1993; Wacker, 1998) was used. The classification system was developed as a polarity diagram with the purpose of encompassing the majority of dimensions charactering PSS+DRE models. For this reason, the first step was to identify which dimensions overlap and could be clustered together. The first group encompasses dimensions #2, #4, #6, #8 and #9:

- Dimension #2, the *value proposition/payment structure*, distinguishes between product, use and result-oriented PSS (Tukker, 2004) and it is strictly connected with *ownership* (#4). In fact, #4 ranges from customer's ownership in product-oriented PSSs, to provider's ownership in use and result-oriented PSSs.
- The type of PSS can also be aligned with dimension #6 which refers to the *energy system operation*. While in product and use-oriented PSSs the user operates on the energy system, result-oriented models see the provider retaining responsibility of operation of the energy system, in order to provide the final result to customers. As discussed before, this is not always valid for energy-using products such as lamps or other appliances. In fact, users always operate on these products, hence this dimension only refers to the energy system operation.
- Dimension #8, the *provider/customer relationship*, ranges from being transaction-based in product-oriented PSS to be relationship-based in result-oriented PSS, where a more intense type of relationship is created between the customer and the provider (Penttinen & Palmer, 2007; Gaiardelli et al., 2014). For this reason, this dimension can be aligned with the *value proposition*.

- The *environmental sustainability potential* (#9) can also be aligned with the value proposition, as it ranges from a low potential in product-oriented PSSs, to a higher sustainability potential in use and result-oriented models[12].

The second group includes the *energy system* dimension (#1) and the *target customer* (#7). These can be aligned because they are strictly related. The energy system ranges from stand-alone systems such as mini kits and individual energy systems, which target individual users, for example a household, a shop or a productive activity. Moving towards charging stations, these systems suit groups of users, for example through a renting model for lanterns or batteries. PSS that involves mini grids (isolated or connected) are suitable for communities. For these reasons, these two dimensions can be combined.

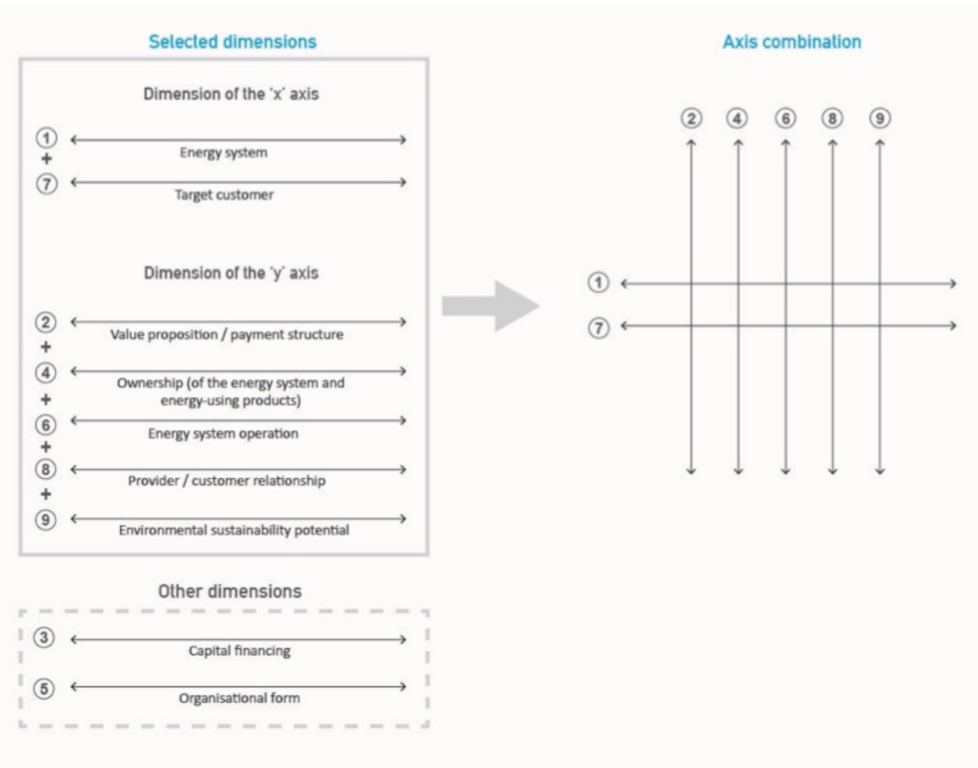


Figure 4.2 - Axis development according to PSS+DRE dimensions

Clustering these main dimensions in two groups led to the development of a polarity diagram (Fig. 4.2 and 4.3). The x-axis includes energy system and *target customer* (dimensions #1 and #7). The y-axis encompasses the *value proposition/payment structure, ownership, energy system operation,*

[12] The value proposition and the environmental sustainability dimension are also aligned, to a certain extent, to energy efficiency and demand side management strategies (EE/DSM). In fact, moving from product-oriented to use-oriented and result-oriented PSSs, providers would be economically interested in adopting EE/DSM techniques. For example, when selling products, providers are not very interested in increasing efficiency of the product in use. On the other hand, in use and result-oriented PSSs providers are economically interested in providing a result that minimise energy consumption and optimise energy efficiency. For this reason, PSS types and EE/DSM strategies can be directly aligned.

provider/customer relationship and environmental sustainability potential (dimensions #2, #4, #6, #8 and #9).

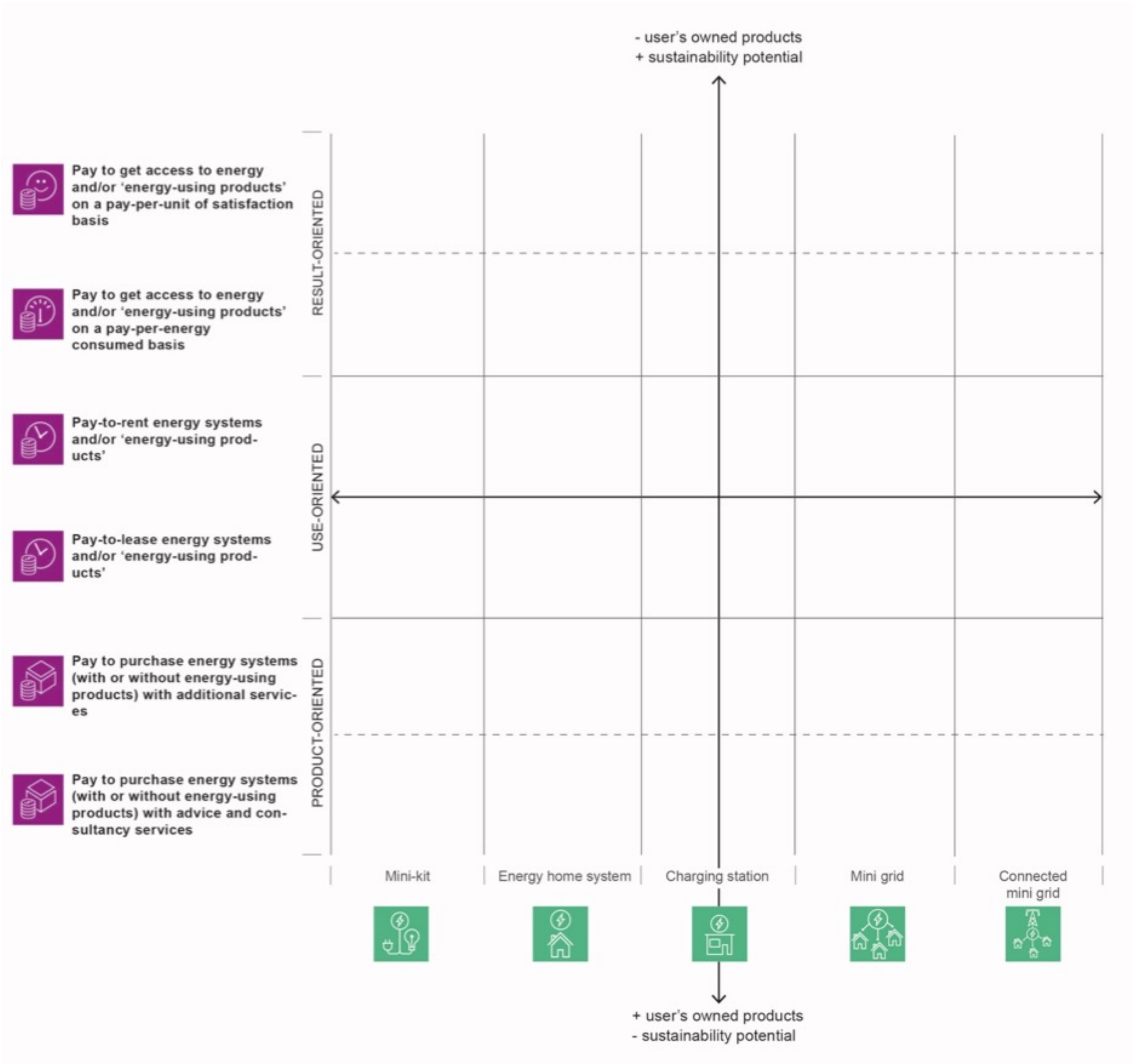


Figure 4.3 - First version of the classification system of PSS applied to DRE[13]

The polarity diagram distinguishes the different types of PSS applied to DRE:

Product-oriented PSSs

- *Pay to purchase with training, advice and consultancy services*. In this model, energy systems (with or without energy-using products) are sold to the customer together with some advice related to the product/s sold, such as how to efficiently use the system, how to dispose of it, management training, etc. This advice can be delivered in many ways (e.g. after the purchase, during the use of the product, through training courses).

[13] The final version of the classification system is presented in Section 5.8, Fig. 5.28

- *Pay to purchase with additional services*. Here, the provider sells the energy system but also offers services related to the installation, use and or end-of-life phases. These services can include a financing scheme, a maintenance contract, an upgrading contract, an end-of-life take-back agreement, etc.

Use-oriented PSSs

- *Pay to lease*. In leasing models, the provider keeps the ownership of the system (and is often responsible for maintenance, repair and disposal), while the customer pays a regular fee for an unlimited and individual access to the leased product.
- *Pay to rent/share/pool*. In this case, the provider keeps the ownership of the energy system and energy-using products and is often responsible for maintenance, repair and disposal. Customers pay for the use of the energy-using products (e.g. pay per hour) without having unlimited and individual access. Other clients in fact can use the product in other moments (different users can sequentially use the product).

Result-oriented PSSs

- *Pay-per-energy consumed*: In this type of PSS, the provider offers a "result" to customers and has the freedom of choosing the most appropriate technology to provide energy services. The energy solution provider keeps the ownership of the products (energy system and energy-using products) and is responsible for maintenance, repair and disposal. Customers pay for the output of the system (energy) according to what they consume (pay-per-kWh).
- *Pay-per-unit of satisfaction*: Here, the provider offers access to energy (and/or energy-using products) and customers pay according to the agreed satisfaction unit e.g. pay to recharge products, pay for a certain amount of energy per day, pay for the output of products for a limited amount of time. The provider chooses the best technology to provide the "satisfaction" and keeps ownership and responsibility for the products (energy system and energy-using products) involved.

The final diagram is then presented as a **classification system of PSS+DRE** (Fig. 4.3) which encompasses the majority of dimensions characterising these models and provides an overview of all possible models of PSS applied to DRE.

It must be pointed out that two dimensions have not been considered in the development of the classification system: *capital financing* (#3) and *organisational form* (#5). Despite being crucial dimensions for PSS+DRE models, for the purpose of the classification system these can be considered secondary. In fact, these dimensions can be considered transversal to different types of models. For example, a PSS that involves providing mini kits on a pay-per consumption basis can present different organisational form and capital financing. However, the main focus of this classification system is to characterise the types of offers of PSS applied to DRE. In other words, for the purpose of this classification system, capital financing and organisational form are not considered crucial dimensions for characterising PSS applied to DRE.

4.3 Case study analysis

The goal of this step was to collect and analyse cases of PSS models applied to DRE in BoP contexts, in order to gain an understanding of characteristics of existing models.
Case study research has been used as a method to build theory on PSS+DRE models, complementing the literature review on critical factors. The case study analysis has been structured according to the following strategy (Fig. 4.4) (Yin, 2009; Eisenhardt, 1989): in a first phase, the dimensions identified through literature review provided a base for the data collection protocol and cases were selected according to the theoretical sampling strategy and maximum variation strategy. Then, the data collection phase was carried out through a first collection round of 21 cases, followed by a second collection round which aimed at confirming and expanding the emergent models. Simultaneously, analysis and comparison of cases was carried out looking for cross-case patterns and confirming theory. The study concluded with the collection of 56 cases.

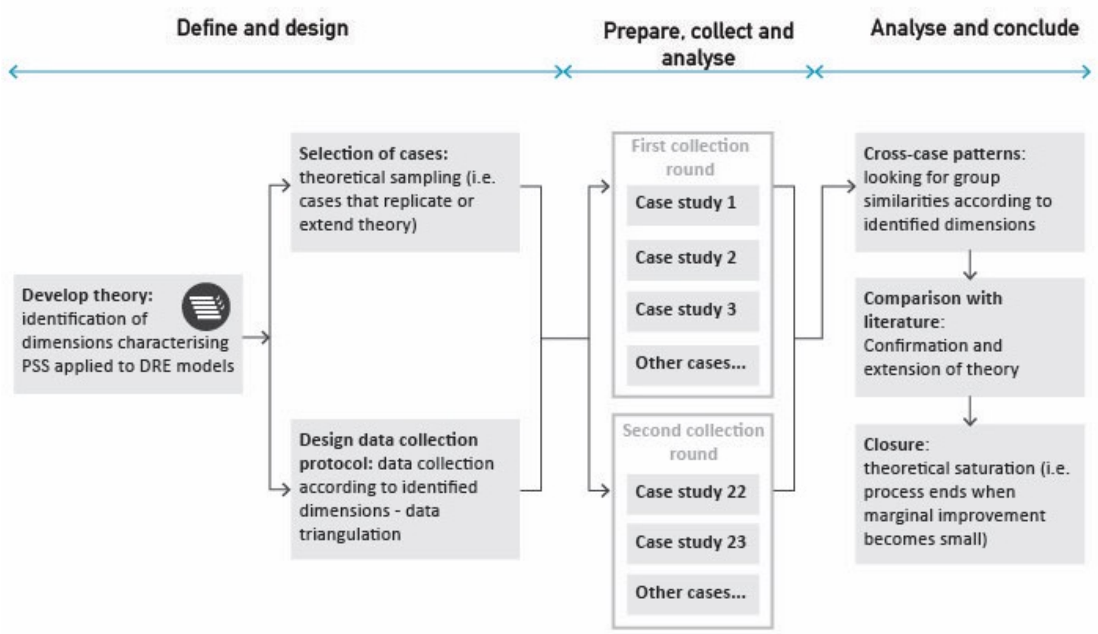


Figure 4.4 - Case study method for this research, based on Yin (2009) and Eisenhardt (1989)

4.3.1 Case selection

The selection of cases initially followed a theoretical sampling strategy, used in this research to "fill theoretical categories and provide examples of polar types" and whose goal was to extend emergent theory (Eisenhardt, 1989 - p.537). Simultaneously to the data sourced from literature review, cases were selected to confirm and extend PSS+DRE dimensions and variables. Additionally, the maximum variation strategy (Miles and Huberman, 1994) was adopted with the aim of sampling for heterogeneity and to select cases that maximise diversity. In particular, cases were selected in order to cover, as much as possible, all the possible differences in the characterising dimensions (e.g. different types of technologies and energy sources, different types of target customers).

Data collection and data analysis were carried out at the same time in order to make adjustments to theory. This resulted in both the addition of cases "to probe particular themes which emerge" (Eisenhardt, 1989 – p.539) and consequently to the addition of variables emerging from the case collection (see examples in the next paragraph). In practice, an initial number of 21 cases was selected according to the previously identified main dimensions. Additionally, the collection of cases continued until *theoretical saturation* (Glaser & Strauss, 1967) was reached, resulting in a total of 56 cases.

In order to enhance reliability and validity of the study, data triangulation (Yin, 1994) was employed, collecting a minimum of three sources for each case. Data collection used academic literature about the same cases under study, news and articles from relevant sources, documents such as companies' reports available from company/project websites. These types of evidences provided specific and precise details and those cases extracted from academic literature had been peer-reviewed, therefore enhancing the reliability of data.

4.3.2 Cases description and cross-case analysis

Cases were categorised according to the dimensions identified through literature review, aiming at searching for cross-case patterns (Eisenhardt, 1989), i.e. to understand which types of PSS models are applied and which characteristics they present. The technique used to analyse cases was the cross-case synthesis (Yin, 2009), which applies particularly to research with multiple cases.

1. **Case description**: first a template for describing cases was created (Table 4.3) where data could be classified according to the dimensions emerging from literature. Collected data from secondary sources was analysed, selected and reduced to the main dimensions to produce a short case description. This process lead to the creation of a catalogue of cases (Appendix I). This catalogue primarily aimed at classifying what models of PSS applied to DRE were used.

OFF GRID ELECTRIC, Tanzania	
Value proposition / payment structure	Offering access to energy and energy-using products through solar mini kits. Customers pay daily fees to use the mini kit for a certain amount of time per day (e.g. 8h) - Pay-per-unit of satisfaction. **SERVICES**: installation, maintenance and repair, product upgrade, basic customer's training
Energy system	Solar mini kit (5-10 Wp), **ENERGY-USING PRODUCTS**: lights, phone chargers and radio
Ownership	Off Grid Electric
Organisational form*	Private enterprise
Energy system operation	Off Grid Electric
Target customer	Individual household and small business
Provider / customer relationship	Relationship-based: customers are assisted with 18h-day call centre and agents provide customers' training and assistance
Environmental sustainability potential	High

CASE DESCRIPTION

The company provides electricity services through solar mini-kits installed at customer's home. Customers can choose the size of the kit according to the appliances they need (starting kit includes two lights and a phone charger for eight hours a day) and upgrade with additional appliances (more lights, radio, TV).
Off Grid Electric retains ownership of systems and appliances and trains a network of local dealers for installation and customer support. Customers pay an initial deposit and pre-pay the energy service through mobile money. When the payment is received, the customer receives an SMS with a code to unlock the system and start using it.

*Table 4.3 - Example of case study description (*refers to the energy solution provider)*

2. **Cross case analysis**: Then, in order to search for cross-case patterns, a list of cases and their characterising dimensions was created to synthetise data (using Excel spreadsheet). Following the "axial coding" process (Strauss & Corbin, 1990), which aims at identifying patterns in cross-case analysis, it was possible to re-examined cases again thoroughly and to have an overview of all PSS+DRE models applied and their characteristics. The comparison across cases also helped to identify similarity and patterns among cases.
3. **Integration of theory**: Following the inductive approach and the grounded theory strategy, cases were then selected and confronted with the critical factors emerging from literature review. An example of how case study analysis complemented theory built from literature review can be explained here: a case study (i.e. Off Grid Electric, see Appendix I) was found and then described according to the already identified dimensions. Then, in analysing the payment structure, the case study presented the use of mobile payments to facilitate a pay-per-unit PSS model. This aspect led to searching for other examples in the literature that would use the same payment structure and modality, and to looking for critical factors that would discuss strengths and weaknesses of this type of payment. This means that the case study analysis helped to integrate theory, resulting in defining variables for the *value proposition/payment structure* dimension (i.e. mobile payments, pay to use the solar kit for a certain amount of hours). Another example is Grameen Shakti's case study (see Appendix I). When this case was found and analysed, an interesting aspect was the role of women in providing maintenance and repair services in the PSS solution. In fact, the involvement of

women in providing some aspects of the PSS solution was an emerging aspect that helped to refine the variable '*training of local technicians*'. This led to a search in the literature for critical factors regarding women's involvement in the energy solution and for training local technicians.

These examples highlight how case studies contributed to the identification of models, variables and critical factors of PSS applied to DRE. It can be affirmed that the case study analysis led to the integration of theory on PSS applied to DRE in BoP contexts by confirming and extending models of PSS+DRE, dimensions and variables found in the literature.

This study presents some limitations. New cases and novel business models are continuously emerging in this field, therefore this study may need to be updated in the future. For the purpose of this PhD a closure needed to be reached within specific time constraints, however the case study collection is a process that can be carried out for future research purposes. This is addressed in Section 9.4.1.

In conclusion, the case study research provided fundamental insights on what are the applications of PSS and DRE models in low-income and developing contexts. Among them, 56 cases from Africa, Latin America, Asia and South and South East Asia were collected. The information collected from the case study research will be used to develop the design support in PS-I.

4.3.4 Classification system population with case studies

The collected and categorised case studies were then positioned on the classification system according to their main dimensions. For example, Off Grid Electric (Table 19), provides solar mini kits (energy system) to individual households (target customer) on a pay-per-unit of satisfaction basis (value proposition/payment structure, ownership, energy system operation, provider/customer relationship, environmental sustainability potential). For this reason, it is positioned in the "mini kit" column and on the "pay-per-unit of satisfaction" row, resulting in the top-left box. This process has been carried out for all cases collected.

The next step involved clustering similar cases in groups (Fig. 4.5), which were defined Archetypal Models of PSS applied to DRE. Cases within a specific archetype are not identical but present similar key features such as target customer, technology choice, value proposition and payment structure. Secondary characteristics such as organisational form, payment modality or capital financing can vary within a certain group.

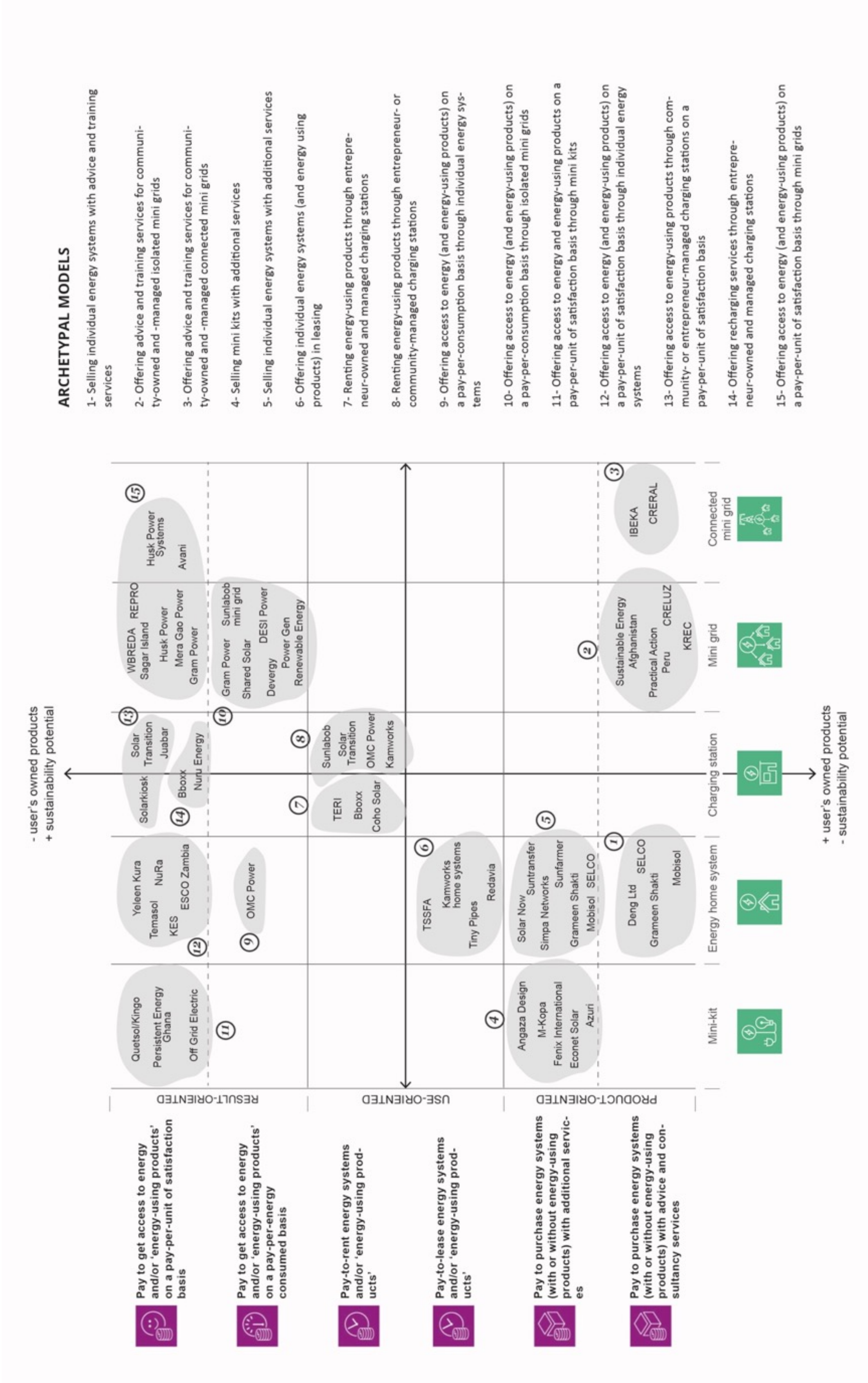


Figure 4.5 - Classification system (populated with case studies) and archetypal models

4.4 Archetypal Models of PSS applied to DRE

This section describes each archetypal model (Emili et al., 2016 (a)). Each model is illustrated with a system map, a visualisation that shows the stakeholders involved, their relationships and the main flows of revenues, products and services (legend described in Fig. 4.6).

Archetypal models are described starting from the bottom-left of the Innovation Map: first the product-oriented one, starting with individual systems and moving towards connected mini grids. Then use and result-oriented models are described.

Figure 4.6 - Legend for the Archetypal Models' system maps

Product-oriented PSS:

In product-oriented PSSs, the first group of archetypal models (1, 2 and 3) is related to ***pay-to-purchase with training, advice and consultancy services***.

- *1. Selling individual energy systems with advice and training services*. In this model, individual energy systems (in most cases, solar home systems) are sold with training and education. These services can focus on design, installation, repair skills, on developing a business on energy systems targeted for example to local entrepreneurs, or they can focus on basic maintenance and environmental awareness. Customers become owners of the systems at the moment of purchase and they are responsible for operation and maintenance.

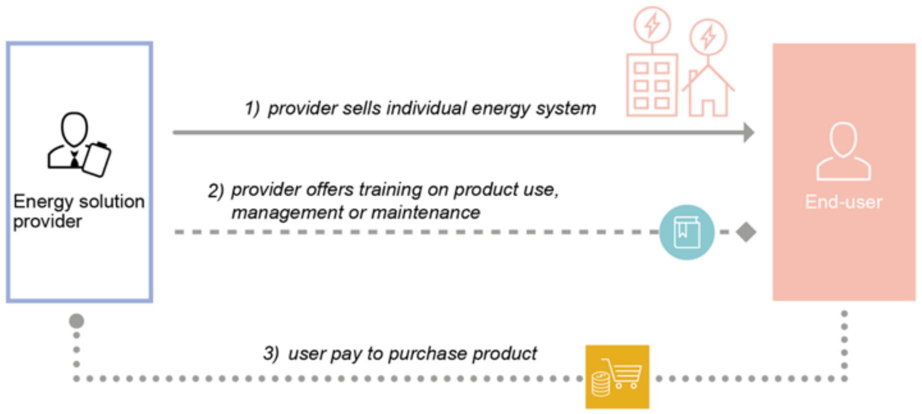


Figure 4.7 - Archetypal model 1

- *2. Offering advice and training services for community-owned and -managed isolated mini grids*. This model involves the energy solution provider to sell mini grids to communities, who are then responsible for operating and managing the system. In some cases, communities can be involved also in designing a payment structure and collecting fees. Coupled with the sale of mini grids, the provider offers training services to a village committee on the operation, maintenance and management of the energy system. In some cases, communities may repay the installation with in-kind contributions such as labour, local materials or land permissions.

Figure 4.8 - Archetypal model 2

- *3. Offering advice and training services for community-owned and -managed connected mini-grids*. Similarly to the previous model, the provider sells connected mini grids that allow the community to not only produce and distribute energy to the local network but also to sell electricity to the national electricity supplier.

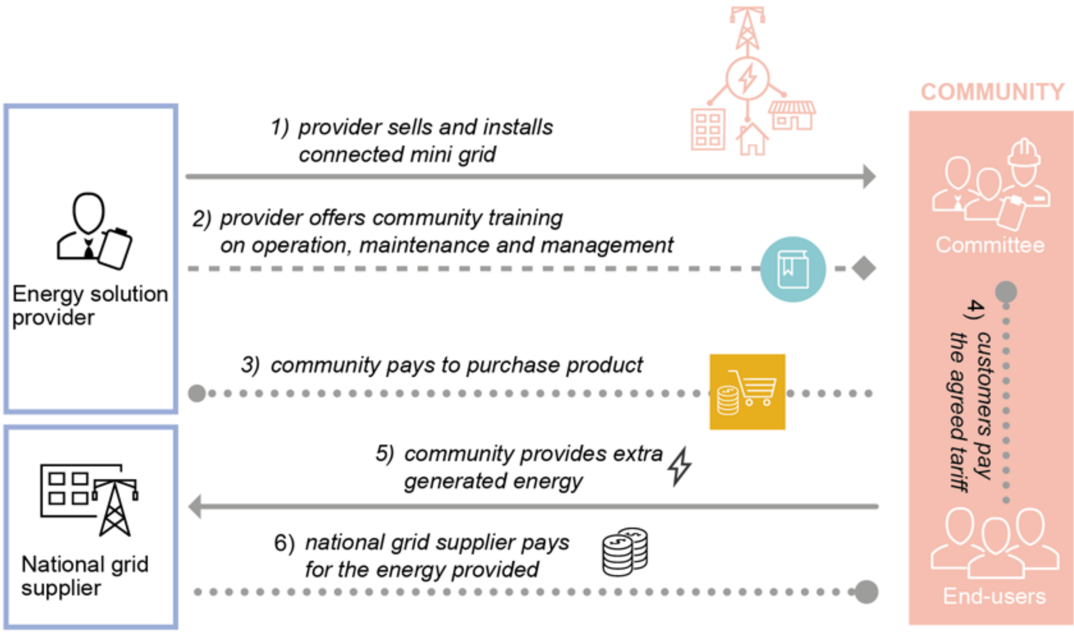


Figure 4.9 - Archetypal model 3

The second group of product-oriented PSSs is defined as ***pay-to-purchase with additional services*** (archetypes 4 and 5).

- *4. Selling mini-kits with additional services*. This model involves the provider selling mini-kits with additional services, such as financing, maintenance and repair or product training. In most cases customers pay through small, flexible instalments over time. After the credit period, usually 1 or 2 years, the ownership is transferred to the customer. Users can receive training on product care and they are responsible for operation and maintenance. During the credit period, the provider offers repair services and sometimes includes extended warranties after the credit repayment.

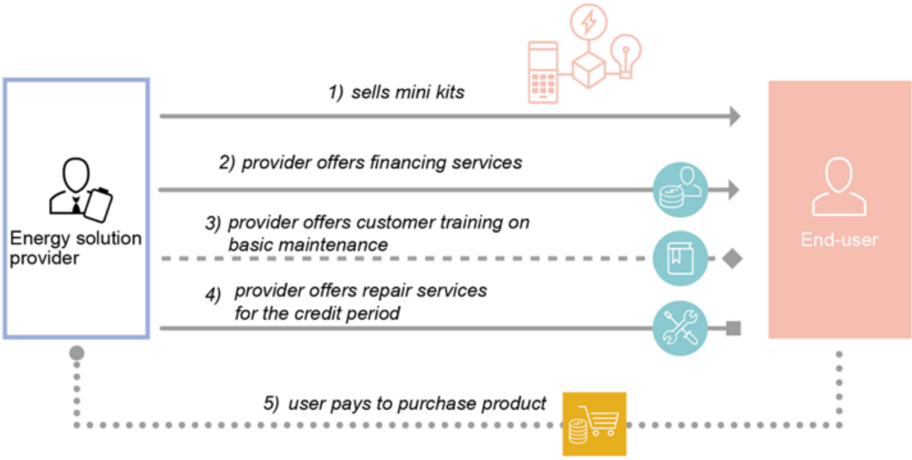


Figure 4.10 - Archetypal model 4

- *5. Selling individual energy systems with additional services*. The provider sells individual energy systems with or without energy-using products, and includes in their offer a package of services such as financing, training, installation and maintenance and repair. End-users pay to purchase the energy system (with or without energy-using products) and become owner of the system, in some cases after the credit period.

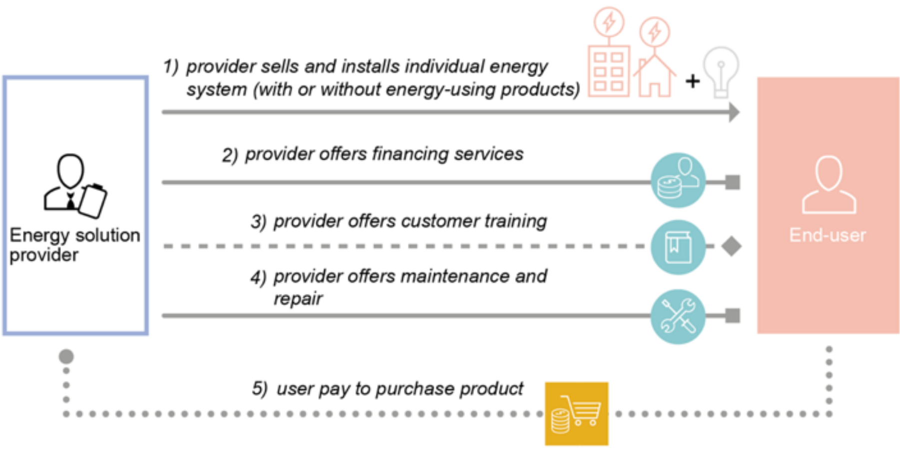


Figure 4.11 - Archetypal model 5

Use-oriented PSS:

This group encompasses ***pay-to-lease*** (archetype 6) and ***pay-to-rent/share/pool*** models (archetype 7 and 8).

- *6. Offering individual energy systems (and energy using products) in leasing*. The provider offers individual systems in leasing, with or without energy-using products, for an agreed period of time. The offer may or not include energy-using products such as lights or batteries. In this case customers do not own the system but have unlimited and individual access to it for the length of the leasing contract. Additional services, such as repairs and maintenance, are included in the product-service package.

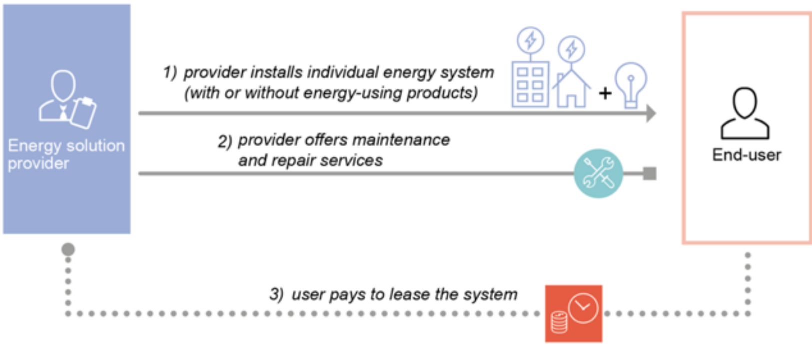


Figure 4.12 - Archetypal model 6

- *7. Renting energy-using products through entrepreneur-owned & -managed charging stations.* A charging station, included with energy-using products, is sold to a local entrepreneur with training on operation and management in some cases financing services. The local entrepreneur provides renting services of the energy-using products. Customers pay a fee when they want to use the products involved (e.g. lanterns or batteries). The entrepreneur is responsible for operation and maintenance of the system and the energy-using products.

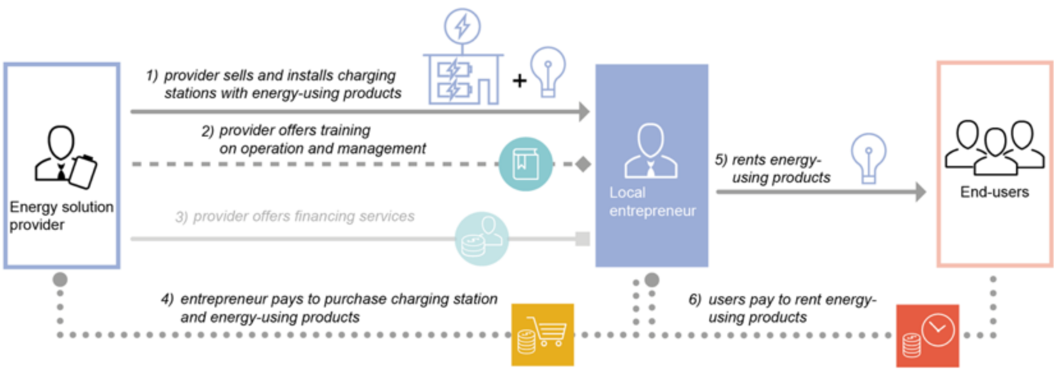


Figure 4.13 - Archetypal model 7

- *8. Renting energy-using products through entrepreneur- or community-managed charging stations*. The energy solution provider installs a charging station for renting out energy-using products to individual users. In this case the provider keeps ownership of the charging system and the energy-using products but trains a local entrepreneur or community for management and operation. The entrepreneur pays a leasing fee to use the charging station, while end-users pay to rent energy-using products when they need.

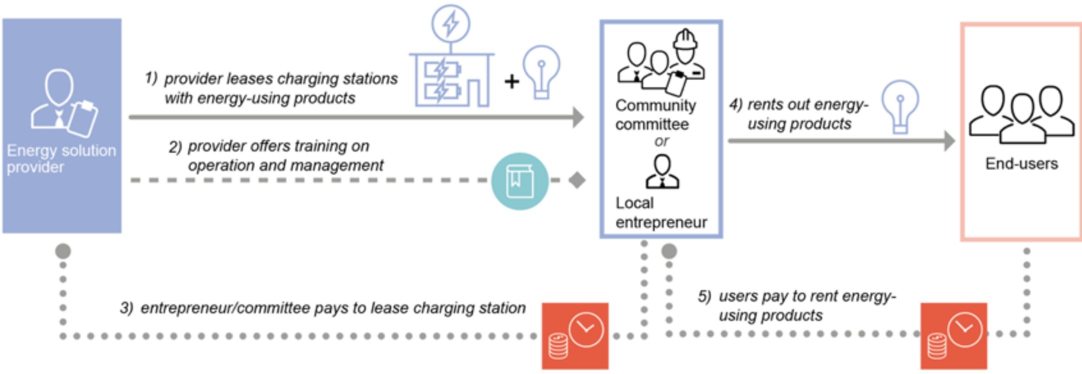


Figure 4.14 - Archetypal model 8

Result-oriented PSS:

This group includes ***pay-per-energy consumed*** models (archetypes 9-10) and ***pay-per-unit of satisfaction*** models (archetypes 11, 12, 13, 14, 15).

- *9. Offering access to energy (and energy-using products) on a pay-per-consumption basis through individual energy systems*. This model involves the energy solution provider to install individual systems at customers' site, sized according to the electricity needs. Customers pay for the energy they consume. The provider retains the ownerships of systems and takes care of operation, maintenance and repairs.

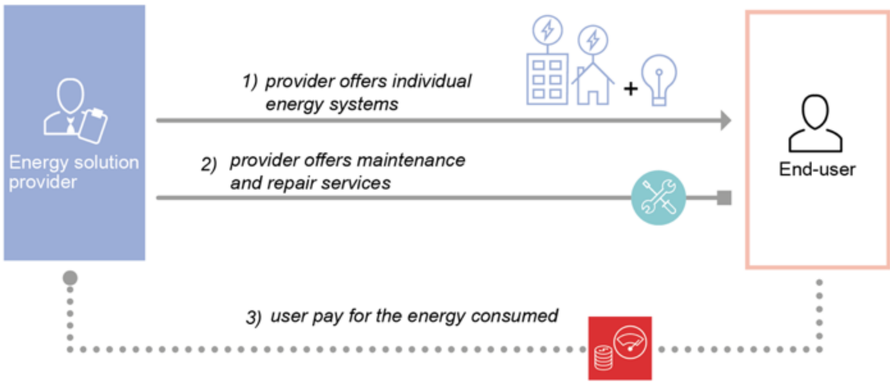


Figure 4.15 - Archetypal model 9

- *10. Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini grids.* The provider offers energy services by installing mini grids (with or without energy-using products) at a community level. Customers gets connected and pay according to the energy they consume. The provider retains ownership and responsibilities of the energy system and products involved. This model can present some variations (flows 5-8): a local community or an entrepreneur can receive training and can be involved in the management, operation and maintenance of the mini grid or fee collection. In this case, customers pay their fees to the committee or entrepreneur, who is responsible for transferring them to the energy solution provider (in this case flow 4 would then disappear).

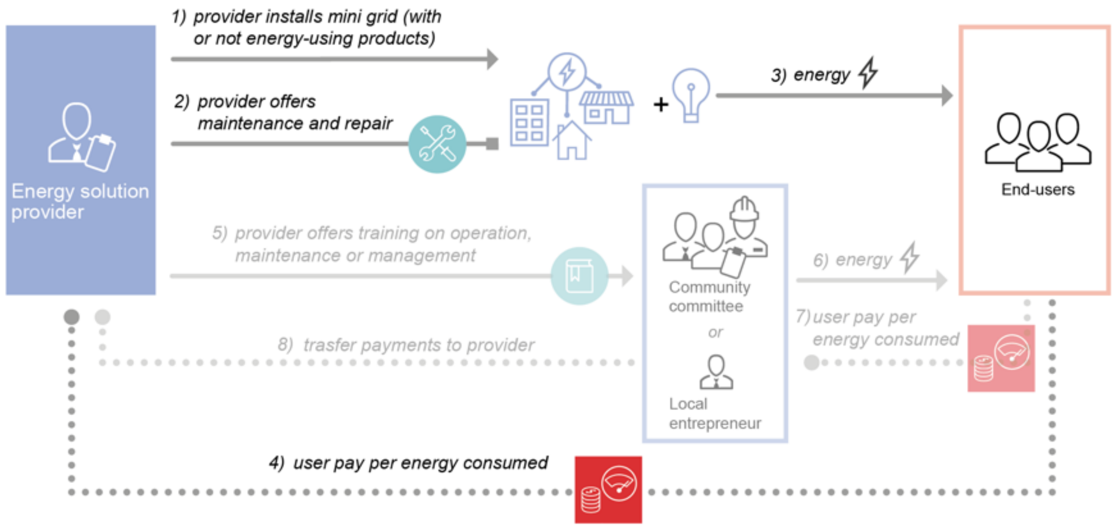


Figure 4.16 - Archetypal model 10

- *11. Offering access to energy & energy-using products on a pay-per-unit of satisfaction basis through mini kits*. The energy solution provider offers energy services through mini kits equipped with energy-using products. Customers pay according to the service package they choose and the appliances they want to use (for example they can pay to use two lights and a mobile charger for a maximum of 8 hours a day). The provider does not transfer the ownership and maintains responsibilities for maintenance and repairs of the mini kits.

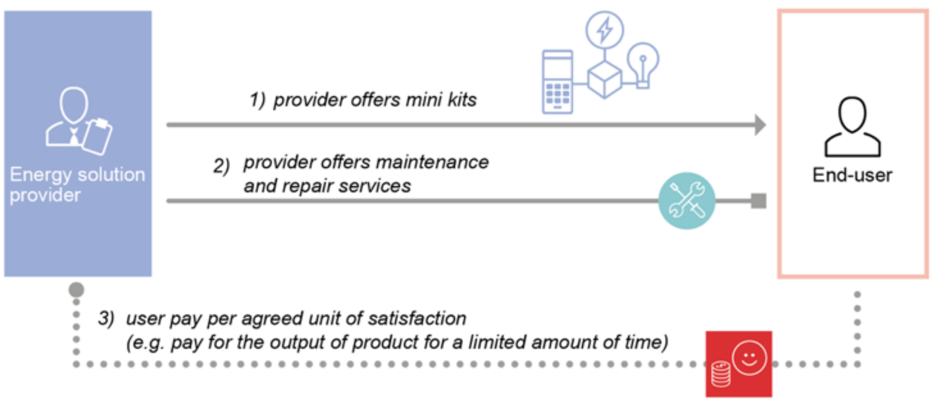


Figure 4.17 - Archetypal model 11

- *12. Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through individual energy systems*. The energy solution provider offers individual systems to provide electricity on a pay-per-unit of satisfaction basis. Customers gets the systems installed and pay a fixed fee to get access to electricity or to use the included energy-using products, usually for an agreed amount of hours a day. The provider always retains the ownerships of the energy system (and energy-using products) and is responsible for maintenance and repairs services.

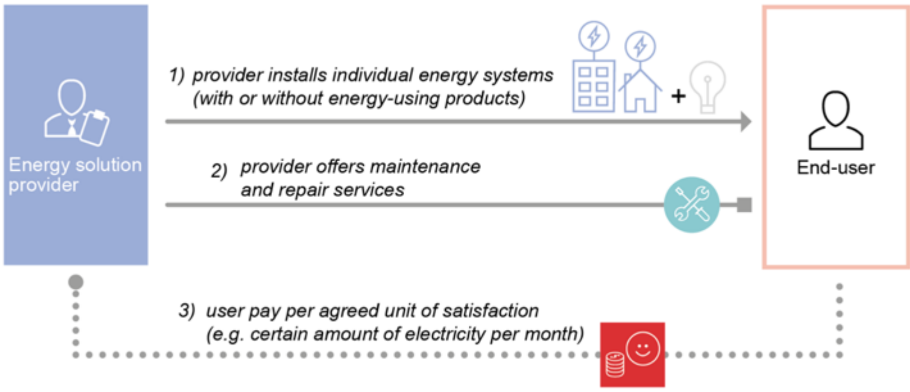


Figure 4.18 - Archetypal model 12

- <u>*13. Offering access to energy-using products through community- or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis.*</u> The provider offers charging stations with energy-using products to a local entrepreneur or a community committee and provides training on operation and management. The entrepreneur or community provides a range of energy-related services to end-users, such as printing, purifying water, IT services to the local community. Customers pay to get access to the energy-using products (e.g. printer, photocopy, computer) on a pay-per-unit of satisfaction basis (e.g. pay per print or pay per unit of purified water). The entrepreneur/committee transfers part of the profits to the energy solution provider and is responsible for operation and maintenance of the energy system and products involved.

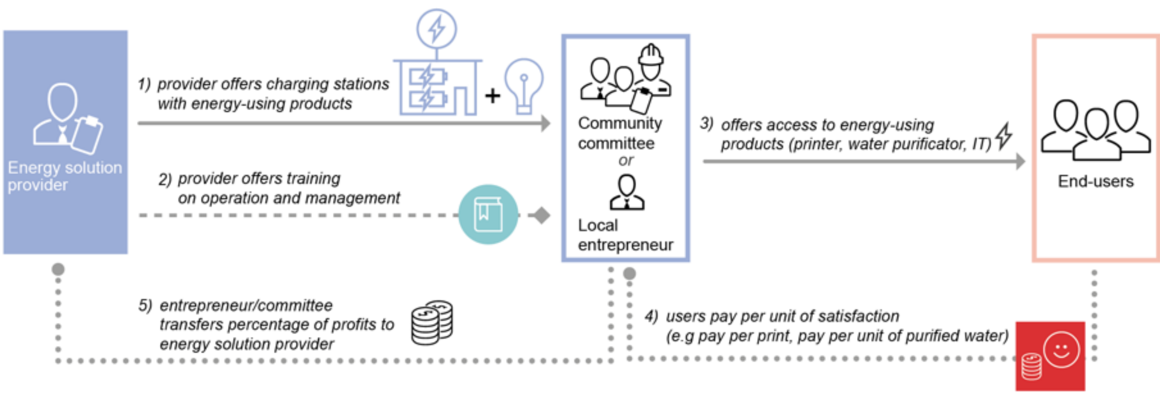


Figure 4.19 - Archetypal model 13

- <u>*14. Offering recharging services through entrepreneur-owned & -managed charging stations*</u>. The energy solution provider sells, with training and sometimes with financing services, the charging station to a local entrepreneur who offers recharging services to customers. End users pay to recharge their products when they need (pay-per-unit of satisfaction), for example they pay to charge mobile phones. The entrepreneur, being owner of the charging station, is responsible for operation and maintenance.

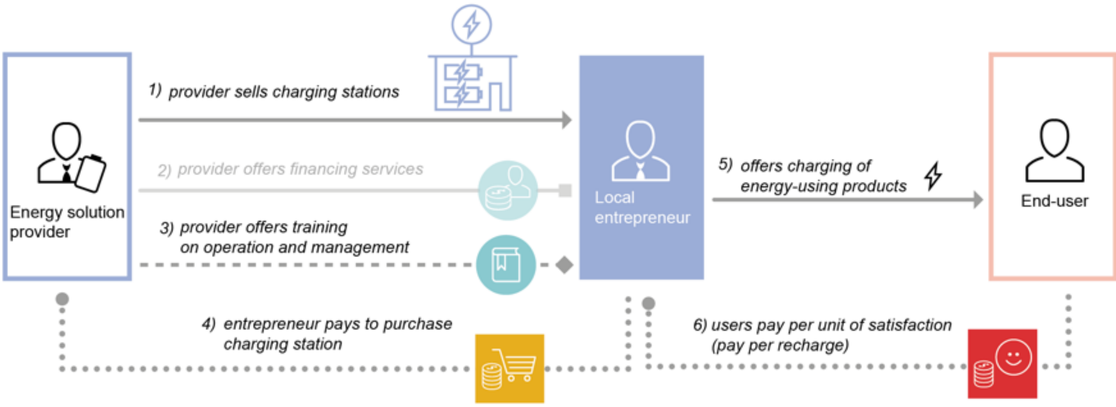


Figure 4.20 - Archetypal model 14

- *<u>15. Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini grids</u>*. The provider offers energy services by installing mini grids (and energy-using products) at a community level. Mini grids can be or not connected to the main grid. End users pay per unit of satisfaction, usually a limited amount of electricity for few hours a day. The provider always retains the ownership of the system and products involved in the offer. This model can present some variations (flows 5-9): in some cases, the local community or an entrepreneur is involved in the operation, management of the mini grid, or in the fee collection as well. In this case end-users pay the agreed tariff to the community committee or entrepreneur and payments are then transferred to the energy solution provider (in this case flow 4 would then disappear).

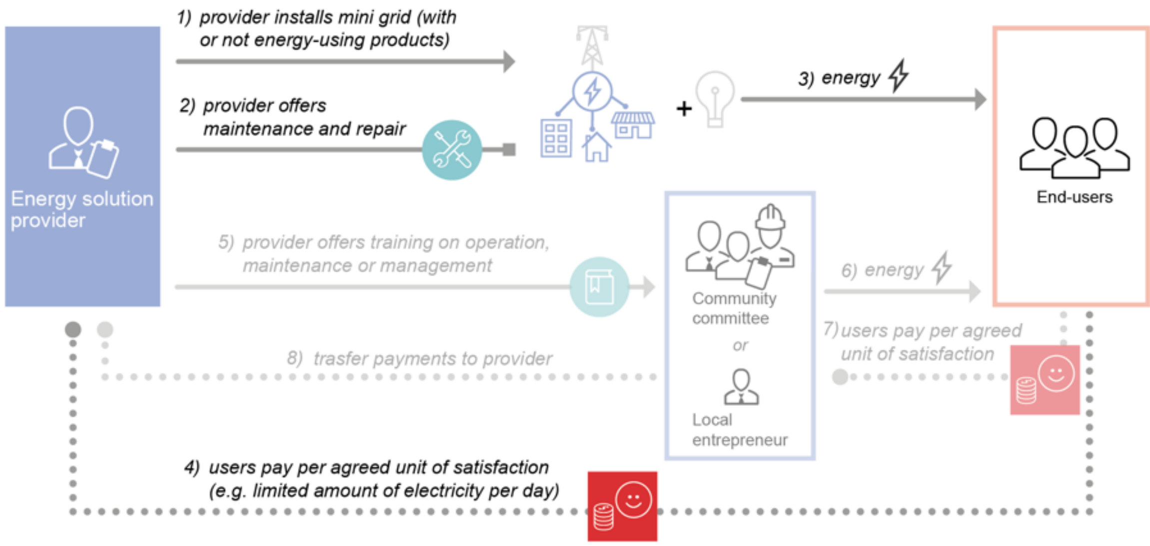


Figure 4.21 - Archetypal model 15

4.5 Critical factors of PSS applied to DRE in BoP contexts

The additional literature review focused on collecting critical factors and best practices of PSS applied to DRE in BoP contexts. As mentioned before, the review has been carried out simultaneously to the case study research in order to integrate the data collected.

An example of how variables and critical factors have been collected can be described here (Fig. 4.22). Within the energy system dimension (#1), variables include the type of connection which distinguishes between mini kits, individual energy systems, charging station, isolated and connected mini grid. For each of these variables (e.g. mini kit), a review of the literature identified specific critical factors, which may include for example strengths and weaknesses of a specific technology option or suggestions for a target user. For example, in the case of mini kits, collected critical factors include that the use of this technology is appropriate for scattered households with low energy demand. The strengths emerging from adopting mini kits include easy installation, low-investment costs and little maintenance required (Rolland, 2011).

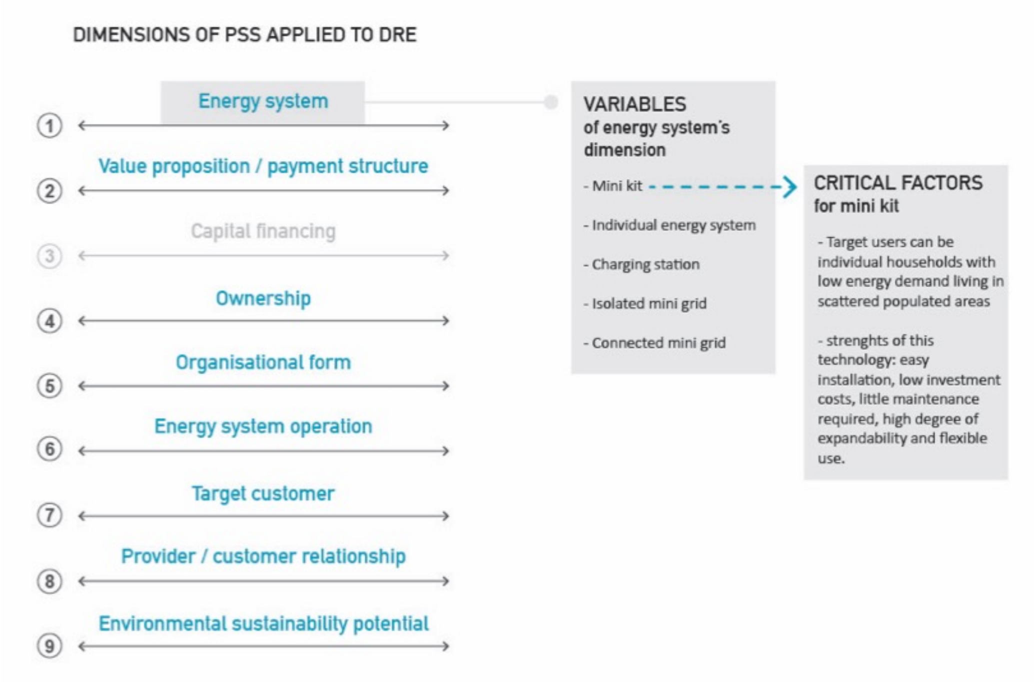


Figure 4.22 - Schematic describing how dimensions of PSS+DRE, variables and critical factors are organised

The process of collecting data from literature and categorising it according to the different dimensions and variables has been carried out following the principle of *theoretical sampling* (Corbin & Strauss, 2008). This method is used for sampling on the basis of concepts derived from data. In fact, the aim was to "collect data that maximize opportunities to develop concepts in terms of their properties and dimensions, uncover variations and identify relationships between concepts" (Corbin & Strauss, 2008).

In practice, an example of how new variations have been uncovered during the process of collecting critical factors can be described here. The value proposition/payment structure dimension (#2) refers to the combination of products and services for which the customer is willing to pay and the payment structure adopted. In other words, it concerns the PSS type (e.g. leasing model) but it also includes types of services offered and payment modalities used. In reviewing the literature, a first step aimed at searching critical factors to identify which services may be offered (e.g. training), then once a new variable emerged (e.g. offer training to end users), the review focused on detailing the related critical factors. An extract of how these critical factors are collected and organised is provided in Table 4.4, while a summary for each element and the complete list are available in Appendix II.

Dimension: Value proposition/payment structure Variable SERVICES: training		
Offer training to end users	*It is important that customers learn capabilities and limitations of systems. User training also creates a lasting relationship between provider and customer.*	May (2002)

	Training for technicians and users through manuals and guide books should be provided in their language and should be adapted to users' and technicians' prior belief structures and knowledge	Tillmanns (2011)
	It is important that customers learn capabilities and limitations of systems. The technical education of consumers to help them to make the best out of their systems and to ensure the project sustainability is fundamental	May (2002); Rolland & Glania (2011)
	Technical problems tend to be linked to overuse of systems and this happens because of a lack of understanding of the limits of the system. Regular visits of technicians would facilitate the learning process. Systems may be installed improperly or wrong components or appliances may be used if training is only provided through manuals.	Lemaire (2009), ISES (2001)

Table 4.4 - Extract of critical factors collected for Services: offer training to end users

The process of sampling continued until the point of *theoretical saturation* was reached, meaning that dimensions and variables were considered sufficiently covered and data collection was no longer generating new leads (Glaser & Strauss, 1967).

It must be pointed out that the review of critical factors does not cover the capital financing dimension (#3). This decision has been made considering the scope of this research and the timeframe available to carry out the activities. In fact, despite being a crucial dimension for the design of the business model and its economic sustainability, financing mechanisms are too complex and too broad to be covered within this PhD. This aspect is further discussed in Chapter 9.

The process of reviewing critical factors and categorising them according to dimensions and their variables, led to the identification of **elements of PSS applied to DRE** (Fig. 4.23). Expanding from Mont's (2002) PSS elements (products, services, network of stakeholders and contract), elements of PSS+DRE can be defined as the characterising components that describe these type of offers. They include:

- **Products**: It refers to the *energy systems*, *renewable energy sources* and *energy-using products* involved in the PSS solution. Energy systems include stand-alone systems (mini kit, individual energy system, charging station) and grid-based systems (isolated and connected mini-grid). The types of renewable energy sources used for DRE systems are: solar, hydropower, biomass, wind, human power or hybrid sources (i.e. combination of different renewables). In the product category are listed the appliances that can be included in the offer in combination with the energy systems (i.e. generator). These include: lantern, lights and bulbs, battery, phone charger, radio, TV, fan, IT and computer devices.

- **Services***:* it includes consultancy services (training, financing) and services provided during or at the end of the product life-cycle (installation, maintenance and repair, product upgrade, end-of-life services).
- **Offer:** This element refers to the different types of PSS+DRE models: product-oriented (pay-to-purchase with training, advice and consultancy services; pay-to-purchase with additional services), use-oriented (pay-to-lease; pay-to-rent/share/pool), and result-oriented PSSs (pay-per-energy consumed; pay-per-unit of satisfaction).
- **Payment modality***:* This element refers to the different ways customers pay for the energy solution. It includes: cash, credit, mobile payments, scratch cards and energy credit codes, in-kind contribution, fee collection and remote monitoring as an activity supporting payment.
- **Customer:** It refers to the type of target customers addressed in the PSS solution and includes: individual household, productive activity, local entrepreneur, public buildings, community, public and governmental entity and mix of target customers.
- **Network of providers:** It refers to the actors involved in providing the energy solution and it includes private enterprise, technology manufacturer, community, local entrepreneur, Non-Governmental Organisation (NGO), Cooperative, Micro-Finance Institution (MFI), public and governmental entity, national grid supplier.

PSS+DRE elements and their respective variables are illustrated in Fig. 4.23. Appendix II includes a summary of critical factors for each of the identified PSS+DRE elements, discussed with some examples of case studies, and provides a complete list of factors and references collected in this study.

In conclusions, this study started with the identification of PSS+DRE characterising dimensions, followed by an additional literature review of their variables, which led to determine their critical factors. These factors have been classified and described according to PSS+DRE elements: products, services, customer, network of providers, payment modality and offer type. This review concluded the exploratory phase of the research, which aimed at answering RQ1. In a second stage, the collected critical factors will be translated into a support for designing PSS+DRE models in BoP contexts (see Chapter 6).

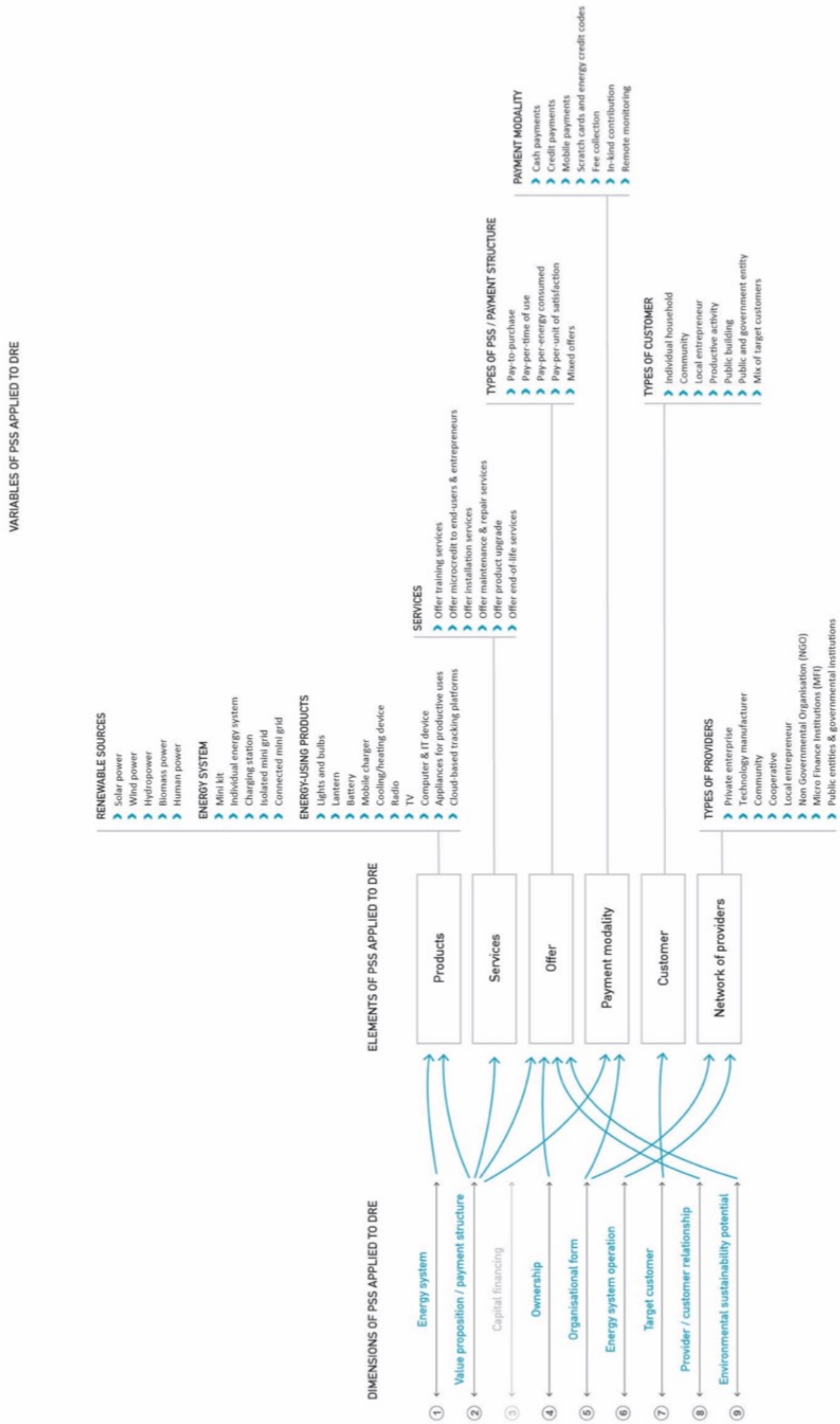


Figure 4.23– Elements of PSS+DRE and their variables

4.6 Study on the target users of this research: DRE companies and practitioners

The literature review on PSS, DRE and BoP tools highlighted that new tools for designing PSS applied to DRE in BoP contexts are needed (see Section 2.5). In fact, while DRE tools are limited and do not cover all characterising dimensions, tools for PSS design are too generic to be adopted for specific applications, such as the energy field. Similarly, BoP design approaches also present some limitations and do not include tools that focus on energy. Having identified these gaps in the literature, a further exploration was necessary with the aim of confirming these findings and getting a deeper understanding of which tools companies and practitioners are actually adopting. In fact, it appeared to be necessary to find out whether any of the tools found in the literature were practically applied by companies and practitioners. In general terms, this study aimed at gathering information about the potential recipients of this research and on which context of use may the design supports (tools) be applied.

In a first phase of the study, companies from Botswana were engaged to gather a general understanding of who is involved in the design of business models, and what may be the dynamics for designing the offer. Semi structured interviews were used in this phase. The second phase built upon the findings collected from the first round of interviews and extended the questions to companies and practitioners from different contexts. In this phase, questionnaires (online and offline) were employed. The changes in data collection between the first round of interviews and the second round of questionnaires allowed the researcher to probe emergent themes and explore more in depth the subject under scrutiny (Eisenhardt, 1989). Questionnaires and interviews' samples are collected in Appendix III.

4.6.1 Sampling

The strategy adopted in this study followed a purposive sampling (Robson, 2002), i.e. companies and practitioners were selected for representing the population under study. Initially, SMEs with a product-oriented offer or a traditional sales-based business model were involved because they would possibly benefit from using the tools to redesign their offer adopting a PSS approach.

In a second phase, other types of participants were selected, including companies providing PSS offers, consultants and practitioners. A list of participants involved in the study is provided in Table 4.5 and 4.6.

Type of business	Focus / type of offer	Country
SME (T1)	Solar systems – product-oriented	Botswana
SME (T2)	Solar systems - product-oriented	Botswana

SME (T3)	Solar systems - product-oriented	Botswana
SME (T4)	Solar systems - product-oriented	Botswana
SME (T5)	Solar systems - product-oriented	Botswana
SME (T6)	Solar systems - product-oriented	Botswana
International company (T7)	Solar charging station – Result-oriented PSS	Botswana

Table 4.5 - List of participants from the interviews in Botswana

Type of business	Focus / type of offer	Country
SME (T8)	Improved cook stoves - Sales	Kenya
SME (T9)	Biogas systems – product-oriented	Kenya
SME (T10)	Improved cook stoves - Sales	Kenya
Consultant (T11)	DRE: design, planning	Kenya
SME (12)	Solar systems – product-oriented	Kenya
Consultant (T13)	DRE: design, planning	South Africa
Consultant (T14)	Business models for renewable energy	South Africa
Consultant (T15)	Business models	South Africa
Medium-size company (T16)	Solar systems – product-oriented	South Africa
Medium-size company (T17)	Mini grids – Result-oriented PSS	India
Large-size company (T18)	Solar home systems – product-oriented	Bangladesh

Table 4.6 - List of participants from online and offline questionnaires

4.6.2 Data analysis

The first round of interviews aimed at understanding the process of business model design adopted by DRE companies. In addition, interviews investigated how companies benchmarked their business model, and, if their offer changed over time, which reasons were behind this choice. This would help understanding what type of actors were involved in the process, their motivations for redesigning the offer and consequently the starting point for the design process.

The second phase of this study, carried out through online and offline questionnaires, aimed at broadening the first results to a wider group of participants from different contexts. In particular, the purpose was to explore more in details what type of tools are used in the design of the business model and what are their limitations. Results from the first and second round of data collection are jointly discussed below.

<u>1. Design of the business model: how the business offer is developed and who is involved in the process</u>

Designing a business model can be a complex process, influenced by multiple factors and depending on different variables. In this study, companies and practitioners were asked how they designed their model, for example whether the starting point was a specific product or a target market. Participants provided a wide range of answers which can be clustered in main categories:

- **Design a business model based on an available technology**. Five participants have affirmed their business model is designed around a specific technology they wanted to market. Some of them ventured in the DRE field coming from different fields of the energy sector (*"we started with smaller products and now we want to expand our portfolio'* (T2); *"we expanded to solar PV 15 years ago"* (T6); *"to expand offerings we ventured into solar PV systems to add on renewable aspect to our own existing customers"* (T16)).
- **Design a business model starting from market conditions** (e.g. availability of financing, availability of resources). Some participants studied the market conditions to design their offer, looking at national grid services and possibilities for investments. The availability of natural resources and skills was also a decisive factor (*"available resources (tech, skills) driven by financing"* (T7); *"looking at the energy challenges Botswana was facing keeping in mind the many resources available"* (T5)).
- **Design a business model based on analysis or research on users' needs**. For some social enterprises, the development of the business model started from direct observation of users' needs or from experiences with communities (*'the original idea was to do something that benefits people with less means to get electricity' (T1); 'the founder drew upon his commitment to a service rather than product approaches to delivering value to the rural poor' (T17); 'all the packages have been designed based on customers' need and requirement' (T18)*).

Having defined the drivers for the business model design, the study focused on understanding who is involved in the process of designing the offer. Most participants (14) responded that the founder or managing director of the company was involved in the design of the business model, in some case assisted by technical team responsible for the design of the DRE (T8, T16, T18). Some participants have benefited from specific training on business model design (T9, T10), while others engaged with business consultants and research departments to develop their offers (T14, T15, T8, T11).

1.2 Supporting tools for business model design

The first round of interviews was carried out mainly with SMEs operating in a specific context (Botswana) and with similar characteristics in terms of offer provided, technologies employed and size of the company. Most of those, in fact, affirmed that the business model was designed around a specific technology they wanted to offer (T2, T3, T4, T6). The second phase of the study aimed at expanding on this aspect and understanding more in detail which tools were employed in the design phase. Some respondents (T10, T15, T18) affirmed they used the Business Model Canvas (Osterwalder & Pigneur, 2010). Other tools mentioned were the growth wheel and balanced scorecards (T15), the excel business model tool (T9). The rest of participants affirmed they did not use any tool to support the design process.

2. Benchmark of the business offer

Another interesting aspect related to the design of the business model, was to understand whether companies looked at competitors and case studies to benchmark their offers as inspiration for their business model. Four participants affirmed they took inspiration from competitors operating in the same area, or providing the same technology ("*We did see what [other company] was doing and learned from what they had been able to do*" (T17); "*I have used other fast moving consumer goods companies in the cook stove industry*" (T10); "*looking at what other competitors provide*" (T11); "*I've seen what companies are doing wrong and we thought how we could improve it*" (T2); "*by looking at competitors' models and trying to come up with a better offer for our customers*" (T8)).

Some companies, those providing product-base offers in Botswana (T3, T4, T5, T6), affirmed they looked at their technology suppliers to design their business model, in particular operating in South Africa.

Others affirmed they were pioneers in a specific context, therefore did not have competing providers in the same area (T1, T2, T18), or simply their business offer had to compete with non-renewable providers ("the offer was benchmarked against kerosene as companies do not compete within this space, they all compete with kerosene", T17).

3. Changing of the business offer: drivers

With this study the researcher aimed also at understanding why companies would change their business model over time and what factors may influence this decision. In fact, most of the companies and practitioners engaged in the study, especially those in the first phase of interviews, have product-oriented business model, i.e. selling products with some additional services. These types of companies represent one type of target user of this research, meaning they could potentially shift their business model towards a PSS-based solution. For these reasons, the results emerging from this study would help understanding how to introduce the Product-Service System approach for DRE companies that have a traditional sales-based business model.

Almost all recipients affirmed that their business model changed over time. Only three of them answered negatively (T6, T12, T16). The reasons for changing business model can be grouped in these categories:

- **Change/upgrade of technology**: the availability of new technologies, larger systems or improved products led most companies to refine their offer. Some of them (T2, T8) built synergies with new stakeholders which enabled a new technology to be introduced or a new service to be added to their portfolio ("*we are now starting to look at supply solar-powered appliances at a credit model*" (T8;

"*attractive financial package scheme has been incorporated in the business model*" (T18); "*to expand offerings we partnered with a company existing in the local market*" (T16)).

- **Customer changes**: the change in energy demand was one of the drivers to refine their business for some companies (T17; T8; T3).

- **Market conditions**: some responded cited the changing market conditions and business environment as the reason for changes in their offering ("*changed severally over time as the evolving environment of doing business changes and new opportunities and challenges faced*" (T10); "*competitive market and inclusion of several energy companies play a vital role in changing the offer*" (T18); "*mostly based on prevailing market conditions*" (T11)).

4. Use of manuals, guides or toolkits for DRE design: purposes, usefulness and limitations

Another aspect to be covered in this study was related to the design of the DRE system, i.e. the energy system and energy-using products. Many participants (7) affirmed to not having used any manual or toolkit in the design of the DRE. This can be explained by the fact that most companies are not directly involved in the design of the energy system but they receive products from technology suppliers. In fact, some participants used toolkits and guides from manufacturers for installation and maintenance of products (T11, T12), and to inform and train customers (T8, T11, T12). T18 was the only respondent that produces in-house products and has its own technical team which prepares guides and manuals for training purposes.

One participant, (T16) affirmed its company used GIS software to determine feasibility of solar projects.

4.6.3 Discussions of results

This study helped to get a better understanding of the recipients of this research and to sustain some conclusions made through literature review.

Target users of this research: the study highlighted that founders or managing directors are principally involved in the design of the business model, in some cases with the support of business consultants or DRE experts. This means that a mix of expertise can be found in designing teams.

The study investigated the reasons for companies to change their business offer over time. It was necessary to understand the drivers for designing a new offer in order to plan how tools may be used by companies already operating in a context and what needs they might have when using them.

This aspect also helped in determining how different users in different stages of the design/redesign of the business model may apply the tools. Many affirmed that the offer changed according to customers and market changes, others affirmed it changed due to availability of technology. Others said it was necessary to introduce services to satisfy customers. This aspect has been considered to define the design phases and activities of application of the tools. For example, a strategic analysis of competitors operating in the same context can be a starting point to identify existing solutions and challenges to exploit. This aspect can also be supported by looking at examples and best practices of companies. In conclusion, this study helped defining the final recipients of this research: start-ups and practitioners wanting to set up a new a business, as well as established companies wanting to re-designing and steering an existing solution towards a more sustainable one.

Tools for design process: most participants were not directly involved in the design of the DRE system, therefore DRE tools appear not to be widely used. Most companies are provided with manufacturers' manuals for product use and maintenance. Some participants highlighted how these manuals were limited or difficult to be understood, especially when used to train technicians and end-users ("*It is not detailed or designed in the right manner*" (T16); "*becomes difficult for them to understand*" (T8); "*some manuals are complex"* (T11)).

The design of the business model, on the other side, has been mostly done without the support of specific tools. The Business Model Canvas appears to be the only tool mentioned by few participants. This aspect supports findings from literature review (see 2.1.6). In fact, tools for business model design are too generic or cover only certain aspects of the solution. For example, the Business Model Canvas does not integrate all aspects in the design process and does not cover the sustainability dimension. In addition, other tools found in the literature do not include lessons learned in the past (i.e. critical factors) and examples from case studies. In conclusion, this study supports the findings from literature review that specific tools for designing business models for DRE, and in particular PSS applied to DRE, are needed.

This study also presents some limitations. The range and amount of companies involved is limited and may not exhaustively represent the panorama of DRE companies and practitioners. However, if the first phase of the study involved mainly small-size companies operating in the solar sector in Botswana, the second phase broadened the sampling to different contexts (South Africa, Kenya, India, Bangladesh) and types of businesses. It is important to highlight that this study is encompassed within the primary studies and aimed at getting a deeper understanding of the topic under investigation. In fact, the data collected is used to reinforce the conclusions drawn from literature review and tools review. In other words, these studies can be seen as complimentary and, in line with the exploratory phase of this research, they contribute to develop a detailed picture of the topic of PSS applied to DRE in BoP contexts.

4.7 Conclusions and summary

Chapter 4 encompasses the primary studies that aimed at answering RQ1: What are the characteristics of PSS applied to DRE? How can these models be classified? What are the applications of these models in BoP contexts? What are the critical factors to successfully implement these models? This chapter also includes a study that aimed at gathering deeper knowledge on the target users of this research. The outcomes of this phase are summarised below.

1. PSS+DRE characterising dimensions have been defined

A first outcome of this phase of the research is the identification of nine PSS+DRE characterising dimensions: *value proposition/payment structure, energy system, target customer, ownership, energy system operation, capital financing, organisational form, provider/customer relationship, environmental sustainability potential*.

2. A new classification system for PSS applied to DRE is presented

The identified dimensions were then used to develop a polarity diagram, which led to the development of a new classification system. This classification encompasses most dimensions of PSS applied to DRE and it is presented as a model to describe and detail different types of PSS applied to DRE. The classification system distinguishes six categories of PSS applied to DRE. In product-oriented PSSs, two types can be defined: *pay to purchase with training, advice and consultancy services*; *pay-to-purchase with additional services*. Use-oriented PSSs differentiates between: *pay-to-lease*; *pay-to-rent/share/pool*. In result-oriented models, two PSS types can be determined: *pay-per-energy consumed*; *pay-per-unit of satisfaction*. Compared to existing classifications of respectively PSS and DRE models, this system represents a multi-dimensional approach and therefore a more comprehensive way to describe PSS applied to DRE solutions.

3. 15 Archetypal Models of PSS+DRE have been identified

A case study analysis was conducted to explore practical applications of PSS and DRE in BoP contexts. This study resulted in a collection of 56 cases, analysed and organised according to the identified PSS+DRE dimensions. Cases were then positioned on the classification system and grouped in similar cases, leading to the identification of PSS+DRE Archetypal Models. The 15 models have been described in terms of offer provided, type of energy system, ownership and payment structures. Each model was also visualised through a system map.

4. Critical factors for designing PSS+DRE models have been collected

The identified PSS+DRE dimensions were then used to define elements of PSS applied to DRE: *products, services, offer, payment modality, customer* and *network of providers*. A review of the literature, carried out simultaneously to the case study research, focused on extracting critical factors for each of the PSS+DRE elements. The critical factors, summarised in Appendix II, constitute the body of knowledge for a successful implementation of PSS applied to DRE in BoP contexts. They would be translated in a design support in the second phase of the research.

5. A study on DRE companies and practitioners confirmed literature findings and helped understanding the target users of this research

The study on DRE companies and practitioners helped defining end-users of this research and identifying how the design of the business model may take place, which drivers and reasons for changing the offer can be considered and what tools have been used in the process. This study supported the findings emerged from literature review and provided insights for the development of the design support.

Chapter 5

PSS+DRE Innovation Map

5: PSS+DRE Innovation Map

This chapter describes the development of the PSS+DRE Innovation Map as a strategic design tool. In this section the design, testing and refinement of the tool are discussed through its several iterations in Botswana, South Africa and Kenya. The chapter concludes with its final version and considerations for future research activities.

The activities described in the previous chapter provided an answer to RQ1 and concluded the first part of this research. The primary studies identified dimensions characterising PSS applied to DRE, developed a new classification system for these models and described 15 Archetypal Models, which represent the applications of PSS+DRE in BoP contexts (Emili et al., 2016 (a)).
In a second phase of the research, the results from RQ1 were used to answer RQ2 (Fig. 5.1): how companies and practitioners might be supported in designing PSS+DRE for the BoP? What tools can be developed?

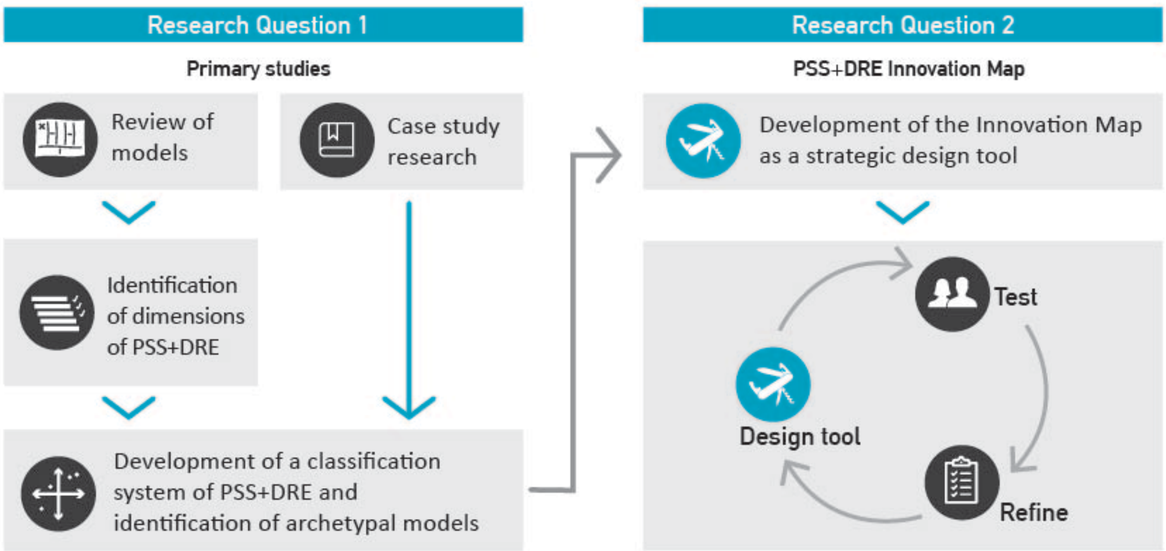


Figure 5.1 - Schematic of activities conducted during the primary studies and those included in this chapter

This chapter introduces the first tool developed to support companies and practitioners in the design of PSS+DRE in BoP contexts: the Innovation Map. Following the several stages of the research methodology (see Figure 5.2 and 5.3), the chapter introduces the tool and its envisioned applications (PS-I), proceeding with description of the several testing activities (DS-II, DS-III, DS-IV) that assessed the completeness, usability and usefulness of the tool. A wide range of companies, practitioners, experts and students were involved in the testing activities, as summarised in Table 5.1.

Study	Activity	Location	Participants
Descriptive Study II	Workshop (W1)[14]	Botswana	39: design students
	Interviews & questionnaires	Botswana	21: mix of companies, experts and academics
Descriptive Study III	Workshop (W4)	South Africa	12: mix of companies and practitioners
	Workshop (W5)	Kenya	11: mix of companies and practitioners
Descriptive Study IV	Workshop (W7)	Kenya	2: NGO and company
	Workshop (W8)	Kenya	8: consultants and DRE students
	Workshop (W9)	Botswana	2: companies

Table 5.1 - Testing activities for the Innovation Map: activities, location and participants involved

[14] The workshops' numbers correspond to the workshops' list in Section 3.6.2 of the methodology chapter.

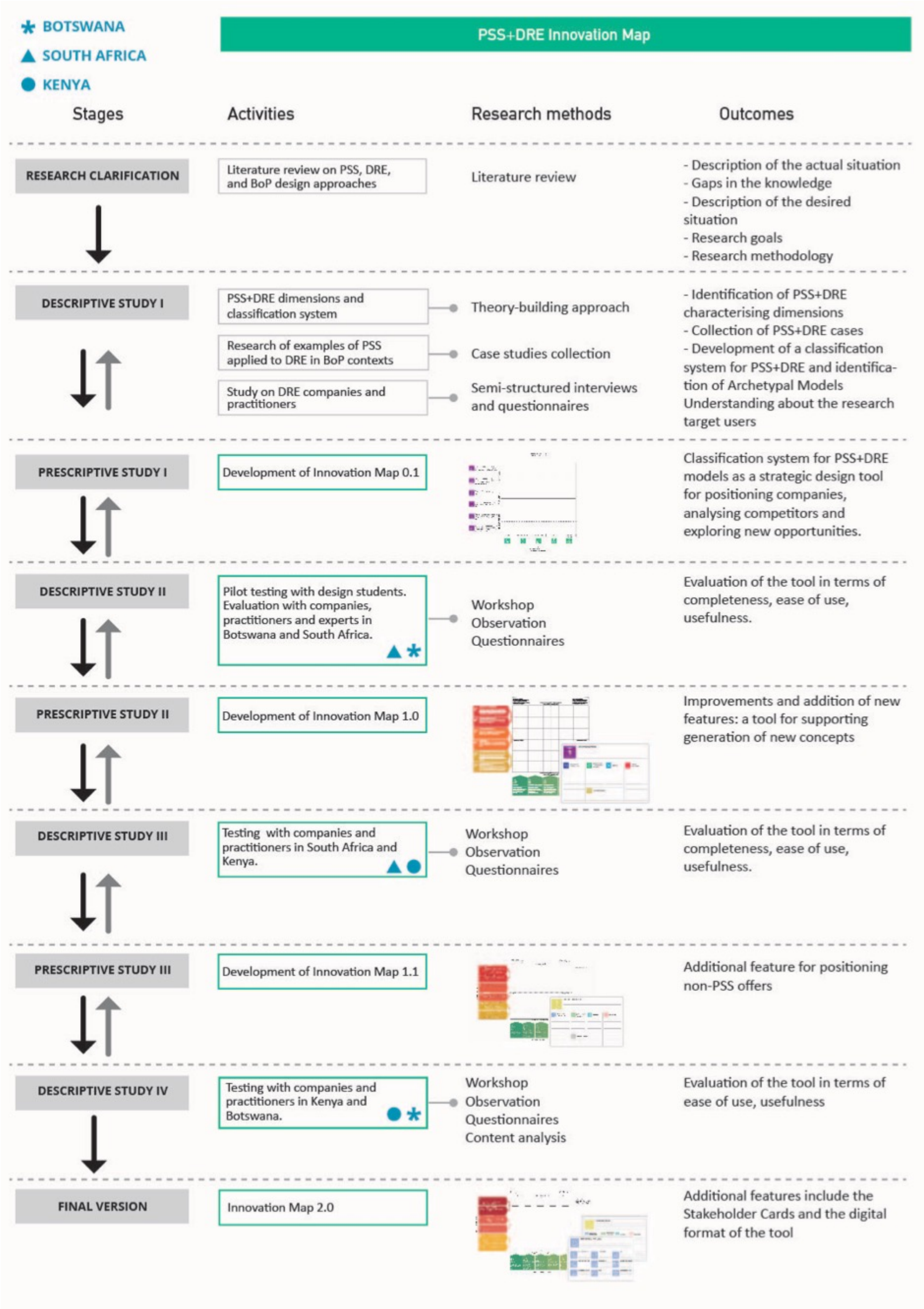


Figure 5.2 – Stages of the Innovation Map's development

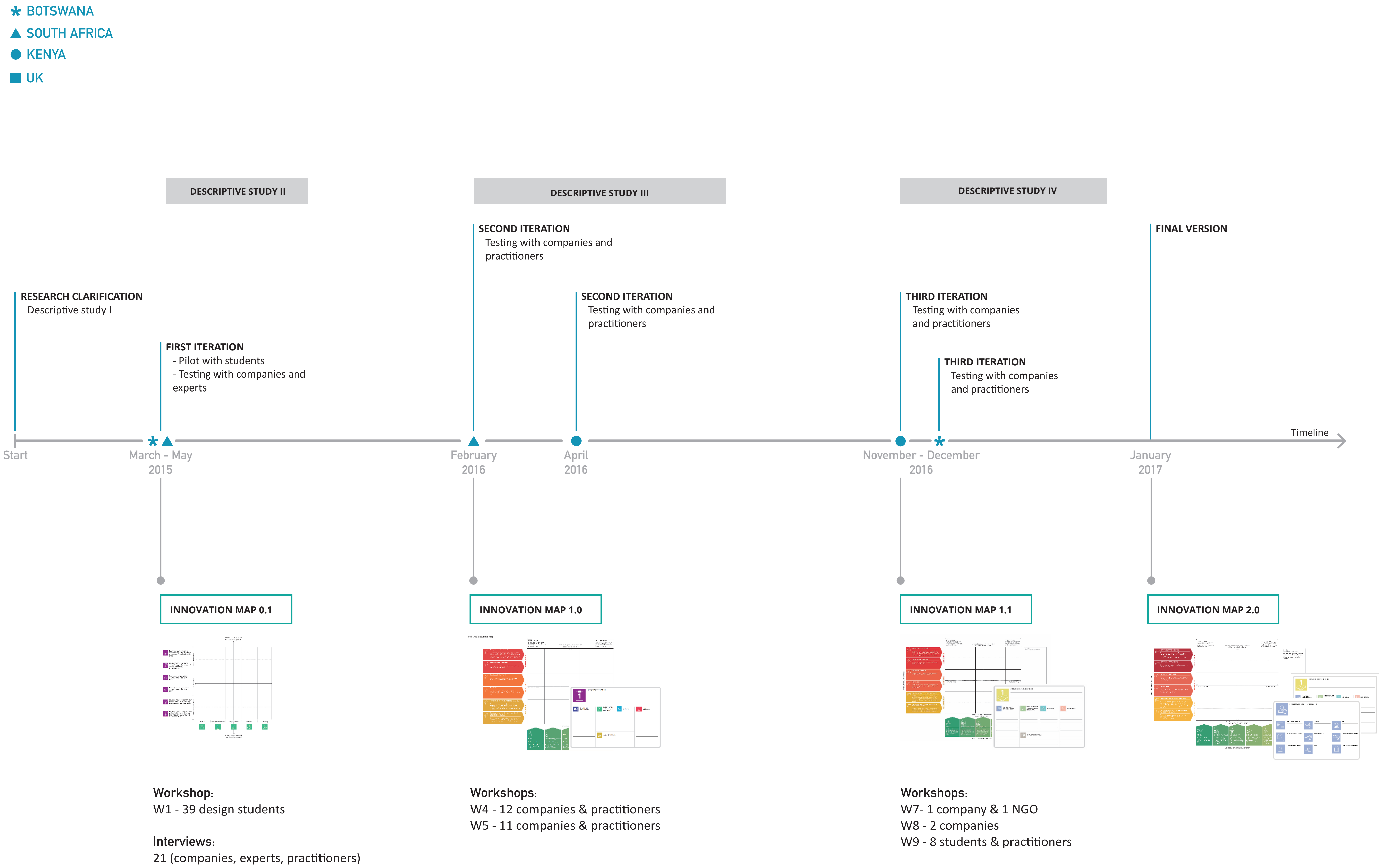


Fig. 5.3: Innovation Map's development timeline

5.1 Prescriptive Study I: Innovation Map 0.1

As discussed in Section 4.2, the new classification system of PSS applied to DRE was built by clustering dimensions of PSS+DRE models on a polarity diagram (Emili et al., 2016 (a)). The x-axis encompasses the type of energy system and the target customer. The y-axis distinguishes types of PSS+DRE, ownership, energy system operation, provider/customer relationship, environmental sustainability potential (Fig. 5.4). The classification system primarily aimed at identifying models of PSS applied to DRE and all their possible combinations. A second outcome of the primary studies was the identification of 15 PSS+DRE Archetypal Models, which describe the current applications of PSS and DRE in BoP contexts (Section 4.4).

This section describes how the new classification system and Archetypal Models can be used as a strategic design tool. In other words, this section presents the first tool developed to support the design of PSS applied to DRE in BoP contexts: the Innovation Map.

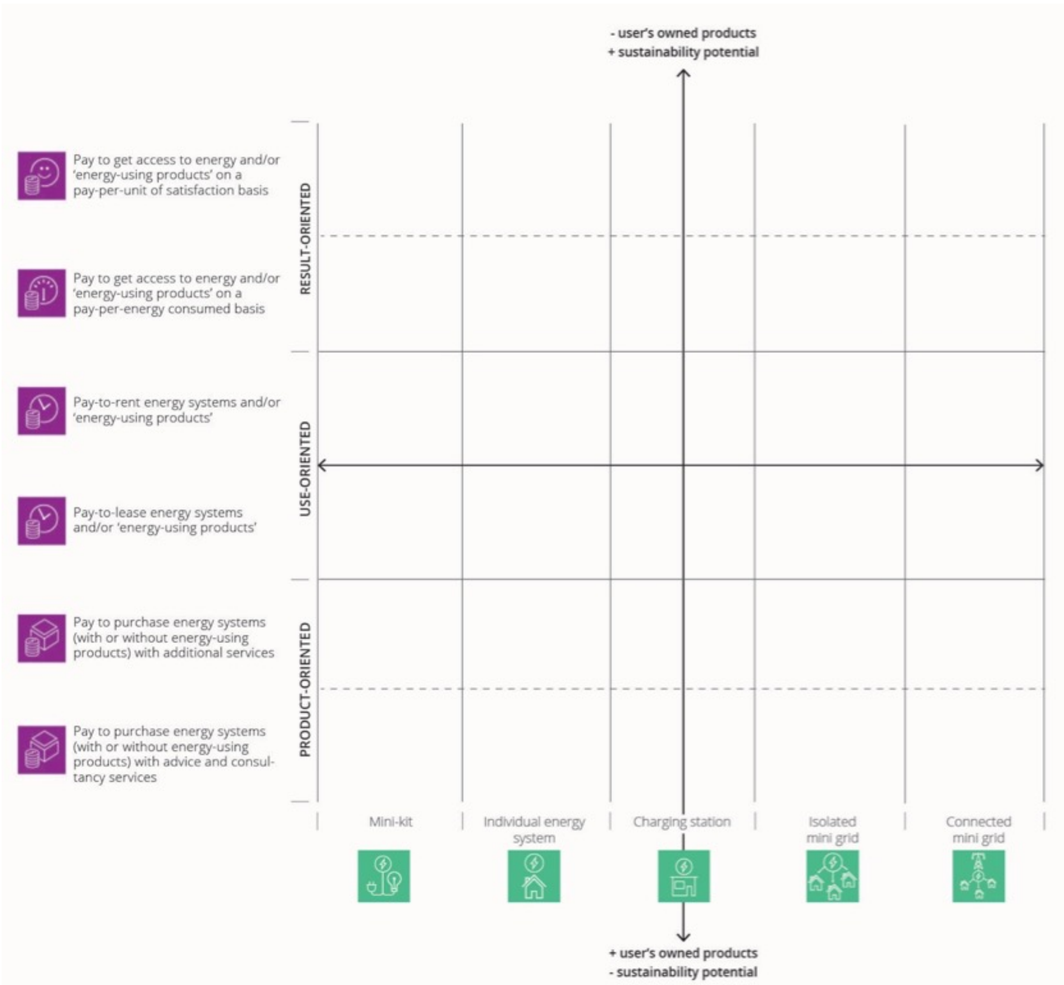


Figure 5.4 - Innovation Map 0.1

The Innovation Map tool is in fact composed by the classification system and the Archetypal Models. The archetypes were organised in the form of cards. Each card describes the archetype, provides a system map visualising the model, and a related case study (Fig. 5.5).

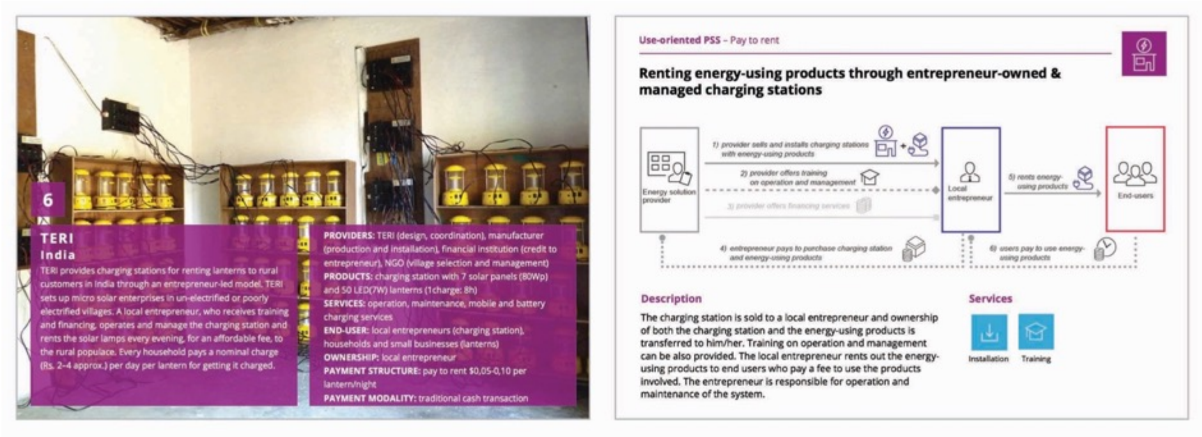


Figure 5.5 - An example of Archetypal Model card (front and back)

5.1.1 Applications

Despite classifying PSS+DRE models and providing an overview of all possible combinations of PSS types and DRE systems, the Innovation Map can be strategically used by companies, practitioners and designers. The envisioned applications are described below.

1. Positioning of a company's offer(s)

A first application for the Innovation Map is to position a company offer(s) (Fig. 5.6). Managers can identify where their company lies by positioning existing offerings on the map. This means that a single company can provide more than one offering, therefore can be simultaneously be positioned in two areas of the map. For example, a company can sell individual energy systems with additional services (Offer A) and also providing renting of appliances through charging stations (Offer B).

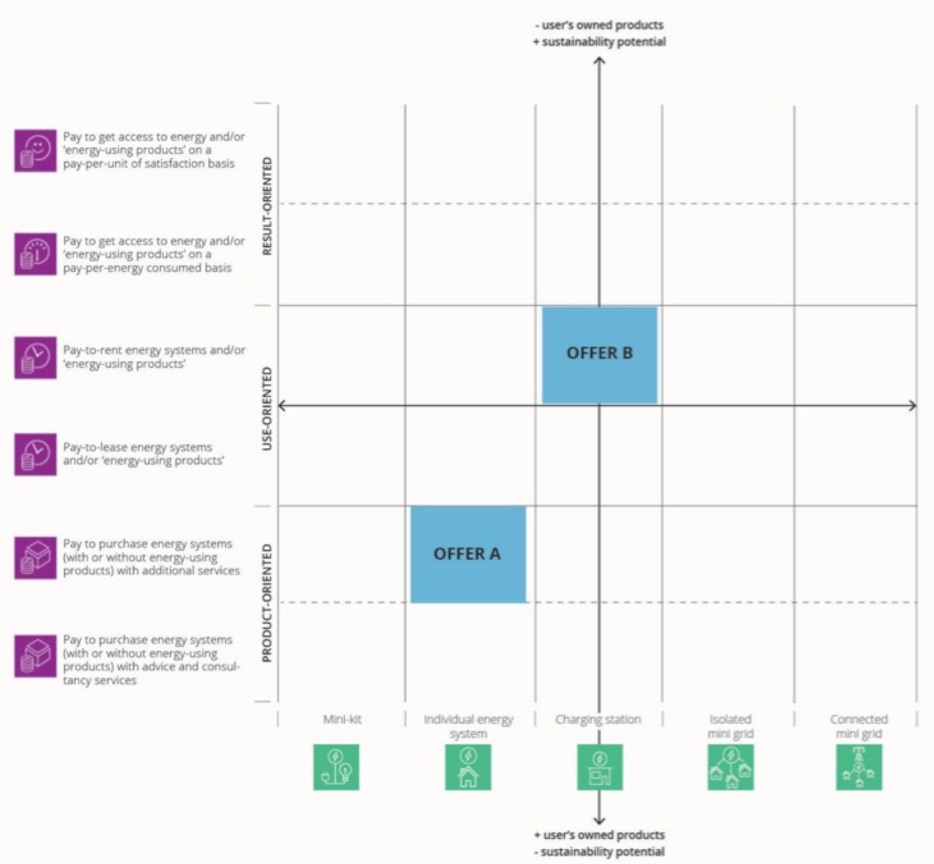


Figure 5.6 - Positioning of company's offers

2. Analysis of offers in a specific context

The Innovation Map can be used to support the strategic analysis of a specific geographical context by mapping competitors operating in the selected area. For example, a company that wants to enter in a specific market can use the Innovation Map to position its competitors, focusing on a specific technology such as individual energy systems or isolated mini grids. Another option is to position all companies operating in the selected area, regardless of technology choice and therefore covering all DRE systems (Fig. 5.7). This application of the tool can support the identification of models that have not been applied and consequently provide an interesting opportunity to explore new applications of PSS+DRE. For example, a company providing individual energy systems can find opportunities for innovation for the same technology choice but adopting models that have not been implemented by its competitors (see 'potential models to explore' in Fig. 5.7).

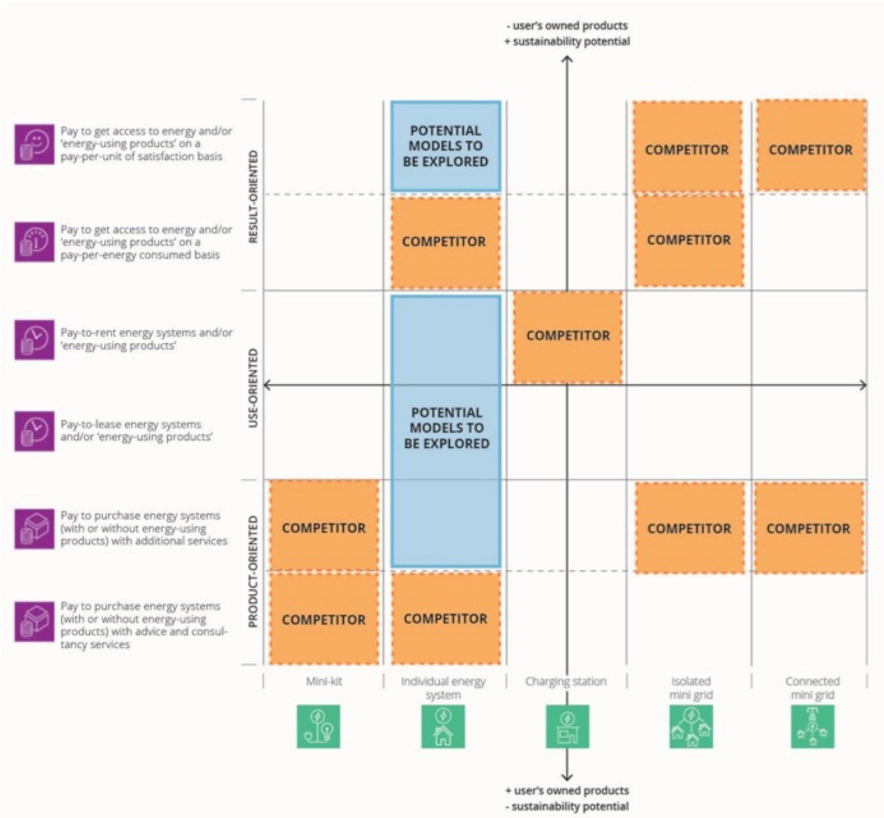


Figure 5.7 - Strategic analysis: positioning of competitors and exploration of new opportunities

3. Exploring new business opportunities: offers' repositioning

Linked with the previous applications, the Innovation Map can support companies and practitioners in identifying new business opportunities. In fact, once a company has positioned itself on the map and has identified its competitors and areas for opportunities, it can use the tool to reposition their current offerings. For example, a company that sells solar home systems with additional services (Offer A) can explore new ways of providing energy solutions by offering its products on leasing (Offer A1) and therefore repositioning its offering in a new area of the map (Fig. 5.8). Another option is to combine different offerings with the aim of reaching new target customers. A company that provides renting of appliances through charging station (Offer B), can expand their customer base by targeting productive activities and providing energy services on a pay-per-consumption basis (Offer B1). In this case, the company will combine two offerings (Offers B and B1), two types of target customers (individual and community) and two technologies (individual energy systems and charging station).

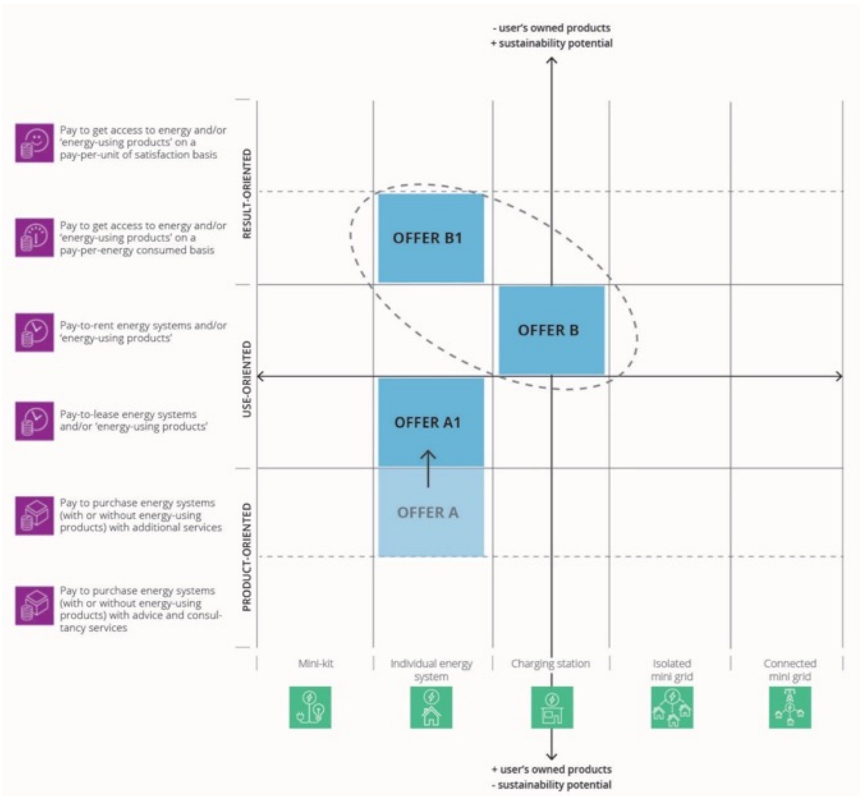


Figure 5.8 - Offer repositioning (A and A1) and offer combination (B and B1)

The identified applications of the Innovation Map envisioned that the tool could be useful for both companies operating in the market and wanting to expand/reposition their offerings, or for start-up ventures willing to enter a new market. Having established those hypotheses, it was necessary to evaluate the tool's applications through empirical testing activities.

5.2 Descriptive Study II (DS-II): testing activities in Botswana and South Africa

A first iteration of testing and evaluation of the Innovation Map and Archetypal Models took place between March and May 2015 in Botswana and South Africa. These activities aimed at evaluating different aspects of the tool:

- *Completeness*: the Innovation Map encompasses all possible models of PSS applied to DRE, the Archetypal Models represent all existing models of PSS applied to DRE.
- *Clarity and ease of use:* the tool can be clearly understood, the meaning of each axis is clear, the positioning of companies' offers can be easily done.
- *Usefulness as strategic design tool*: the Innovation Map is useful for the envisioned applications (positioning a company's offers, for analysis of offers in a specific context, exploring new business opportunities).

For these reasons, different types of participants were involved in the testing activities and different research methods were adopted. In particular, the first iteration of testing activities involved the following:

- *Pilot testing with undergraduate design students* (5.2.1): aiming at testing the clarity, ease of use, and assessing the usefulness as design tool. This study was carried out with a workshop at University of Botswana and feedback were collected through questionnaires. Participant observation was also used as research method.
- *Testing with companies, practitioners and experts* (5.2.2): aiming at testing the completeness and usefulness of the Innovation Map and Archetypal Models. Interviews and questionnaires were used in this study.

5.2.1 Pilot testing with design students

The Innovation Map 0.1 was first tested with 39 design students in their final year of Bachelor of Industrial Design and Technology at University of Botswana. This pilot study was carried out within the LeNSes course[15], organised in March 2015. The two-week course included theoretical sessions and practical activities about System Design for Sustainable Energy for All and it was designed and implemented by Brunel University London and University of Botswana. The focus of the course was about designing sustainable energy systems applying the concept of PSS and DRE. After an introduction to the concepts of PSS, DRE, design for the BoP, students were given a brief to design a sustainable PSS applied to DRE for a low-income community in Gaborone.

The pilot test aimed at evaluating the tool from a usability and clearness point of view, and at assessing its application as design support. This section describes the activities undertaken by students and summarises the feedback collected, which were then considered for the tool's further developments.

5.2.1.1 Description of activities

Students were firstly introduced to the tool and to the Archetypal Models for exploring different types of PSS applied to DRE. For this purpose, they were asked to position Archetypal Models' case studies on the Innovation Map.

In a second phase, they used the tool to position their design concepts. They wrote the concept description on a post-it and mapped it according to the type of offer, target customer and energy system. Later they were asked to explore concepts' variations by moving their concepts in other promising areas of the map and to eventually select one final solution.

[15] As anticipated in 1.5.1, the pilot didactic curricular course was implemented in collaboration with the African partner university over the course of two weeks.

At the end of the course they were provided with questionnaires to rate the usability and the applications of the Innovation Map. The quantitative data collected is presented in Table 5.2, while the qualitative responses are discussed below.

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Testing the ease of use						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
2. To what extent is the Innovation Map easy to understand (i.e. the meaning of each axis is clear)	-	-	13% (5)[16]	61% (24)	26% (10)	**4.1**
3. To what extent is the positioning of case studies in the Innovation Map easy for you?	-	-	28% (11)	54% (21)	18% (7)	**3.8**
Testing the usefulness						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
4. To what extent the Innovation Map helped you to understand the different types of PSS+DRE offers?	-	-	13% (5)	59% (23)	28% (11)	**4.1**
5. To what extent has the positioning of your concept ideas in the innovation map been easy?	-	5% (2)	23% (9)	46% (18)	28% (10)	**3.9**
6. To what extent the innovation map helped you to explore different variations of your concept ideas (i.e. moving the concept from an area of the map to another one)?	-	-	18% (7)	64% (25)	18% (7)	**4.0**
7. To what extent the innovation map helped you to facilitate the discussion to select the most appropriate/promising concept idea?	-	-	8% (3)	64% (25)	28% (11)	**4.2**

Table 5.2 - Questionnaires' results from the pilot workshop at University of Botswana

Clearness and ease of use

Most participants (61%) highly rated the clearness of the Innovation Map, however some found difficulties in positioning case studies (average rating 3.8). One of the main issues was related to the distinction between PSS types, either due to the terminology adopted (*"comprehending the meaning of the terminology used in the map",* S36; *"I had a problem in finding the difference between paying per consumption and paying per unit of satisfaction",* S23; *"it was a bit tricky to understand the types of PSS offers",* S28; "*it has been hard to ascertain what the customers were supposed to be paying for", S29*), or because the case studies descriptions were not clear. In fact, some participants affirmed that some cases could be positioned in two areas of the map, others said they could not understand the type of energy system involved. For instance, it was observed that community-owned models were mostly misunderstood and that students found it difficult to link mini grids systems with product-oriented PSSs and product ownership. Most of those who encountered difficulties affirmed that it was a matter of time necessary to familiarise with the tool and to properly

[16] Percentage of responses (number of respondents)

read the case studies descriptions. Some participants suggested to add further text explanation for the PSS types and the energy systems (*"brief description of the elements on the left side of the map",* S3; *"brief explanations along with the sub-topics",* S10; *"there should be a brief description to differentiate product oriented, use oriented and result oriented",* S3).

Other suggestions included differentiating colours for PSS types ("*the major rows need a colouring to make clear and outstanding",* S31; *"maybe the use of different colours could make it more clear for the users",* S9) and to add a guide or information on how to use the tool ("*adding more examples and information on how to use the map"*, S35; *"there should be notes to explain",* S27; *"there should a small manual that will help first users",* S26).

Applications

The pilot testing aimed also at assessing the envisioned applications for the Innovation Map and at understanding how companies and practitioners may use the tool.

<u>Understanding different types of PSS applied to DRE:</u>

Students were asked to rate the usefulness of the tool to support the understanding of different types of PSS applied to DRE. Participants highly rated this application (avg. 4.1). Some affirmed that the tool helped understanding the PSS classification ("*it guides and lead to deeper understanding of the PSS and on how the technologies, PSS offer inter-relate",* S22*; "it helped me to classify between product-oriented, use and result oriented",* S26).

<u>Positioning of concepts:</u>

Participants were asked to use the Innovation Map to position their concepts. Although most students found this task easy to be completed (46% rated 4 and 28% rated 5), some difficulties were encountered. Similarly to the positioning of case studies, terminology used and difficulties in understanding payment structures was mentioned by some students (S33, S31, S5). However, most participants highlighted that this activity helped them in clarifying their ideas and coming up with innovative solutions ("*really helped me to now start to develop more innovative ideas",* S8; *"it assists in being creative and coming up with solutions",* S9; *"very helpful for concept positioning",* S1).

<u>Exploration of new concepts:</u>

Participants were asked to use the tool for exploring variations of their concepts, for example by re-positioning them in other areas of the map and exploring new opportunities. Although this application was found useful by most participants (64% rated 4, 18% rated 5), observations made during the workshop led to notice that only few groups actually changed their concepts by moving or combining offers. Some expressed difficulties in moving concepts because did not have examples of how other concepts were implemented, such as other case studies (S38, S34). This can be justified by the fact that students did not carry out a strategic analysis of competitors and therefore were not aware of gaps in the market or promising areas to explore.

Supporting strategic conversations:

Most students affirmed that the Innovation Map helped them in selecting the most promising concepts (avg. rating 4.2). In particular, some participants affirmed that the tool "*helps selecting the best approach*" (S4) and it is useful for "*coming up with feasible and viable concepts and it assists in ensuring that the concept become clearer*" (S1).

5.2.1.2 Design considerations

The pilot study provided important insights for the Innovation Map's applications and design features. Drawing conclusions from the feedback collected, it can be stated that the tool required some improvements from a usability and clearness perspective. Some considerations can be made to address this aspect:

- Text descriptions of PSS types and energy systems should be added to the Innovation Map, ensuring payment structures and ownership are clearly communicated.
- Colour differentiation of PSS types should be used to better distinguish models.
- Definition of individual and community target should be added to the map.
- Description of cases and archetypes should be revised and should adopt the same structure, avoiding misinterpretation.

Other conclusions can be made concerning the applications of the Innovation Map. It must be pointed out that the tool was used during the course together with the other tools for PSS+DRE design (see Chapter 6 and 7) and some considerations were made according to the applications of the tools in the design process. In this pilot study students used the tool for mapping case studies and exploring types of PSS applied to DRE, for mapping their concepts and exploring concepts' variations, selecting a final concept. While the tool clearly helped students to understand different types of PSS applied to DRE, its application in the design process encountered some issues.

As previously discussed, the issue with positioning case studies can be linked to a lack of understanding of the different PSS types and the map's axis. However, the positioning of concepts and the exploration of new opportunities (concepts' repositioning) encountered some difficulties that may not be related to the clarity of the tool. In particular, some participants highlighted that they would not understand benefits from changing their concepts once these were defined. Others affirmed that they did not have a clear reference context of other cases or examples to guide the process of concepts' repositioning. Furthermore, without having carried out an extensive strategic analysis of competitors, participants were not aware of models applied in their chosen context and opportunities emerging from gaps in the market. In practice, out of ten groups of students, only one group changed their concept using the Innovation Map. All other participants used the tool to position and select their concepts and did not explore any new option.

This suggests that the Innovation Map could be used first to position existing companies (strategic analysis) and then to support the generation of new concepts. Once that new concepts are generated on the map, these can be discussed leading to repositioning or combination of different concepts, thus stimulating users to innovate with new models. In other words, the Innovation Map could be used to generate new ideas of PSS applied to DRE, to position these concepts and consequently select the most promising ones, considering also other competitors in the market. The application of the tool as a support for generating new concepts also emerged through the interviews carried out with DRE companies and described in the primary studies (see 4.6). In fact, most participants had affirmed that an analysis of competitors was often the starting point for designing the business model.

This new potential application of the Innovation Map was considered for further discussions through the interviews with companies, practitioners and experts that followed the pilot study.

In conclusion, the pilot study helped clarifying some issues related to the clearness of the tool and provided a general evaluation of its application. In addition, the pilot with students provided important insights for the application of the Innovation Map as a tool to generate new concepts of PSS+DRE. These considerations were used to improve the tool (version 1.0) and to assess the envisioned applications with companies and practitioners (see next section).

5.2.2 Testing with companies, practitioners and experts

After the pilot test with students, the tool was evaluated by companies, practitioners and experts in Botswana and South Africa. This study aimed at testing the completeness and usefulness of the tool, as well as evaluating its clearness and usability.

5.2.2.1 Sampling

A total of 21 participants were involved in the study (Table 5.3): eight DRE companies, five experts of DRE and PSS, one from a national research centre on innovation and technology, and three from a strategic design consultancy. The strategy adopted was purposive sampling, i.e. participants were selected because they represented the type of users being studied.

Regarding the sample size, the principle of theoretical saturation (Morse, 1995; Strauss and Corbin, 1990) was adopted, i.e. data collection was concluded when any new insights were generated. In particular, an initial sample size of 15 participants was used. Six additional participants were then involved. Based on the data collected from the second group of participants and the lack of new information emerging (comments and suggestions provided by interviewees were similar to the ones provided by the first group of participants), sampling was completed with 21 participants.

Participant	Firm type and main business	Numbers of interviewees, job title / department.
C1	Small-sized company: sale of solar systems/mini kits with additional services	1: Technical director
C2	Small-sized company: sale of solar systems with additional services	1: CEO/owner
C3	Medium-sized company: sale of large solar systems with additional services	3: Managing Director, operations
C4	Medium-sized company: sale of solar systems, solar water heaters with training and additional services.	3: Finance director, Head of Mechanical Department, Head of Solar
C5	Small-sized company: sale of solar systems and consultancy services	1: CEO/owner
C6	Small-sized company: sale of solar systems, mini kits and solar water heaters with additional services	1: Operations
C7	Medium-sized company: sale of solar systems with additional services; energy provision through mini grids	1: CEO
C8	Big-sized company: offering energy provision through charging stations	1: Operations manager
Experts		
E1	University of Botswana	1: Clean Energy Resource Centre director, lecturer
E2	Department of Energy, Ministry of Minerals, Energy and Water Resources	1: Energy engineer
E3	University of Botswana	1: Business model, accounting and finance lecturer
E4	University of Botswana	1: Electrical engineering and power distribution lecturer
E5	University of Botswana	1: PSS lecturer
Others		
O1	Botswana Institute of Technology Research and Innovation	1: DRE researcher
O2	Product and strategic design consultancy	3: CEO, product designer, strategic designer

Table 5.3 – List of participants from testing activities in Botswana and South Africa, DS-II

5.2.2.1 Testing the completeness

A first aspect to be tested was the completeness of the Innovation Map and Archetypal Models. The first objective of the testing activities was to validate the completeness of the classification system, i.e. to what extent it can encompass all possible models of PSS applied to DRE. Then the completeness of the Archetypal Models was evaluated, i.e. to what extent they are able to represent all existing models. For this purpose, companies and experts were asked them to point out cases or offers that fall out of the defined Archetypal Models. After the introductory presentation and description of Archetypal Models, interviewees had about 20 minutes to again observe the Innovation Map and the archetypes. Among all the interviewees, none of them could identify cases that were not included in the identified Archetypal Models (21 out of 21 responses). This implies that participants considered the tool to be complete. In fact, if all possible cases can be encompassed by the archetypes, and no case fall outside of the map, it can be concluded that it covers all possible models of PSS applied to DRE.

Although participants have confirmed that the archetypes cover all existing models and that the classification system encompasses all possible models of PSS applied to DRE, the involvement of a broader set of companies and experts, in particular from other geographical contexts, was considered necessary to provide a more robust validation. This aspect is covered with the following round of testing activities (DS-III).

5.2.2.2 Testing the ease of use

A second aspect to be evaluated was that the tool was clear and easy to use, i.e. the polarity diagram and its axis were understandable and case studies could be easily and correctly positioned on the map. Similarly to the pilot with students, participants were asked to undertake a practical exercise with the aim of exploring the different models of PSS applied to DRE. They were provided with a set of case studies (5–7 per interview) and were then asked to map these cases on the Innovation Map and discuss the ease of use. Most participants highly rated the clarity of the tool (avg. rating 4.5) and affirmed that the positioning exercise was easy to be carried out. Some participants reported that "*the visual nature of the mapping tool makes it extremely user-friendly*" (O8) and *"[the map] clearly separates cases [offers], making it easy to use*", C6). Four interviewees reported initial doubts in differentiating between leasing and renting models and between mini-kits and individual energy systems (in the case of solar home system), but a short reflection led to clarified initial hesitations ("*It's straightforward but one would need a bit of time to understand*", C5; "*took some time to understand*", C6). Some suggestions to improve the clearness of the tool included the addition of a description for PSS types and energy systems and the use of color-coded distinction of PSS types.

5.2.2.3 Testing the usefulness

In order to evaluate the usefulness of the tool, interviewees were asked to use the Innovation Map for position their offers and then to discuss potential applications. Similarly to the mapping exercise with case studies and to the positioning of concepts with design students, companies wrote down their offer description and then positioned them on the map. Interviewees then discussed and rated through the questionnaire potential applications of the Innovation Map as a strategic design tool.

<u>1. Positioning of a company offers</u>

As described in Section 5.1.1, the Innovation Map can be used to strategically position a company's offers. In particular, one company can provide more than one offer, such as selling individual systems with additional services and providing renting of energy-using products through charging stations (Fig. 5.6). Interviewees were asked to position their companies on the Innovation Map and to discuss this application of the tool. The majority of participants considered the tool very useful to position companies' offerings (38% rated 4, 52% rated 5) and all of them affirmed that they would use it for this purpose in the future. Some interviewees highlighted that the map can support the understanding of where a company's offering is positioned in relation to the other potential alternatives ("*a company can easily locate where it fits in*", E1; "*companies can see where they are and plan where they want to be*", C4; "*I see this as a perfect tool to position our company offers and break into new markets*", C8).

2. Analysis of offers in a selected context

The hypothesis was that the Innovation Map could be useful for mapping the existing situation of a specific context or country, and companies could use it to have an overview of competitors operating in the area. As discussed in 5.1.1, companies can analyse all DRE offers provided in the context or instead focus on a specific technology, such as mini kits, and map those providing PSS using this technology. This assumption was tested by asking interviewees to rate the use of tool for mapping existing offers of PSS applied to DRE. Most of them commended this application (43% rated 4 and 52% rated 5). Some stated that "*by using the tool, one can immediately understand where gaps exist*" (E1), that "*you can clearly see gaps in the market"* (C1), and leads to a "*better understanding of competition"* (C10). It should be pointed out that a competitors' analysis and strategic positioning may be more complex and depends on several factors. However the Innovation Map is intended to be used for mapping offerings and painting a general overview of possible competitors.

3. Exploration of new business opportunities.

The Innovation Map could support the exploration of new business opportunities by visualising companies' offerings, repositioning existing offers or combining different models.

In order to validate these assumptions, participants were asked to discuss this application of tool. With an average rating of 4.4, interviewees particularly appreciated the possibility of envisioning possible opportunities in a visual way, "*painting a picture of opportunities that lie outside of what [the company] does"* (C10). Most participants stated that they were not aware of some types of offerings or other options to provide energy solutions and that the Innovation Map helped them in "*broadening minds*" (C2) and thinking outside of the box for "*other ways by providing solutions instead of the traditional way of selling products*" (C6).

4. Generation of new concepts of PSS applied to DRE

Having concluded from the pilot with students that the tool may be used for generating new concepts, interviewees were asked to rate the potential application of the tool to support idea generation of PSS+DRE. Participants gave this potential application the highest rating (4.6). Some affirmed that "*it makes it easy to visualise opportunities*" (C8) and that "*the Innovation Map could be used to generate solutions, tease out ideas at an early stage and support the initial brainstorming*" (E5).

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Testing the completeness						
1. Can you think of other types of offer or other examples/cases that are not included in the archetypal models? If yes, which ones?	100% of interviewees (21/21) agreed that there are no other cases that fall outside the classification system and that cannot be included in the archetypal models.					
Testing the ease of use						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
2. To what extent is the Innovation Map easy to understand (i.e. the meaning of each axis is clear)	-	-	10% (2)	33% (7)	57% (12)	**4.5**
3. To what extent is the positioning of case studies in the Innovation Map easy for you?	-	-	10% (2)	28% (6)	62% (13)	**4.5**
Testing the usefulness						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
4. The Innovation Map is intended to be used for positioning a company's offer(s). To what extent is the Innovation Map contributing to the achievement of this objective?	-	-	10% (2)	38% (8)	52% (11)	**4.4**
4.1 Would you use the Innovation Map for this purpose in the future?	Yes: 100% (21) No: 0% (0)					
5. The Innovation Map is intended to be used for mapping the existing offers of PSS applied to DRE (competitors in the same business sector, other companies operating in the selected context etc.). To what extent is the Innovation Map contributing to the achievement of this objective?	-	-	5% (1)	43% (9)	52% (11)	**4.5**
5.1 Would you use the Innovation Map for this purpose in the future?	Yes: 95% (20) No: 5% (1)					
6. The Innovation Map is intended to be used for exploring new business opportunities (repositioning of offer, combination of different offers). To what extent is the Innovation Map contributing to the achievement of this objective?	-	-	-	57% (12)	43% (9)	**4.4**
6.1 Would you use the Innovation Map for this purpose in the future?	Yes: 100% (21) No: 0% (0)					
7. The Innovation Map and archetypal models can be used for generating ideas. To what extent is the Innovation Map contributing to the achievement of this objective?	-	-	5% (1)	33% (7)	62% (13)	**4.6**

7.1 Would you use the Innovation Map for this purpose in the future?	Yes: 100% (21) No: 0% (0)

Table 5.4 - Questionnaires' results from the testing activities in Botswana (Innovation Map 0.1), DS-II

5.2.3 Conclusions from the Descriptive Study II

The DS-II provided an evaluation of the Innovation Map and Archetypal Models with a number of companies, experts and practitioners from Botswana and South Africa.

The first pilot study with 39 students highlighted the need for design improvements in terms of clarity and ease of use. These were then confirmed in the evaluation with companies and practitioners. Although many affirmed the confusion was mainly related to more time needed to fully understand the Innovation Map, some improvements should be considered.

The second study engaged 21 participants and demonstrated the completeness of the Innovation Map and Archetypal Models and its envisioned applications. The tool was assessed to provide an overview of PSS applied to DRE and visualise all possible models; to analyse companies and competitors operating in a selected geographic area; to map companies' offerings and explore new business opportunities. Lastly, the testing activities provided suggestions for a new application of the tool as support for idea generation of PSS+DRE. What emerged is that the tool can support strategic conversations within a company's managerial team and facilitate discussions about the existing situation and new innovation in the chosen context. Participants have particularly appreciated the possibility of envisioning new business opportunities and plan what possible offerings the companies might add to their portfolio.

This study also presents some limitations. Participants engaged were from a similar socio-economic context (i.e. Botswana and South Africa) and thus they might not have a broad picture of the energy sector. However, in order to reduce this risk, experts (i.e. academics, researchers) who have such a broad picture of the energy sector were involved in the study. Nevertheless, further testing activities will involve a greater and broader number of companies and practitioners operating in different contexts. The following testing activities will also focus on applying the tool through workshops with companies and practitioners, aiming at evaluating its usefulness and usability in practice.

5.3 Prescriptive Study II: Innovation Map 1.0

Drawing conclusions from the first round of testing activities, the Innovation Map has been redesigned and some additional features have been added (Emili et al., 2016 (d)). The main changes of this version, Innovation Map 1.0 (Fig. 5.9), are listed here:

- A text describing PSS types and DRE technologies was added.

- Colour distinction of PSS types and DRE was adopted to facilitate distinction of models. Consequently, Archetypal Models were also differentiated by colour (Fig. 5.10).
- A text describing type of customer (individual or community) was added in the top of the map.
- Text about environmental sustainability potential and ownership polarities were revised to avoid misunderstanding.
- The tool was redesigned to be applied in idea generation sessions: the Concept Card (Fig. 5.11) was created to detail new concepts of PSS applied to DRE. The card was designed to be filled out with information on each design element of PSS+DRE: type of offer, energy system and energy using products, services, network of providers, customers and payment modality. Once the card is filled with the generated concept, the corresponding number can be positioned on the map (Fig. 5.12).
- A short guide on how to use the tool was also designed (Fig. 5.13).

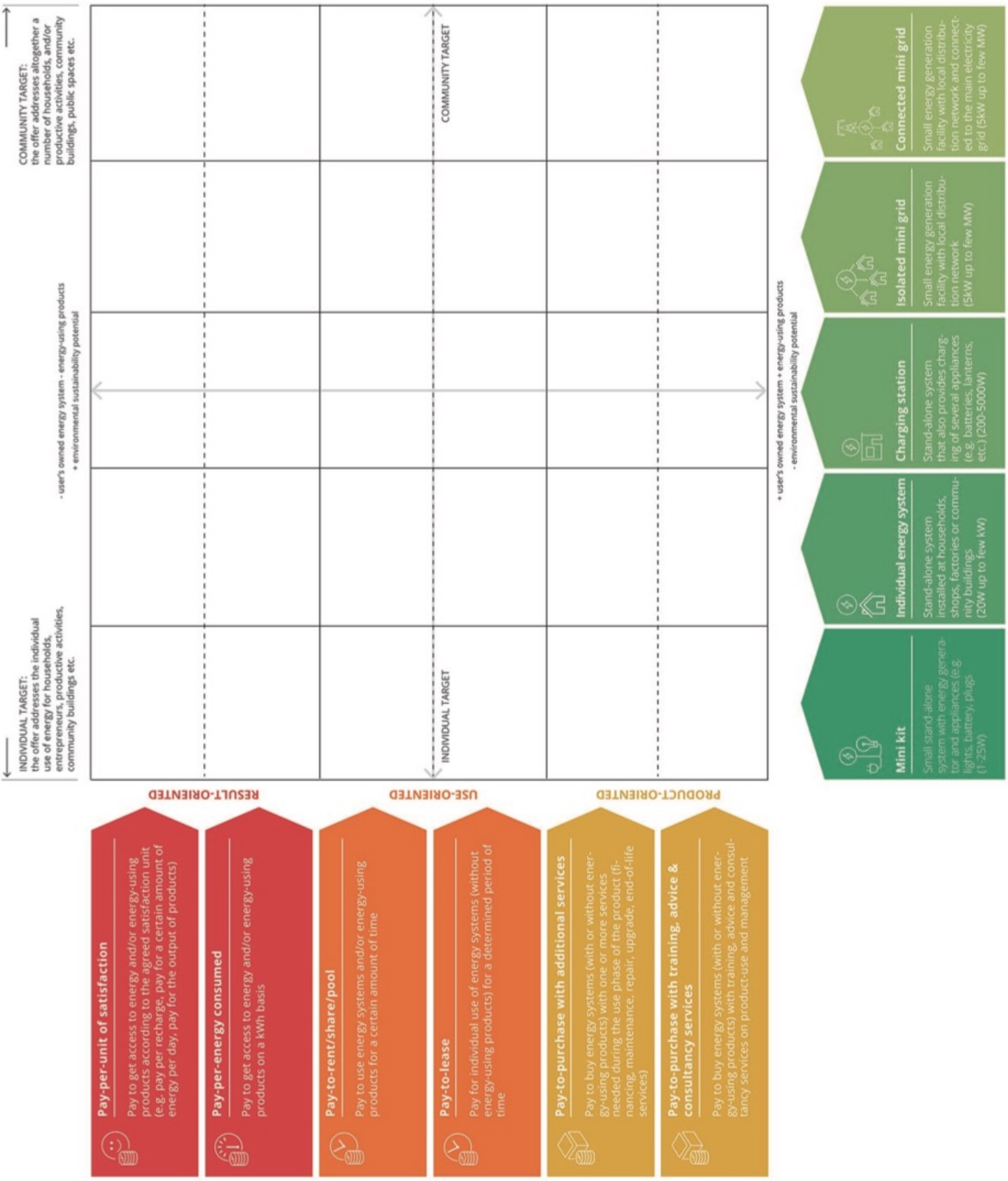


Figure 5.9 - Innovation Map 1.0

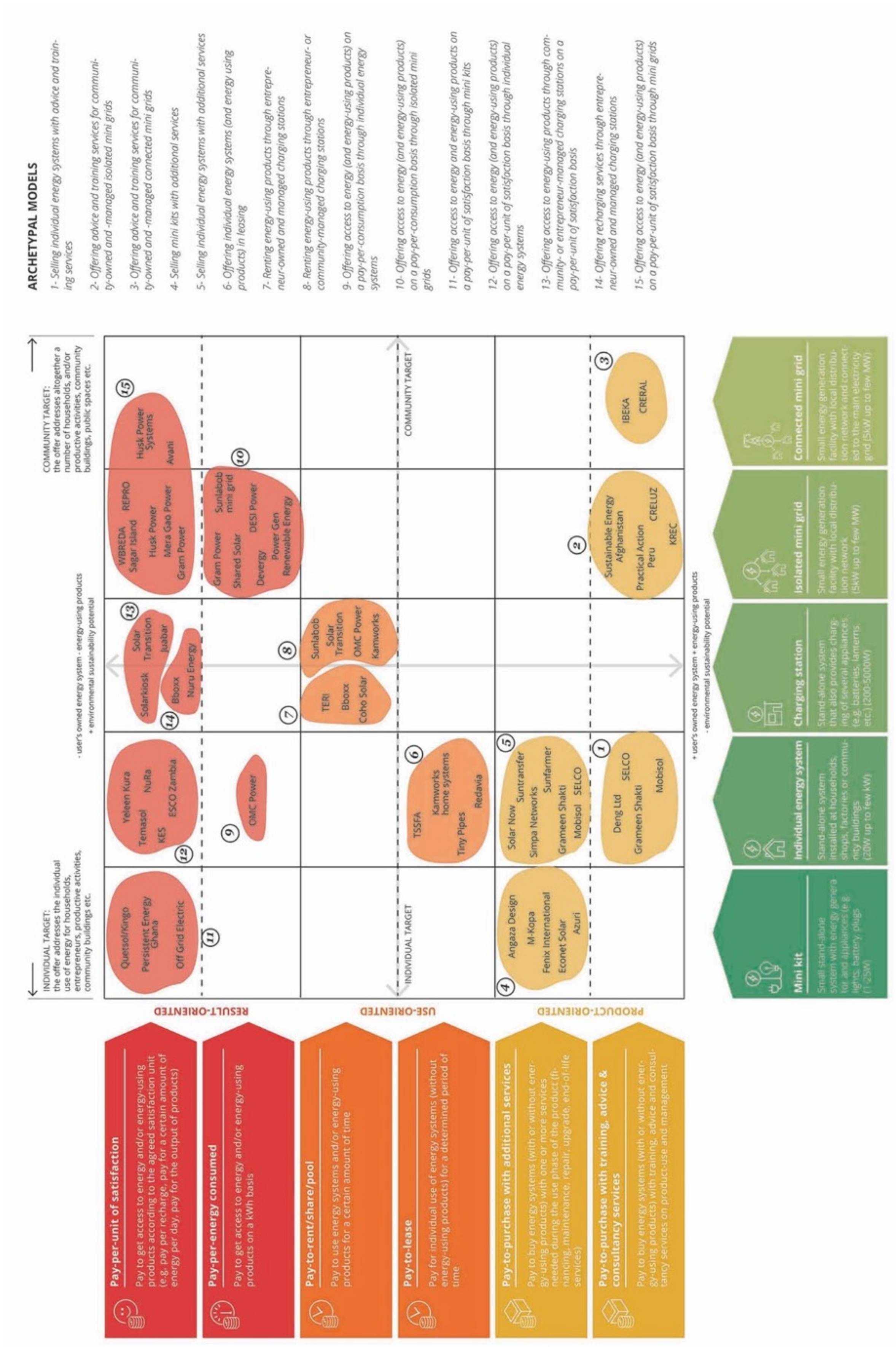


Figure 5.10 - Innovation Map 1.0 with Archetypal Models

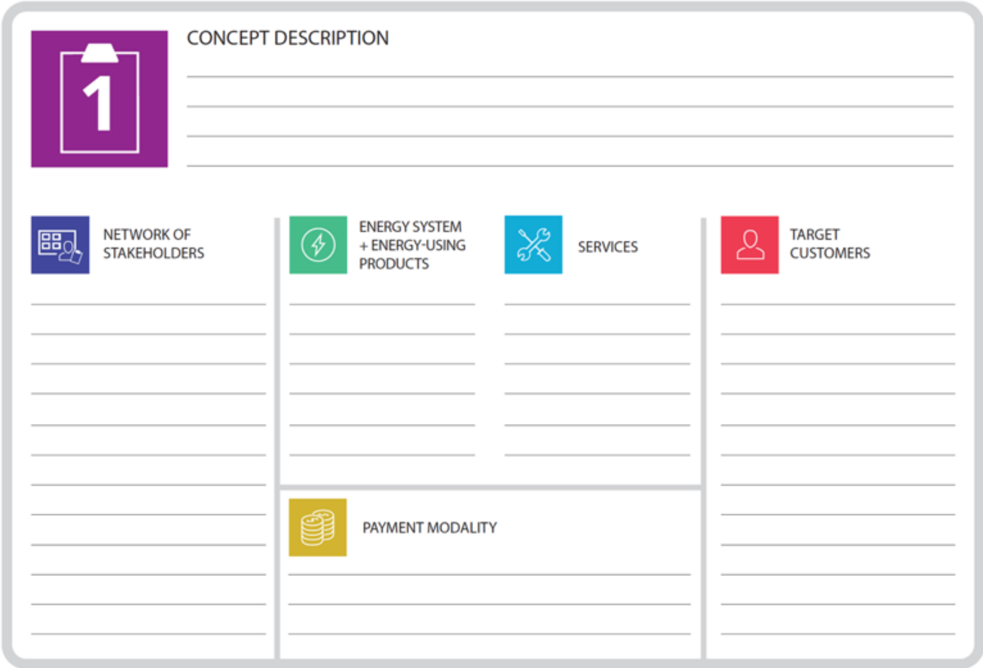


Figure 5.11 - Concept Card

Figure 5.12 - Concept Card positioning on the Innovation Map

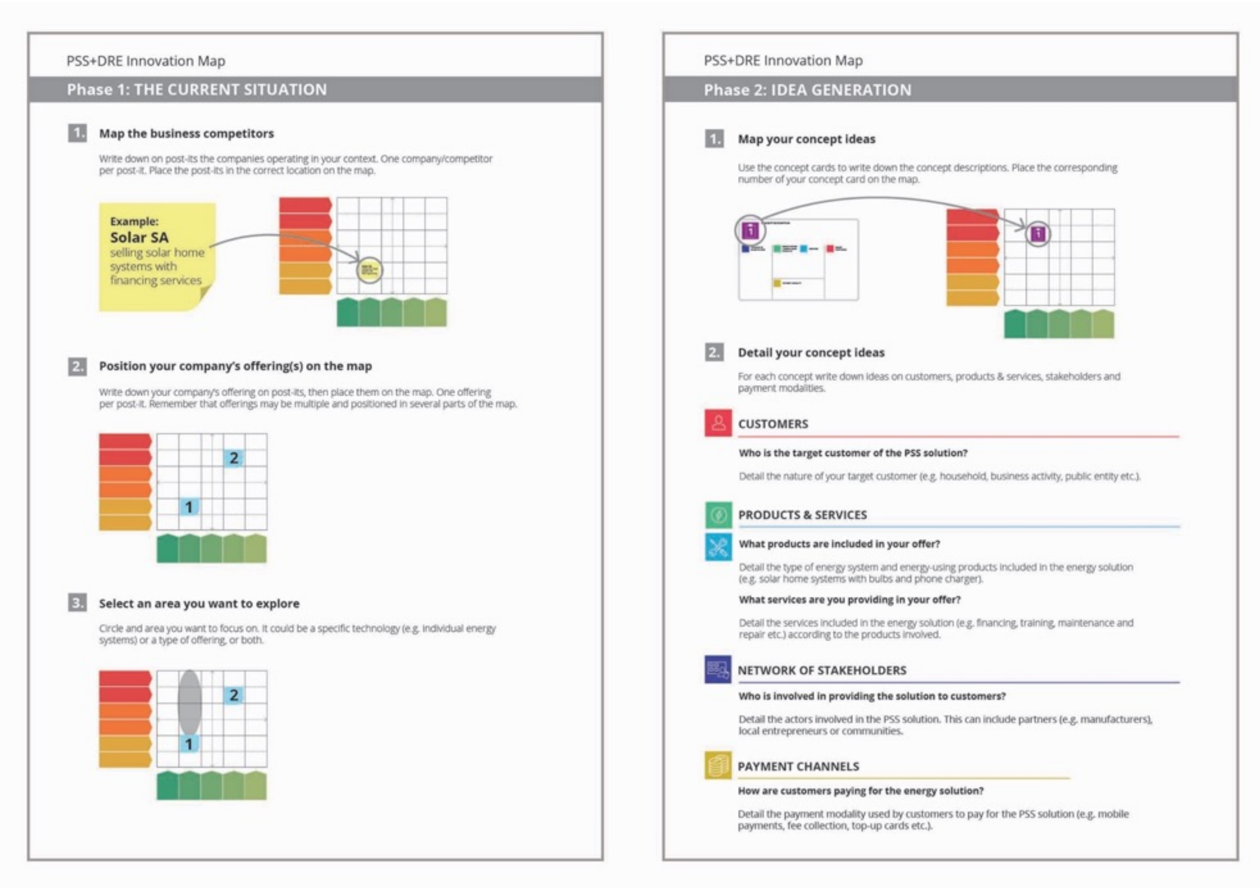


Figure 5.13 - Short guide on how to use the tool

5.3.1 Applications of the Innovation Map 1.0

Phase 1: the current situation

In a first step the tool can be used to understand the current scenario of competitors, existing energy solutions and the company's offerings. This phase includes the previously tested applications: positioning the competitors' offerings, mapping the company's existing offers and selecting an area that users want to explore. At the end of this stage, users are able to draw a picture of gaps in the market and to consider possible solutions to explore.

2. Phase 2: idea generation

In a second phase, the Innovation Map can be used to support the idea generation of new PSS+DRE concepts. In addition, the Archetypal Models and corresponding case studies can be used to support the process as inspiration for SMEs and practitioners.

Users can use the Concept Cards to detail their concepts and then position the corresponding numbers on the Innovation Map (Fig. 5.12). For each area of the map it is possible to brainstorm different ideas, therefore, placing several concepts' numbers and possibly combining more than one together. The final result (Fig 5.14) should be a set of concepts that detail all design elements of PSSs applied to DRE and that can be easily visualised on the map and compared to existing solutions and to the other offers provided in the area.

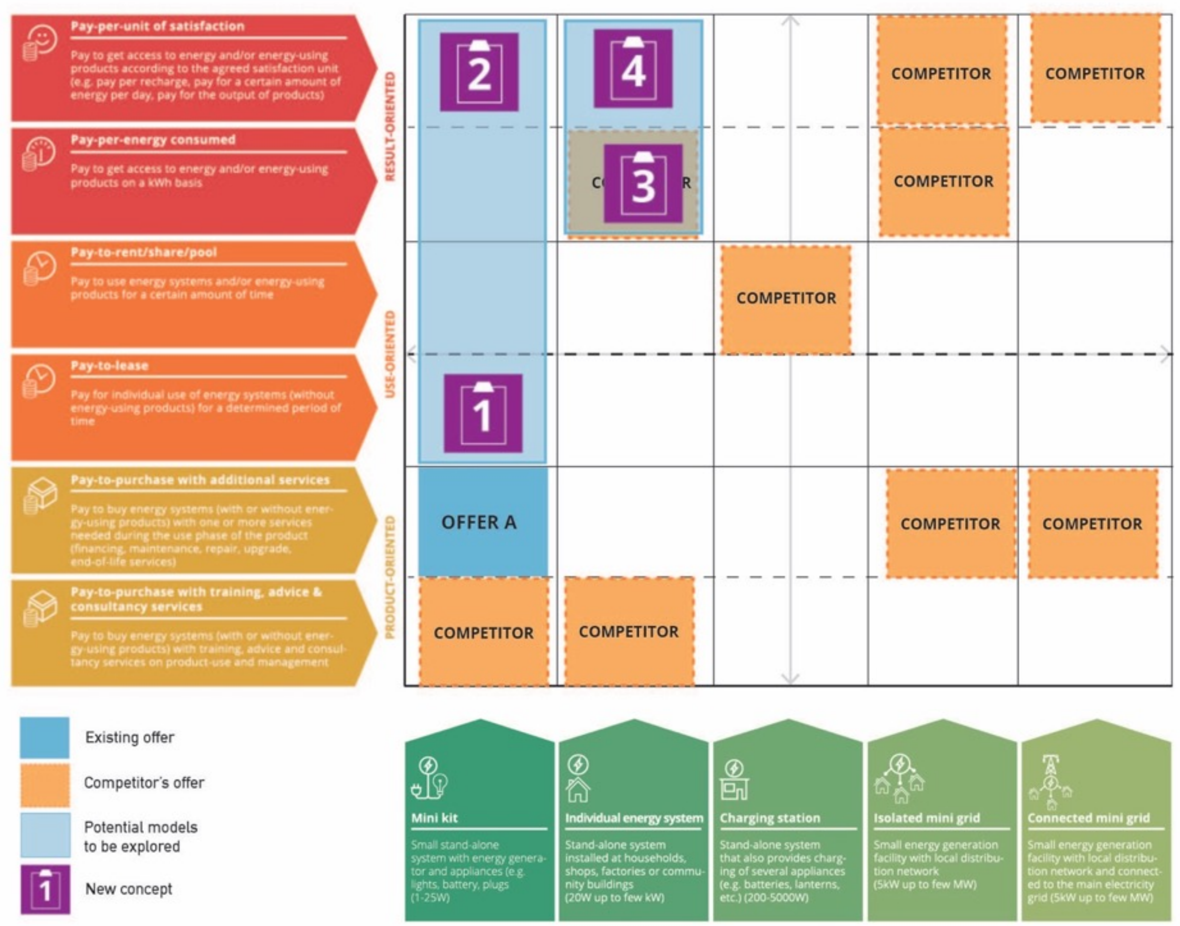


Figure 5.14 - A completed strategic analysis, company's positioning and idea generation with the Innovation Map 1.0

5.4 Descriptive Study III (DS-III): testing activities in South Africa and Kenya

The Innovation Map 1.0 has been tested through the DS-III, carried out in South Africa and Kenya. The first testing took place during a course[17] organised in Cape Town in February 2016 in collaboration with TU Delft University, Brunel University London and Cape Peninsula University of Technology, as part of the LeNSes project. The course, structured in five days of activities, aimed at applying PSS and DRE models for designing sustainable business models for energy access in low-income and developing contexts. Twelve participants attended the short course and worked in groups on a design brief of their choice with the aim of designing a detailed business offer and presenting it at the end of the course. They were then asked to provide feedback and to evaluate the tool through questionnaires.

[17] The course is part of the lifelong-learning modules organised within the LeNSes project (see 1.5.1)

The second testing, which followed a similar structure, took place in Nairobi in April 2016 as part of the LeNSes project and it was organised by Brunel University London and the University of Nairobi. Eleven participants were involved in a four-day long course about designing sustainable business models for energy access in low-income contexts. Following the same procedure, participants were introduced to the topics of PSS and DRE and then were organised in groups to work on their chosen design briefs. Questionnaires were used to collected feedback.

This section jointly discusses results from both workshops in Cape Town and Nairobi.

5.4.1 Sampling

This study followed a snowball sampling, where partner organisations (University of Nairobi, CPUT and KEREA – Kenya Renewable Energy Association) selected local companies and practitioners to be involved in the workshops. A total of 23 participants was involved in the study (table 5.5): twelve people participated in Cape Town and eleven people attended the short course in Nairobi. In both cases participants were from companies, consultancies and NGOs working on financing, business models or design of renewable energy systems. Attendees were organised in groups of three to five people according to their topic of interest. Where more representatives of a company were attending (P6, P7 and P8; P11 and P12), these worked as a group on their chosen brief, for example introducing a new offer for their existing target customers.

Participant	Focus	Numbers of interviewees, job title / department,
Cape Town (W4)		
Consultancy (P1)	Energy (DRE design)	1, energy management engineer
Consultancy (P2)	Business models, circular economy	1, founder and CEO
Consultancy (P3)	Business models for renewable energy	1, consultant
Consultancy (P4)	Business models, DRE recruitment	1, director
Consultancy (P5)	Energy (DRE design)	1, quality manager
Consultancy (P6, P7, P8)	Energy policy and financing	3, finance
Academic (P9)	Electrical engineering	1, lecturer and researcher
SME (P11, P12)	Energy management and solar appliances: product-oriented offer	2: technical engineer, manager
Nairobi (W5)		
Consultancy (P13)	Energy access	1, HSE advisor
Consultancy (P14)	Energy (DRE design)	1, renewable energy engineer

Consultancy (P15)	Energy (DRE and business model)	1, consultant
Company (P16)	Solar systems: product-oriented	1, project engineer
SME (P17)	Cookstoves: product-oriented	1, director
NGO (P18)	Energy access and poverty alleviation	1, energy consultant
Company (P19)	Energy (renewable plants design)	1, chief engineer quality
SME (P20)	Energy/cookstoves: product-oriented	1, business unit director
SME (P21)	Training + cookstoves: product-oriented	1, managing director
Company (P22)	Solar systems: product-oriented	1, technical manager
Consultancy (P23)	Energy & women empowerment	1, consultant

Table 5.5 - List of participants from Cape Town and Nairobi, DS-III

5.4.2 Description of activities

The workshops in Nairobi and Cape Town followed a similar structure. After an introduction to PSS, DRE, the combination of these models and relative benefits for BoP contexts, participants were introduced to the Innovation Map as a classification system for PSS and DRE models. In a second phase, participants worked in teams and used the tool for their chosen design briefs. In details, the activities are described below.

1. Exploring the applications of PSS and DRE in low-income and developing contexts.

Participants used the Innovation Map and the Archetypal model cards to map existing case studies on the map. They were given five cases per group and they were asked to position them according to the type of PSS, energy system involved and target user. This activity helped them in differentiating PSS models and in familiarising with the use the tool. This activity took about 20 minutes for positioning the cases and 45 minutes for discussing them.

2. Positioning of company's offers, strategic analysis of competitors, identification of business opportunities

Participants were asked to position their current offerings on the Map according to the type of energy system, the target customer and the PSS type. Consultants, NGOs and academics positioned a project they worked on, for example in collaboration with a company, or, when this was not applicable, they helped other participants in the group to position their offerings. This activity helped participants listing actors and businesses operating in the chosen area and to identify areas of exploration. The strategic analysis lasted for about one hour.

3. Idea generation

In this phase, participants used the tool to brainstorm about new concepts. They used the Concept Cards to detail up to four new business models and then position them on the corresponding area of the map. This activity was carried out in about two hours.

5.4.3 Discussion of results

The data collected in this study through questionnaires and participant observation resulted in a qualitative analysis of the completeness, ease of use and usefulness of the Innovation Map. The results are discussed in this section.

5.4.3.1 Testing the completeness

As discussed in 5.3.3, the completeness of the tool and of the Archetypal Models needed to be assessed by a wider number of companies and practitioners in order to ensure validity of results. Participants were asked if they were aware of models that cannot be encompassed in the Archetypal Models and that fall out of the Innovation Map. Most respondents (19 out of 23) could not think of examples or cases that are not included the Archetypal Models, thus implying that the Innovation Map covers exhaustively all models of PSS applied to DRE. Two participants (P21, P5) pointed out that the map focuses on electricity, therefore other types of energy may not be included in the Archetypal Models (such as thermal energy or energy for cooking). This aspect could be further explored in future research activities, however, for the purpose of this research, the tools developed focus on electricity generation.

The other two respondents (P15, P14) that answered negatively showed doubts in mentioning offers that are not included in the archetypes. One participant (P18) mentioned that sale-based offers cannot be included in the map. Since the map only classifies PSS+DRE models, other offers do not fall within its limits and it can be argued that the person did not fully understood that. Nevertheless, this observation can be considered for further developments of the tool (see Section 5.6). Another person (P10) affirmed that monitoring systems (i.e. demand side management, DSM) could be included in the offers' types. However, as discussed in section 4.2, DSM services are aligned with the PSS type dimension and the potential environmental sustainability dimension. In fact, moving from product-oriented towards use-oriented and result-oriented PSSs, providers would be more interested in adopting DSM techniques.

It can be concluded that, despite some misunderstanding, participants have assessed that the Innovation Map and Archetypal Models cover exhaustively all models of PSS applied to DRE.

5.4.3.2 Testing the clearness and ease of use

In order to test clearness and usability of the tool, participants were asked to rate the clearness of the axis and the ease of positioning case studies. Most of them considered the tool clear (avg. rating 4.6) and easy to be used (avg. rating 4.4), affirming that "*everything was clear*" (P2), the tool is "*easy to use*" (P14) and "*clear and straight to the point and the case studies were helpful too*" (P10).

Some participants encountered issues in the positioning exercise (Fig. 5.15) but affirmed that with enough time and discussions within the group the task became clearer (*"some options seem ambiguous or duplicated, but with some discussion they become clearer",* P4; *"it was clear but more time is required to clearly understand",* P17). Two people (P1, P9) affirmed that they had difficulties in establishing the ownership of products involved in the offer.

Figure 5.15 - Exploring PSS+DRE models: positioning case studies in Cape Town, DS-III

5.4.3.3 Testing the usefulness

This section discusses the applications of the tool as a support for strategic analysis and company's positioning, as well as for exploration of new opportunities and design of new concepts.

<u>Positioning a company's offers:</u>

The first activity aimed at positioning their offerings on the map. Most participants commended this application of the tool (56% rated 5, 26% rated 4) and affirmed they would use the tool for this reason in the future.

<u>Analysing competitors in the selected market:</u>

Mapping competitors was also considered helpful in the process, in fact participants highlighted that the strategic analysis helped them in understanding which gaps exist in the market and what opportunities lie there ("*understanding competitors in the same sector the map helps us differentiate* *ourselves from competitors and allows us to offer different strategies to adapt to the market*", P12; "*it helps to identify where one is currently at in the PSS. Identifying areas that are currently not covered and what opportunities are available*", P16; "*it helps in promoting gaps and market areas you can expand to*", P15).

Some participants, especially those involved in Cape Town, had issues in positioning competitors and affirmed that the "*process was not easy*" (P9). It was observed that the strategic analysis led to the identification of only few competitors. This may be related to their knowledge of the market ("*However this may have less to do with the model and more to do with my own awareness of the market*", P19) and to the fact that the energy scenario in South Africa does not present many PSS solutions, compared to Kenya for example. Nevertheless, all participants expressed that they would use it for this purpose in the future.

This aspect suggested that the strategic analysis may include positioning of non-PSS offers, such as sales-based models or even non-renewable solutions such as kerosene or diesel generators. In fact, while they cannot be positioned on the map because they are not PSS+DRE, they still present influencing factors in the design of an offer that competes in a market where these options are provided. This element can be considered for future implementations.

<u>Exploring new business opportunities</u>:

The tool's usefulness in supporting the exploration of new opportunities was highly commended by participants. With an average rating of 4.2 for this application of the tool, companies and practitioners assessed that the Innovation Map "*offers opportunities to rethink*" (P11), "*it is useful in exploring all viable opportunities*" (P1) and "*practically opens your mindset*" (P6).

Most responses highlighted that the utility of the Innovation Map is to visualise gaps in the market and simultaneously possible models to be implemented, supporting strategic conversations about which directions the business might take ("*this map allows a company to plan future business. The tool allows you to look at what you have missed out*", P5; "*the innovation map may help us identify key areas for investigation and a way forward*", P12;"*it is a perfect tool to continuously perfect my business model, to gain new business opportunities and reposition existing systems*", P17: "*the map allows us to build a business model and to refine it, discussing pros and cons*", P4).

One participant pointed out that the map is limited to the first stage but it would be not "*good for implementation as some these unexplored new business opportunities are normally capital and labour intensive with few case studies*". This observation reflects the barriers that companies may face when implementing a PSS-oriented solution. The use of other tools and methods for implementation and monitoring of these types of offers may be required in a later stage.

<u>Generating new concepts of PSS applied to DRE:</u>

Similarly to the previously discussed applications, the Innovation Map was considered helpful in supporting idea generation for PSS+DRE. Participants highly rated this application (avg. rating 4.3) and positively supported the usefulness ("*this has opened the thinking into more renewable ideas we can offer to our customers*", P12; "*the map is an eye opener*", P13; "*the innovation map offers a combination of different business models and with a bit of creativity I can play around with the options",* P20). During the workshop participants filled between three and four Concept Cards per group and detailed all design elements on the cards, positioning the corresponding number on the map (Fig. 5.16 and 5.17). They affirmed that this process facilitated the idea generation ("*it makes the idea generation much easier and gives it a process, a framework*", P4; "*the map provides a thought process that is easy to follow through during idea conceptualisation*", P16; "*the Innovation Map gives you insights for your idea*", P6).

Some participants mentioned that other idea-generation supporting tools may be more appropriate for the design process. P9 stated that mindmaps or other brainstorming tools may be preferable, while P19 affirmed that "*Having used a model like the 4 lenses of innovation, this model will help me when I have a basic idea already*".

Most participants stated they would use the tool for this purpose in the future, while some highlighted it would be useful when they already have a basic idea to be developed (P1, P19). It was also noted that the Innovation Map could be useful to "*continuously evaluate my model and identifying opportunities*" (P17), meaning that after a first idea generation session the tool can be used over time to monitor and support the innovation process.

Figure 5.16 – Participants generating new concepts of PSS+DRE in Cape Town, DS-III

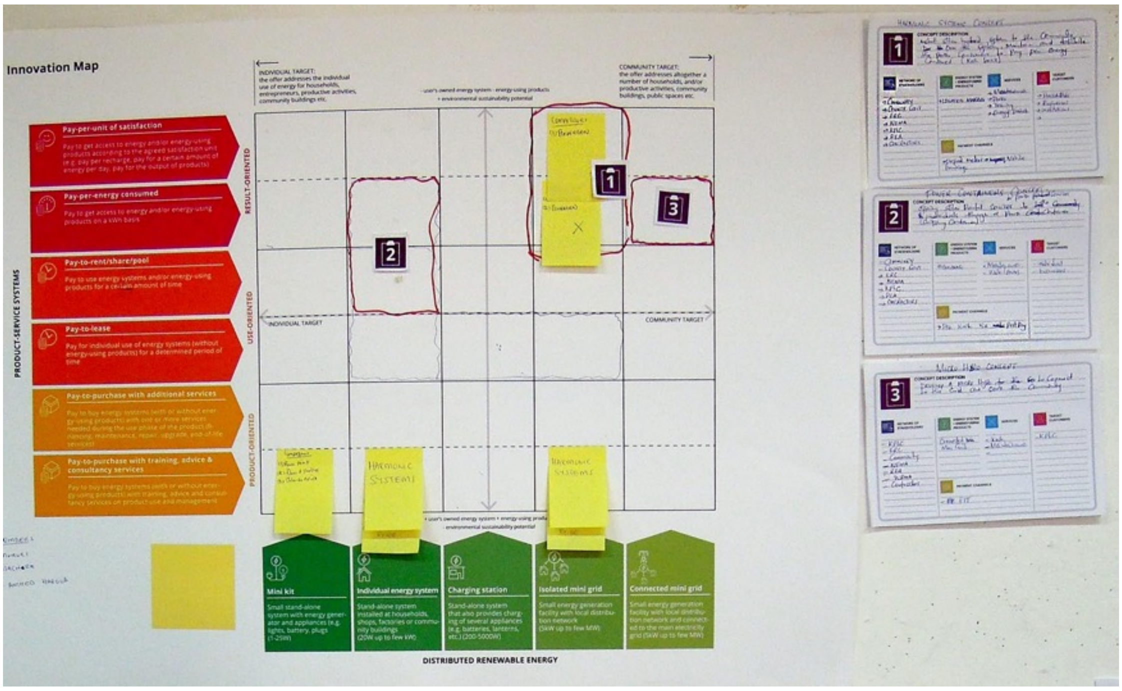


Figure 5.17 - Results from using the Innovation Map in Nairobi, DS-III

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Testing the completeness						
1. Can you think of other types of offer or other examples/cases that are not included in the archetypal models? If yes, which ones?	No: 82% (19) Yes: 18% (4)					
Ease of use of the Innovation Map	**1**	**2**	**3**	**4**	**5**	**Avg**
1. To what extent is the innovation map easy to understand (i.e. the meaning of each axis is clear)?	-	-	-	39% (9)	61% (14)	**4.6**
2. To what extent is the innovation map easy to use (e.g. positioning of case studies, positioning of your offer etc.)?	-	-	4% (1)	48% (11)	48% (11)	**4.4**
Applications of the Innovation Map	**1**	**2**	**3**	**4**	**5**	**Avg**
1. The innovation map is intended to be used for positioning a company's offer(s). To what extent is the innovation map contributing to the achievement of this objective?	-	-	18% (4)	26% (6)	56% (13)	**4.3**
1.1 Would you use it for this purpose in the future?	Yes: 94% (18) No: 6% (1)					
2. The innovation map is intended to be used for mapping the existing offers of PSS applied to DRE (competitors in the same business sector, other companies operating in the selected context etc.). To what extent is the innovation map contributing to the achievement of this objective?	-	-	15% (3)	50% (10)	35% (7)	**4.2**
2.1 Would you use it for this purpose in the future?	Yes: 94% (18) No: 6% (1)					

3. The innovation map is intended to be used for exploring new business opportunities (repositioning of offer, combination of different offers). To what extent is the innovation map contributing to the achievement of this objective?	-	-	22% (5)	30% (7)	48% (11)	**4.2**
3.1 Would you use it for this purpose in the future?	Yes: 100% (19) No: 0%					
4. The innovation map and archetypal models are intended to be used for generating ideas. To what extent is the innovation map contributing to the achievement of this objective?	-	-	17% (3)	35% (8)	48% (11)	**4.3**
4.1 Would you use it for this purpose in the future?	Yes: 100% (19) No: 0%					

Table 5.6 - Questionnaires' results from South Africa and Kenya, DS-III

5.4.4 Conclusions from the Descriptive Study III

The DS-III provided important insights for the applications of the Innovation Map. The tool has been practically used by 23 people working in DRE companies, NGOs and consultancies in two workshops in South Africa and Kenya. Compared to the previous version, the Innovation Map 1.0 supported the process of idea generation of new PSS+DRE concepts and this resulted in an average of three concepts generated for each group. Each concept detailed type of offer, products and services, payment channels, target customer and network of providers (Fig. 5.17). The tool was evaluated in its use through participant observation and questionnaires collected at the end of the workshop.

In term of clarity and usability, this version of the tool received high ratings about clearness and ease of use on the questionnaires and these aspects were confirmed through participant observation. In fact, no particular issue was encountered during the positioning of case studies and later during the positioning of concepts, meaning that the Innovation Map 1.1 has improved on this aspect.

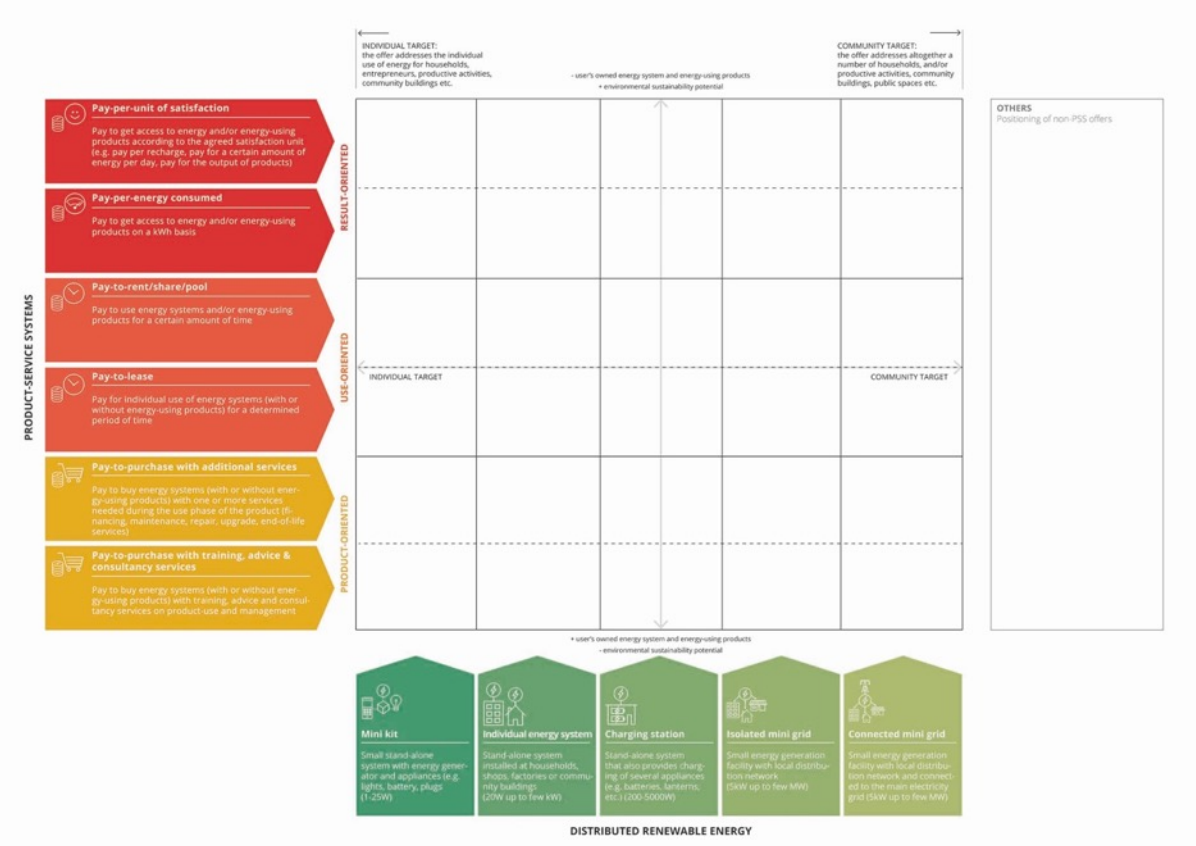
The applications of the tool for positioning competitors and exploring new opportunities have also been assessed, suggesting that the Innovation Map is very useful to support the strategic analysis of a specific context. Observations of the tools in use and comments from participants suggested that the tool may be improved to include non-PSS solutions in the context analysis.

Other general comments for future improvements have been collected through the questionnaires. A first aspect relates to the inclusion of other types of energy besides electricity (suggested by P12, P20). Other participants highlighted that financial viability and sustainability of each model should be assessed, thus supporting the selection of a concept over another. Another improvement suggested was the inclusion of regulatory and policy components that influence the decision making. Despite being crucially important, financing and regulatory aspects of PSS+DRE are not included in this PhD research. However they represent interesting areas for further research activities and they can be considered in future developments of the tool (see Chapter 9).

5.5 Prescriptive Study III: Innovation Map 1.1

The testing activities in Kenya and South Africa led to some minor design changes for the Innovation Map 1.1 (Fig. 5.18):

- A box for positioning non-PSS offers was added. This feature allows users to position competitors during the strategic analysis even though they are not providing PSS solutions. For example, sales-based offers of mini kits or energy-using products can be considered important when analysing the selected context. At the same time, non-renewable solutions such as kerosene or diesel generators can influence a model in terms of customers' habits and willingness to pay, payment structures and channels.
- Some icons have been redesigned to facilitate understanding and colours from the Concept Card have been changed. These graphic changes were made following an evaluation of icons and appearance of the tools, which was carried out as part of the testing of the Visualisation System of PSS+DRE (see 7.3.2).



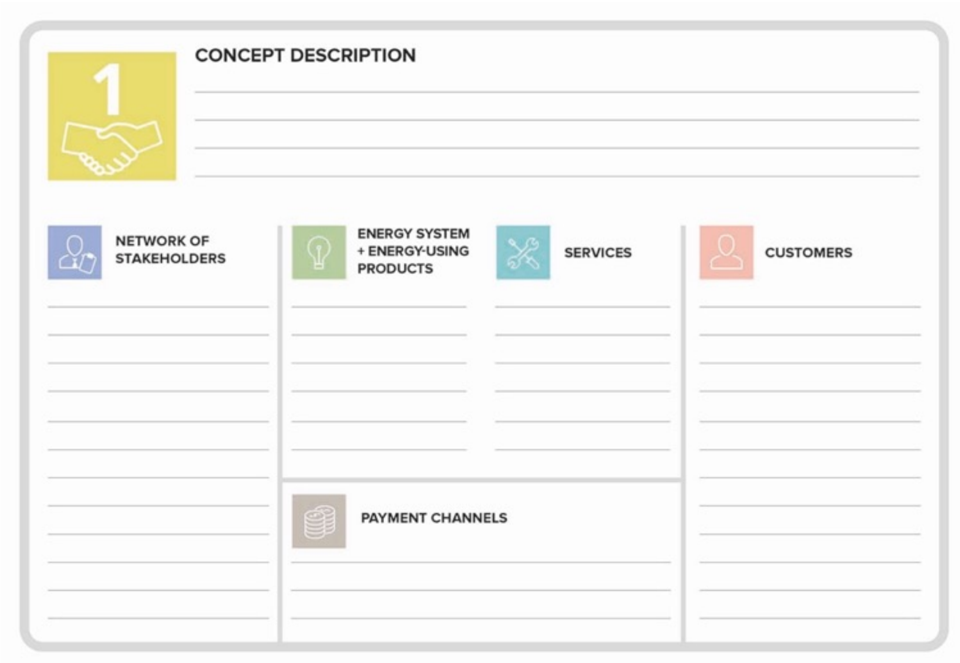


Figure 5.18 - Innovation Map and Concept Card 1.1

5.6 Descriptive Study IV (DS-IV): testing activities in Kenya and Botswana

The Innovation Map 1.1 was evaluated through three workshops in Kenya and Botswana. These testing activities were carried out within the EPSRC-funded project "Design and innovation tools to support SMEs in developing sustainable Product-Service Systems for energy access in African contexts", between November and December 2016. The DS-IV principally aimed at evaluating the tool with a small number of participants who would apply the Innovation Map for their selected brief, thus mimicking a 'real-life' design application. The purpose was to collect qualitative feedback on the last version of the tool. For this reason, questionnaires were used to collect data and a discussion with participants at the end of the workshops was used to gather in-depths considerations about the tool, possible improvements and its applications in the design process. In addition, content analysis of the Innovation Map filled with concept ideas was employed to evaluate the effectiveness of the tool. The triangulation of sources led to a comprehensive analysis of the data collected.

In addition to the two workshops with companies, the DS-IV includes a short workshop conducted at Kenyatta University (Section 5.7.4), where the researcher was invited from the Chendaria Business Incubator Centre to facilitate a session with eight participants, mainly MSc students in renewable energy, some consultants and some affiliates of the centre. This workshop aimed at gathering additional comments on this version of the tool and at providing additional quantitative data to the study.

5.6.1 Sampling

A smaller number of participants were involved in this study (Table 5.7): one NGO and one company in Kenya and two companies in Botswana. A purposive sampling was adopted in this phase, in particular aiming at involving companies focused on different DRE technologies (i.e. solar and biomass) and an NGO working on a wider range of energy solutions in collaboration with local and global stakeholders.

The workshop organised at Kenyatta University (W8) involved participants selected by the hosting institution, based on recommendations from the researcher and on the availability of participants. This workshop is described in section 5.7.4.

Testing activities in Kenya (W7 and W8)		
Type of business	**Focus**	**Number of participants and position**
Workshop at University of Nairobi (W7)		
NGO and consultancy (P1)	Energy access and poverty alleviation	1, energy management engineer
SME (P2)	Biomass: product-oriented	1, founder and CEO

W8: workshop at Kenyatta University		
Education, business-support	DRE, business development	8, consultants and DRE students
Testing activities in Botswana (W9)		
SME (P3)	Solar: product-oriented	1, DRE manager
SME (P4)	Biomass: product-oriented	1, technical advisor /managing partner

Table 5.7 - Participants of the DS-IV

5.6.2 Description of activities

The workshops at University of Nairobi (W7) and University of Botswana (W9) were carried out in three half-days of activities and followed the same structure. After an introduction to the topic of PSS, DRE and PSS+DRE, participants were introduced to the Innovation Map and were asked to perform a practical exercise to explore the different types and applications of these models. In a second phase, they worked in teams and used the tool for their own design briefs. In detail the activities are discussed below.

1. Exploring the applications of PSS and DRE in low-income and developing contexts.

Participants used the Innovation Map and the Archetypal model cards to map existing case studies on the map. They were given five cases and they were asked to position them according to the type of PSS, energy system involved and target user. This activity helped them in differentiating PSS models and in familiarising with the use of the tool. This activity took about 30 minutes for positioning the cases and 1.30h for discussing them.

2. Strategic analysis with the Innovation Map

Participants were asked to position their current offerings on the Map according to the type of energy system, the target customer and the PSS type. Non-PSS offers were positioned on the right-hand side of the Map. This activity helped participants listing actors and businesses operating in the chosen area and to identify areas of exploration. The strategic analysis lasted for about three hours.

Figure 5.19 - Participants carrying out the strategic analysis in Botswana, DS-IV

3. Idea generation with the Innovation Map

In this phase, participants used the tool to brainstorm about new concepts. They used the Concept Cards to define one or three new business models and then position them on the corresponding area of the map. This activity was carried out in two hours.

After having completed the activities with the Innovation Map, participants used the other PSS+DRE design tools for detailing and visualising their concepts (see respectively 6.6.1 and 7.5).

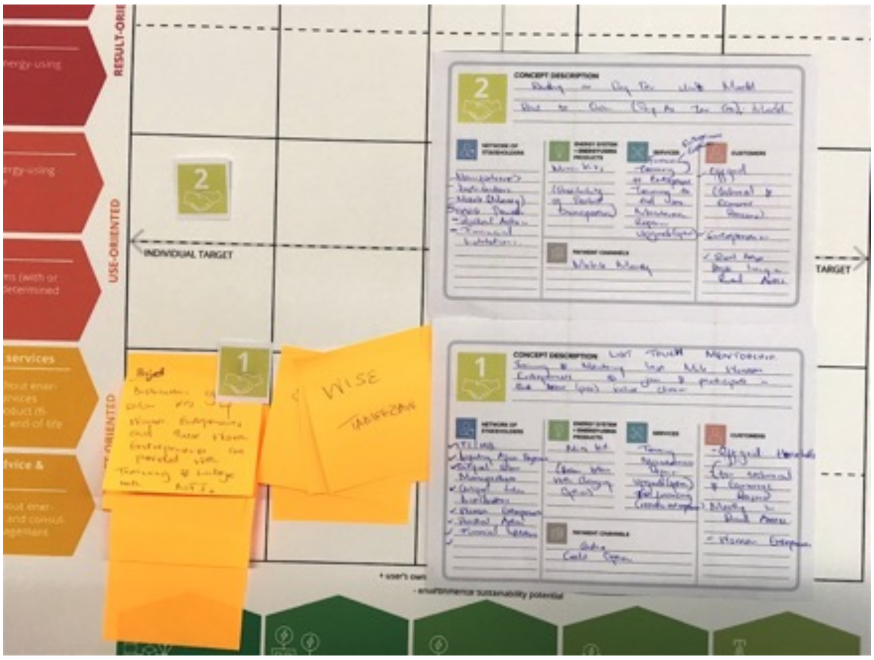


Figure 5.20 - Results from the idea generation in Kenya, DS_IV

5.6.3 Data analysis

The data from the workshops were collected with multiple methods. Questionnaires were used to gather quantitative data (multiple answers) and qualitative data (open-ended questions) at the end of the workshop (Table 5.7). The feedback from participants was also integrated with a recorded group discussion at the end of the activities, which helped to identify limitations of the tools and discuss possible improvements. Participants' observations were used during the workshop, where the researcher took down notes on how people used the tool and what issues they encountered. This method helped in understanding how the tools were used without intervening in the design process and the notes taken by the author have been integrated with other data emerging from questionnaires. Content analysis was used to evaluate the output of the tools in use, in particular the ideas and concepts generated[18].

2. Positioning of companies' offers and strategic analysis with the Innovation Map

The first activity undertaken with the Innovation Map, the strategic analysis, helped participants to map existing offers, positioning competitors and exploring opportunities.

P1 positioned companies operating in the product-oriented area (Fig. 5.21), since their focus was on sale of solar mini kits through women entrepreneurs, and in the Non-PSS area where they identified key actors and programs engaging in similar projects. P1's initial business concept is positioned as 'offering mini kits on a pay to purchase with additional services'.

P2 focused on biogas plants for farmers and coffee cooperatives and positioned their competitors in the individual energy system column, on 'pay to purchase with training and consultancy services' (Fig. 5.22). This also represented the area for their initial business offer, which consisted in selling biogas plants with additional services to coffee farmers and cooperatives.

At the workshop in Botswana, P3 positioned their company on a "pay-to-purchase with advice and consultancy services" of mini kits. Their initial idea was to move towards leasing models and pay-per-unit of satisfaction of both mini kits and bigger individual solar systems as they realised most competitors in the market are operating in the 'pay-to-purchase' area (Fig. 5.23).

P4 position themselves in the 'pay-to-purchase with additional services' of individual energy systems, as their current offerings involve the sale of biogas plants with installation and maintenance services. Other stakeholders in the market are also operating in the same area (Fig. 5.24). P4 also provide energy on a pay-per-consumption basis through biogas plants, therefore positioned another post-it in the result-oriented area / individual energy systems. P4 identified the area of result-oriented PSS as promising and decided to focus on the mini grid technology.

[18] The results of the content analysis are provided in Appendix IV.

The application of the tool for positioning their offers was highly commended by participants (avg. rating 4.7), who affirmed that *"the differentiation of offers and DRE's makes it useful to position the offers" (P2);* the tool "*helps a company define its position in the market and better identify ways of expanding or breaking into other markets"* (P4) and that it "*was very helpful to clearly see who your current target market is as well as the current payment structure" (P3).* Positioning competitors was also considered an important exercise (100% rated 4) because it "*helps the company to identify its niche to separate it from its competitors (P4)* and "*it was helpful to see where this niche markets are amongst competitors. It gives a good visualisation of where the current market is heading" (P3).*

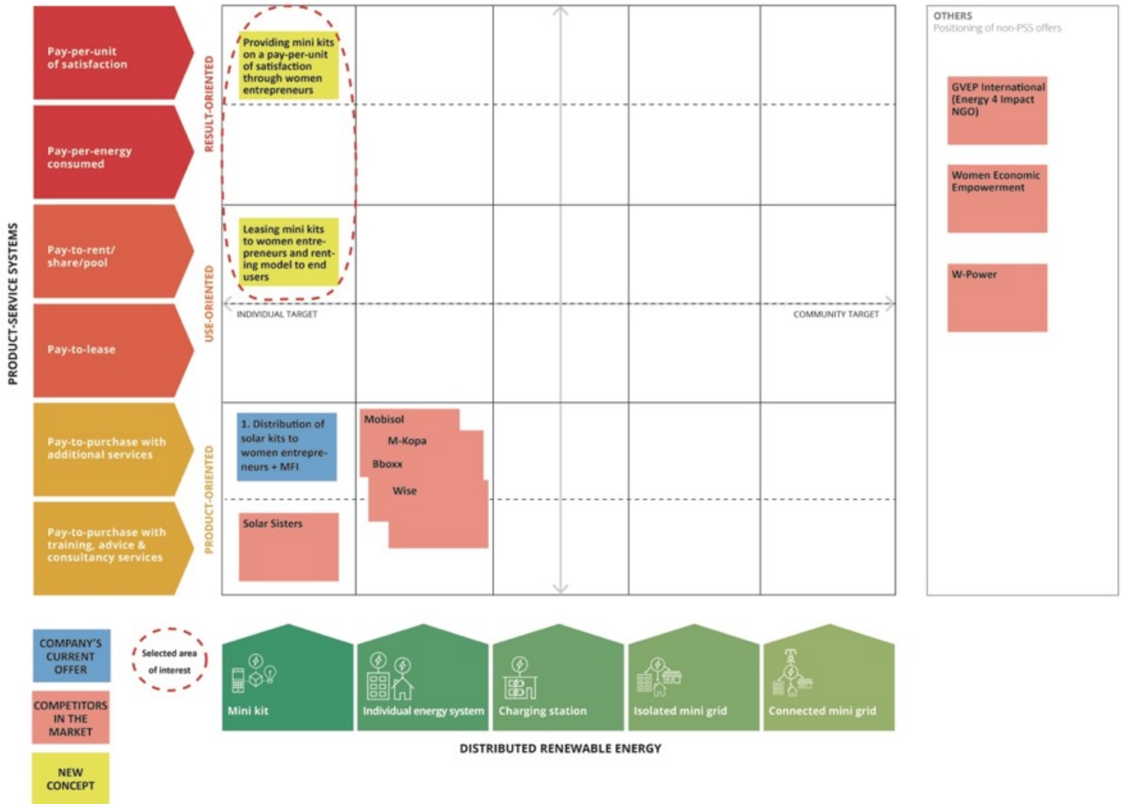


Figure 5.21 - Innovation Map completed by P1, DS-IV

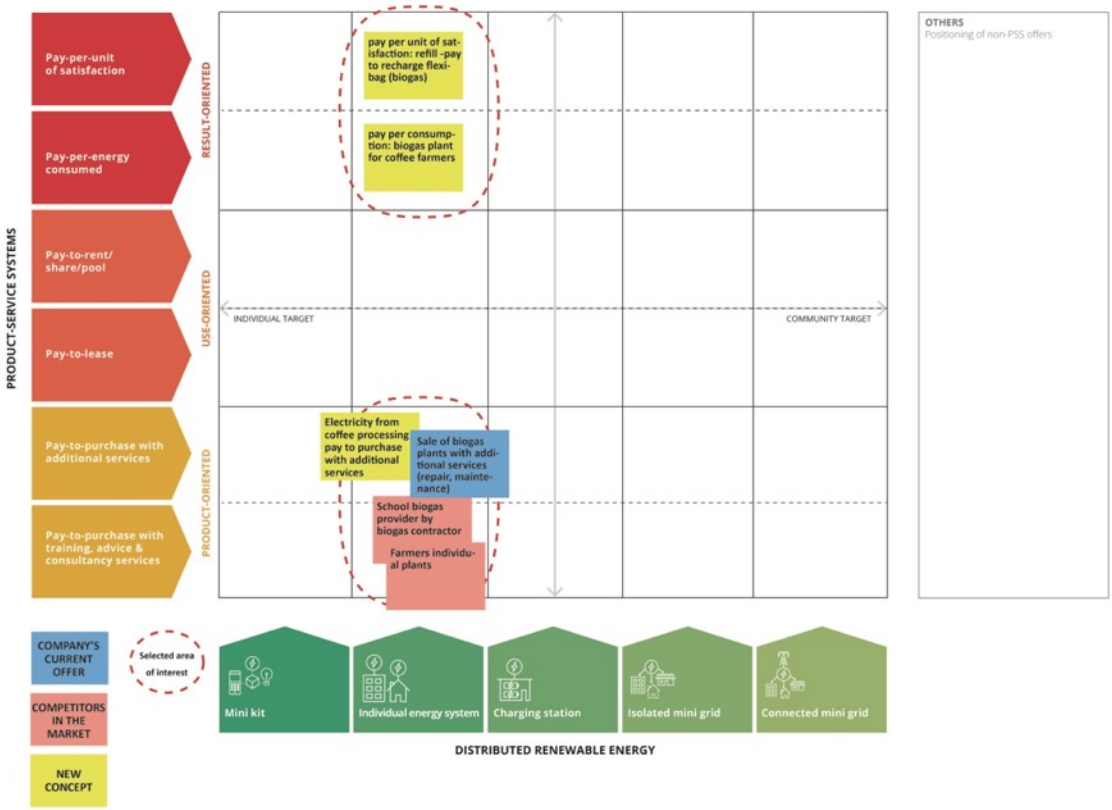


Figure 5.22 - Innovation Map completed by P2, DS-IV

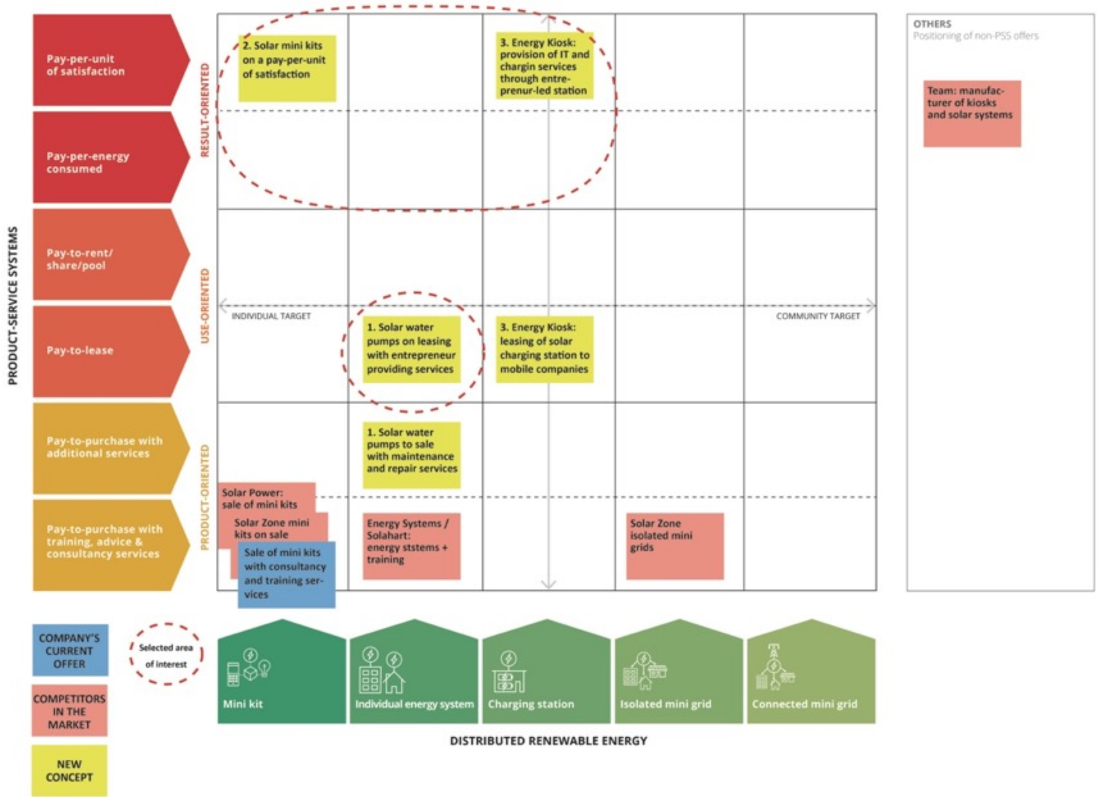


Figure 5.23 - Innovation Map completed by P3, DS-IV

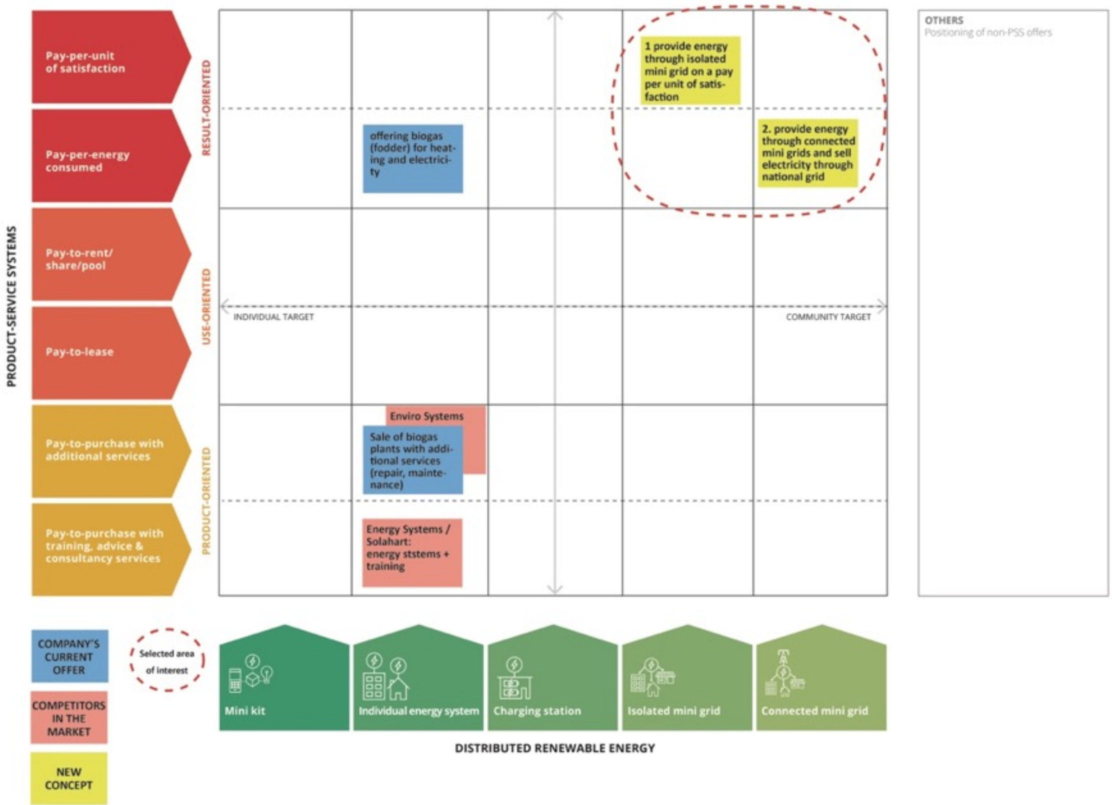


Figure 5.24 - Innovation Map completed by P4, DS-IV

3. Idea generation with the Innovation Map

In the idea generation session participants used the Innovation Map to generate new concepts (Appendix IV). Once participants had identified the areas to focus on, for new business opportunities, they used the Concept Cards to generate new ideas and positioned the corresponding number on the Map.

P1 designed two concepts (Fig. 5.21): the first one (Concept 1) emerged from an idea generation on the current business model (product-oriented model), while the second one, Concept 2, is a combination of use and result-oriented PSSs.

P2 generated one concept that encompassed two types of offerings (Fig. 5.22): a product-oriented one and a result-oriented one. Details of the concepts generated with the Innovation Map are presented in Table 3.

P3 generated three concepts: Concept 1 involves the lease and sale of solar water pumps through entrepreneurs; Concept 2 involves the provision on energy services through solar mini kits on a pay-per-unit of satisfaction; Concept 3 relates to the lease of charging stations (solar kiosks) to mobile producers, employing local entrepreneurs to provide charging services to end-users. Fig. 5.23 shows the Innovation Map completed by P3 at the end of the process.

P4 generated two concepts focusing on the mini grid technology: Concept 1 involves the provision of energy through isolated mini grids on a pay-per-unit of satisfaction basis; Concept 2 involves connected mini grid that sells electricity to the main national grid on a pay per consumption basis. Fig. 5.24 illustrates the results of P4 using the Innovation Map.

Participants were asked to rate the use of the tool for exploring new opportunities (25% rated 4 and 75% rated 5) and generating new concepts (avg. rating 4.7) through the questionnaire. Comments emerging on this application of the tool highlighted that *"the map allows one to look at the system comprehensively hence generate better ideas" (P2)* and that the tool helped define and detail aspects of their business model idea (*"my business is new and was rather vaguely described before the preparation of the map., thus the map made a valuable contribution" (P1)).* P3 affirmed that the tool helps visualising opportunities for new businesses ("*once you see where your position is in the market as well as your competitors, you are able to take advantage of opportunities not being explored"),* while P4 commended the step-by-step approach that guides the brainstorming process *("it serves from my point of view as roadmap to a destination. Brainstorming can be a disadvantage as one maybe lead astray, but with the innovation map you never lose sight of the goal").*

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Ease of use of the Innovation Map	**1**	**2**	**3**	**4**	**5**	**Avg**
1. To what extent is the innovation map easy to understand (i.e. the meaning of each axis is clear)?	-	-	-	25%	75%	**4.7**
2. To what extent is the innovation map easy to use (e.g. positioning of case studies, positioning of your offer etc.)?	-	-	-	25%	75%	**4.7**
Applications of the Innovation Map	**1**	**2**	**3**	**4**	**5**	**Avg**
3. The innovation map is intended to be used for positioning a company's offer(s). To what extent is the innovation map contributing to the achievement of this objective?	-	-	-	25%	75%	**4.7**
4. The innovation map is intended to be used for mapping the existing offers of PSS applied to DRE (competitors in the same business sector, other companies operating in the selected context etc.). To what extent is the innovation map contributing to the achievement of this objective?	-	-	-	50%	50%	**4.5**
5. The innovation map is intended to be used for exploring new business opportunities (repositioning of offer, combination of different offers). To what extent is the innovation map contributing to the achievement of this objective?	-	-	-	25%	75%	**4.7**
6. The innovation map and archetypal models are intended to be used for generating ideas. To what extent is the innovation map contributing to the achievement of this objective?	-	-	-	25%	75%	**4.7**

Table 5.8 - Questionnaires' results from the workshops in Kenya and Botswana, DS-IV

5.6.4 Discussion of results

Clearness and ease of use

Clarity and usability of the tool was assessed with the responses from the questionnaire and participants' observation. This aspect of the tool has been highly rated in the questionnaire, meaning that the Innovation Map is easy to understand (50% rated 4 and 50% rated 5) and easy to be used (100% rated 5). Although, no particular issues have been observed during the use of the tool, P2 affirmed that "*initial unfamiliarity with the models was an obstacle in the initial stages. This was however easily overcome*" and that "*understanding terminology initially was not easy, but it was solved with continued usage*". P3, on the other side, "*found the tool very clear*". It can be concluded that an initial introduction on PSS types, case studies and classification must be provided before using the tool.

Usefulness

One of the assumed contributions of this tool was that it should help companies and practitioners in thinking in a 'systemic way', by considering simultaneously several elements (providers, customers, products etc.). Participants have expressed that the tool allows to "*look at the system comprehensively"* (P1), hence the Innovation Map and in particular the Concept Cards helped them to start thinking in terms of 'building blocks' of a PSS solution, considering not only the technology but also the services, customers and network of stakeholders and payment structure. Also, it helped in understanding elements of the business model, which was "*broken down into practical and easily understandable units"* (P2).

<u>Positioning of companies' offers and analysis of the energy sector in a determined context</u>

The tool helped participants in thinking about models that can be applied in a specific context and in analysing competitors. This application was commended by the participants through the questionnaire, and the group discussions at the end of the workshops helped to get further feedback., P3 stated that the tool helped understanding the current energy scenario ("*It's really a way of helping me focus directly and looking at other opportunities. With the innovation map we looked at everything in Botswana. …was at the bottom [product-oriented area]"*, P3).

Some insights for facilitating the strategic analysis also emerged. P1 stated that often, in the context of Kenya, "*models are quite unique, and success factors depend on who runs the project*". In fact, organisational form (i.e. the nature of the provider of the energy solution, such as private enterprise, NGO, community) is one of the PSS+DRE characterising dimensions, however it has not been considered in the development of the Innovation Map (Emili et al., 2016 (a)). This aspect can be integrated in the next version of the tool, for example providing other layers of analysis of the existing situation. This may be translated in adding "organisational form" cards to describe existing models (see 5.8).

Exploring new opportunities and supporting the design of innovative business models.

This application of the tool was confirmed by the fact that both P1 and P2 generated concepts that were not existing in the selected context of interest and that were different from the initial business offer (*"through the tool I adopted a new offer compared to the initial one", P1).* Furthermore, P1 designed a solution that falls outside of the PSS+DRE archetypal models, hence it has not been applied so far. Although, this will require a follow up verification on the concept implementation, the Innovation Map in this case supported the design of an innovative business model.

In Botswana, P4 observed that having the tool helped to focus during the idea generation ("*brainstorming can be a disadvantage as one maybe lead astray, but with the Innovation Map you never lose sight of the goal*"). Both P3 and P4 shifted their current offerings and generated ideas on different areas of the Map: P3 explored the individual energy systems field and the charging stations, while P4 shifted from individual systems to mini grid technologies. In terms of offering, they generated concepts in the use and result-oriented areas, moving away from the product-oriented one where they currently operate. Moreover, P3 combined two models, leasing option and pay-per-unit of satisfaction, in their solar kiosk concept.

P3 initially decided to focus on result-oriented PSS (pay per unit of satisfaction) for their mini kit concept (see highlighted area, Fig. 5.25), and decided to position the new concept in the corresponding area of the Map. However, after having discussed implications for implementing this model and necessary resources needed (such as capital financing), they decided to return to their initial business offer (offering mini kits on a pay to purchase with additional services) and kept the result-oriented model idea for the future. This suggests that the Innovation Map helped P3 in identifying where they would like to be positioned in the future and what kind of offerings they might provide, even though these cannot be implemented straight away *("we came with a couple of ideas and this helped me rethink that product and how we would do it", P3)*. In the discussion after the workshop, P3 affirmed that they will use the tool after a period of implementation and see what conclusions they might gather in terms of barriers for adopting a specific model. *("To review the innovation map when you have your ideas, you can set yourself up and then looking at it again in 6 months or 2 years-time and say "how successful we are? Is this market just doesn't work because of the barriers?").*

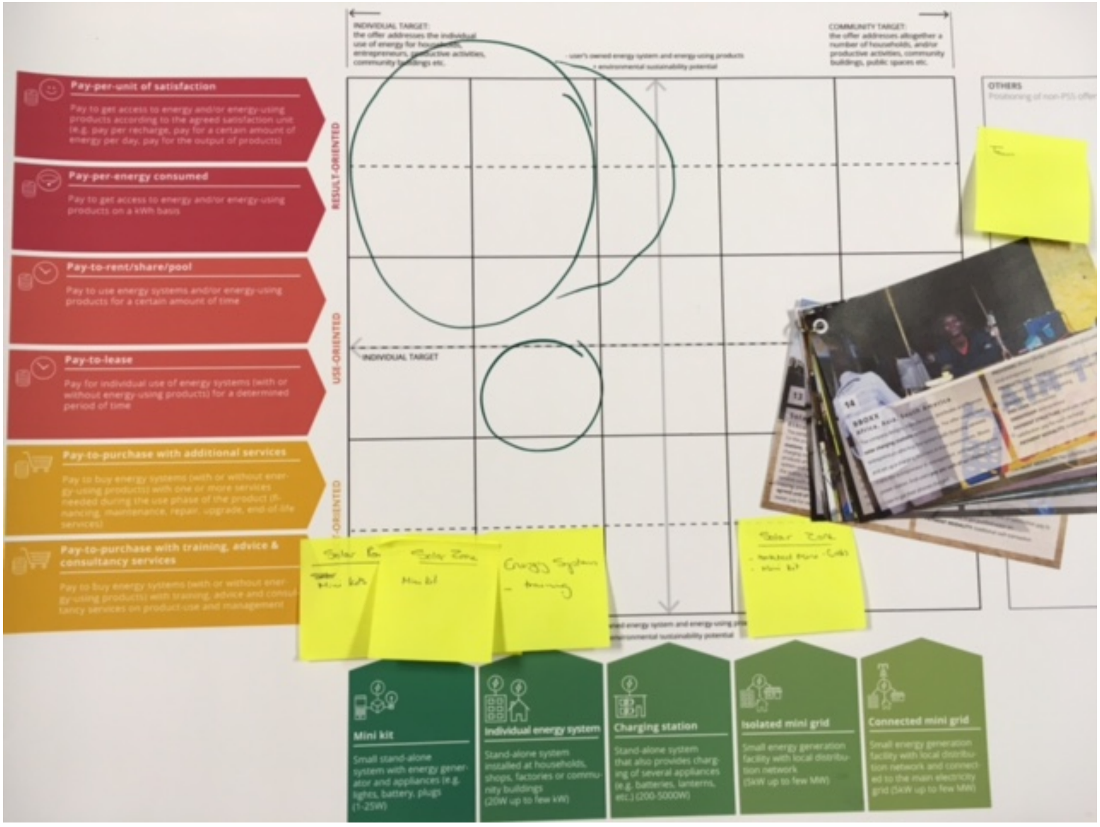


Figure 5.25 - P3 highlighted the promising areas to explore, DS-IV

5.6.5 Workshop at Kenyatta University

The researcher was invited by the Chendaria Business Incubator Centre and the Department of Renewable Energy to run a workshop with a mix of master students and practitioners. Eight participants attended.

This workshop was aimed particularly to gather more quantitative data on the usability and usefulness of tool and to explore their applications at the Incubator Centre and at the Kenyatta University. This activity also helped engaging further partners for dissemination of results and who will be interested in applying the tools and the resources as part of their program.

Due to time constraints, the workshop lasted four hours, including an introductory part on PSS, DRE and on how to use the tool. In the following section, the main results collected in this workshop are summarized by discussing usability and the applications of the Innovation Map. Table 5.9 presents the data collected with questionnaires at the end of the workshop.

<u>Clearness and ease of use</u>: participants highly rated the clearness of the tool (75% rated good and 25% very good) and how it *"clearly shows how to do the positioning pictorially"* (S2)*,* although one of them affirmed that *"it need explanation to be understood"* (S4) and that positioning of case studies was not so straightforward due to first time of use.

Applications: most of the workshop attendees commended the usability of the tool for positioning companies and mapping competitors, affirming that it *"greatly helps companies to identify niches which they can drive into"* (S5). Moreover, the tool allows a company to *"be able to identify the services not provided"* (S7) and that *"it has helped map the various key players in similar positions helping identify the level of competition"* (S5).

Some encountered difficulties in positioning companies and highlighted that *"it can be tricky when companies are multi-purpose"* (S4) and that *"the tool needs guidance to be understood"* (S4). One participant (S6) suggested that a short explanation for the column concerning 'non-PSS' offers' positioning may be needed.

Concerning the idea generation session, participants highly rated this application of the Innovation Map (62%=very good, 25%=good) and affirmed that the concept cards made it *"easy to expand on your concept"* (S4), *"invite new ideas to address gaps"* (S1) and that the tool makes it *"easier to reposition offers and/or combine, reaching more targets"* (S5).

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Ease of use of the Innovation Map	**1**	**2**	**3**	**4**	**5**	**Avg**
1. To what extent is the innovation map easy to understand (i.e. the meaning of each axis is clear)?	-	-	-	75%	25%	4.2
2. To what extent is the innovation map easy to use (e.g. positioning of case studies, positioning of your offer etc.)?	-	-	-	50%	50%	4.5
Applications of the Innovation Map						
1. The innovation map is intended to be used for positioning a company's offer(s). To what extent is the innovation map contributing to the achievement of this objective?	-	-	-	38%	62%	4.6
2. The innovation map is intended to be used for mapping the existing offers of PSS applied to DRE (competitors in the same business sector, other companies operating in the selected context etc.). To what extent is the innovation map contributing to the achievement of this objective?	-	-	13%	25%	62%	4.5
3. The innovation map is intended to be used for exploring new business opportunities (repositioning of offer, combination of different offers). To what extent is the innovation map contributing to the achievement of this objective?	-	-	-	25%	75%	4.7
4. The innovation map and archetypal models are intended to be used for generating ideas. To what extent is the innovation map contributing to the achievement of this objective?	-	-	13%	25%	62%	4.5

Table 5.9 - Questionnaires' results from the workshop at Kenyatta University, DS-IV

5.6.6 Conclusions from the Descriptive Study IV

The testing activities of DS-IV evaluated the Innovation Map 1.1 in terms of usability and usefulness. The first two workshops described in this section, at University of Nairobi and University of Botswana, offered the opportunity to evaluate the tool with a small and selected number of participants. This study aimed at assessing the tool's effectiveness through the analysis of the concepts generated, in combination with feedbacks from questionnaires and participant observation.

These two workshops confirmed the applications of the Innovation Map and demonstrated that the tool supports the idea generation of new business models.

The other workshop at Kenyatta University confirmed the previous findings, providing additional quantitative and qualitative data, and contributed with insights on how the tool may be used in different contexts and with different users. This aspect is addressed in Chapter 8.

5.7 Final version: Innovation Map 2.0

Drawing conclusions from the activities in Kenya and Botswana, the final version of the Innovation Map was developed. Changes to the tool included:

- Addition of short text description for "Others: positioning of non-PSS offers", aimed at clarifying the purpose of that area of the map (see Fig. 5.28).
- Addition of Stakeholders Cards (Fig. 5.26) for detailing the strategic analysis of competitors. This feature was implemented to introduce a new layer of analysis that includes the organisational form dimension. When analysing solutions provided in a selected context, the Stakeholders Card can be filled out detailing actors and their roles for a specific offer. This would help defining what type of stakeholders are involved in the solution and potentially what strategic partnerships can be created.
- The tool was also prepared in a digital version (interactive pdf file). An example of digital format for the Archetypal Model cards is provided in Fig. 5.27.

The final version of the tool was then uploaded to the website www.se4alldesigntoolkit.com, which was created to disseminate this project results. The tool is available to be downloaded in its print and digital version. The diffusion and impact of this tool is further discussed in Chapter 8.

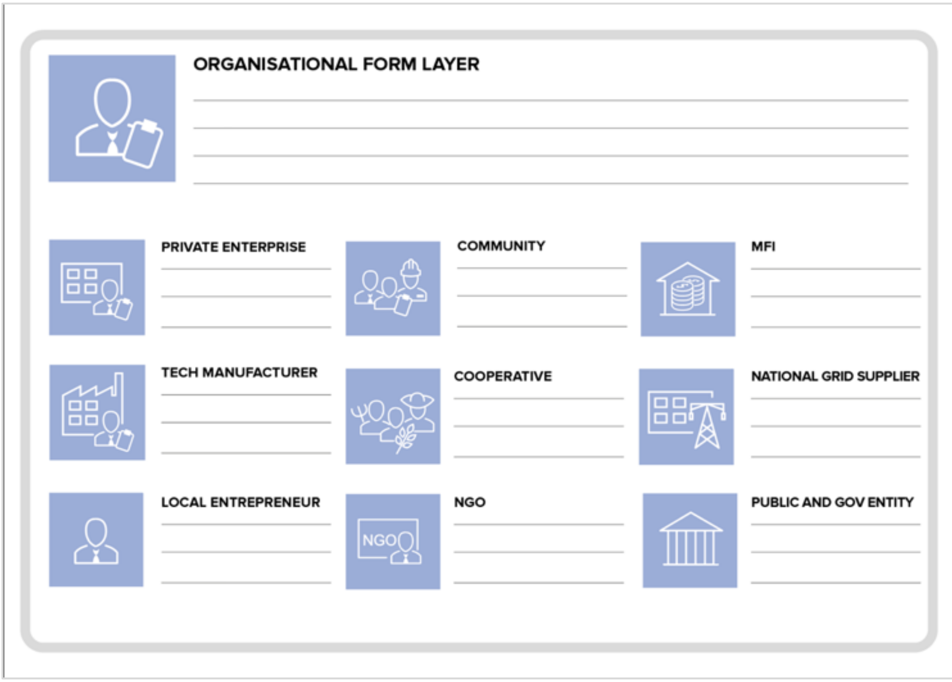


Figure 5.26 - Stakeholders Card

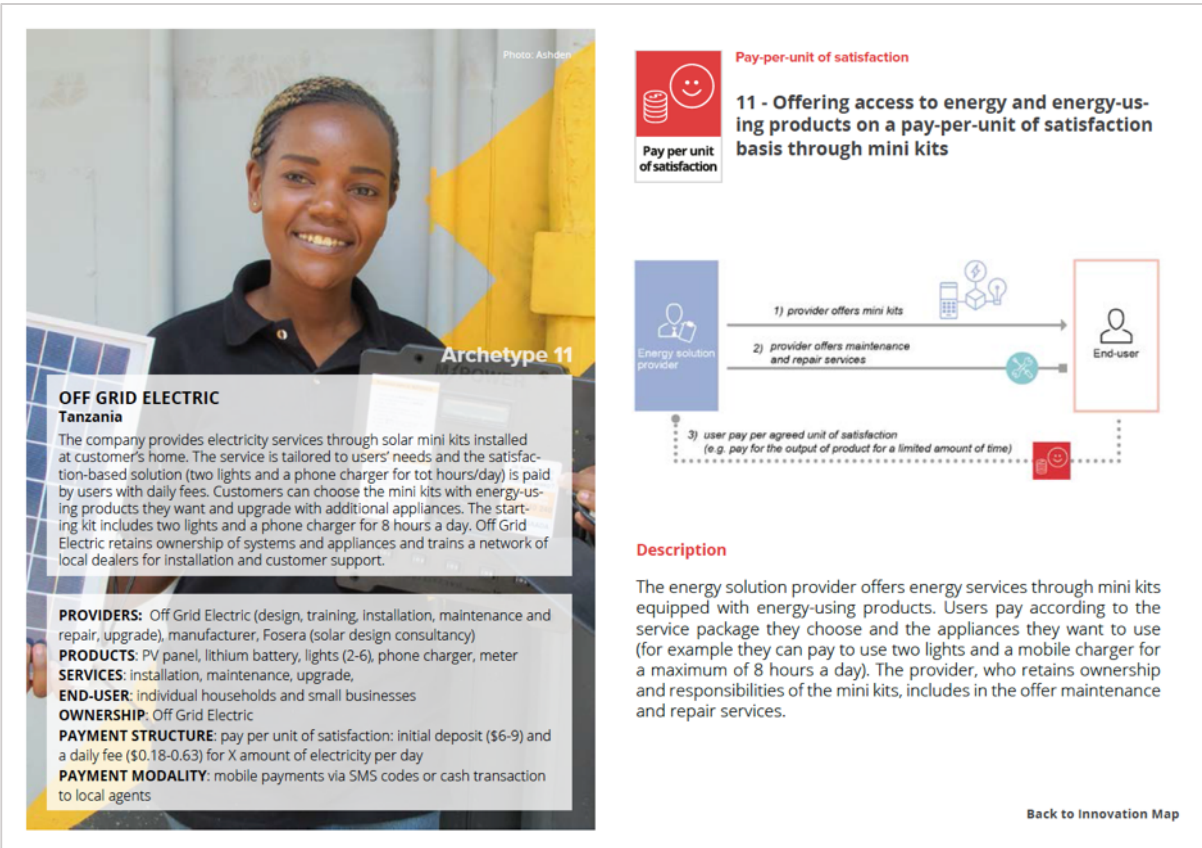


Figure 5.27 - An example of Archetypal Model card in digital format

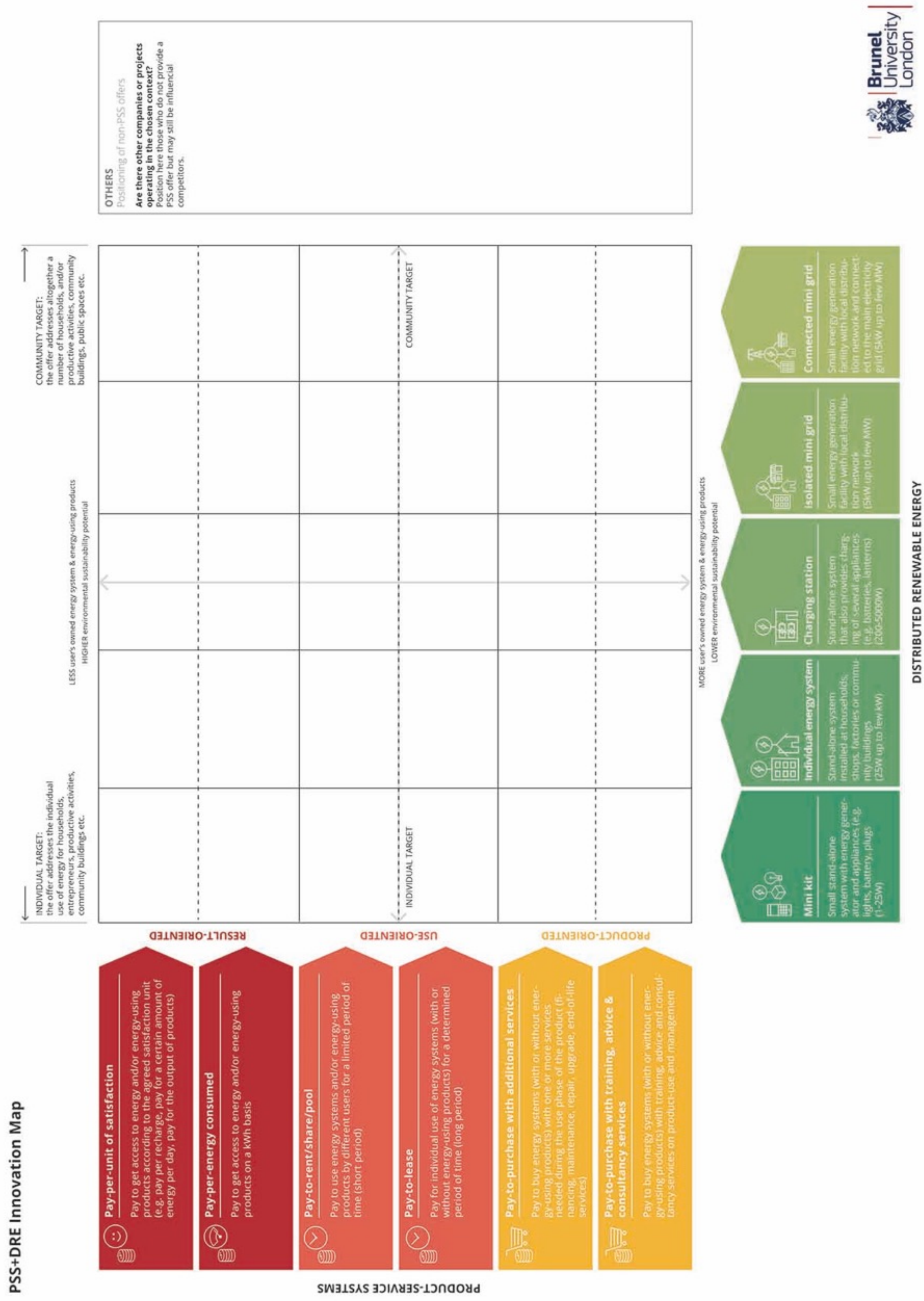


Figure 5.28 - Innovation Map final version (2.0)

5.8 Chapter summary

This chapter described the design and evaluation of the PSS+DRE Innovation Map. The tool was developed building upon some of the outcomes of the primary studies: the classification system of PSS+DRE (4.2) and the identified Archetypal Models (4.4). In addition to the pilot evaluation with 39 design students, the tool has been tested with a wide range of practitioners from different disciplines: 40 people from companies, consultancies and NGOs, 6 experts of PSS and DRE, 8 DRE students and practitioners. Therefore, with 93 participants involved in the evaluation of the tool over its several iterations, it can be concluded that the Innovation Map has been empirically tested from a qualitative and quantitative perspective. These studies were carried out in three different countries, Botswana, South Africa and Kenya, contributing to results' validity and reliability.

The activities described in this chapter can be summarised here.

1. PS-I: The Innovation Map 0.1

The first version of the tool was presented as a support to positioning company's offers, mapping competitors and exploring new business opportunities.

2. DS-II: testing in Botswana and South Africa

The Innovation Map 0.1 was applied in a pilot test with design students from University of Botswana, during the LeNSes course. This study provided insights on usability and clearness of the tool and on its applications.

Then, the tool was evaluated through interviewees and questionnaires with companies, practitioners and experts in Botswana and South Africa. The tool was evaluated in its completeness, ease of use and usefulness.

3. PS-II: Innovation Map 1.0

The second version of the tool presented improvements to ensure clarity and usability (i.e. added text descriptions, colour-coding) and new features (Concept Cards) to use the tool in idea generation sessions.

4. DS-III: testing in South Africa and Kenya

The Innovation Map 1.0 was then evaluated by companies and practitioners during two workshops organised in Cape Town and Nairobi. The applications of the tool were demonstrated, as well as its completeness.

5. PS-III: Innovation Map 1.1

Minor changes in the appearance and usefulness of the tool were developed. In particular, a new feature aimed at positioning non-PSS offers during the strategic analysis.

6. DS-IV: testing in Kenya and Botswana

The Innovation Map 1.1 was tested through three workshops in Kenya and Botswana with companies and practitioners. The usefulness and usability of the tool were finally assessed.

7. Innovation Map final version

The last version of the tool, Innovation Map 2.0 was presented. Here an additional feature was developed to detail the strategic analysis of competitors through the Stakeholder Card. A digital version of the tool was also prepared.

Chapter 6

PSS+DRE Design Framework & Cards

6: PSS+DRE Design Framework & Cards

This chapter describes the development of the PSS+DRE Design Framework & Cards as a strategic design tool to support the idea generation of PSS applied to DRE. In this section the design, testing and refinement of the tool are discussed through its several iterations in South Africa, Kenya, Botswana and UK. The chapter concludes with its final version and considerations for future research activities.

The Primary Studies (Chapter 4) aimed at developing knowledge on PSS+DRE in BoP contexts and at answering RQ1 (Fig. 6.1). The first part of this research resulted in the identification of PSS+DRE dimensions, the definition of elements of PSS+DRE, followed by a literature review of their variables, which led to determine their critical factors for successfully designing these solutions. In a second phase of the research, the results from RQ1 were used to answer *RQ2: how companies and practitioners might be supported in designing PSS+DRE for the BoP?* How can the identified critical factors and successful cases be translated to support the design of PSS applied to DRE? What tools can be developed? In this stage, the elements and variables of PSS+DRE and the collected critical factors were translated in a support for designing PSS+DRE models in BoP contexts: the Design Framework & Cards.

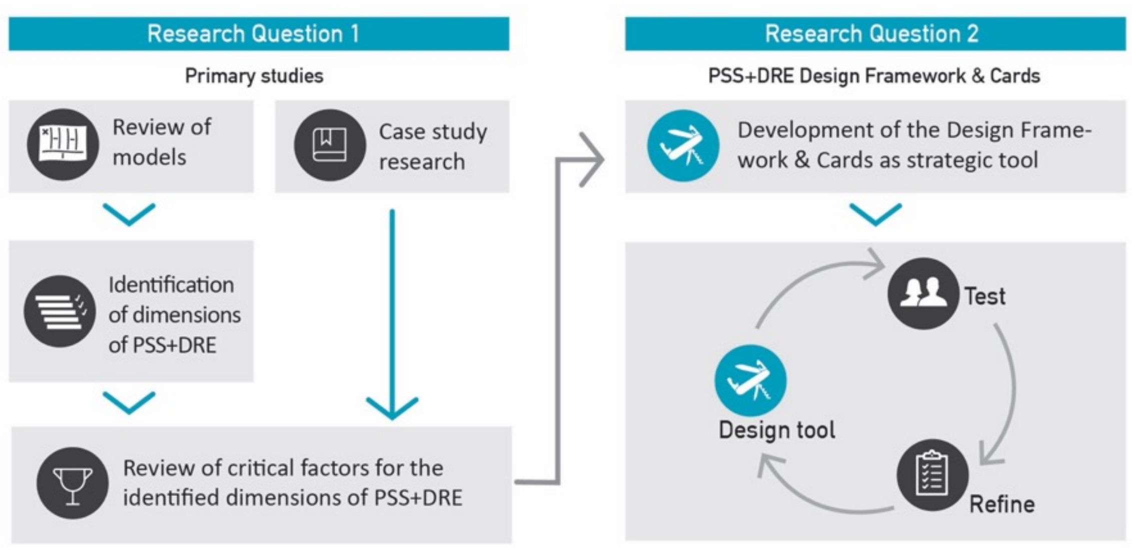


Figure 6.1 - Schematic of activities conducted during the primary studies and those included in this chapter

This chapter illustrates the development of the tool and how it can be applied in the design process (PS-I), followed by the description and analysis of testing activities (DS-II, DS-III, DS-IV) carried out in South Africa, Botswana, Kenya and the UK. The tool has been evaluated by a wide range of companies, practitioners, designers and experts, as summarised in Table 6.1.

The stages of the methodology for the Design Framework & Cards, with respective activities and outcomes, are illustrated in Fig. 6.2, while a timeline that illustrates the tool development is pictured in Fig. 6.3.

Study	Activity	Location	Participants
Descriptive Study II	Workshop (W1)[19]	Botswana	39: design students
	Workshop (W2)	Botswana	4, experts on DRE and PSS
	Workshop (W3)	South Africa	3, strategic design consultants
Descriptive Study III	Workshop (W4)	South Africa	12: mix of companies and practitioners
	Workshop (W5)	Kenya	11: mix of companies and practitioners
Prescriptive Study II	Workshop (W6)	UK	12: designers
Descriptive Study IV	Workshop (W7)	Kenya	2: NGO and company
	Workshop (W8)	Kenya	8: consultants and DRE students
	Workshop (W9)	Botswana	2: companies
	Interviews	Kenya and Botswana	12, practitioners and experts on DRE, business models, PSS

Table 6.1 - Testing activities for the Design Framework & Cards: activities, locations and participants involved

[19] The workshops' numbers correspond to the workshops' list in Section 3.6.2 of the methodology chapter.

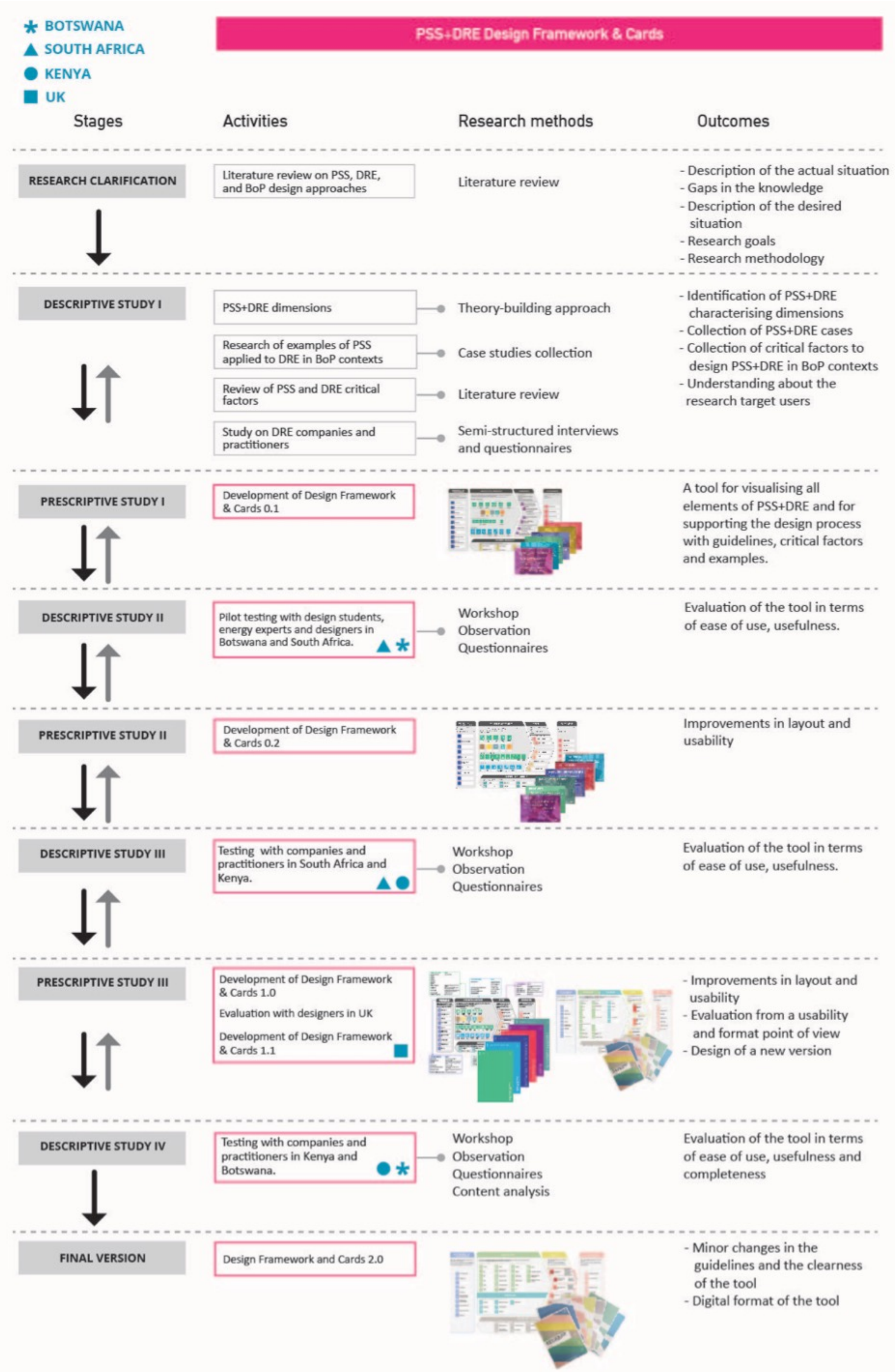


Figure 6.2 - Stages of the Design Framework & Cards' development

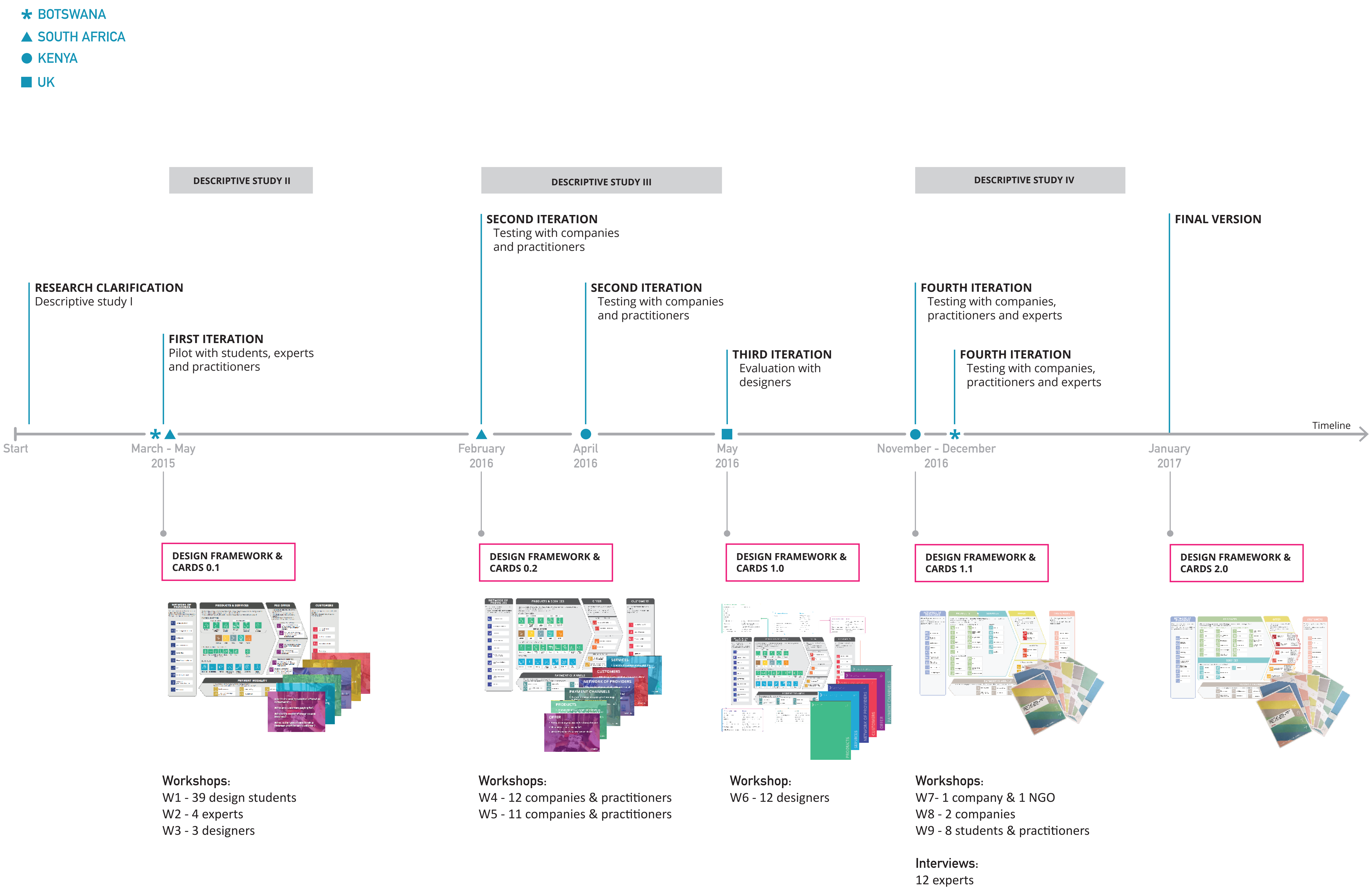


Fig. 6.3 - Design Framework and Cards' development timeline

6.1 Prescriptive Study I: Design Framework & Cards 0.1

The tool (Emili et al., 2016 (b)) aims at supporting the idea generation and concept detailing of PSS applied to DRE in BoP contexts. The tool is in fact composed by three elements:

- the Design Framework, that visualises all elements to consider in the design process;
- a set of Cards, to trigger idea generation through guidelines and successful examples;
- and the Design Canvas, an empty framework where to position generated ideas.

After having concluded the first phase of this research (DS-I), it was necessary to develop the design specifications of the tool. These design specifications were prepared on the basis of the outcomes of the review on design tools for DRE, PSS and BoP project, and on the outcomes of DS-I, considering the results emerged in the interviews and questionnaire with DRE companies and practitioners (4.6.3). In particular, the following points were identified:

- The tool must provide an overview on the various **elements of PSS applied to DRE and their variables** (see section 4.5). In other terms, the tool should communicate the complexity of PSS+DRE models and encourage users to generate ideas on all elements of PSS applied to DRE.
- The tool must **inform about critical factors** for designing PSS applied to DRE in BoP contexts (see section 4.5). The tool would collect the outcomes of DS-I and transform it in communicable and usable knowledge.
- The tool must **support idea generation**. The aim is to apply the tool in ideation sessions and for this reason the literature review on design tools was useful to detail characteristics and format of the tool. In addition to that, previous studies on designing tools for idea generation purposes were also considered (e.g. Lockton, 2013; Jones, 2013) for better understanding the process of developing tools to stimulate ideation processes. Some conclusions were made for the tool's design specifications: the tool would be used in workshops and ideation sessions, therefore a printed format seemed appropriate. The format of ideation cards was considered convenient, together with a reference framework or canvas that illustrates all elements. Taking inspiration from other idea-generation supporting tools, the use of ideation cards was justified for their application in workshops and brainstorming sessions (see 6.1.2).
- **The tool must allow both prescriptive and inspiration use modes**. In prescriptive mode, the user should have an overview of all elements of PSS applied to DRE and their variables, being able to follow a structured process in concepts generation and to go from general to detail (for example: going from *services* to more in detail *training services*. Then, among training

services, the user could explore *training local technicians*, and even more in detail he/she could look at *training women technicians*). In inspiration mode, the user should be able to follow an unstructured way of generating ideas, provided with specific problems and solutions and be able to go from detail to general (for example from training women technicians to offering training services). Different ways to use the tool reflects different purposes of applications identified in DS-I (4.6). For example, a company may want to change its business model by introducing a new product and designing a new offer around it, or it may want to focus on a specific aspect such as payment modality. The tool should enable users to flexibly apply it for their needs.

- The tool must allow the **use by teams of people with a mix of expertise** (e.g. business, design, DRE). As described in 4.6.3, most companies and practitioners do not have experience in using tools for designing their business model, therefore the tool should be easily understood by users with different backgrounds. In addition, it should allow people with different perspectives and expertise to actively contribute in the design process. Despite its primary aim being for group sessions, the tool could also be used individually, for example in inspiration mode.

The following section describes how, following these above specifications, the tool was developed and how it can be applied in the idea generation process.

6.1.1 Development of the Design Framework

The Design Framework was built drawing from the literature review on PSS and DRE models.
As discussed in Section 4.1, the first part of this research identified dimensions of PSS and DRE models with the purpose of classifying them (Emili et al., 2016 (a)). These dimensions are: *target customer, energy system, value proposition/payment structure, ownership of energy system, energy system operation, provider/customer relationship* and *environmental sustainability potential*.
The first part of this research also identified **elements of PSS applied to DRE** which encompasses most dimensions specified before. These are: products, services, offer, network of providers, customers and payment modality.
First attempts to organize the PSS+DRE elements and their variables were made following existing frameworks from the PSS and DRE literature. In particular, Mont (2004), Gradl & Knoblock (2011) and Osterwalder & Pigneur (2010) were taken as inspiration to resonate how elements may be organised and visualised. These existing frameworks illustrate elements as 'blocks', without depicting their interactions. However, in this research the aim was not only to visualise elements and variables of PSS applied to DRE, but also to illustrate their relationships, thus simplifying the complexity of these

models. For this reason, the elements of PSS applied to DRE were organised in 'building blocks' (Fig. 6.4), adopting a similar approach to Osterwalder and Pigneur's Business Model Canvas (2010) and of DRE tools such as the Delivery Model Canvas (Bellanca & Garside, 2013). But, differently from previous approaches, the development of the Framework followed the same visualisation logic adopted to describe PSS+DRE Archetypal Models (see 4.4). *Providers* were described on the left-hand side of the framework, *Customers* on the right-hand side and the *PSS offer* is visualised between them. In particular, Product and Services and the type of Offer are depicted on the upper part of the framework while Payment Modality is illustrated at the bottom, with a shape of an arrow that goes from Customer to Provider. It has to be highlighted that Products and Services were combined in one 'block' because a PSS solution is defined as "an integrated product and service offering" (Baines, 2007), thus they need to be jointly designed.

Each design element includes its variables (described in 4.5), provided with a distinctive icon and colour to facilitate understanding (Fig. 6.5).

Following the examples of Business Model Canvas and Delivery Model Canvas, questions were added to each design element with the aim of guiding the user in the design process. For example, within the Network of Stakeholders' block, the user should answer: what are the actors involved in the provision of the PSS solution? What are their roles and responsibilities? What partnerships can be established?

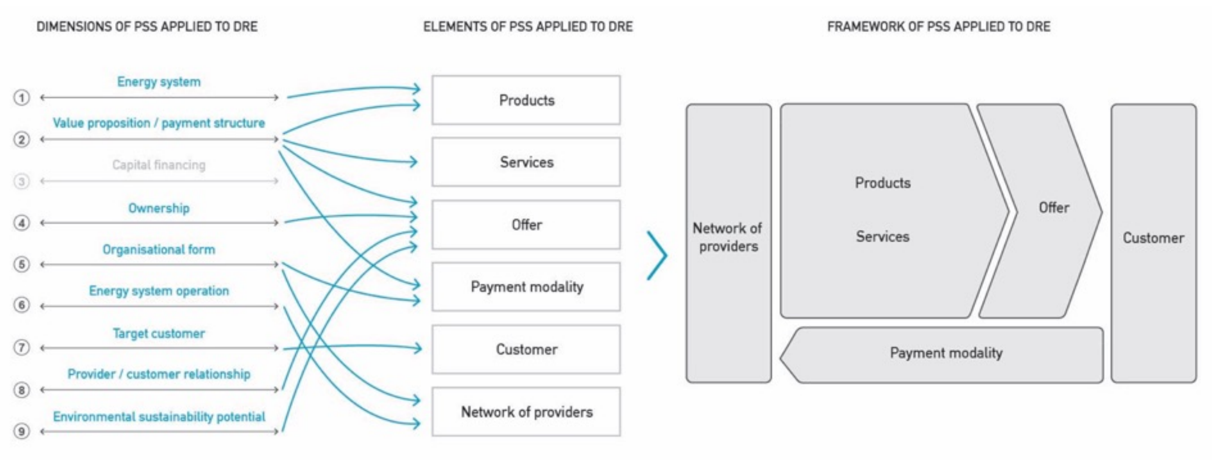


Figure 6.4 - Development of the Design Framework starting from PSS+DRE dimensions and elements

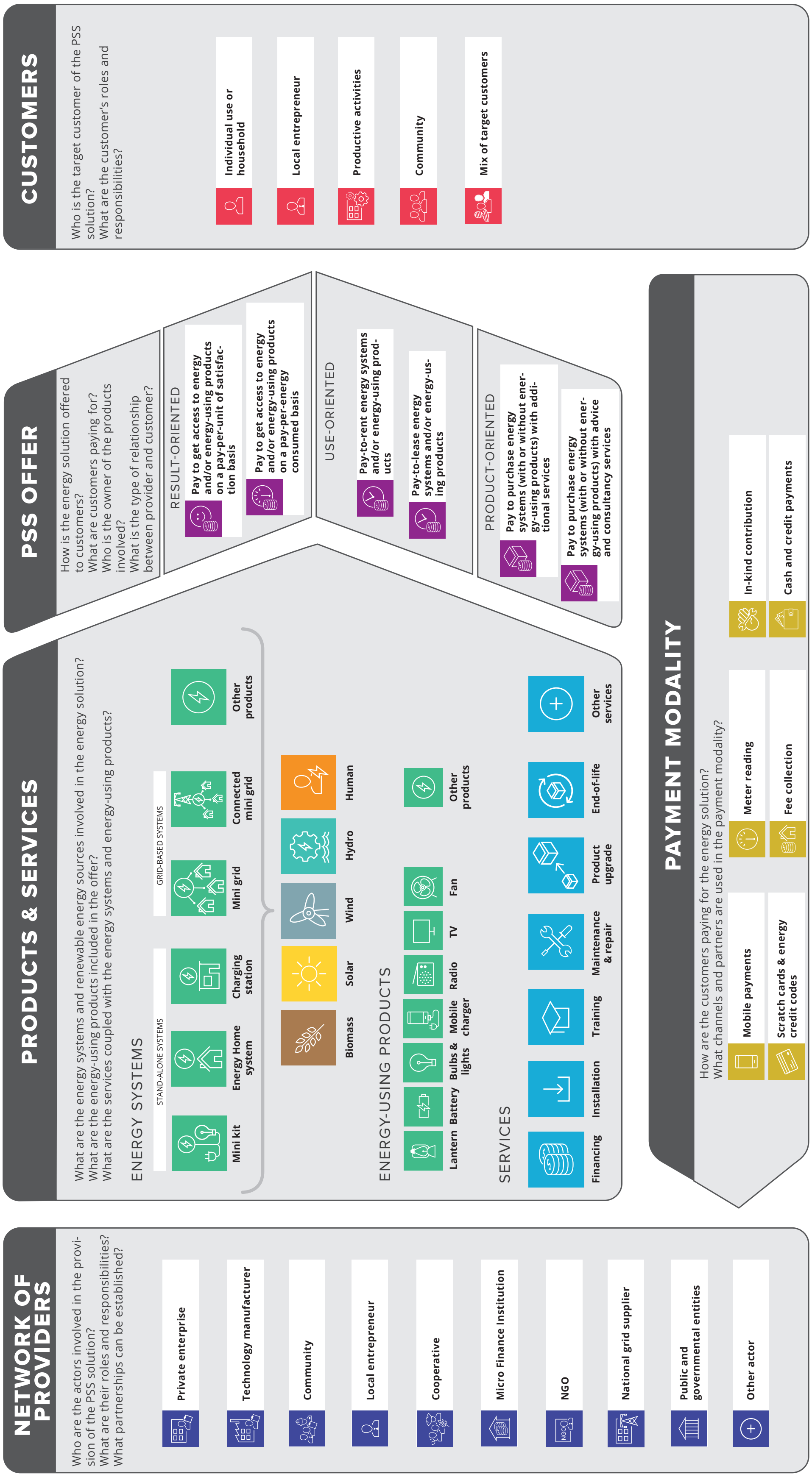


Figure 6.5 - PSS+DRE Design Framework 0.1

In summary, the Design Framework was developed with the aim of visualising all elements and variables of PSS applied to DRE and in supporting users in adopting a systemic approach when designing these solutions. In order to achieve this goal, it was developed to be used as a reference during the design process, where companies and practitioners could complete their own Design Framework with ideas.

6.1.2 Cards development

The Cards have been developed with the aim of providing support to companies and practitioners in designing PSSs applied to DRE. In particular, they aim at informing about critical factors and successful examples of PSS+DRE in low-income and developing contexts. The process of developing the Cards was characterised by several trials and iterations due to the complexity and amount of factors that needed to be considered. In this section a summary of this process is described.

A first step for translating collected critical factors (see 4.5) into a tool was to match them with practical examples from collected case studies. A first attempt was carried out through the development of two categories, 'challenges' and 'solutions', linking a specific critical factor with an example of how this has been addressed.

Following this approach, critical factors where mapped with specific examples and categorised according to some identified 'design problems' such as "how can community-owned and managed energy solutions be designed and implemented?". A first attempt to develop these categories resulted in the development of identified challenges and possible solutions (Fig. 6.6).

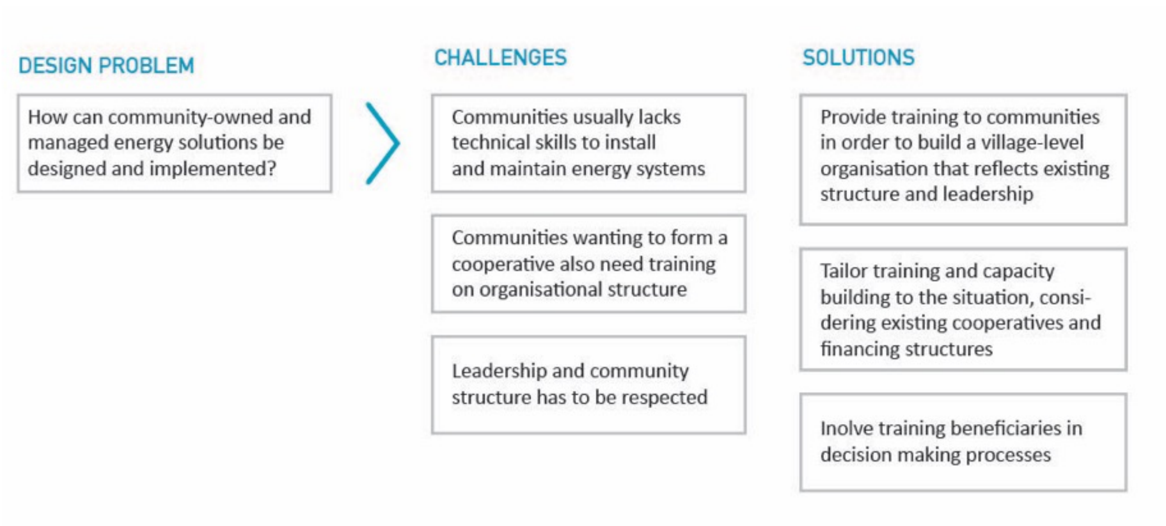


Figure 6.6 - A first attempt to categorise critical factors in challenges and solutions

The aim of adopting this approach was to develop a tool that could be used in both prescriptive and inspiration mode. In prescriptive mode, the "general questions" should help users to go from a general problem to a detailed solution, categorised according to the design element (e.g. services). In inspiration mode, instead, users could generate ideas starting from a specific solution or case study without necessarily having identified a general problem. A first mock-up prototype (Fig. 6.7) of the tool was developed envisioning that users may benefit browsing the general design questions and linking challenges with possible solutions.

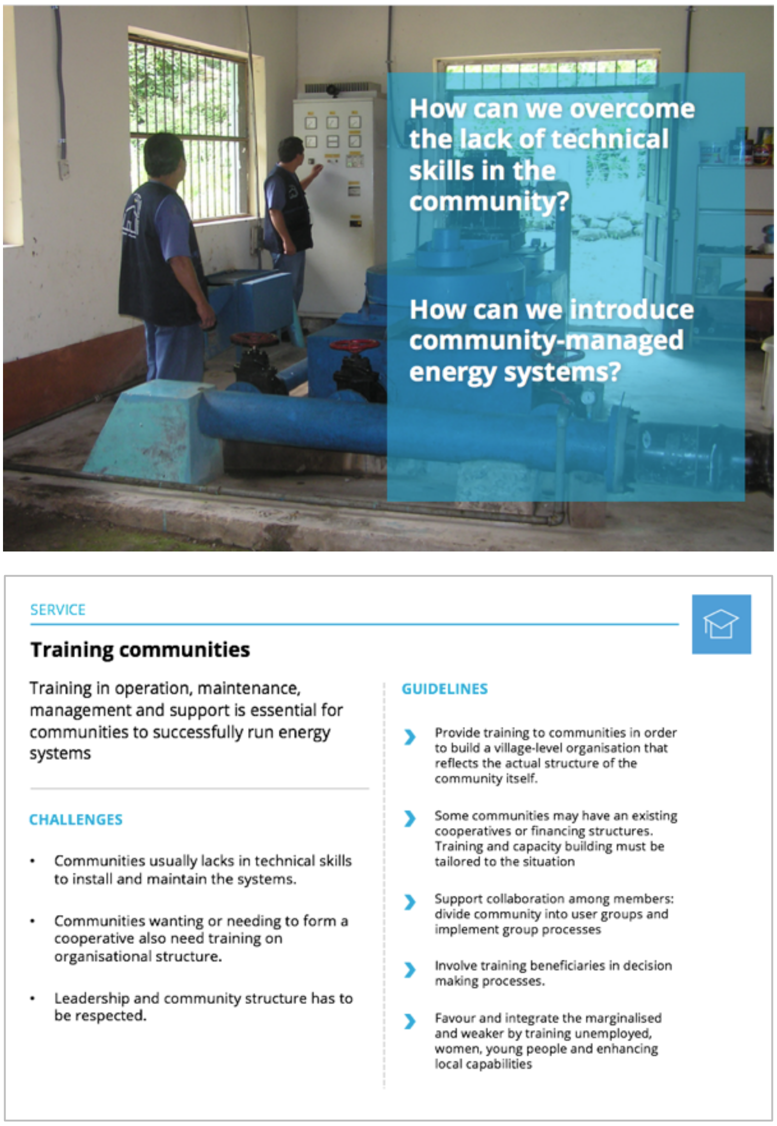


Figure 6.7 - First attempt to translate the critical factors in a tool: both sides of a card

However, this approach presented some issues. While at the beginning, this process seemed to be straightforward, it was noted that for some elements such as the customer segment, challenges could be linked to a variety of different solutions. In order to achieve that, each challenge should have been matched with multiple solutions. This would have resulted in a very complex categorisation, difficult to be translated in a usable design tool. In addition, the quantity and complexity of collected critical factors would have been complicated to evaluate.

In order to address this issue, another approach was explored to transform critical factors into design guidelines. For this purpose, instead of splitting the collected critical factors in 'challenges' and 'solutions', it was decided to organise them in the form of guidelines.

The guidelines were structured in questions, with the aim of stimulating idea generation. The use of design questions to trigger conversations and ideation processes has been used in several tools, from the Business Model Canvas (Osterwalder & Pigneur, 2010) to Nesta's Idea Generator (Nesta, 2013) and to Delivery Model Canvas (Bellanca & Garside, 2013) and it was considered appropriate for stimulating users in considering the specific critical factors.

For example, the problems of "communities need training on organisational structure" and "need to respect leadership and community structure" was coupled with another critical factor of "providing training and capacity building", resulting in this guidelines: "*Are you respecting community's structure?* You should provide training in order to create a community organisation that reflects the existing structure and leadership of the community in terms or roles and responsibilities".

Along with the collection of critical factors, case studies have been selected to best provide an applied example of the guidelines. Table 6.2 provides an example of how critical factors, guidelines and a case study have been organised under 'Training end-users', while Appendix II provides the complete list of critical factors for all elements of PSS applied to DRE.

The purpose of the guidelines and case studies is to facilitate the idea generation process of designing a PSS applied to DRE. For these reasons, the information collected have been organised in cards so that they could be applied in workshops and brainstorming sessions.

The use of cards-based tools for idea generation is common in design practice (Golembewski, 2010; Lockton, 2013). This format was chosen because cards can be grouped in different ways, they can be used among different people in a workshop and easily picked and shuffled according to users' needs.

In order to avoid an 'unstructured' use of the tool, in the first version the Cards were grouped together with a metal ring, suggesting that cards from the same design element are grouped together but they could also be picked up and used individually.

Fig. 6.8 shows an example of the "Services" group of cards and their structure: the group contains ten cards, organised according to the type of service offered. Each of them is characterised by the colour indicating the group of cards (e.g. light blue), title, subtitle explaining the relevance of the card, a set of guidelines, and a case study providing an applied example.

In the first version of the tool, a total of 88 Cards were developed and grouped according to the six design element of the Framework: network of providers, products, services, offer, customers, and payment modality (Fig. 6.9).

Dimension: Value proposition/payment structure Variable SERVICES: training			
Variable	**Critical factors**	**Reference**	**Guideline**
Offer training to end users	*It is important that customers learn capabilities and limitations of systems. User training also creates a lasting relationship between provider and customer.* *Education of end-users on the uses of electricity is important. Wise consumption can help prevent system blackouts*	May (2002); Terrado et al. (2008)	Providing information on optimal use and limitations of the system is essential to build an enduring provider/customer relationship and educate end-users on sustainable behaviour.
	Training for technicians and users through manuals and guide books should be provided in their language and should be adapted to users' and technicians' prior belief structures and knowledge	Tillmanns (2011)	Are you communicating in the right way? Training through manuals and guide books should be provided in the users' language and should be adapted to their prior knowledge and background. Use illustrations.
	It is important that customers learn capabilities and limitations of systems. The technical education of consumers to help them to make the best out of their systems and to ensure the project sustainability is fundamental	May (2002); Rolland & Glania (2011)	Can you educate or provide tools to end-users to enable them in reducing energy consumption? Wise consumption can prevent system blackouts and help end-users to save money.
	Technical problems tend to be linked to overuse of systems and this happens because of a lack of understanding of the limits of the system. Regular visits of technicians would facilitate the learning process. Systems may be installed improperly or wrong components or appliances may be used if training is only provided through manuals. *User training is conducted immediately after installation to ensure that the users are not only made aware about proper usage but are also trained on the institutional pattern to enable them to seek proper after-sales.*	Lemaire (2009), Chaurey et al. (2012)	Why not coupling installation with training services? You can provide end-user training about product use, limitations and care during the installation of the system. If a maintenance service is provided, technicians can also train end users during regular visits.
	Case study: SELCO sells energy home systems and products with an inclusive service package. In order to prevent users from misuse or damage the solar systems, the company provides user training during installation of systems. Technicians, qualified by in-house training programs, explain clearly what the user should expect from the system and how to use it. A manual is provided.		

Table 6.2 - Extract of collected critical factors and developed guidelines

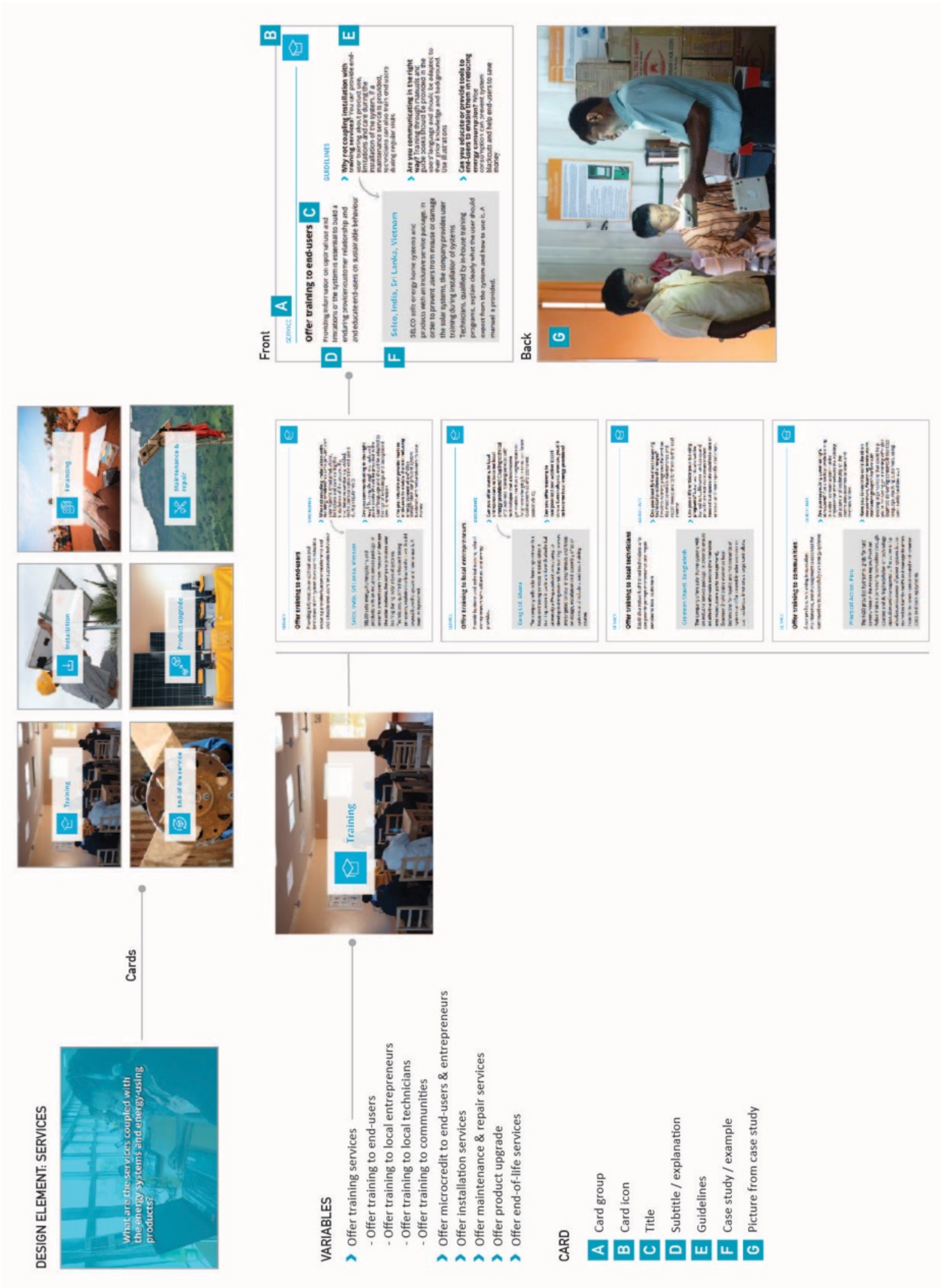


Figure 6.8 - Example of cards' structure and layout: Services (tool version 0.1)

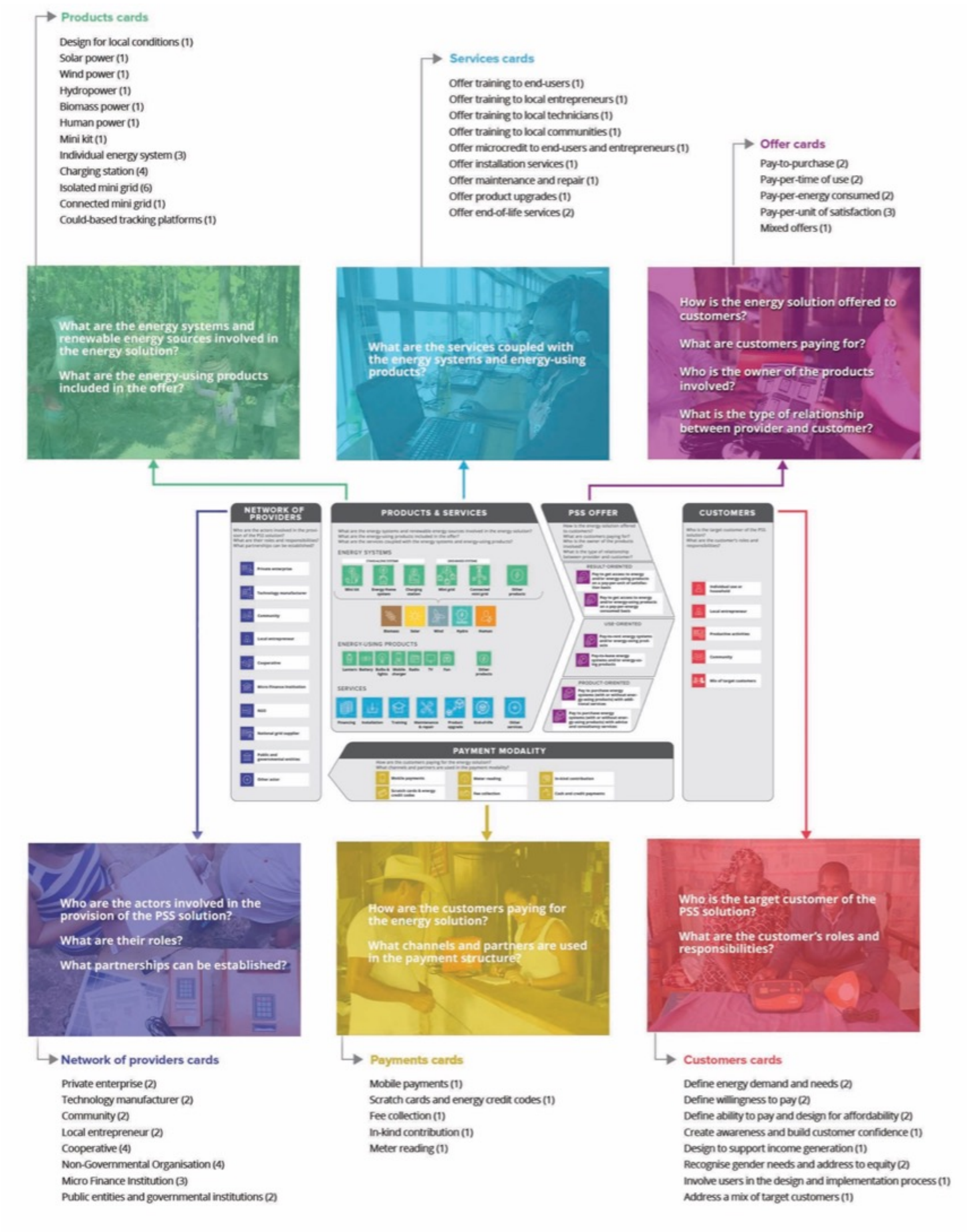


Figure 6.9 - List of Cards for each element of PSS applied to DRE (tool version 0.1)

6.1.3 Applications

The Design Framework and Cards aim at supporting the design process of PSS+DRE and they have been developed to be used by companies and practitioners as a reference for detailing their own business model or for generating new business models from scratch. The Framework and Cards are thought to be used in combination with an "empty" Canvas to be filled during idea generation sessions (Fig. 6.10). The tool (Framework + Cards + Canvas) can be used in several ways, according to the needs and knowledge of its users. For example, a company can start with a previously developed business idea and then use the tool to detail its concept. Another application emerges when a company only wants to focus on one specific aspect of the energy provision (e.g. payment modality) and therefore can search for inspiration among the selected group of cards and generate ideas on one design element. These envisioned applications were tested through three Descriptive Studies which included eight workshops.

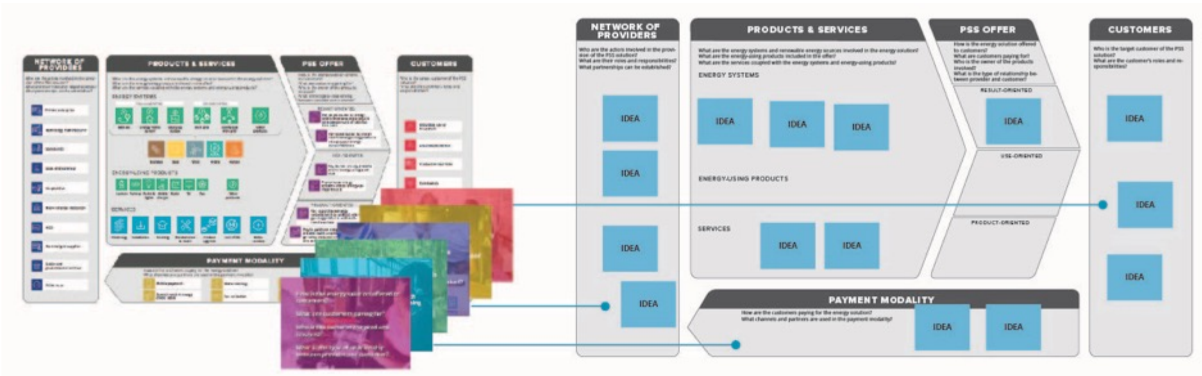


Figure 6.10 - Design Framework and Cards combined with the Design Canvas (version 0.1)

6.2 Descriptive Study II: pilot testing in Botswana and South Africa

The first testing activities took place in Botswana and South Africa between March and May 2015. These activities aimed at testing the tool mainly from a clearness and usability point of view. Additionally these pilot studies aimed at grasping general feedback about the applications of the tool and its usefulness in the design process.

- *Clarity and ease of use*: aimed at assessing that the tool can be clearly understood and that the combination of Cards and Framework is easy to apply. In other words, the purpose was to evaluate that the elements of the Design Framework and their relations are clear, the guidelines and case studies on the Cards are easy to be understood, the layout and format of the tool is appropriate for its applications.
- *Usefulness as a design tool*: additionally, the pilot studies aimed at testing the Design Framework and Cards in use and at gathering feedback on the usefulness of the tool to generate concepts of PSS applied to DRE.

The DS-II included different types of participants and data collection methods:

- Pilot testing with undergraduate design students (6.2.1): aiming at testing the clarity, ease of use and usefulness of the tool. The testing activities took place at University of Botswana and data was collected through questionnaires and participant observation.

- Pilot workshops design practitioners and experts (6.2.2): two workshops with designers and experts were organised with the aim of testing clarity, ease of use and usefulness of the tool in use. Data was collected through questionnaires and participant observation.

6.2.1 Pilot testing with design students

The Design Framework and Cards was applied during the LeNSes course at University of Botswana. As described in Section 5.3.1, this study involved 39 undergraduate design students for a two-week course on System Design for Sustainable Energy for All. The course was carried out in collaboration between Brunel University London and University of Botswana.

6.2.1.1 Description of activities

Following a theoretical introduction on PSS, DRE, PSS applied to DRE in BoP contexts, the workshop was structured in steps:

1. Introduction to PSS+DRE models and classification: students were firstly introduced to the PSS+DRE Innovation Map and the Archetypal Models to explore different types of PSS applied to DRE. As described in section 5.3.1, case studies were positioned on the Innovation Map.

2. Idea generation with the Design Framework & Cards: in a second phase, they were introduced to the Design Framework & Cards to generate new concepts, given a brief to design a sustainable PSS applied to DRE for a low-income community in Gaborone. They wrote ideas on post-its and positioned them on the empty Canvas (Fig. 6.11). Students were encouraged to cover all elements of the Design Canvas and to generate a high number of ideas, aiming at developing more than one concept.

3. Concept selection and refinement: in a last stage, students positioned concepts on the Innovation Map and selected one final concept. They then proceeded to detail and refine it, using the Design Framework and other tools (i.e. the Energy System Map, see Chapter 7).

At the end of the course they were provided with questionnaires to rate the usability and the applications of the tool. The quantitative data collected is presented in Table 6.3, while the qualitative responses are discussed below.

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Design Framework						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
2. To what extent is the Framework clear (i.e. the various elements of the Framework and their relations are clear)?	-	-	18% (7)[20]	44% (17)	38% (15)	**4.2**

[20] Percentage of responses (number of respondents)

3. To what extent are the design questions (for each design element of the Framework) clear?	3% (1)	-	10% (4)	56% (22)	31% (12)	**4.1**
Cards						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
4. To what extent is the content of the cards clear?	-	2.5% (1)	2.5% (1)	44% (17)	51% (20)	**4.4**
5. To what extent are the cards easy to be used?	-	-	8% (3)	46% (18)	46% (18)	**4.3**
6. To what extent are the guidelines easy to understand?	-	-	8% (3)	46% (18)	46% (18)	**4.3**
7. To what extent is the layout of the cards appropriate to its content?	-	-	2% (1)	54% (21)	44% (17)	**4.4**
8. To what extent are the cards grouped in a clear way?	-	-	-	51% (20)	49% (19)	**4.5**
9. To what extent are the guidelines useful in the generation of ideas?	-	-	5% (2)	38% (15)	57% (22)	**4.5**
10. To what extent are the case studies described in the cards useful in the generation of ideas?	-	-	-	33% (13)	67% (26)	**4.6**

Table 6.3 - Questionnaires results from the pilot study at University of Botswana, DS-II

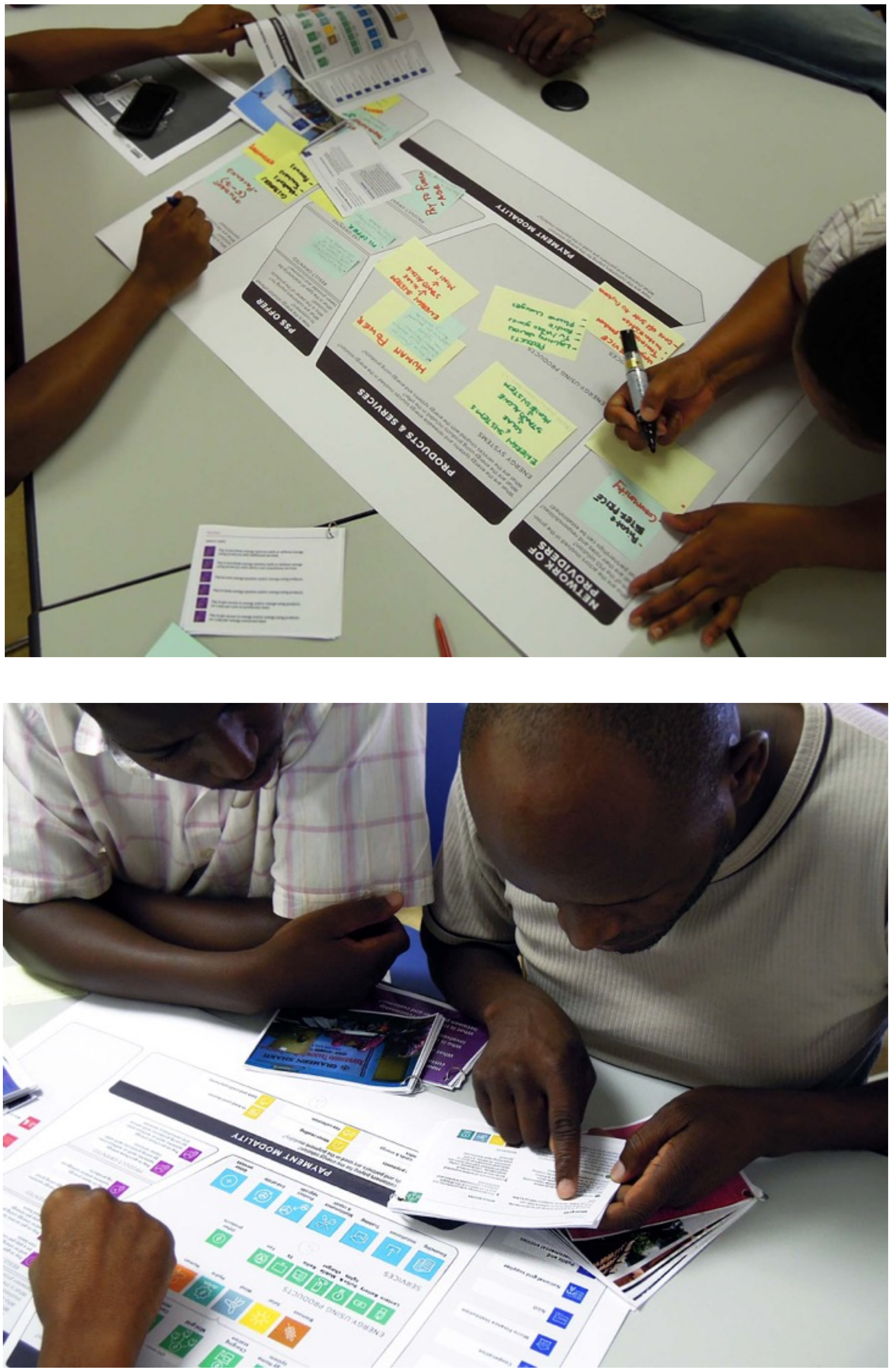


Figure 6.11 - Students using the tool, DS-II

6.2.1.2 Discussion of results

Clearness and ease of use

The Design Framework was considered clear by most participants (44% rated 4 and 38% rated 5), and the questions for each design element were judged to be understandable (average rating 4.1). Some participants affirmed that the Framework provides a clear focus and structure for the concept generation ("*it is very clear and guiding on to come up with a solution*", S27; "*the design framework* *was interesting because it categorises all the relevant steps orderly, and it was also easy to understand and follow*", S13; "*the framework helped me broaden my understanding of the design problem and it gave me a clear focus*", S22; "*It is clear and that has been made because of the clear questions stated. They help one to follow and work on his or her own*", S23; "*its layout is good and clear to understand*", S24)

Despite these positive feedback, some participants encountered difficulties due to the high amount of information and elements provided by the Framework ("*there is a bulk of information piled on the one framework*", S36; "*it's too complicated and complex*", S6). Suggestions provided aimed at "*reduce its complexity*" (S6) and "*reduce information*" (S29, S36) and "*break it down in two parts, first being general and then being specific*" (S34).

The Cards were also considered clear by most participants, in terms of content (avg. rating 4.4) and clarity of guidelines (avg. rating 4.3). Some students affirmed that the content is "*very good and easily understandable" (S19),* and that the Cards *"are easy to understand and use"* (S24, S25).

In terms of usability, the tool was considered easy to be used (avg. rating 4.3) and participants understood well how the Framework and Cards are linked ("*the cohesion between the cards and the framework is seamless*", S1). Some students highlighted that the usability of the tool was clarified through colour-coded design elements (*"the colour identity played an important role"* (S5); "*different colours have been used as a way of guiding and identifying different groups*" (S26); "*colours used made the grouping quite easy to understand the category the cards belong to"* S36).

Some problems were observed in the design process, in particular when participants had to search for specific information on the Cards. Students highlighted that the high amount of information on the Cards requires enough time to go through them in detail, which may hinder the design process. For this reason, some students (S3, S11, S34; S29) suggested to summarise information in bullet points.

Despite the layout of cards was considered appropriate to its content by most participants (average rating 4.4) and comments collected included *"well-designed cards with attractive layout"* (S3), some suggestions were provided to improve this aspect. These included the addition of headings on the first card of each element (e.g. Services); moving case study description on the same page of picture, for easier readability; numbering cards.

Applications

Visualise all elements of PSS+DRE design:

The first aim of the Design Framework & Cards is to visualise all elements necessary for designing PSS+DRE in BoP contexts. All groups completed the concept generation by generating ideas for each design element (Fig. 6.10), thus covering all elements of PSS+DRE. It was also noted that the combination of Framework and Cards works well in providing details for each element of the system (“*the cards help to identify what exactly is needed on the elements*”, S23).

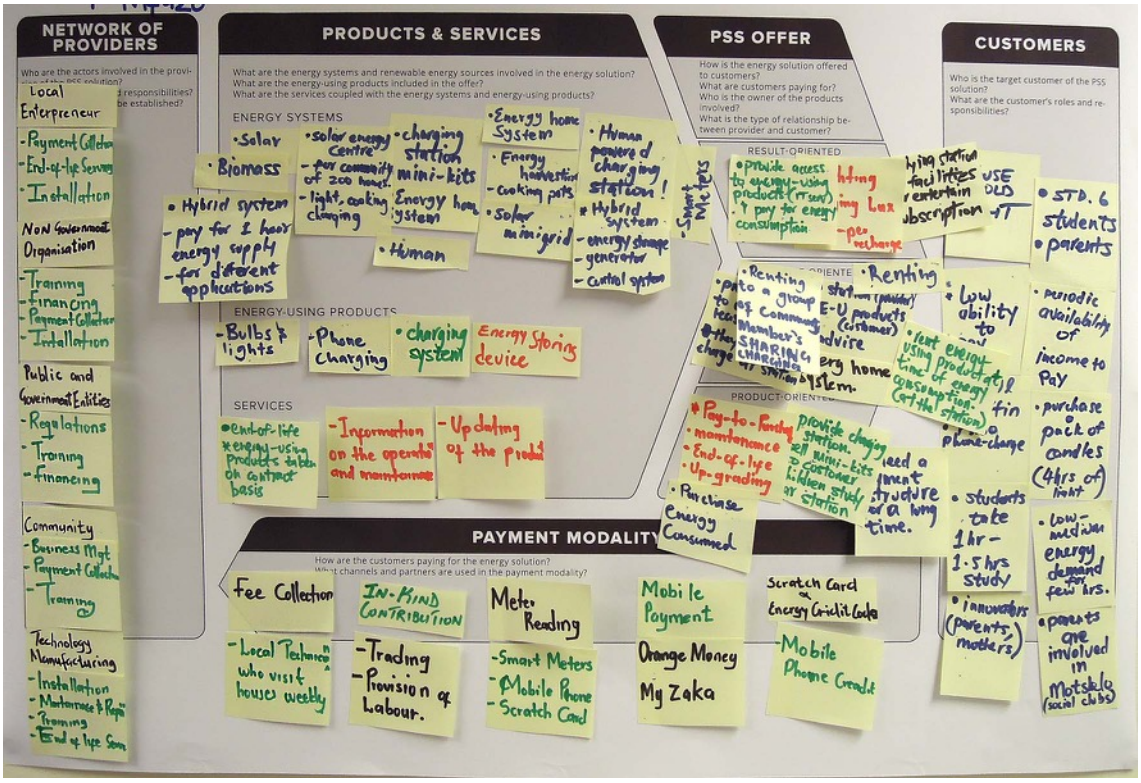


Figure 6.12 - A Design Canvas filled with concept ideas

<u>Support the generation of concepts:</u>

The hypothesis was that the tool could support the generation of ideas by providing guidelines and successful examples of PSS+DRE in BoP contexts. Participants highly commended this application of the tool (avg. rating 4.5), affirming that “*the framework allows easier generation of concepts*” (S37) and that *“the guidelines give a much better understanding of both the framework and the cards, thus idea/concept was made easy and flexible*” (S1).

In particular, case studies were considered very useful to support the concept generation (avg. rating 4.6) and appropriate for the context of use (“*the case studies guide the user on this stage of the process”,* S1; “*very useful as some case studies apply to Botswana”*, S2); “*case studies were useful as some of them were African context based*”, S18).

6.2.1.3 Design considerations

The pilot study with students helped clarifying usability and usefulness of the tool in the design process and some considerations for improvements can be made.

Students’ observations highlighted that the amount of information and complexity of the Cards was in some cases a barrier in the design process. It was also observed that most groups generated a high amount of ideas (see for example Fig. 6.12) but that many of them were not used in their final concepts. This aspect can be compared with the outcomes of the Innovation Map 0.1, which was used in the same workshop (see section 5.3.2.1). In fact, students used first the Design Framework & Cards to generate new concepts and then the Innovation Map to position their concepts and explore new opportunities. Thus, following this process, participants were 'overwhelmed' by a detailed idea generation in the first stage and they encountered difficulties in selecting the most appropriate/promising ideas for the final concept. Their difficulties can be related to the fact that they did not have a clear understanding of other competitors in the market and of promising PSS types. For these reasons, an inverted process can be more effective: first supporting the idea generation through the Innovation Map and then detailing the concept with the Design Framework & Cards. This process would facilitate the development of innovative PSS+DRE models in a first stage, based on a strategic analysis of competitors and on considerations about most promising opportunities. Once that a concept is detailed in its main elements (i.e. type of offer, customers, energy system), the idea generation can focus on refining each aspect in detail, thus following guidelines and examples from the Cards. This process would allow users to go from a more general concept to a detailed business model.

Other considerations can be made regarding how participants used the tool. Students were not given instructions about where to start (i.e. from which design element) but instead were encouraged to use the tool in a flexible way, starting to browse the cards according to their chosen process. This aspect caused some confusion in the idea generation and some participants affirmed they would have preferred a more step-by-step approach. Suggestions to improve this aspect included the provision of a step-by-step approach ("*the suggested process of stages be numbered according to what follow after the other*", S2; "*if each stage could be on separate page and have notes explaining each stage*", S32; "*there could be direction on how to use and follow the framework in a sequence format*" S38). Despite these comments, participants commended the tool's adaptability in providing a support for generating ideas ("*I love the fact that the framework allows flexibility: one can combine ideas and come up with a concept*", S1).

6.2.2 Workshops with experts and practitioners

The DS-II included two additional pilot workshops carried out between April and May 2015. The first one (W2) took place in Cape Town and involved a design consultancy. This workshop principally aimed at evaluating the clearness and usability of the tool.

The second workshop (W3) was organised at University of Botswana and involved four participants working on a village grid-connected solar PV project in Mmokolodi (Botswana), funded by the ACP-

EU Edulink II[21]. This workshop aimed at testing the application of the Design Framework & Cards in a live brief and, some of the key stakeholders involved in the project were invited to discuss potential business models for the PV project. The results of this application were published by Kiravu et al. (2015). This section discusses the activities undertaken in both workshops and the feedback collected through questionnaires and participant observation.

6.2.2.1 Sampling

The strategy adopted for these pilot tests was a purposive sampling. In the first workshop, three people from a design consultancy were involved as they represented possible target users of this research. Their expertise in product and strategic design, and especially in designing solutions for BoP contexts, was considered useful to provide feedback on the usability of the tool as well as its possible applications. In addition, design consultants did not have an energy background or experience with energy projects, therefore it was considered useful to pilot test the tool with practitioners that did not have DRE knowledge. This would provide insights about the clarity of the content and about the tools' applications with a wider range of practitioners.

The workshop organised at University of Botswana consisted in four participants: academics with expertise in the field of DRE, PSS and business models. Three of them (P5, P6 and P7) were the stakeholders involved in the design and planning of the Mmokolodi project. Participants involved are summarised in Table 6.4.

Workshop in South Africa (W2)		
Type of business	**Focus**	**Number of participants and position**
Design consultancy (P1, P2, P3)	Strategic and product design	3: CEO, strategic designer, product designer
Workshop in Botswana (W3)		
Type of business	**Focus**	**Number of participants and position**
Academic (P4)	Design, PSS	1, lecturer and researcher
Academic (P5)	Business and DRE	1, lecturer and researcher
Academic (P6)	DRE and renewable energy	1, lecturer and researcher
Academic (P7)	DRE, engineering	1, lecturer and director of Clean Energy Research Centre

Table 6.4 - Participants involved in the pilot workshops, DS-II

[21] PARTICIPIA (Participatory Integrated Analysis of energy systems). Project partners: University of Botswana including the Okavango Research Institute, Universidad Autonoma De Barcelona, Universidad Autonoma De Madrid, Universidad Carlos III De Madrid, Stellenbosch University, Polytechnic of Namibia, University of Bergen, FAO and NEPAD

6.2.2.2 Description of activities

The workshop in South Africa focused on a 'fictional' brief identified by participants, while the one in Botswana aimed at designing a business model for the Mmokolodi project. In W2 participants decided to focus on designing a solution for Khayelitsha, an informal settlement in Cape Town, as they were aware of energy issues in that area and wanted to brainstorm about promising solutions. W3, on the other side, aimed at designing a sustainable business model for the Mmokolodi project, which already had defined stakeholders and designed DRE system but was lacking a clear ownership model, a payment structure, and a definition of roles and responsibilities for the community.

Both workshops were structured in two parts. The first stage aimed at exploring models of PSS+DRE, case studies and at envisioning business opportunities. Participants used the PSS+DRE Innovation Map to position case studies and later to discuss possible areas to be explored, i.e. promising models of PSS+DRE to be implemented in their selected context. Having considered applications of the Innovation Map to generate new concepts (as discussed in Section 5.3.3), participants were asked to position a general concept on the Map. This activity lasted about one hour and resulted in two concepts identified for each workshop.

In the second phase, participants used the Design Framework & Cards to support the concept development, generating ideas for their previously identified concepts (Fig. 6.11). They wrote ideas on post-its and positioned them on the Design Canvas, using different colours for different concepts (Fig. 6.14).

For example, participants in W3 generated ideas on two concepts. The first one is a community-owned system, where the community receives training from the technology provider and then takes responsibilities for operation and management of the PV system. The community participates in establishing tariffs and payment modalities, and sells the extra-generated electricity to the national grid supplier. The second concept involved offering energy services on a pay-per-consumption basis, where the ownership of PV system is kept by the providers and customers get connected to the mini grid and pay according to the kWh consumed.

The idea generation with the Design Framework & Cards lasted about one hour and resulted in the detailing of both concepts, which covered all areas of the Design Framework.

At the end of the session, participants were asked to fill up a questionnaire to provide feedback (Table 6.5).

Figure 6.13 - Participants using the Design Framework & Cards in Botswana, DS-II

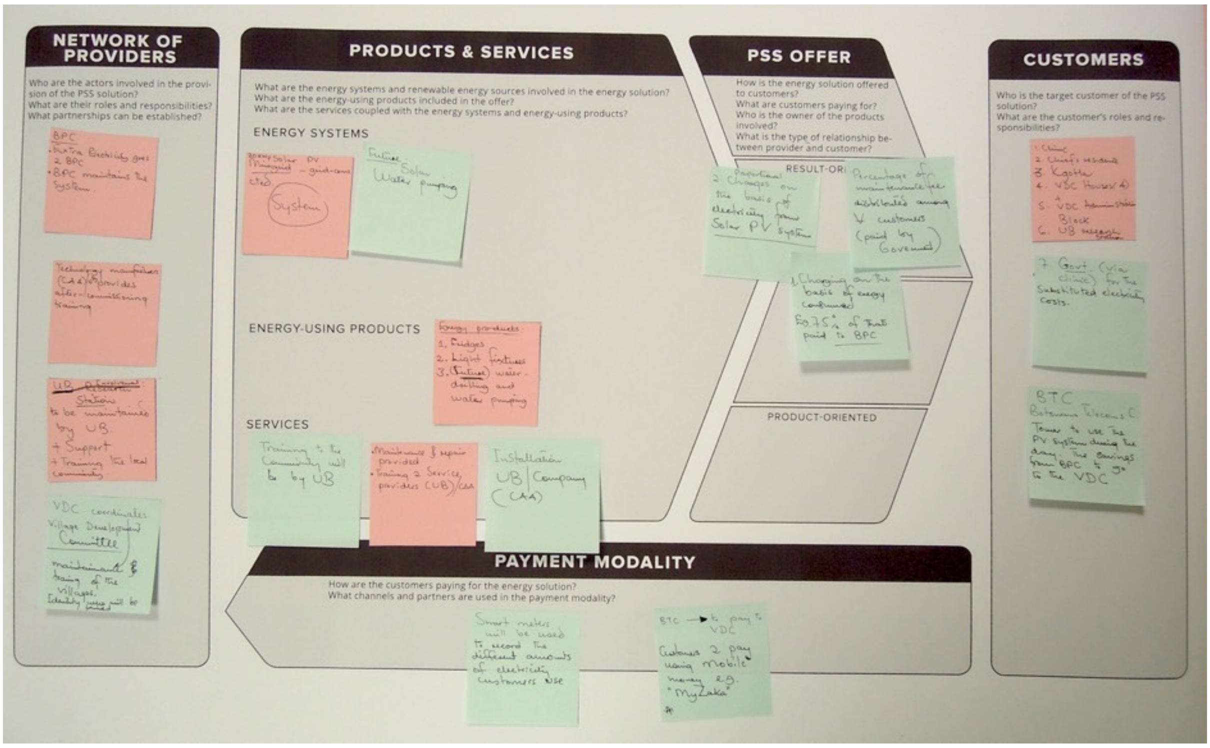


Figure 6.14 - Result from the idea generation in Botswana, DS-II

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Design Framework						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
2. To what extent is the Framework clear (i.e. the various elements of the Framework and their relations are clear)?	-	-	-	57% (4)	43% (3)	**4.4**
3. To what extent are the design questions (for each design element of the Framework) clear?	-	-	-	57% (4)	43% (3)	**4.4**

Cards						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
4. To what extent is the content of the cards clear?	-	-	15% (1)	28% (2)	57% (4)	**4.4**
5. To what extent are the cards easy to be used?	-	-	15% (1)	57% (4)	28% (2)	**4.1**
6. To what extent are the guidelines easy to understand?	-	-	-	57% (4)	43% (3)	**4.4**
7. To what extent is the layout of the cards appropriate to its content?	-	-	-	43% (3)	57% (4)	**4.5**
8. To what extent are the cards grouped in a clear way?	-	-	15% (1)	28% (2)	57% (4)	**4.4**
9. To what extent are the guidelines useful in the generation of ideas?	-	-	14% (1)	43% (3)	43% (3)	**4.2**
10. To what extent are the case studies described in the cards useful in the generation of ideas?	-	-	14% (1)	43% (3)	43% (3)	**4.2**

Table 6.5 – Questionnaires' results from pilot workshops with practitioners and experts, DS-II

6.2.2.3 Discussion of results

These pilot workshops were used to gather insights on the usability and usefulness of the tool and at identifying opportunities for improvements. Similarly to the workshop with students, the feedback collected was generally positive and critical issues were not observed in the use of the tool. The results are discussed in this section.

Clearness and ease of use

Most participants considered the Framework clear (avg. rating 4.4) and the design questions for each element were considered understandable and useful ("*very clear, the different questions under each heading really helps*", P3). One participant (P2) had issues in defining the provider/customer relationship ("*how do you define provider/customer relationship?*") and this may be related to the fact that an introduction on PSS and on the tool should include an explanation of PSS+DRE dimensions and their meaning. Cards were judged clear in terms of content (54% rated 5, 28% rated 4) and the guidelines were considered easy to be understood (avg. rating 4.4), however some clarification was needed in terms of terminology used ("*what is 'productive activities'? Maybe define what each customer represents?*", P3).

Regarding the tool's ease of use, participants commended this aspect affirming that the Cards are easy to be used (avg. rating 4.1). However, P4 affirmed that "*too much detail on the cards makes them not easy to use for a quick brainstorming/ idea generation session*". In fact, due to time constraints, the workshops were carried out in three hours, therefore it was not possible to generate detailed concepts and to read all Cards in depth.

Not particular issues were observed in sorting and selecting Cards and participants commended the layout and organisation of the Cards as appropriate (avg. rating 4.5) ("*the landscape layout is fine for the purpose of keeping much detail contained in the cards*", P4; "*the colours indicate the groups nicely*", P3).

Suggestions for improving the ease of use included: to provide an introductory guide to use the tool (P7); to add a reference list for the Cards in order to make the idea generation quicker and helping the selection of cards (P4); to add a title for the first card of each design element (P4).

Applications

The Design Framework & Cards was considered very useful to support the idea generation process (avg. rating 4.2). However, P4 observed that the amount of information and guidelines *"may slow down idea generation*". This aspect can be tackled by ensuring appropriate time to read the cards and select them, and even enough time for a detailed idea generation.

Some other considerations can be made. As observed in the pilot testing with students, participants often wrote down on post-it's the exact guideline or example provided in the Cards, without specifying further details. This was noticed especially for the PSS offer where sometimes a 'copy and paste' of the PSS type was done. Especially in terms of payment structures, in both workshops participants did not detail what exactly customers where paying for. P2 stated that the tool did not help in generating innovative ideas and this aspect was confirmed especially for some elements such as Products and Offer. While time constraints can justify the lack of depth and details of concepts generated, it should be stated that innovation lays not only in the type of ideas but also in their combination. In fact, the tool aims at stimulating a systemic approach in idea generation, considering all elements of PSS applied to DRE and combining them. This aspect can be considered innovative per se.

6.2.3 Conclusions from the Descriptive Study II

This study aimed at testing the first version of the tool, the Design Framework & Cards 0.1. The tool was applied in three workshops with design students (W1), design practitioners (W2) and experts (W3), resulting in quantitative and qualitative data collected through questionnaires and observations. These pilot tests principally aimed at evaluating clearness and usability of the tool. Despite feedback were mostly positive, some reflections for improvements emerged and these were considered for the next version of the tool. Additionally, these pilot studies provided insights for the tool's usefulness in the design process. Considering also conclusions made for the Innovation Map 0.1 and its applications as idea generation support, the Design Framework & Cards appeared to be more appropriate for detailing a concept rather than as starting point for concept generation. This aspect was also confirmed during the workshop with experts (W3), where participants brainstormed on a concept that was previously developed. However, the following versions of the tool aimed at tackling the issue of flexibility and adaptability within the design process and according to different users' needs.

In addition, after the testing activities in Botswana and South Africa, the Design Framework & Cards 0.1 was also discussed with an expert of DRE and BoP businesses in the UK. The tool was presented to the lead researcher from Ashden, a non-profit that support companies and organisations working in the renewable field in low-income and developing contexts. The semi-structured interview was carried out in July 2015 and provided interesting insights about the tool completeness and its possible applications. In particular, suggestions for its improvement included the addition of elements such as computer/IT devices among energy-using products, the addition of some customer types (public building and government entity) and to separate cash and credit payments. Some rewording was also suggested, in particular to change 'Payment Modality' in 'Payment Channels' as well as to remove PSS from 'PSS Offer' as this is already made explicit in the name of the tool. Other comments covered the use of the tool and its limitation, and especially the type of users who may benefit for applying this in idea-generation sessions. This aspect is discussed in Chapter 8.

6.3 Prescriptive Study II: Design Framework & Cards 0.2

Drawing conclusions from DS-II, it was necessary to improve the tool from a usability point of view.

The new version of the tool, Design Framework & Cards 0.2, was then prepared and the main changes are listed in Table 6.6:

Issues encountered and suggestions made in version 0.1	Changes in version 0.2
Design Framework	
Missing variables	Addition of variables: computer/IT device (energy-using products); public building and government entity (customers); separate cash and credit payments
Colour-coding helped matching Cards and Framework, however difficulties emerged when distinguishing PSS types	Colour-coding was changed according to the changes in Innovation Map 1.0, distinguishing PSS types
Appropriateness of some definitions	Rewording: 'payment modality' changed in 'payment channels' PSS types' description reduced in wording
Too much information, resulting in cluttering of icons and texts, felt overwhelming for first time users	The amount of variables presented on the Framework could not be reduced, however sizes and positioning of the icons are improved to enhance clarity

Cards	
Comments on layout improvements included the suggestion to add bigger heading for each card.	Addition of title of design element (e.g. Services) on the first card of each group (Fig. 6.15)
High number of cards and high amount of information made difficult for some users to navigate through the tool.	Addition of numbering on the Cards
The layout and organisation of the cards does not allow to look at a case study and guidelines at the same time, due to flipping pages	Change of layout: case study description and picture are on the same side, while guidelines appear on the back of the Cards (Fig. 6.16)
Confusion regarding the starting point of the idea generation. High number of cards and high amount of information made difficult for some users to navigate through the tool.	A list of Cards and corresponding case studies was prepared to ease navigation (Fig. 6.17)

Table 6.6 - Changes of the tool's version 0.2 according to identified issues.

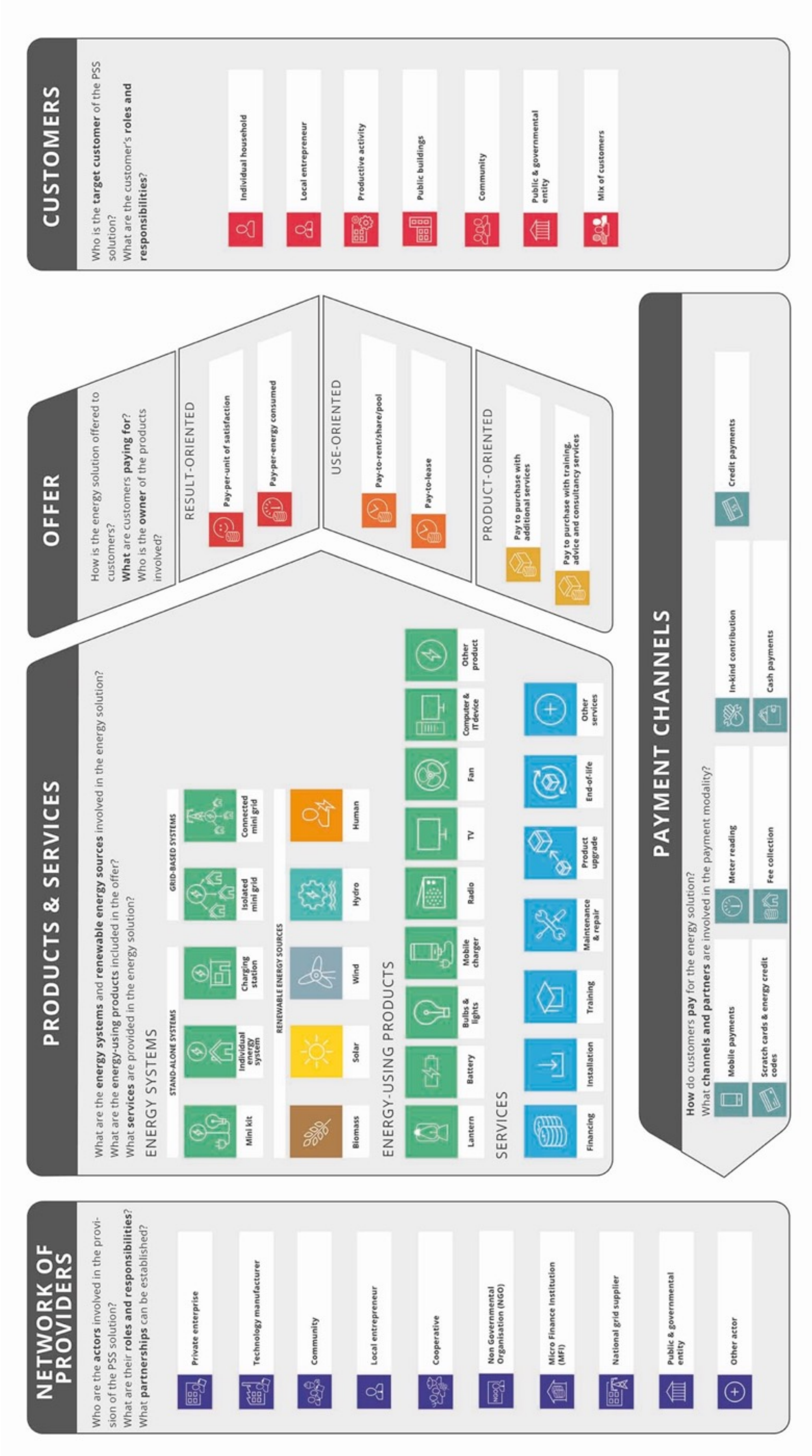


Figure 6.15 - Design Framework 0.2

Figure 6.16 - Cards 0.2

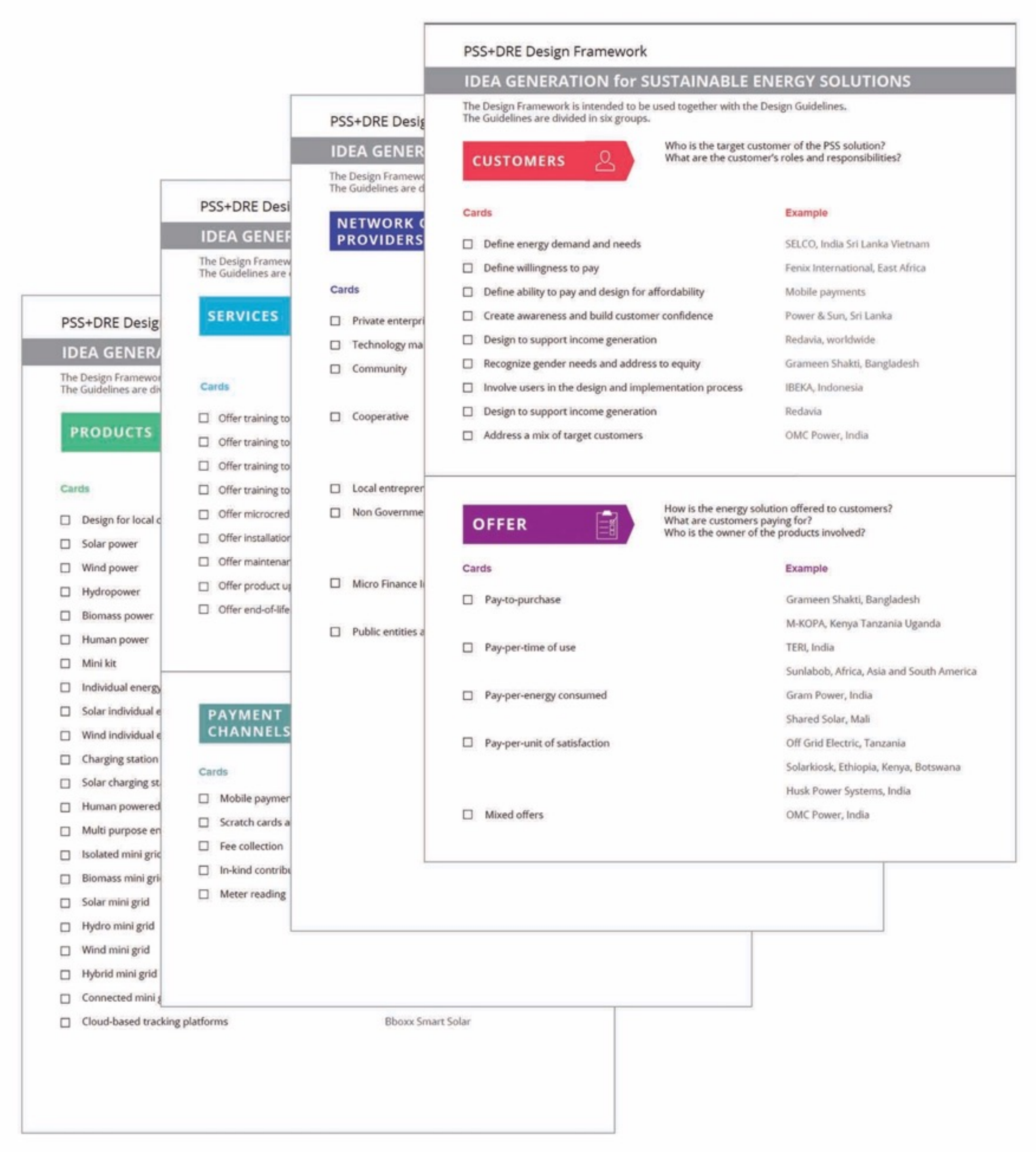


Figure 6.17 - List of Cards for each design element

6.4 Descriptive Study III: testing activities in South Africa and Kenya

The Design Framework & Cards 0.2 was applied in testing activities with companies and practitioners in South Africa and Kenya between February and April 2016. These testing activities correspond with the DS-III of the Innovation Map (Section 5.5), i.e. the courses carried out with the LeNSes project. The first testing took place at Cape Peninsula University of Technology during the course organised by TU Delft University, Brunel University London and Cape Peninsula University of Technology. Twelve participants attended the five-day long course and worked in groups on a design brief of their choice with the aim of designing a detailed business offer and presenting it at the end of the course.

The second testing, followed a similar structure and took place in Nairobi in April 2016, organised by Brunel University London and the University of Nairobi. Eleven participants were involved in a four-day long course about designing sustainable business models for energy access in low-income contexts. Following the same procedure, participants were introduced to the topics of PSS and DRE and then worked in groups on their chosen design briefs.

In both courses, questionnaires and participant observation were used to collect data about clearness, usability and usefulness of the tool.

The following sections jointly discusses results from both workshops in Cape Town and Nairobi.

6.4.1 Sampling

Sampling for this study has been discussed in 5.5.1: a total of 23 participants were involved, including companies, consultancies and NGOs working in financing and business models in the energy sector (Table 6.6).

Participant	Focus	Numbers of interviewees, job title / department,
Cape Town (W4)		
Consultancy (P1)	Energy (DRE design)	1, energy management engineer
Consultancy (P2)	Business models, circular economy	1, founder and CEO
Consultancy (P3)	Business models for renewable energy	1, consultant
Consultancy (P4)	Business models, DRE recruitment	1, director
Consultancy (P5)	Energy (DRE design)	1, quality manager
Consultancy (P6, P7, P8)	Energy policy and financing	3, finance
Academic (P9)	Electrical engineering	1, lecturer and researcher
SME (P11, P12)	Energy management and solar appliances: product-oriented offer	2: technical engineer, manager
Nairobi (W5)		
Consultancy (P13)	Energy access	1, HSE advisor
Consultancy (P14)	Energy (DRE design)	1, renewable energy engineer
Consultancy (P15)	Energy (DRE and business model)	1, consultant
Company (P16)	Solar systems: product-oriented	1, project engineer
SME (P17)	Cookstoves: product-oriented	1, director
NGO (P18)	Energy access and poverty alleviation	1, energy consultant

Company (P19)	Energy (renewable plants design)	1, chief engineer quality
SME (P20)	Energy/cookstoves: product-oriented	1, business unit director
SME (P21)	Training + cookstoves: product-oriented	1, managing director
Company (P22)	Solar systems: product-oriented	1, technical manager
Consultancy (P23)	Energy & women empowerment	1, consultant

Table 6.7 - List of participants from Cape Town and Nairobi, DS-III

6.4.2 Description of activities

The workshops in Nairobi and Cape Town followed a similar structure. After an introduction to PSS, DRE, the combination of these models and relative benefits for BoP contexts, participants were organised in groups and they worked on a design brief of their choice, with the aim of designing a detailed business offer and presenting it at the end of the course. In some cases, companies chose a brief linked to their business activity and that could be implemented in their company; in other cases, companies and consultants worked together on a common brief chosen according to their interests (e.g. biomass system for South Africa).

The first phase aimed at understanding types of PSS+DRE, by mapping Archetypal Models, carrying out a strategic analysis of competitors and at mapping companies' offers. For this phase, carried out on the first day of the workshop, the Innovation Map was used (see 5.5.2).

In a second moment, having identified a concept they would work on, and having detailed its main characteristics through the Innovation Map (Concept Cards), participants used the Design Framework & Cards for detailing their selected business concept (Fig. 6.18 and 6.19). This session was completed in about six hours and was carried out in the second day of the workshop. Participants were not given instructions on where to starting with the idea generation session, but they were simply provided with the Framework + Cards + Canvas and asked to generate ideas to complete all design elements and answer the respective questions (Fig. 6.20).

At the end of the course, questionnaires were used to collected feedback (Table 6.8).

Figure 6.18 - Participants using the Cards in Nairobi, DS-III

Figure 6.19 - Participant positioning ideas on the Canvas in Nairobi, DS-III

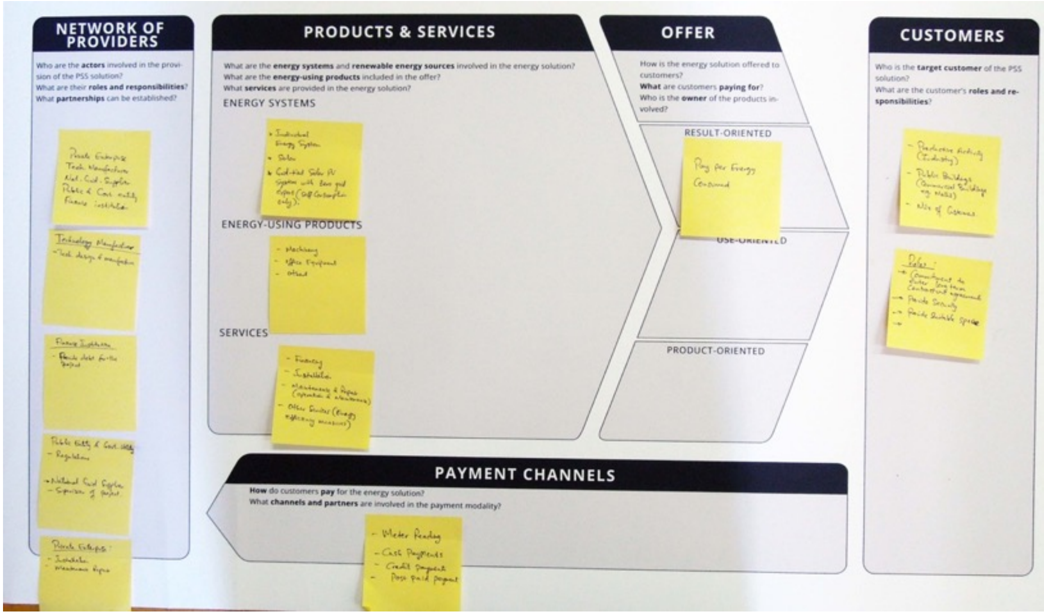


Figure 6.20 – An example of the results from the idea generation session, Cape Town, DS-III

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Design Framework						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
2. To what extent is the Framework clear (i.e. the various elements of the Framework and their relations are clear)?	-	-	13% (3)	40% (9)	47% (11)	**4.3**
3. To what extent are the design questions (for each design element of the Framework) clear?	-	-	5% (1)	43% (10)	52% (12)	**4.4**
Cards						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
4. To what extent is the content of the cards clear, i.e. the guidelines and case studies are easy to understand?	-	-	5% (1)	30% (7)	65% (15)	**4.5**
5. To what extent are the cards easy to be used (e.g. looking for information, browsing cards)?	-	-	5% (1)	35% (8)	60% (14)	**4.5**
6. To what extent is the layout of the cards appropriate to its content?	-	-	-	35% (8)	65% (15)	**4.6**
Testing the usefulness						
7. The guidelines on the cards are intended to be used to support the generation of ideas. To what extent are the guidelines contributing to this objective?	-	-	-	44% (10)	56% (13)	**4.5**
8. The case studies in the cards are intended to be used as inspiration for generating ideas. To what extent are the case studies contributing to the achievement of this objective?	-	-	-	37% (8)	63% (14)	**4.5**

Table 6.8 - Questionnaires' results from the activities in Cape Town and Nairobi, DS-III

6.4.3 Discussion of results

The data collected in this study through questionnaires and participant observation resulted in a quantitative and qualitative analysis of the tool's clearness, ease of use and usefulness. The results are discussed in this section.

6.4.3.1 Testing the clearness and ease of use

A first aspect to be tested was the usability and ease of use of the Design Framework and Cards, i.e. that the tool could be clearly understood and that the combination of Cards, Framework and empty Canvas was easy to apply. Most participants found the Framework and the design questions for each element to be clear (average score 4.3 and 4.4) and the content of Cards easy to be understood (average score 4.5). Some affirmed that "*it's clear as it is*" (P6) and "*the tool works very well*" (P12) and "everything was clear" (P22). However enough time was necessary to fully understand and use it (P9; P21). One participant expressed doubts in linking guidelines on the Customers cards with each type of customer visualised in the Framework ("*the criteria used to define the customers were not clear, whether one should list the defined characteristics in the customer box*", P18). Another participant (P14) highlighted his confusion in including 'meter reading' as part of payment channels and suggested to keep it separate.

Another aspect to evaluate was related to the appropriateness of the layout and format of the Cards in relation to its content. Participants were asked to give rating to the process of browsing Cards and looking for information and to provide comments about the layout. Most participants rated the layout appropriate for its content (64% rated 5, 36% rated 4) and the process of looking for information and browsing cards easy to be carried out (average rating 4.5).

Some participants (P3, P21) highlighted the need for more time to browse the Cards and suggested a larger format for the cards to reduce their volume ("*too bulky to go through at an inspectional rate"* P18; *"use a booklet or big foldable sheet*", P19). It was also observed that participants did not make extensive use of the list of Cards provided with the tool (Fig. 6.17). One person (P9) suggested to have a list of Cards directly on the Framework itself so that would make browsing them more straightforward.

6.4.3.2 Testing the usefulness

Visualising all elements of PSS applied to DRE. The first purpose of the Design Framework is to visualise all elements needed in the design of a PSS applied to DRE. Each group participating in the workshops completed the idea generation by covering all elements of the Framework (an example in Fig. 6.18). Participants have commended the use of the framework as a tool that "*works very well*"

(P12) and "*it is a good condensed business tool"* (P10). Some participants (P14; P15) suggested the inclusion of regulatory entities to complete the Framework, while P5 recommended to add other forms of energy (such as thermal energy or cooking products) besides electricity.

Support the generation of ideas. Participants highly commended this application of the tool and some stated that "*the cards were impressive, well-researched and well-summarised. The pictures on the cards also helped in visualisation of the case studies*" (P20), "*the cards help jog one's mind and thus help generate ideas, their content was great*" (P19), and "*guidelines are useful*" (P22). In particular, participants highly rated the usefulness of guidelines to support the generation of ideas (45% rated 4 and 55% rated 5), and the majority of them (62%) affirmed that the case studies were useful to gather inspiration for their business model.

One participant (P4) commented that case studies were not easily applicable for the context of South Africa, affirming that "*the examples have been very inspiring although they seem to have come from 4th and 5th world countries*". However, for some these resulted in expanding their perspective ("*this has changed the thinking of the offering in South Africa",* P12) and another participant suggested that "*regionalising the cards e.g. Africa, Asia etc. would help"* (P16).

Most participants (14) affirmed they would use the tool for generating ideas in the future. While some limited its application to a tool for "*background information*" (P3, P9), others (P5) expressed the Cards' usefulness in combination with the Innovation Map and for "*modifying the business cases*" (P14). This suggests that the Cards are useful for inspiration in generating innovative business models, which can be compared with existing ones (i.e. Archetypal Models) on the Innovation Map.

6.4.4 Conclusions from the Descriptive Study III

The DS-III included two workshops in South Africa and Kenya, where the Design Framework & Cards 0.2 has been evaluated by 23 people, including companies and practitioners working in the renewable energy field. The tool has been tested from usability, clearness and usefulness points of view and feedback were collected with the aim of improving the tool. Some of the suggestions provided could not be considered in this PhD, such as the inclusion of regulatory entities and other forms of energy, while others will be partially implemented in the tool's following versions (creation of a software version suggested by P22, P14). Other layout and format improvements were considered for the PS-III (see next section).

The DS-III demonstrated the usefulness of the tool for supporting the idea generation of PSS+DRE in BoP contexts. Participants highly commended this application of the Framework & Cards and the process of idea generation resulted in the detailing of business models that cover type of offer, products and services, payment channels, target customer and network of providers.

Drawing conclusions from the DS-III, the testing activities have demonstrated that the Design Framework & Cards 0.2 is a useful support for designing PSS+DRE in BoP contexts and further research activities will aim at refining the tool and testing the completeness of its content.

6.5 Prescriptive Study III: Design Framework & Cards 1.0

The testing activities with companies and practitioners led to consider some improvements and adjustments in the tool. In details the following changes have been made considering suggestions and comments made by companies and practitioners:

Issues encountered and suggestions made in version 0.2	Changes in version 1.0
Design Framework	
Missing variables	Addition of 'hybrid systems' in the product category
Wording	Specification of 'meter reading' as activity supporting payment among payment channels.
Browsing Cards and linking them to the PSS+DRE elements was considered difficult. The provided list of Cards was not extensively used.	Inclusion of a list of Cards on the Framework itself (Fig. 6.21)
Cards	
Cards were considered "too bulky" and difficult to be explored on a inspectional rate.	New format: A5 portrait orientation, multiple cards from the same category collected in foldable sheets. Cards were grouped with elastic bands instead of metallic rings (Fig. 6.22, 6.23)
	New layout: combination of case study, guidelines and pictures on the same side
Case studies from the same geographic area were considered useful, therefore users may want to know where is it implemented.	Inclusion of geographic areas of case studies (i.e. Africa, South America, South Asia, South East Asia, Asia)

Table 6.9 - Changes in the tool's version 1.0 according to the identified issues

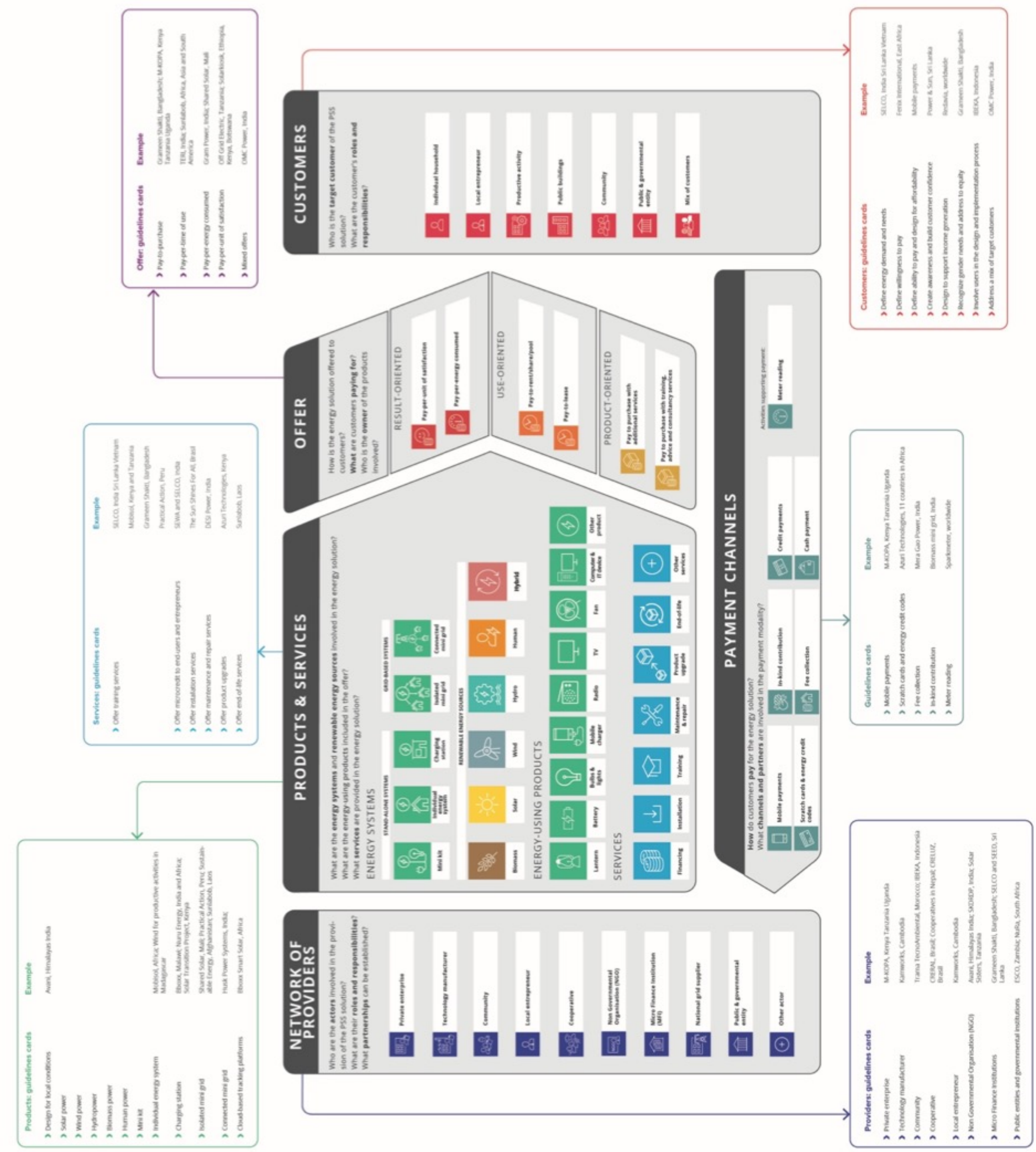


Figure 6.21 - Design Framework 1.0

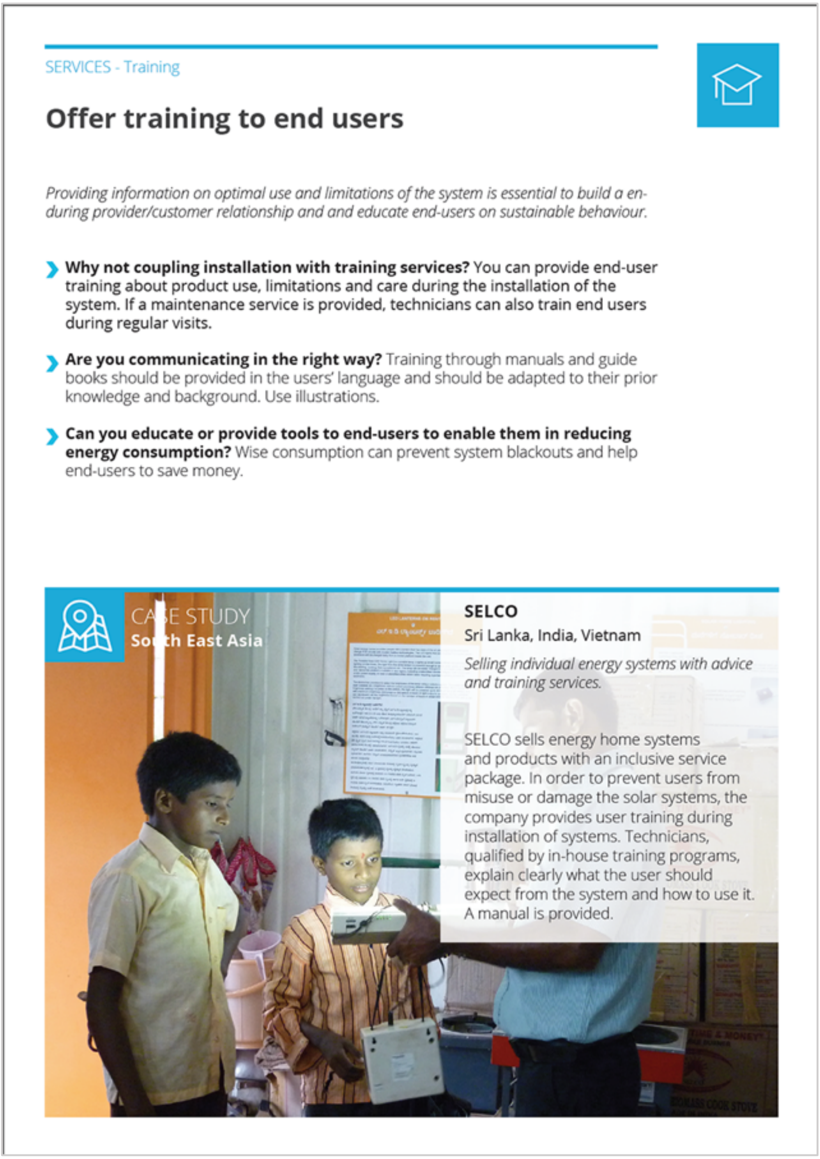


Figure 6.22 - Example of Card's new layout

Figure 6.23 - Cards grouped in foldable sheets and examples of Customer Cards

6.5.2 Evaluation with designers at Brunel University London

Once the version 1.0 of the Design Framework & Cards was designed, an empirical study with designers at Brunel University London was organised to evaluate the tool's usability and ease of use.

This study aimed at collecting feedback from a design perspective, in terms of layout, format and in its usability in the design process. This iteration of the PS-III was considered necessary to assess some aspects of the tool and to prepare a refined version (1.1) that would be used with companies and practitioners in DS-IV. The workshop with designers was organised in May 2016, feedback was collected through questionnaires and participants were asked to write suggestions for the improvements of the tool on post-its and canvases.

6.5.2.1 Sampling

This study involved 12 participants, including design researchers and master students selected initially following a purposive strategy but also involving convenience sampling to reach a certain number of participants. Some of the participants had experience in developing design toolkits and all of them were familiar with different design tools for idea generation. Therefore they were considered appropriate for evaluating the usability and effectiveness of the Design Framework & Cards.

6.5.2.2 Description of activities

The workshop lasted about two hours and was organised in two main phases. After a brief introduction to the topic, the design tool and its applications (20 minutes), participants were divided in groups of four people. They were provided with the Design Framework & Cards and with an example of a concept of PSS+DRE (Fig. 6.24). The two main phases are:

- Phase 1: Familiarise with the tool. Participants were invited to read the concept example of PSS+DRE and to use the tool for a quick brainstorming session (30 minutes). They were asked to browse the Cards and select the ones they needed, looking for information and reading case studies (Fig. 6.25). This activity was carried out to help designers to test the tool in use and to understand its applications, without necessarily going in depth on each element.
- Phase 2: Improving the tool. In a second phase, participants were invited to provide suggestions, comments and feedback about the tool and were engaged in a brainstorming session for redesigning the tool. Groups were provided with a larger print of some Cards (Fig. 6.26) as example and a list of features to discuss about. These included its format (size, cards grouping, transitions and connections amongst cards, composition of Framework + Cards + Canvas) and layout (quantity of information on a single card, position of elements on a card, proportions, colours). Suggestions were collected through post-its, notes on the canvases and through questionnaires (Table 6.10).

Figure 6.24 - Concept example prepared for the workshop

Figure 6.25 - Some participants during the quick idea generation

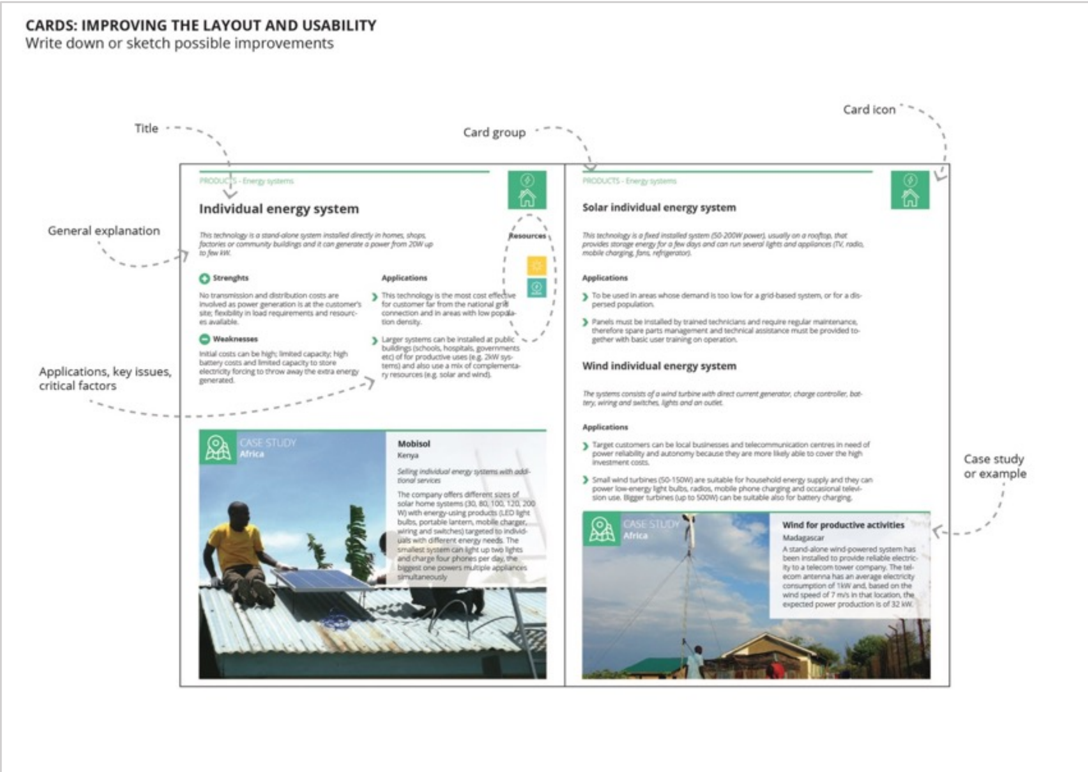


Figure 6.26 - Print of Card example to collect feedback and suggestions

6.5.2.3 Discussion of results

Tool's ease of use:

The first aspect to be evaluated was whether the tool was easy to be used, i.e. looking for information and browsing Cards. The usability of the tool was rated with an average of 3.4, and some participants affirmed that "*the cards were easy to use overall, but I found them quite cluttered with info and icons (as a first time user)*" (D1) and that "*they are easy to use but could be improved by increasing the consistency and emphasizing the key points more clearly*" (D9). These comments were in fact justified by the short time available to use the tool and by the lacking of familiarity with the concepts of PSS and DRE. It was observed that in the first phase of the workshop participants had difficulties in grasping information from the tool. However, some interesting suggestions emerged to improve ease of use. Some participants recommended to link colours on the Cards with corresponding element on the Framework "*in order to make the link between them more intuitive*" (D8). Other suggestions aimed at adding an "*induction card for each group that explains each section of cards*" (D8) and at providing an overall instruction card that explains what each design element means (D9).

Layout:

In terms of layout and format, most participants commended the size of the Cards (avg. rating 4.2) ("*size seems great*", S2; "*the sizes of the cards are good*", S4) and considered the layout appropriate for its content (57% rated 4, 32% rated 5). Suggestions for improvements included: increase font sizes both on the front and back of Cards; avoid redundancy of logos on front and back; increase card name on the back; avoid the use of icons in transparency.

This version of the tool, compared to the previous one, had a list of Cards visualised directly on the Framework itself and the hypothesis was that this would facilitate its use. However, participants did not consider it very helpful for its purpose, rating this aspect at 3.6. Some comments included that "*it's not clear enough to suggest its function*" (D10), and that "*I don't think it's necessary given the cards are already associated with the Framework text and icons*" (D9).

Regarding the usability of Cards, some participants suggested to reduce the amount of information on them, especially those related to case studies. Despite this suggestion emerged in previous testing activities with students and companies, it was not considered for future improvements. In fact, reducing the amount of guidelines would result in deleting important factors that are necessary for designing a sustainable PSS+DRE concept. The Design Framework & Cards requires appropriate time to be understood and applied, and it is not intended to be used as quick brainstorming support, but rather as a tool to design and detail complex solutions. Therefore it should be clearly stated before using the tool that enough time should be dedicated to its use.

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
1. To what extent are the cards easy to be used (e.g. looking for information, browsing cards)?	-	-	58% (7)	42% (5)	-	**3.4**
2. To what extent you think the current composition of framework+cards+empty canvas are appropriate for the idea generation session?	-	-	25% (3)	58% (7)	17% (2)	**3.9**
3. To what extent is the size of the cards appropriate to its content and its use?	-	-	17% (2)	50% (6)	32% (4)	**4.2**
4. To what extent is the layout of the cards appropriate to its content?	-	10% (1)	-	58% (7)	32% (4)	**4.2**
5. To what extent are the cards grouped in a clear way?	-	-	-	42% (5)	58% (7)	**4.6**
6. The list of cards (presented on the Design Framework) is designed to facilitate the process of browsing cards and selecting them. To what extent do you think it contributes to this objective?	-	19% (2)	9% (1)	36% (4)	36% (4)	**3.6**

Table 6.10 - Questionnaires' results from testing with designers, PS-III

Design process:

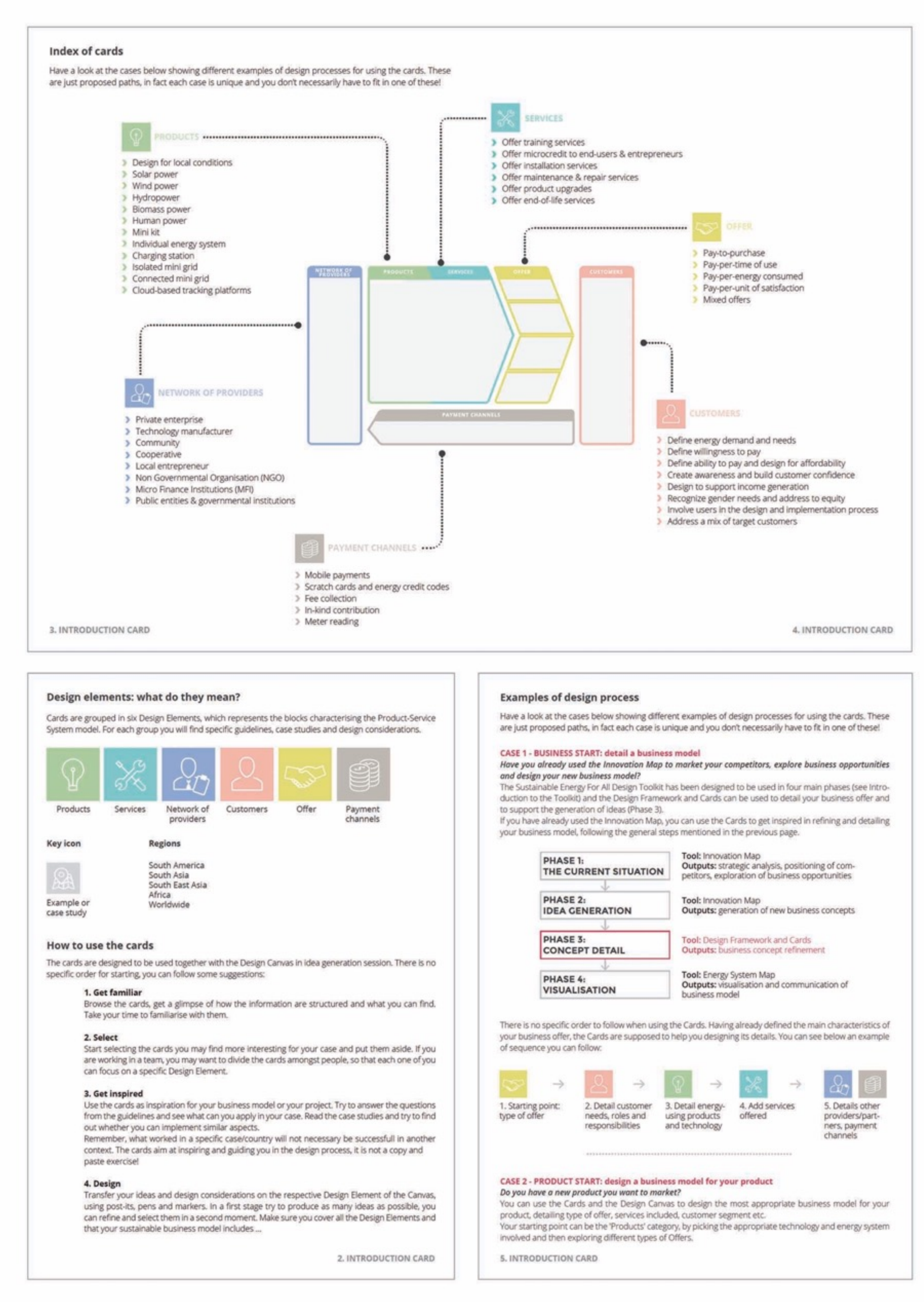
Participants were asked to give a rating to the current composition of the tool (Framework + Cards + Canvas) and were asked to provide feedback in terms of the effectiveness in the design process. This aspect was rated with an average of 3.6 and some affirmed that "*the current composition is appropriate and helpful to support an idea generation session. Great for brainstorming!"* (D1) and that "*it's really useful. The toolkit provides complex ideas in a feasible way*" (D5).

Suggestions for improvements in the design process included the provision of a step-by-step process for first time users ("*create a clearer sequence of activities to allow a team to move through the elements (step 1…)*", D9; "*for some individuals starting anywhere may be daunting. Having recommended routes for those who are struggling may be beneficial*", D4). Other comments highlighted the benefits that may emerge from a software version of the tool, which could provide a guide in the design process and could be updated and shared amongst collaborators ("*would like an online version of it to "easily share" with other partners / collaborators*", D1; "*some of the elements/guidelines exclude or include some others. Some of them are linked. An interactive tool can help the design process?*", D3).

6.5.3 Design Framework & Cards 1.1

Drawing conclusions from the evaluation with designers, a new refined version of the tool was prepared. This included a review of main icons and colours, changes in font sizes and reduction of text in bullet points where possible. A short introduction for the Cards was prepared (Fig. 6.27), which included a list of Cards for each element, as well as some examples of design process (Fig. 6.28). In addition, each group was provided with an Intro Card that detailed structure and content of that group. The Design Framework was updated with new colours and icons (Fig. 6.29).

Figure 6.27 - Introductory guide and Cards 1.1



Index of cards

Have a look at the cases below showing different examples of design processes for using the cards. These are just proposed paths, in fact each case is unique and you don't necessarily have to fit in one of these!

PRODUCTS
- Design for local conditions
- Solar power
- Wind power
- Hydropower
- Biomass power
- Human power
- Mini kit
- Individual energy system
- Charging station
- Isolated mini grid
- Connected mini grid
- Cloud-based tracking platforms

SERVICES
- Offer training services
- Offer microcredit to end-users & entrepreneurs
- Offer installation services
- Offer maintenance & repair services
- Offer product upgrades
- Offer end-of-life services

OFFER
- Pay-to-purchase
- Pay-per-time of use
- Pay-per-energy consumed
- Pay-per-unit of satisfaction
- Mixed offers

NETWORK OF PROVIDERS
- Private enterprise
- Technology manufacturer
- Community
- Cooperative
- Local entrepreneur
- Non Governmental Organisation (NGO)
- Micro Finance Institutions (MFI)
- Public entities & governmental institutions

CUSTOMERS
- Define energy demand and needs
- Define willingness to pay
- Define ability to pay and design for affordability
- Create awareness and build customer confidence
- Design to support income generation
- Recognize gender needs and address to equity
- Involve users in the design and implementation process
- Address a mix of target customers

PAYMENT CHANNELS
- Mobile payments
- Scratch cards and energy credit codes
- Fee collection
- In-kind contribution
- Meter reading

3. INTRODUCTION CARD

4. INTRODUCTION CARD

Design elements: what do they mean?

Cards are grouped in six Design Elements, which represents the blocks characterising the Product-Service System model. For each group you will find specific guidelines, case studies and design considerations.

Products | Services | Network of providers | Customers | Offer | Payment channels

Key icon: Example or case study

Regions: South America, South Asia, South East Asia, Africa, Worldwide

How to use the cards

The cards are designed to be used together with the Design Canvas in idea generation session. There is no specific order for starting, you can follow some suggestions:

1. Get familiar
Browse the cards, get a glimpse of how the information are structured and what you can find. Take your time to familiarise with them.

2. Select
Start selecting the cards you may find more interesting for your case and put them aside. If you are working in a team, you may want to divide the cards amongst people, so that each one of you can focus on a specific Design Element.

3. Get inspired
Use the cards as inspiration for your business model or your project. Try to answer the questions from the guidelines and see what can you apply in your case. Read the case studies and try to find out whether you can implement similar aspects.
Remember, what worked in a specific case/country will not necessary be successfull in another context. The cards aim at inspiring and guiding you in the design process, it is not a copy and paste exercise!

4. Design
Transfer your ideas and design considerations on the respective Design Element of the Canvas, using post-its, pens and markers. In a first stage try to produce as many ideas as possible, you can refine and select them in a second moment. Make sure you cover all the Design Elements and that your sustainable business model includes ...

2. INTRODUCTION CARD

Examples of design process

Have a look at the cases below showing different examples of design processes for using the cards. These are just proposed paths, in fact each case is unique and you don't necessarily have to fit in one of these!

CASE 1 - BUSINESS START: detail a business model
Have you already used the Innovation Map to market your competitors, explore business opportunities and design your new business model?
The Sustainable Energy For All Design Toolkit has been designed to be used in four main phases (see Introduction to the Toolkit) and the Design Framework and Cards can be used to detail your business offer and to support the generation of ideas (Phase 3).
If you have already used the Innovation Map, you can use the Cards to get inspired in refining and detailing your business model, following the general steps mentioned in the previous page.

PHASE 1: THE CURRENT SITUATION	Tool: Innovation Map Outputs: strategic analysis, positioning of competitors, exploration of business opportunities
PHASE 2: IDEA GENERATION	Tool: Innovation Map Outputs: generation of new business concepts
PHASE 3: CONCEPT DETAIL	Tool: Design Framework and Cards Outputs: business concept refinement
PHASE 4: VISUALISATION	Tool: Energy System Map Outputs: visualisation and communication of business model

There is no specific order to follow when using the Cards. Having already defined the main characteristics of your business offer, the Cards are supposed to help you designing its details. You can see below an example of sequence you can follow:

1. Starting point: type of offer → 2. Detail customer needs, roles and responsibilities → 3. Detail energy-using products and technology → 4. Add services offered → 5. Details other providers/partners, payment channels

CASE 2 - PRODUCT START: design a business model for your product
Do you have a new product you want to market?
You can use the Cards and the Design Canvas to design the most appropriate business model for your product, detailing type of offer, services included, customer segment etc.
Your starting point can be the 'Products' category, by picking the appropriate technology and energy system involved and then exploring different types of Offers.

5. INTRODUCTION CARD

Figure 6.28 - Extract from the intro guide to the Cards

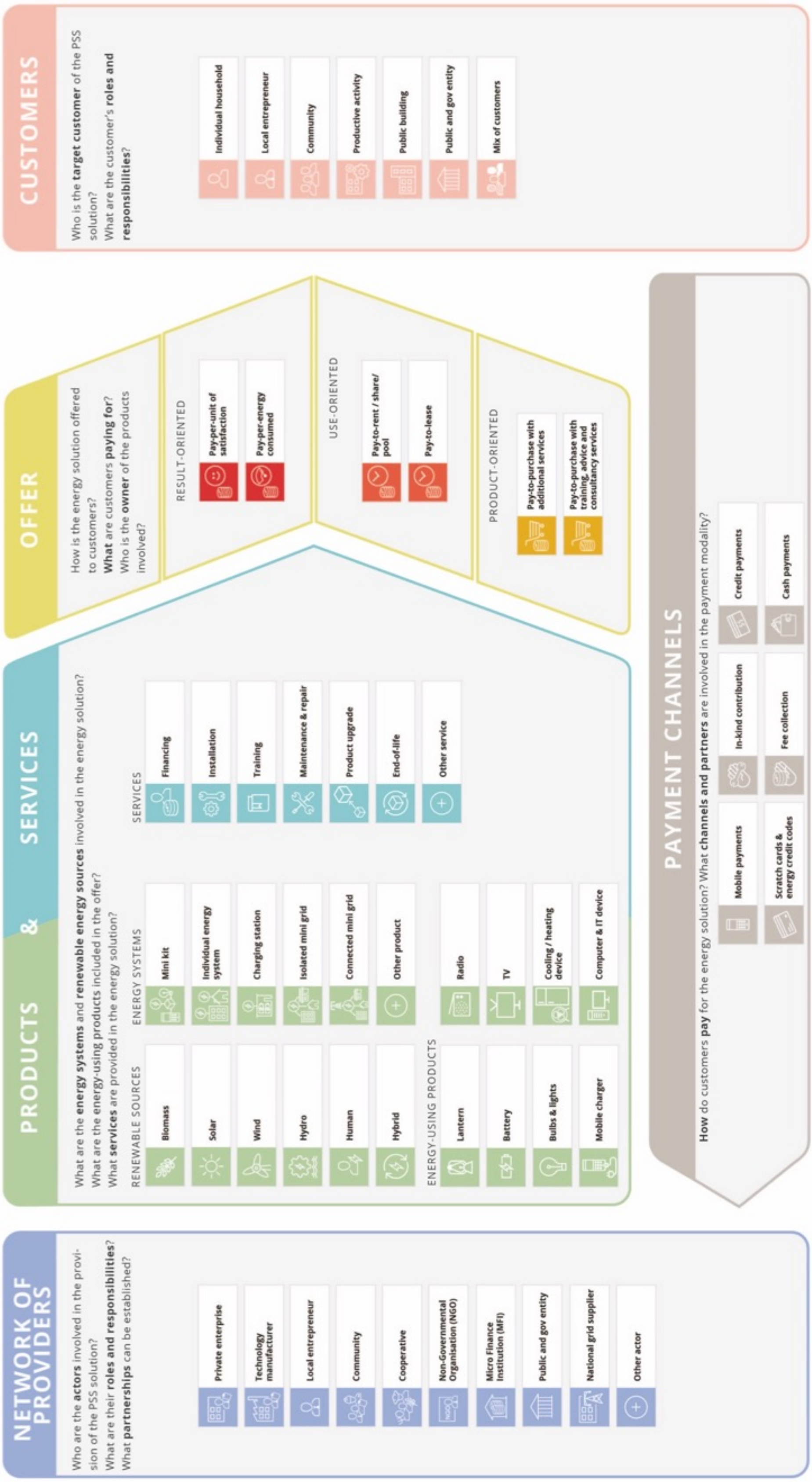


Figure 6.29 - Design Framework 1.1

6.6 Descriptive Study IV: testing in Kenya and Botswana

The Design Framework & Cards 1.1 was evaluated through three workshops in Kenya and Botswana, carried out between November and December 2016. These activities were organised as part of the EPSRC-funded project "Design and innovation tools to support SMEs in developing sustainable Product-Service Systems for energy access in African contexts". As described in Section 5.7, these testing activities aimed at evaluating the tool with a small amount of participants for a long session of activities (the workshop lasted three days). They applied the Design Framework & Cards for their chosen brief. Questionnaires, participant observation and a discussion with participants were used to collect feedback. Additionally, an analysis of concepts generated with the tool was employed to triangulate the data collected.

In addition to the workshops with companies, a four-hour long workshop was carried with DRE students and consultants at Kenyatta University (6.6.1.4).

The DS-IV also included a series of interviews with experts from the energy and design field, specialised in design for the BoP, PSS, DRE technology, business models and policy for renewable energy. The interviews aimed at evaluating the completeness of the tool and its content.

6.6.1 Workshops in Kenya and Botswana

6.6.1.1 Sampling

A smaller number of participants were involved in this study: one NGO and one company in Kenya and two companies in Botswana. A purposive sampling was adopted in this phase (Table 6.9), in particular aiming at involving companies focused on different DRE technologies (i.e. solar and biomass) and an NGO working on a wider range of energy solutions in collaboration with local and global stakeholders.

The workshop organised at Kenyatta University (W8) involved participants selected by the hosting institution, based on recommendations from the researcher and on the availability of participants. This workshop also aimed at testing the Innovation Map 1.1, therefore its activities are described in section 5.7.4.

Testing activities in Kenya (W7 and W8)		
Type of business	**Focus**	**Number of participants and position**
Workshop at University of Nairobi (W7)		
NGO and consultancy (P1)	Energy access and poverty alleviation	1, energy management engineer
SME (P2)	Biomass: product-oriented	1, founder and CEO

W8: workshop at Kenyatta University		
Education, business-support	DRE, business development	8, consultants and DRE students
Testing activities in Botswana (W9)		
SME (P3)	Solar: product-oriented	1, DRE manager
SME (P4)	Biomass: product-oriented	1, technical advisor /managing partner

Table 6.11 - List of participants of DS-IV

6.6.1.2 Description of activities

After a first introduction to the topic, participants were introduced to the Innovation Map and used the tool for mapping case studies, for positioning company's offers and competitors in the contexts, and for a first idea generation using the Concept Cards (see 5.7.2). The second day of the workshop focused on detailing the concepts generated by using the Design Framework & Cards. Participants had about four hours to complete this activity. There were given the Framework with Cards and a Design Canvas to be filled out with post-its. By browsing the Cards and getting inspiration from case studies and guidelines, participants completed their own Design Framework (Fig. 6.30).

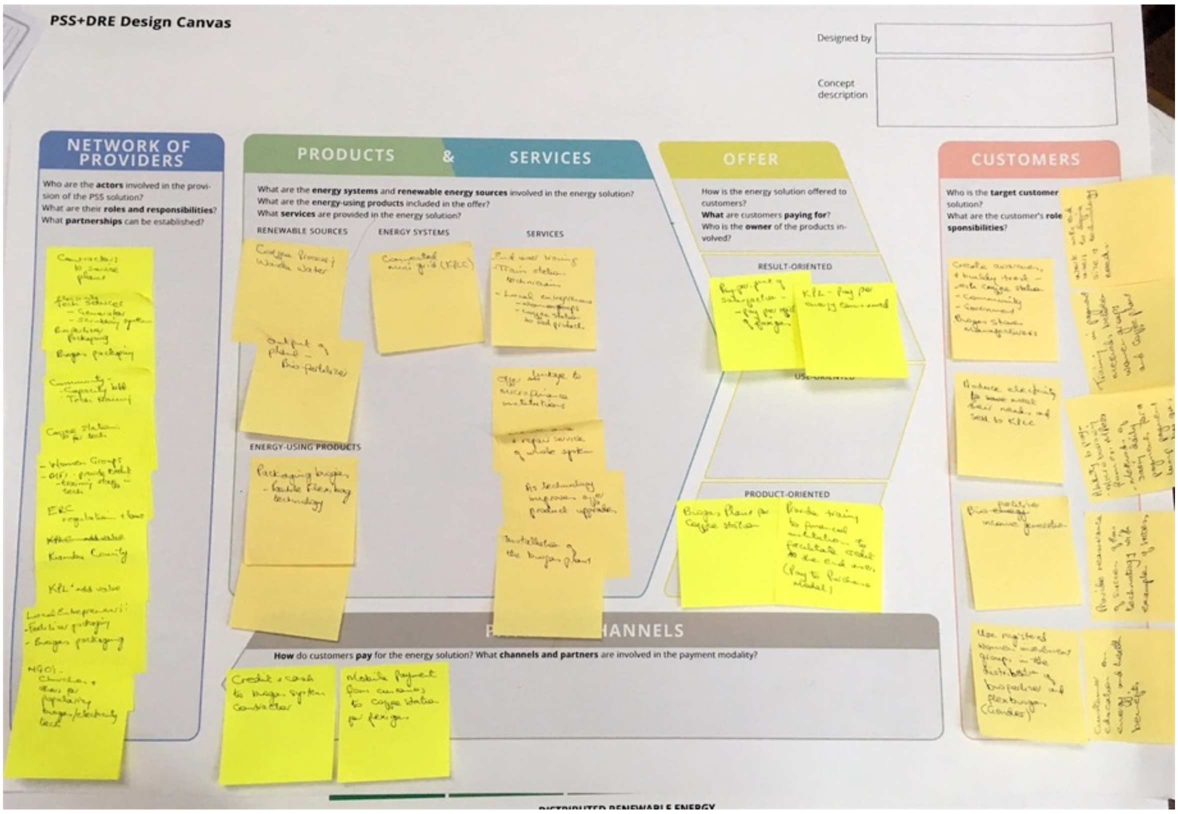


Figure 6.30 – Canvas completed by P1 in Kenya, DS-IV

6.6.1.3 Data analysis

Data was collected through multiple methods (questionnaires, participant observation) and provided a comprehensive evaluation of the tool's clearness, usability and usefulness. The feedback from questionnaires (Table 6.13) was integrated with a recorded group discussion at the end of the activities, which helped to identify limitations of the tool and discuss possible improvements. During the workshop, the researcher took down notes on how people used the tool and what issues they encountered. This method helped in understanding how the tool was used without intervening in the design process and the notes taken by the author have been integrated with other data emerging from questionnaires. Content analysis was used to evaluate the output of the tool in use, in particular the ideas and concepts generated (Appendix IV).

After having completed the first idea generation with the Innovation Map (Table 6.12), participants selected one concept and proceeded to the concept detailing session using the Design Framework and Cards. Participants were asked to produce detailed ideas and to fill all elements of the Design Canvas.

Participant	Concept developed with the Innovation Map
P1	**Concept 1**: product-oriented model where women entrepreneurs sell mini kits with additional services to households; **Concept 2**: providing mini kits through an entrepreneur-led model on renting and on a pay-per unit of satisfaction basis.
P2	**Concept 1:** sale of biomass plants to coffee cooperative and provision of energy services on a pay-per-unit (recharge of biogas flexibag for nearby farmers) and pay-per-energy consumed (for coffee farmers) basis to end users
P3	**Concept 1**: the lease and sale of solar water pumps through entrepreneurs; **Concept 2**: the provision on energy services through solar mini kits on a pay-per-unit of satisfaction; **Concept 3:** lease of charging stations (solar kiosks) to mobile producers, employing local entrepreneurs to provide charging services to end-users
P4	**Concept 1**: provision of energy through isolated mini grids on a pay-per-unit of satisfaction basis; **Concept 2**: connected mini grid that sells electricity to the main national grid on a pay per consumption basis.

Table 6.12 - Concepts generated by participants with the Innovation Map (DS-IV)

P1 integrated the two concepts emerging from the previous session in one business model proposal (see Appendix IV). In this phase, several details emerged, from the stakeholders' roles, the different services provided and customers characteristics.

On the other hand, P2 detailed the business model by adding a new energy system (connected mini grid) in combination with the biogas individual system, consequently focusing on identifying the stakeholders to be involved (such as Kenya Power Limited – KPL) and different payment structures (pay-to-purchase, pay-per-unit of satisfaction and pay-per-energy consumed).

In Botswana, P3 detailed three concepts focusing on individual energy systems, mini kits and solar charging stations. While main providers were similar in all concepts, payment structures and type of customers were defined in detail.

P4 focused on a selected concept that involved isolated mini grid on a pay-per-consumption basis, detailing several stakeholders involved, payment channels customers' roles.

The first aspect to be evaluated was the clearness and usability of the Framework and Cards. Participants were asked to rate the clearness of the Design Framework and the content of the Cards, meaning that the elements of the framework and their relations are clear and the guidelines and case studies are easy to understand. Clearness of the Framework was highly rated by participants (50% rated 4, 50% rated 5), while the Cards received the highest rating for the clearness of their content (100% rated 5). P2 suggested having a "*written tutorial*" to help in familiarising with the tool and understanding how to use it, and that "*initial familiarisation with the cards is important and time is needed to be able to follow through*".

In terms of applications of the tool, participants were asked to rate their use for supporting idea generation (50% rated 5 and 50% rated 4) and the usefulness of case studies as inspiration for generating concepts (avg. rating 4.7). Observation of participants confirmed the feedback collected through other methods, and no particular issue was encountered in terms of tool's usability.

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Design Framework	**1**	**2**	**3**	**4**	**5**	**Avg**
1. To what extent is the framework clear (i.e. the various elements of the framework, and their relations, are clear)	-	-	-	50%	50%	**4.5**
2. To what extent are the design questions (for each design element of the framework) clear?	-	-	-	75%	25%	**4.2**
Cards	**1**	**2**	**3**	**4**	**5**	**Avg**
3. To what extent is the content of the cards clear, i.e. the guidelines and case studies are easy to understand?	-	-	-	-	100%	**5**
4. To what extent are the cards easy to be used (e.g. looking for information, browsing cards etc.)?	-	-	-	-	100%	**5**
5. To what extent is the layout of the cards appropriate to its content?	-	-	-	25%	75%	**4.7**
6. The guidelines on the cards are intended to be used to support the generation of ideas. To what extent are the guidelines contributing to the achievement of this objective?	-	-	-	50%	50%	**4.5**

7. The case studies in the cards are intended to be used as inspiration for generating ideas. To what extent are the case studies contributing to the achievement of this objective?	-	-	-	25%	75%	**4.7**

Table 6.13 - Questionnaires' results from Kenya and Botswana, DS-IV

6.6.1.4 Discussions of results

Clearness and ease of use

This aspect was assessed through questionnaires and participants' observation and the tool is believed to be clear enough, i.e. the meaning of each design element is clear, so as the guidelines on the Cards. Although, the ratings of this aspect were high and no particular issue emerged from the observation of participants in using the tool, P1 noted that the content of Cards was "*quite long […] and a way to condense the information would be ideal for easy comprehension*" and that "*sufficient time is needed to be able to follow through*" (P2).

It was also noticed that participants tend to use the Cards in a systematic order, i.e. reading them one by one according to how they are sorted. This led, for example, to decide the type of energy system and payment structure before having gone through the Customers' Cards. In fact, participant had already chosen technology and payment options when they read guidelines about defining energy needs and ability to pay. This led some confusion and the necessity to go back to the relevant design element (i.e. products and offer) and reconsider some aspects. The same approach was used in deciding the order of brainstorming for each element: first, the network of providers, then products, services and offer type, followed by customers and payment channels. Although, it was highlighted that no specific order needed to be followed in the generation of ideas, this sequence, from left to right, was adopted by all participants in the workshop. The researcher observed that when some issues where encountered, it was difficult to go back to the relevant card or guideline and connect all the aspects together. This may be related to the unfamiliarity with the tool, but also to the high amount of information, guidelines and case studies present in the Cards. The possible improvements may include connections among cards, such as suggestions for considering other aspects from another group of cards, enabling users to be guided through the process.

<u>Flexibility and adaptability</u>

Another aspect that needed to be evaluated was the adaptability and flexibility of the tool for different contexts and types of users. This feature has been discussed further through experts' interviews, however, the group discussion at the end of the workshops highlighted that *"the tools are flexible enough, traditional business plans do not go into these details. It is very comprehensive"* (P1). It can also be pointed out that P3 and P4 were both in a design/redesign phase of their current business model and they used the tool to generate ideas for new offers. P3 highlighted that "*I found it very useful to start up a business"* but can be also applied by those who already have a product and a business in place (*"it's still a very useful tool, because it's still guiding you, it's still giving you new ideas").*

Usefulness

Participants have highly rated the application of the tool to support idea generation of PSS+DRE models (*"for me it's really a way of helping me focus directly",* P3). The concepts' analysis helped clarifying the usefulness of the tool in terms of quantity and quality of ideas generated.

<u>Support the idea generation of PSS applied to DRE</u>

The results from questionnaires were compared with the ones that emerged from the content analysis of the filled Design Canvases. It was noted that in some cases participants followed the guidelines in a superficial way. This resulted in 'copying and pasting' ideas from the Cards to the Design Canvas. For example, P3 did not generate a great amount of ideas compared to the previous session with the Innovation Map, with the exception of the customer's element. A possible reason for this result could be that ideas were discussed within the team but not entirely recorded on post-its. Due to the nature of these testing activities, it was not possible to record the discussions emerging from using the tool and the interactions between team members. However, this aspect might be implemented in further research activities with the aim of understanding how the tool trigger conversations and their impact in the idea generation (see Section 9.4.2.2).

<u>Support the concept detailing of PSS applied to DRE</u>

The Design Frameworks & Cards has helped participants in detailing their offer. Considering the starting concept described with the Innovation Map, both P1 and P2 added several elements to their concept. In particular, they defined roles of each stakeholder, added services such as take-back and detailed who is responsible for them, added characteristics to the customers' element ("*as we brainstorm more ideas are coming…I didn't realise we had so many stakeholders!",* P2). Some elements such as energy systems and energy-using products have been less explored. This was mostly related to time constraints but could also be influenced by the fact that they wanted to focus on specific aspects of the business model and detail technical matters in the second stage. On this matter, P1 affirmed that the tool "*helps to focus on specific ideas*".

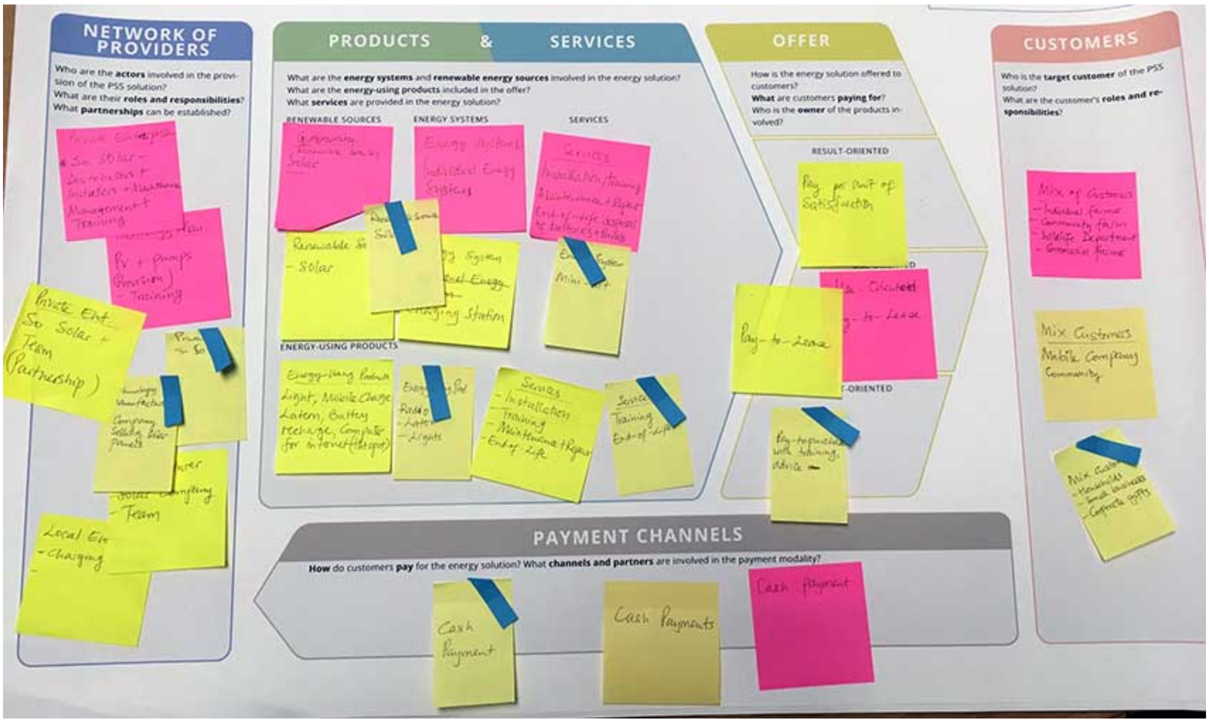


Figure 6.31 - Canvas filled by P3 in Botswana, DS-IV

On the other hand, the analysis of ideas generated shows that P3 did not go very much into detail compared to the idea generation with the Innovation Map, especially in the type of payment and type of offer. This can be justified by time constraints and by the fact that three different concepts were chosen (Fig. 6.31 shows different post-its used for different concepts), suggesting that a more focused brainstorming session would have helped to detail more in depth. P4, on the other hand, clarified their concept in terms of providers, products and services, suggesting that the use of the Design Framework and Cards greatly helped them in designing a more detailed concept. Similarly to the results obtained in Kenya, the idea generation on customers revealed a higher amount of ideas for both P3 and P4.

Another interesting aspect emerging from the application of the tool was that it supported triggering conversations and considering key aspects of the solution that were not considered before. For example, P1 highlighted important aspects by circling them on the framework or leaving them in forms of questions (Fig. 6.30), suggesting that these factors will require further discussion within the team.

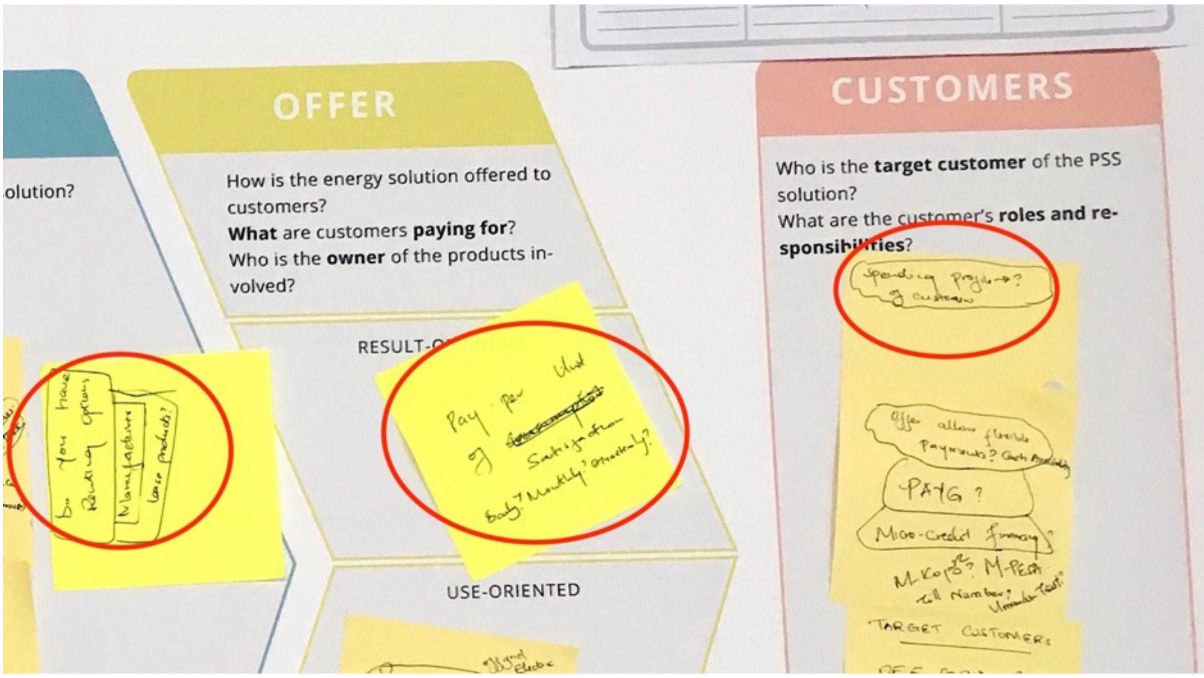


Figure 6.32 - Detail of Canvas filled by P1 in Kenya, DS-IV

6.6.1.5 Workshop at Kenyatta University

In addition to the two workshops with companies and practitioners, the DS-IV involved a short workshop (W9) at the Chendaria Business Incubator Centre with eight people, including master students and DRE practitioners. As described in Section 5.7.4, this workshop was aimed particularly to gather more quantitative data on the usability and usefulness of tool and to explore their applications at the Incubator Centre and at the Kenyatta University.

The workshop lasted four hours, including an introductory part on PSS+DRE in BoP contexts and the use of the Innovation Map (5.7.4) first to position companies operating in the context. Then participants used the Design Framework and Cards for a short idea generation (30 min) (Fig. 6.33). In the following section, the main results collected in this workshop are summarized by discussing usability and the applications of the tool. Table 6.14 presents the data collected with questionnaires at the end of the workshop.

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Design Framework	**1**	**2**	**3**	**4**	**5**	**Avg**
1. To what extent is the framework clear (i.e. the various elements of the framework, and their relations, are clear)	-	-	14% (1)	72% (5)	14% (1)	**4**
2. To what extent are the design questions (for each design element of the framework) clear?	-	-	-	57% (4)	43% (3)	**4.4**
Cards	**1**	**2**	**3**	**4**	**5**	**Avg**

3. To what extent is the content of the cards clear, i.e. the guidelines and case studies are easy to understand?	-	-	-	43% (3)	57% (4)	**4.5**
4. To what extent are the cards easy to use (e.g. looking for information, browsing cards etc.)?	-	-	-	43% (3)	57% (4)	**4.5**
5. To what extent is the layout of the cards appropriate to its content?	-	-	-	14% (1)	86% (6)	**4.8**
6. The guidelines on the cards are intended to be used to support the generation of ideas. **To what extent are the guidelines contributing to the achievement of this objective?**	-	-	-	66% (4)	34% (2)	**4.3**
7. The case studies in the cards are intended to be used as inspiration for generating ideas. **To what extent are the case studies contributing to the achievement of this objective?**	-	-	-	66% (4)	34% (2)	**4.3**

Table 6.14 – Questionnaires' results from the workshop at Kenyatta University, DS-IV

Figure 6.33 - Participants using the tool at Kenyatta University, DS-IV

Clearness and ease of use: participants used the Design Framework and Cards for a brief idea generation session. Although, some pointed out that *"it takes some time to understand it"* (S4) and *"users need to be guided"* (S7) in the process, the majority of participants (72%) rated the clearness of the tool 4=good, affirming that *"the framework is easy to understand and simple to use"* (S6) and that *"the design framework is clear and straight forward"* (S8). The content of the Cards was also considered clear enough (57% rated=5, 43% rated=4) and easy to be used (57% rated=5, 43% rated=4) and some commented that they were *"well designed"* (S1), *"clear and well organised"* (S8) and in particular that the guide *"provides the best and straight cut method of going through the entire series of cards"* (S6).

Applications:

Most participants commended the application of the Design Framework and Cards as support for the idea generation and as an inspiration for business model design (66% rated 4 and 34% rated 5), affirming that the tool *"provides a simple straightforward guideline that will be helpful during the brainstorming phase of a project/business"* (S6). All participants expressed their interest in using the tool for generating ideas for their business or project in the future.

6.6.2 Evaluation with experts

The DS-IV included a study with experts of DRE technology, business, policy and design, carried out through interviews in Kenya and Botswana. This study aimed at evaluating in detail the content of the tool and in particular the completeness of the Design Framework and the usefulness/appropriateness of guidelines in the Cards. Participants were selected following a purposive sampling in order to evaluate the several aspects of the tool and to provide insights on its flexibility and adaptability to different users and contexts. The sessions were structured with an introduction phase, a general discussion on the tool and how it is used, followed by semi-structured questions. Depending on the availability of interviewees, sessions lasted between one to two hours. In some cases, the interview was coupled with a questionnaire as some participants preferred to provide feedback at a later stage. Details of the participants involved are summarised in Table 6.15.

Expert	Sector	Position	Date of interview
Interviews in Kenya			
E1	NGO – support of businesses in technology, skills, access to capital	Business development advisor	7 Nov 16
E2	Design agency – design in low-income contexts	Lead designer	8 Nov 16
E3	NGO – supporting communities in adopting renewables	Director of development	9 Nov 16
E4	Academia – Business Incubator Centre	Director	11 Nov 16
E5	Academia – Renewable energy	Lecturer / researcher	11 Nov 16
E6	Design agency – strategic design	Strategic designer	15 Nov 16
E7	NGO – support of businesses in technology, skills, access to capital	Head of advisory services	16 Nov 16

Interviews in Botswana			
E8	Research – Technology and energy research centre	Senior researcher	05 Dec 16
E9	Business – Innovation Hub – business incubator	Coordinator	06 Dec 16
E10	Research – Technology and energy research centre	Lead designer	09 Dec 16
E11	Academia – Design (Product Service Systems)	Lecturer / researcher	09 Dec 16
E12	Policy – renewable energy department	Energy engineer	09 Dec 16

Table 6.15 - List of participants engaged in the study, DS-IV

Interviews were recorded and transcribed and the information emerging from these sessions was merged with the ones collected through the questionnaires. Data was analysed both from a quantitative and qualitative perspective. In particular, the quantitative data (Table 6.16) was used to integrate comments emerging in the interviews.

Completeness					Yes	No
1. The framework includes all element of a PSS applied to DRE offer.					88%	12%
Usefulness (1=strongly disagree; 2=disagree; 3=sort of agree; 4=agree; 5=strongly agree)						
Evaluation of the Design Framework	**1**	**2**	**3**	**4**	**5**	**N of responses**
1. The design framework aims is useful to give an overview of all design elements of the energy solution.			17%	66%	17%	8
2. The design framework is useful to stimulate idea generation of the energy solution by suggesting elements to be considered.				28%	72%	8
Evaluation of the Cards						
Cards: Services						
1. The content of the cards is appropriate / useful				25%	75%	4
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.				50%	50%	4
Cards: Customers						

1. The content of the cards is appropriate / useful				40%	60%	5
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.				40%	60%	5
Cards: Payment channels						
1. The content of the cards is appropriate / useful				66%	44%	3
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.				34%	66%	3
Cards: Network of providers						
1. The content of the cards is appropriate / useful				34%	66%	3
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.				50%	50%	2
Cards: Products						
1. The content of the cards is appropriate / useful				66%	34%	3
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.				66%	34%	3
Cards: Offer						
1. The content of the cards is appropriate / useful				50%	50%	2
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.				50%	50%	2

Table 6.16 - Quantitative results from experts' interviews

6.6.2.1 Discussion of results

Evaluating the completeness of the Design Framework:

The first aspect to be tested through the experts' interviews was the completeness of the Framework, i.e. whether it covers all the elements necessary for the design of PSS applied to DRE. Most participants in the study responded positively to the question (88% responded "yes"). One expert highlighted that the distribution of products should be represented as a separate element and that is not visible in the Network of Providers' block. However, this choice is justified by the fact that distribution channels are related to roles and responsibilities that providers may have. For example, a cooperative may be involved as a distribution partner, or a private enterprise can use local vendors and businesses to distribute its products. The final version of the tool will include explicit reference to the role of distributors in the Cards.

Another suggestion, related to the energy-using products block, included adding products for productive activities, such as farming appliances or water pumping. This suggestion, pointed out by companies, has already been considered for the final version of the tool, which will also include a specific Card on energy for productive uses.

Some experts noted that the Framework *"is a living tool"* (E1) and it *"is a general tool"* (E8, E10), (*This tool gives a basis, a foundation, giving a structured approach to address that dynamism of DRE, E1*) pointing out that more elements can be added, for example, other forms of energy such as cooking can be integrated. A possible solution for the new version is to add a general icon "+" for each design element, highlighting the possibility of adding ideas (e.g. "+ customer"). This should communicate to the users that the Design Framework can be updated and it should be used as a reference in the design process, but it may not exhaustively cover all possible elements. The final version of the tool is also available online in an open-source and copy-left format (see Chapter 9), enabling anyone to add or modify Cards, guidelines, case studies or elements on the Design Framework.

Another aspect that emerged from the conversations with experts is the influence of the so-called 'enabling environment' on the design of a business model. The Design Framework and Cards do not cover regulations, policies and capital financing aspects, which fall out of the scope of this research. Nevertheless, these elements are crucial for the implementation of PSS applied to DRE ("*to apply to the local situation the energy regulators need to be in place*", E9). As suggested in the testing activities, future developments of the tools could be looking at "*bringing on board other factors that may affect the adoption of renewable energy*" (E4), integrating regulatory and financing factors. Further research activities are discussed in Chapter 9.

Evaluating the usefulness

In order to receive feedback on the applications of the tool, experts were asked to rate the usefulness of the tool in giving an overview of elements to consider in the design process and in supporting the idea generation of PSS and DRE.

1. Visualise all elements of PSS models applied to DRE: most participants considered the tool useful in this application (66% rated 4, 16% rated 5) and affirmed that the Framework helps focusing on several elements simultaneously ("*one thing that I'm getting from this is that you need to look at all elements at the same time"*, E8). One interviewee affirmed that the Framework does not include distribution channels, thus is does not exhaustively visualise all elements. However, distribution channels can be identified among roles and responsibilities that providers may have rather than a

type of actor in the PSS solution, therefore an explicit reference can be added as guideline in the Cards.

2. Support the idea generation of PSS applied to DRE: interviewees highly commended the usefulness of the tool for idea generation sessions (72% rated 5), appreciating especially the visual representation of elements ("*the more visual it is, the easier it gets to use*", E10) and the fact that the tool collects creative ideas and supports innovation by presenting them in an organised way ("*This is organising the information that exist in the sector. There are quite a lot of creative ideas in the sector but there is a shortfall in how these ideas are organised. So I see this as the role of this tool*", E1).

Flexibility and adaptability

The flexibility and adaptability of the tool was discussed with experts to get insights on what changes may be needed and how the tool may be further developed to be suitable for specific contexts, types of users or applications.

Flexibility across different contexts:

Most interviewees found the tool flexible enough to be adapted in different contexts ("*The tool is very flexible and can easily be adapted to the local context*", E4; "*The tool is flexible as it can easily be applied to off-grid renewable energy situation across the world*", E9; "*I like its diversity and flexibility, also like the way the tool is easy to adopt*", E1). Further implementations and applications of the tool may include context-specific information such as regulatory and financing frameworks.

Flexibility across different types of users:

Another aspect discussed was how different types of users and organisations may use the tool having different expertise, skills and backgrounds. Having already assessed its applications with companies and practitioners through the workshops, experts were asked whether they will apply the tool in their organisation and if it will be useful for their purposes. The responses were greatly positive, nine of them affirmed that they see how the tool will benefit their activities, ranging from business development, to academia, to design consultancies. ("*I have four projects on my table and all of them are in the design stage. This is a tool that really puts everything in a structured manner. So this tool is a perfect fit for me*", E1; "*I could boost this in applications in clean energy research. I have a platform where this can fit so well and benefit so many other people*"; "*I can use it as a guide to my methodology, it would give me a more controlled, more structure*", E10; "*I can use them with students on my course*", E11; "*Especially for us researchers, if it lands on me I would be able to communicate better to stakeholders*", E8).

In the discussions with experts, another relevant aspect that emerged was related to the complexity and unfamiliarity of the tool for first-time users, and especially for those who do not receive proper training/introduction to the topic of PSS+DRE and to the tool. The aim of this research is, in fact, to evaluate how these tools can be improved and to prepare a final version that can be disseminated across different channels, reaching a wider number of adopters. In order to do so, it is critical to assess how the material developed in this research may be communicated and diffused among different stakeholders. Most interviewees suggested providing a guide for the tool or consultancy services to be assisted through the whole process (“*you need to sit with the companies for them to benefit from this. The thing is, first time around you might need a consultant to assist you through the process*”, E8; “*you sit with them and do step by step*; “*it needs guidance*”, E2; “*you would then offer case examples on how to be guided*”, E10). An extensive guide on for use all PSS+DRE design tools and particularly addressing different types of users and their different needs will be prepared (see Section 8.1).

Flexibility across different stages of the design process:

The Design Framework and Cards has been designed as a flexible tool that can support the idea generation process of a PSS applied to DRE. Its practical applications in the workshops for concept detailing assessed its usefulness for this application. The tool, however, should be flexible to different uses in the design process, for example, to detail a specific aspect of the business model (e.g. services), or it can also be used in inspiration mode to gather ideas. In discussing this with experts, some points can be laid out:

- Start-up a new business – design of a new business model: this application has been already commended by companies participating in the workshop (“*very useful to start up a business, to help you focus in what you are doing”, P4)* and it has been also highlighted by some experts *(“start-ups might find this interesting*”, E8), especially those working in the business incubator centres who expressed their interest in adopting the tool for mentoring start-up businesses (E4, E9).
- Refine an existing business model: the tool can be used to focus on specific aspects of the business model and it can be applied by companies and practitioners that already have an offer in place, but may want to expand on one element (i.e. payments). Experts affirmed that it can be used “*for the review and monitoring phase and you can just concentrate on one aspect”* (E3), or it can be used to assess a previously-designed model after it has been implemented (“*it's very good to do it again. Every time you do it, new ideas come or a new challenge arises*”).
- Get inspired: the tool can be used in inspiration mode (“*just to use these cards to product brainstorming cause it's not prescriptive in the way you're laying it out*”, E3) and it can be used in teams to trigger conversations and to explore opportunities *(“It's a very good discussion template*”, E8).

Limitations in the applications of the tool

Another aspect that emerged from the experts' interviews was the need to clarify what output is expected from using the Design Framework and Cards and what are the limitations of the tool. As pointed out by some, Cards do not go too much in depth on some aspects, such as technology choice, but they simply give an overview of available choices, strengths and weaknesses and general consideration for choosing a specific energy system. Designing and implementing DRE models require a whole set of tools, capabilities and resources that cannot be exhaustively covered through an idea generation session with this tool. To this matter, partners from the LeNSes project developed tools that focus on other aspects of the solution, such as the design of the technology and the estimated energy production. In this way the Design Framework and Cards, together with the Innovation Map and the Energy System Map (see Chapter 7) can be complemented.

On the other hand, detailing customers and designing solutions for Base of the Pyramid contexts require a set of resources and activities that fall out of the scope of this research. As pointed out by E2, can be also necessary to "*have design tools like personas, customer journeys, stakeholder mappings*" and the Design Framework and Cards may be included in "*sort of a roadmap"* within the design process.

It is important to highlight that the Design Framework and Cards can be used in conjunction with other tools and that its main contribution is in the ideation phase of a business model. In fact, concepts generated with the tool might require further evaluation in terms of financial sustainability, technical feasibility, availability of appropriate regulations and other external factors.

Considerations of the content of the Cards

The sessions with experts were also helpful to review some of the content of the Cards, aiming at testing the completeness and appropriateness of guidelines. Due to time constraints and availability of interviewees, not everyone had the opportunity to provide feedback on the Cards, however, some general comments have been collected. In this section we report some of the changes and suggestions collected for each group of Cards.

- Network of providers: distributors need to be included among the providers, or their role must be highlighted (E7). This will be integrated within the 'roles and responsibilities' of providers.
- Customers: general comments on the customers' cards were positive *"their content is appropriate because they are very determinant of what a customer would be looking for"* (E1). Suggestions included: making explicit how benefits of renewable energy can be communicated to customers (E10), how cultural adoption of products is important in designing the offer (E4).

- Products: more information on the technology, i.e. what types of solar PV panels exists can be added to support the product' choice (E8). This aspect, however, can be implemented with adding references and links in the tool guide (‘*add some links in a way with more details to the available literature*”, E8). Other suggestions included: to add availability of resources, impacts of exploration and exploitation, application area and sustainability issues to ‘Design for local conditions’ card and to the renewable sources cards.
- Services: this group of Cards was considered comprehensive (“*the content is very useful, because the way the various aspects of services identified it's comprehensive. Secondly, it addresses the way this comes as a package*”, E1). However, some additions can be made: in ‘Training services’ it should be highlighted that skilled technicians must be involved and must be certified to provide installation and repair services (E8); information regarding empowering customers for troubleshooting basic issues (E5) can be added to end users training.
- Offer: add how the offer tackles ability and willingness to pay, customers' payment cultures and which technology can facilitate this (E5). This can be implemented by providing links to the customer cards.
- Payment channels: overall the group of cards was considered appropriate and that it covers the state-of-the-art in the field, however, E1 pointed out that some payments are context specific, for example in Kenya, “*scratch cards are becoming almost obsolete and innovation is done around mobile money platforms”.*

6.6.3 Conclusions from the Descriptive Study IV

The Design Framework & Cards 1.1 was evaluated through two workshops with companies and practitioners in Kenya and Botswana, which provided in-depth analysis of the tool in use and qualitative feedback collected through multiple sources. Additionally, the DS-IV included a third workshop with eight students and practitioners, which confirmed findings previously collected.

The tool was then evaluated through twelve interviews with experts, which assessed the completeness and usefulness of the tool. Some important considerations emerged in terms of future research developments, while some minor changes will be implemented in the final version of the tool.

6.7 Design Framework & Cards final version

The main changes in the Design Framework are relative to the addition of “appliances for productive uses” among energy-using products, and the “remote monitoring” among the payment channels. The ‘services’ and ‘products’ blocks have been rearranged to be easily distinguished, while the types of PSS offer have been detailed with a PSS description to enhance clarification (Fig. 6.32). The Cards' improvements include: added links between cards (Fig. 6.33) and some minor changes in the guidelines, following the comments of DS-IV.

Some insights collected in the testing activities have not been implemented in the final version, or they have been considered for future developments (see Chapter 9). For example, one company suggested reducing or condensing the information on the Cards to facilitate their use in workshop sessions. Other experts highlighted that the amount of cards may be "overwhelming". However, the aim of the tool is to provide support for a detailed idea generation of concepts, and reducing information or condensing them would not achieve this result. In fact, this tool requires enough time to go through all the Cards and to read and consider all guidelines and critical factors. The time factor for completing an idea generation with the Design Framework and Cards has been highlighted in the Guide for the use of the tools (see Section 8.1).

The final version of the tool was also prepared in its digital version and uploaded online (www.se4alldesigntoolkit.com - see Chapter 8).

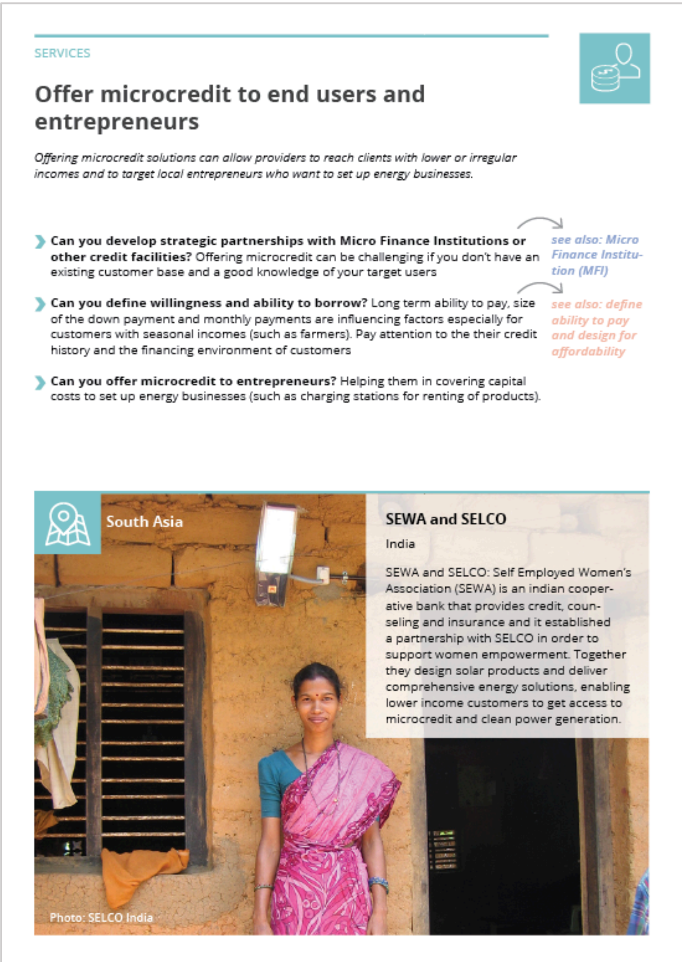


Figure 6.34 - Example of Card's final version (2.0)

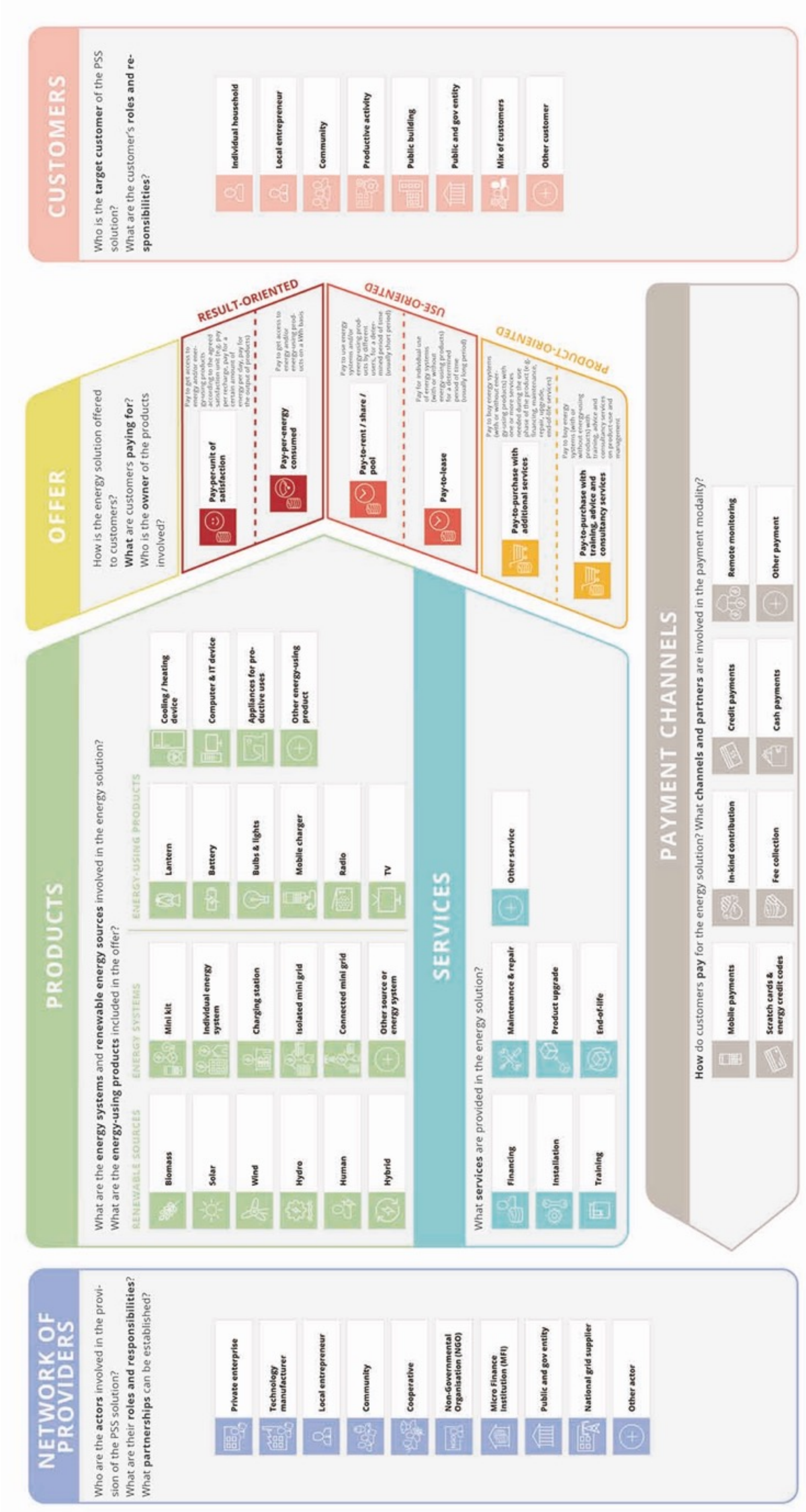


Figure 6.35 - Design Framework final version (2.0)

6.8 Chapter summary

This chapter described the design and evaluation of the PSS+DRE Design Framework & Cards. The tool was developed building upon some of the outcomes of the primary studies: the identified dimensions of PSS+DRE and their variables (4.1), the collection of critical factors (4.5) and case studies (4.3) of PSS+DRE in BoP contexts.

The tool was firstly tested through some pilot workshops with 39 design students, DRE and PSS experts and design practitioners. A more refined version of the Design Framework & Cards (0.2) was then tested with a wide range of practitioners from different disciplines: 23 people from companies, consultancies and NGOs, 12 designers, 8 DRE students and practitioners, 12 experts of design and DRE. Therefore, with 101 participants involved in the evaluation of the tool over its several iterations, it can be concluded that the tool has been empirically tested from a qualitative and quantitative perspective. These studies were carried out different countries, Botswana, South Africa, Kenya and the UK, contributing to results' validity and reliability.

The activities described in this chapter can be summarised here.

1. PS-I: Design Framework & Cards 0.1

The first version of the tool was presented as a support to visualise elements of PSS+DRE and to support the generation of ideas with guidelines and case studies organised in the form of Cards.

2. DS-II: pilot testing in Botswana and South Africa

The Design Framework & Cards 0.1 was applied in a pilot test with design students from University of Botswana, during the LeNSes course. This study provided insights on usability and clearness of the tool and on its applications.

Then, the tool was further tested with practitioners and experts in South Africa and Botswana through two workshops, which provided feedback on its ease of use and usefulness.

3. PS-II: Design Framework & Cards 0.2

The second version of the tool presented improvements to ensure clarity and usability.

4. DS-III: testing in South Africa and Kenya

The Design Framework & Cards 0.2 was then evaluated by companies and practitioners during two workshops organised in Cape Town and Nairobi. The usefulness of the tool was demonstrated.

5. PS-III: Design Framework & Cards 1.0, evaluation with designers, refined version 1.1

The new version of the tool presented a different layout and organisation of the Cards, as well as a list of content provided on the Design Framework. This version was then evaluated through a workshop with designers at Brunel University London, which provided insights for improving usability and clearness. These suggestions led to the development of the Design Framework & Cards 1.1.

6. DS-IV: testing in Kenya and Botswana

The new version of the tool was tested through three workshops in Kenya and Botswana with companies and practitioners. The usefulness and usability of the tool were finally assessed.

Then, the tool was assessed from a completeness and usefulness point of view through interviews with twelve experts in Kenya and Botswana.

7. Design Framework & Cards final version

The last version of the tool, Design Framework & Cards 2.0 was presented. A digital version of the tool was also prepared.

Chapter 7

PSS+DRE Visualisation System

7: PSS+DRE Visualisation System

This chapter describes the development of the PSS+DRE Visualisation System. In this section the design, testing and refinement of the tool are discussed through its iterations in Kenya, Botswana and UK. The chapter concludes with its final version and considerations for future research activities.

The third outcome of this research is the development of a Visualisation System for PSS+DRE models (Emili et al., 2016 (c)). As discussed in Section 2.2.6.1, the literature on PSS design tools can be considered mature enough and several tools are available for designing and visualising PSS models. However, there is the need to adapt these tools for specific applications, such as PSS+DRE in BoP contexts. To this respect, the aim was to develop an appropriate visualisation system to support the designing and communication of PSS+DRE models. For these reasons, the first outcomes of this research, i.e. the identification of PSS+DRE dimensions and variables and the review of PSS tools, were used to develop a Visualisation System for PSS+DRE models (Fig.7.1).

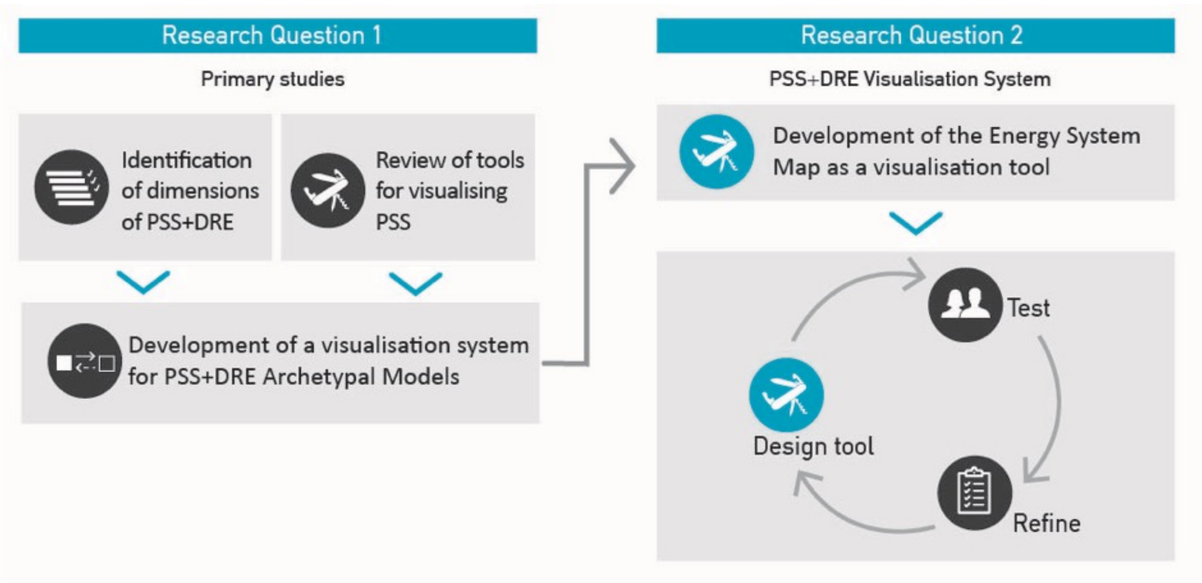


Figure 7.1 - Schematic of activities conducted during the primary studies and those included in this chapter

In particular, the Energy System Map[22] is presented as a tool to (co)design solutions, identifying stakeholders and their relationships within the system. This chapter describes how the Visualisation System was developed, then applied as a design tool and refined through testing activities in Kenya and Botswana.

[22] The name Energy System Map refers to the Visualisation System used as a design tool. In other words, the Energy System Map = Visualisation System.

The tool was tested through two main iterations (Descriptive Study II and III, Table 7.1) which involved companies, practitioners and designers. Testing focused on evaluating the tool in its completeness, usefulness and usability.

Study	Activity	Location	Participants
Descriptive Study II	Workshop (W5)[23]	Kenya	11: mix of companies and practitioners
	Workshop (W6)	UK	12: designers
Descriptive Study III	Workshop (W7)	Kenya	2: NGO and company
	Workshop (W9)	Botswana	2: companies

Table 7.1 - Testing activities for the Visualisation System: activities, locations and participants involved

This chapter is structured according to the main stages of the methodology (Fig. 7.2 and 7.3): first the PS-II introduces the development of the Visualisation System 0.1, then this chapter describes how it has been adapted into a design tool, the Energy System Map (or Visualisation System 1.0). The testing activities of DS-II are then illustrated, followed by a second version of the tool in PS-III (Visualisation System 1.1). This version is then further evaluated through DS-III. The chapter concludes with the last version of the tool.

[23] The workshops' numbers correspond to the workshops' list in Section 3.6.2 of the methodology chapter.

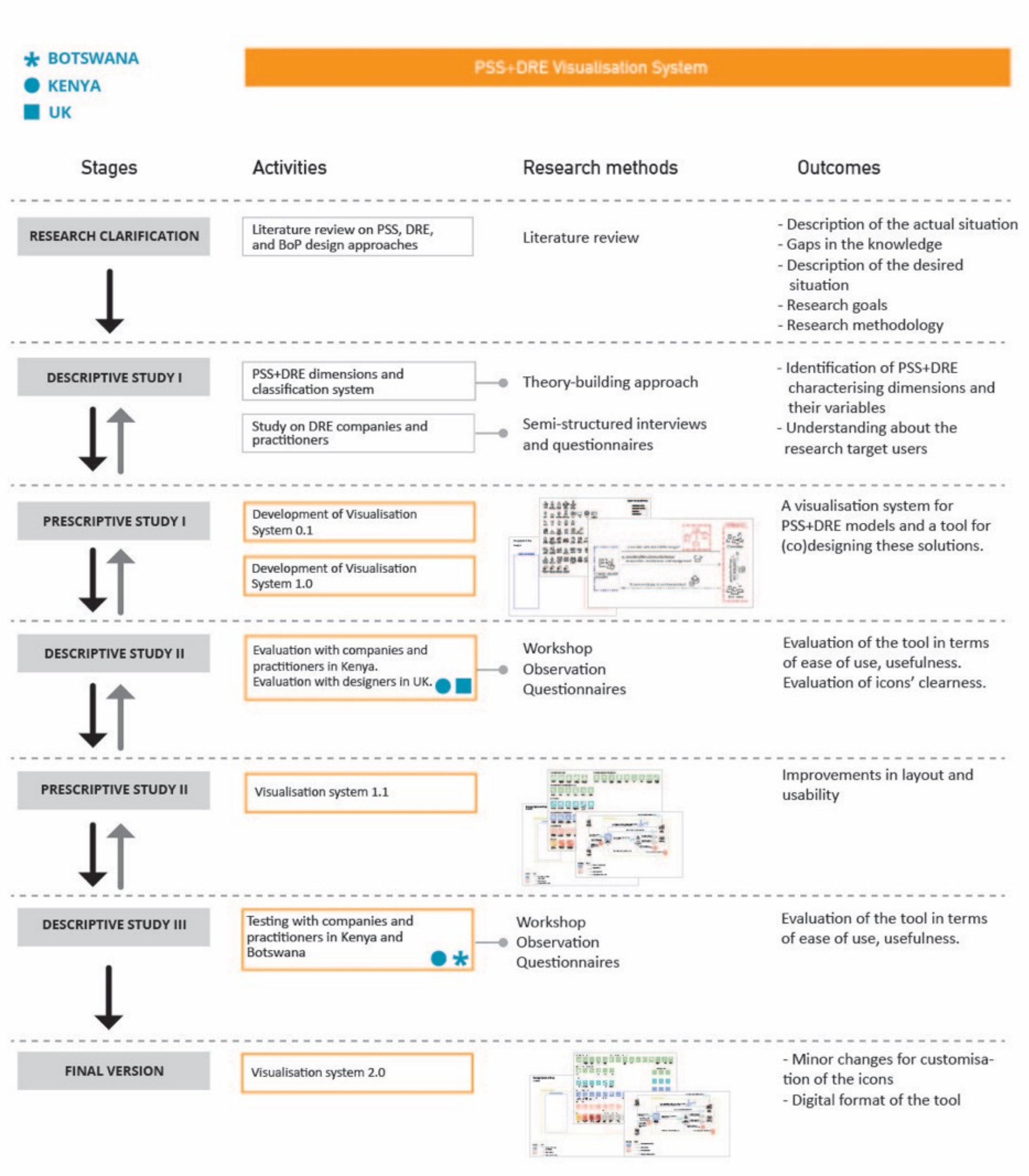


Figure 7.2 - Stages of the Visualisation System' development

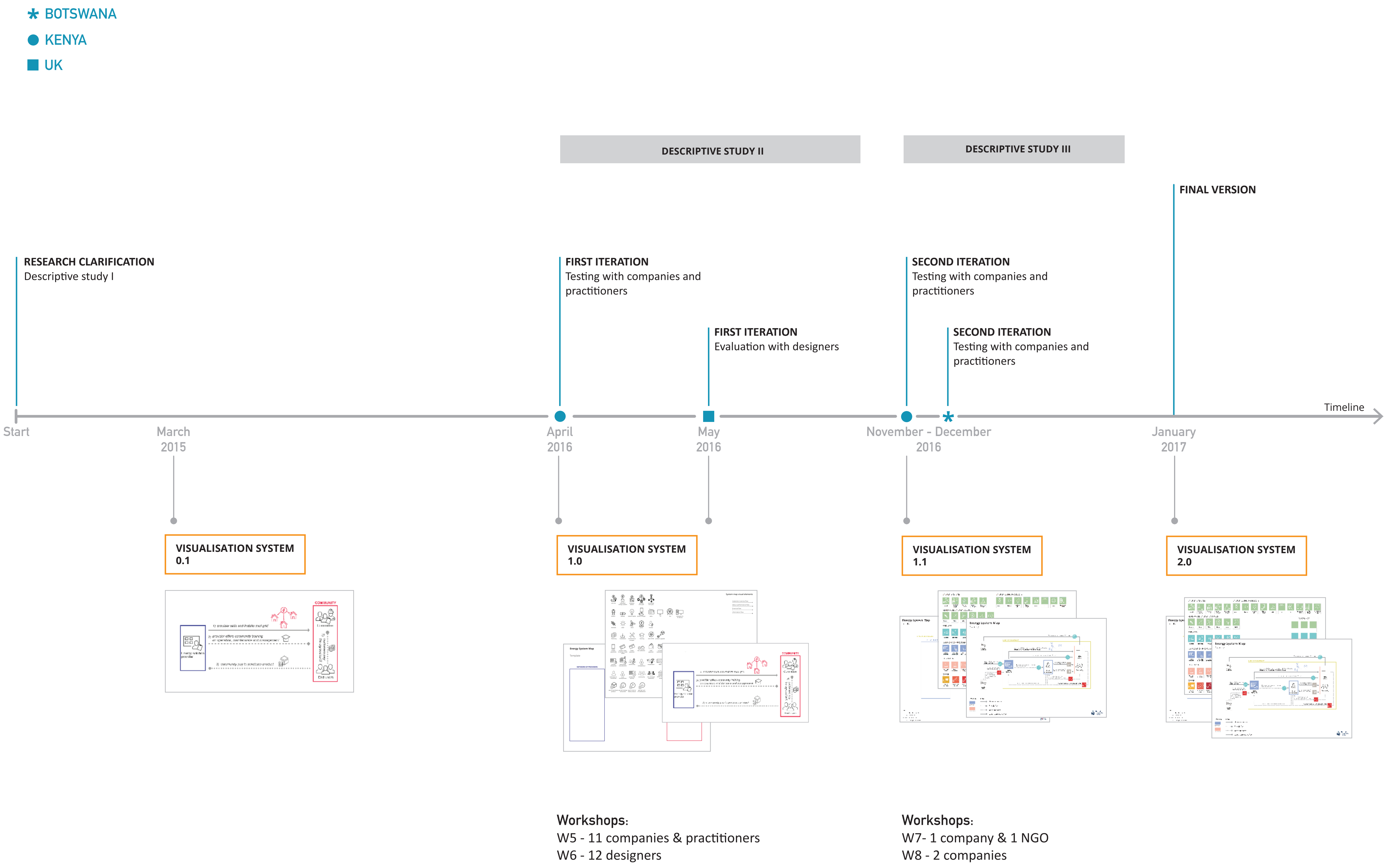


Fig. 7.3 - Visualisation System's development timeline

7.1 Introduction: the need for a new visualisation system for PSS applied to DRE

The literature review on tools for PSS design illustrated that several tools have been developed to visualise PSS models (see section 2.2.6.1). Available tools cover different phases of the design process, from the strategic analysis to the ideation and visualisation phase. These approaches are flexible enough to be adapted to various disciplines, however, they appear to be too generic for specific applications, such as the DRE field. In fact, due to the complexity of DRE models and to the specific requirements of BoP contexts, PSS tools such as the system map may need to be adapted.

The Stakeholders system map (Fig. 7.4), developed by Jégou et al. (2004) within the HiCS project, visualises actors involved in a PSS solution, their interactions and flows of goods, services and information. This tool can be applied in several phases of the design process, as it represents a map of how the system works. In particular, the system map can be used to visualise the socio-economic stakeholders involved in the PSS and their relations (in terms of material, financial and information flows). This tool is also helpful to support co-design and participatory processes as it can be used in teams. The system map presents the advantage of being general enough to be adapted to various contexts of applications and to various phases of the design process, however, in regards to the DRE field, some specific characteristics needed to be developed. When applied to PSS+DRE models, the system map needed to reflect all PSS+DRE design elements and their variables, as well as their relationships, in order to provide a visualisation system for these models.

The following section illustrate how the Stakeholders system map has been used to develop the Visualisation System for PSS+DRE, and how this can be used in the design process.

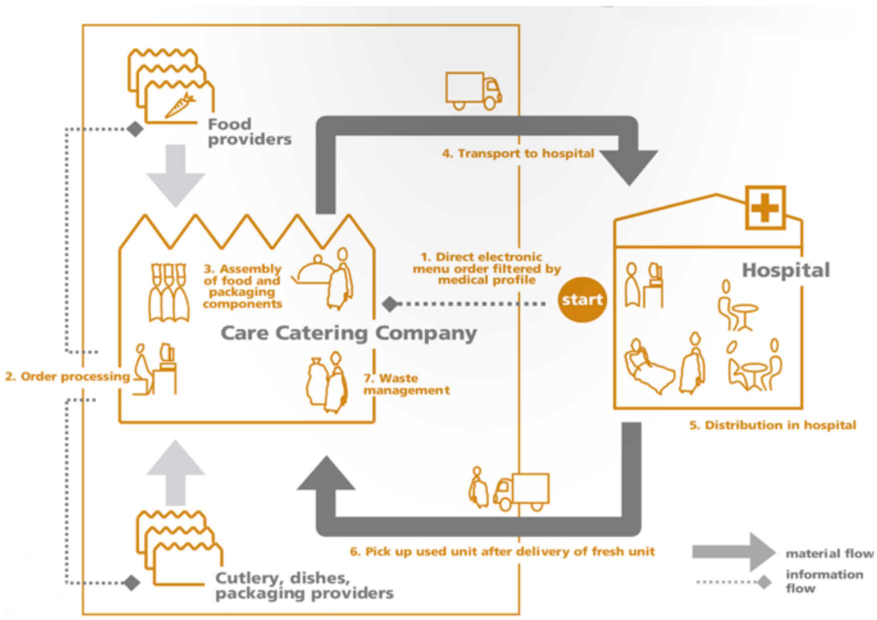


Figure 7.4 - System Map, Jégou et al. 2004

7.2 Prescriptive Study I: Visualisation System 0.1

The first version (0.1) of the Visualisation System has been developed on the basis of the outcomes of the DS-I, i.e. the identification of PSS+DRE characterising dimensions and variables.

The first step was the identification of *elements of PSS applied to DRE* (products, services, offer, customer, network of providers, payment channels) and their variables. Having described these in the first part of the research (section 4.5), each of those design elements was represented with an icon that is characterised by colour-coding and a short text describing the actor, product or activity (Fig. 7.5). Icons were developed for all variables (Fig. 7.6).

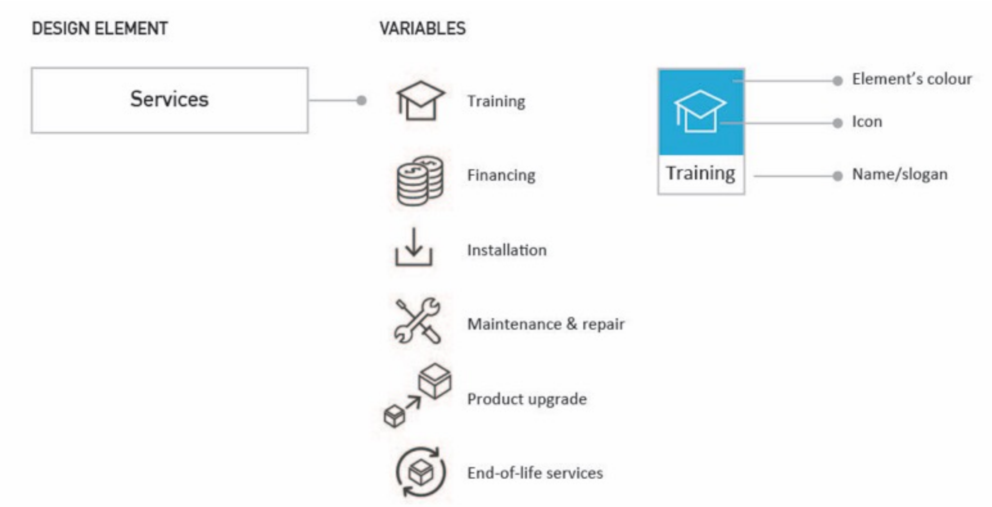


Figure 7.5 - Representation of design elements

Figure 7.6 - Icons developed for each design element

A first application of the new Visualisation System was to clarify Archetypal Models of PSS+DRE (Section 4.4) and to provide a visual representation of these models (Emili et al., 2016 (c)), in order to simplify their understanding (in terms of type of offer, products and services included, ownership, actors involved). For these reasons, the Visualisation System follows some specific rules (Fig. 7.7) that aim at standardising each PSS+DRE model (Fig. 7.8 and 7.9):

- The energy solution provider/s, which can include a single actor or a partnership of actors, is represented on the left hand side of the map and it is characterised by a purple colour.
- The customer is always placed on the right-hand side of the map and it is characterised by a red colour.
- Ownership of the energy system and energy-using products are described with corresponding colours and dotted lines.
- Flows of products and services are pictured in the top-middle part of the map, showing transactions between provider and customer. In order to facilitate the reading of the map, flows are ordered with progression numbers.
- Payments are described in the bottom of the map, showing what the customers pay for and what modalities/channels are used.

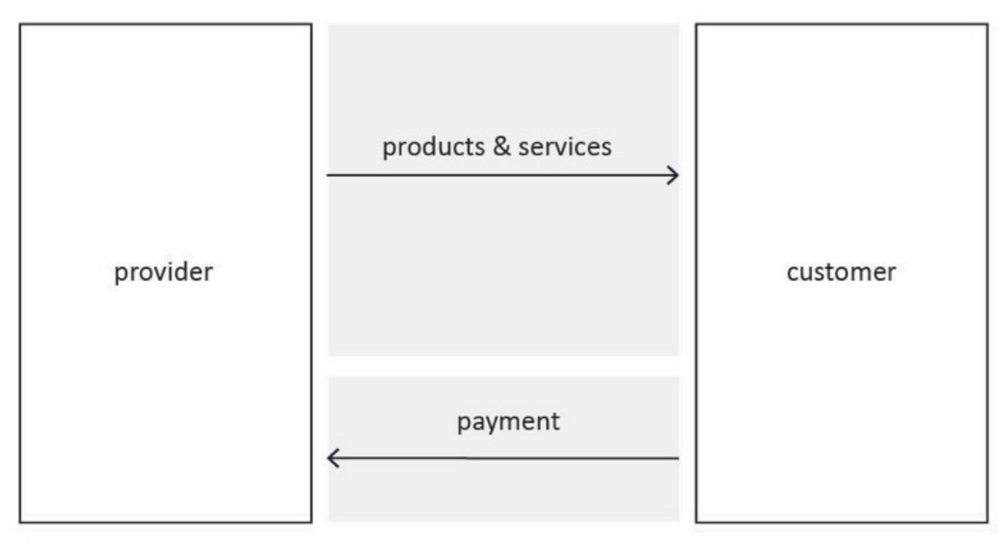


Figure 7.7 – An empty system map: rules of visualisation

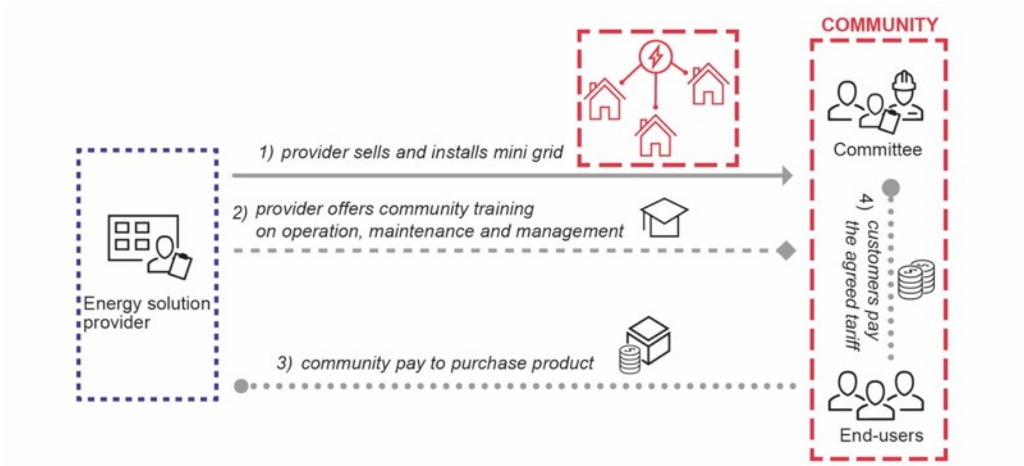


Figure 7.8 – First version of the energy system map developed for archetypal model 2

Figure 7.9 - System maps' legend: icons and flows

These visualisations of PSS+DRE models were presented with the Archetypal Models in the first studies of this PhD. First they were used in the pilot workshop with students in Botswana, then during the evaluation of the Innovation Map 0.1 with companies and experts (DS-II) (see Section 5.3.2). In particular, experts commended the usefulness of this Visualisation System for understanding and simplifying PSS+DRE models. Students, on the other hand, used the icons and set of rules to visualise their own concepts during the workshop at University of Botswana (Fig. 7.10). In order to use the Visualisation System as a support in the design process, it needed to be formalised as a design tool. The following section describes how the Visualisation System 0.1 was adapted to be used as a design tool in workshop sessions.

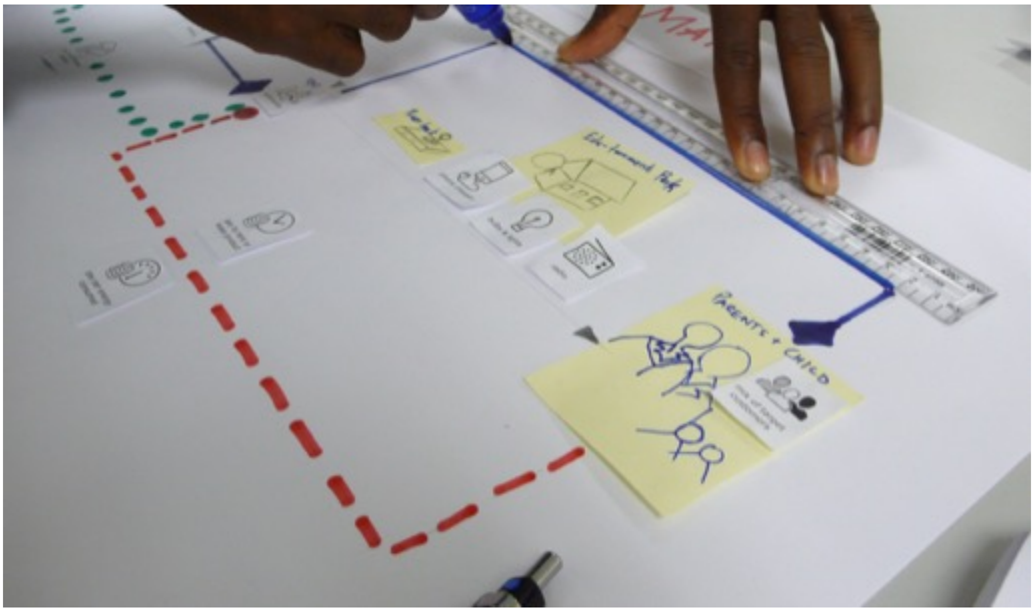


Figure 7.10 - A student visualising his concept following rules of the Visualisation System 0.1, Botswana

7.2.1 The Energy System Map: Visualisation System 1.0

The icons and rules developed for the Visualisation System were employed to design a tool that could support companies and practitioners in detailing and visualising PSS applied to DRE. For these reasons, a brief was prepared highlighting the following points:

- To develop a tool that **helps understanding models of PSS applied to DRE.** The tool would support the communication of these models by providing a set of icons and rules of visualisation which aim at simplifying these complex solutions.
- To develop a tool that **supports the visualisation and communication of PSS+DRE solutions.** In order to achieve this goal, the tool should be useful in co-design and participatory sessions and should enable users to design solutions with a high level of detail.
- The tool should be **flexible** enough **to be adopted in different phases of the design process**. It could be applied to visualise existing business models by identifying main stakeholders and their interactions. Then it could be used in later stages of the design process, for visualising a newly-designed PSS+DRE solution and to define in detail all stakeholders and flows.
- To develop a tool that can be **used by teams of people with a mix of expertise.** The tool should support users without a professional design background and without prior experience in using visualisation and design tools.

A first version of the tool, renamed Energy System Map, was designed to be used in workshops in a printed version. A set of icons was prepared on one sheet (Fig. 7.11), while a template (Fig. 7.12) was designed to include these icons and to draw corresponding flows among them.

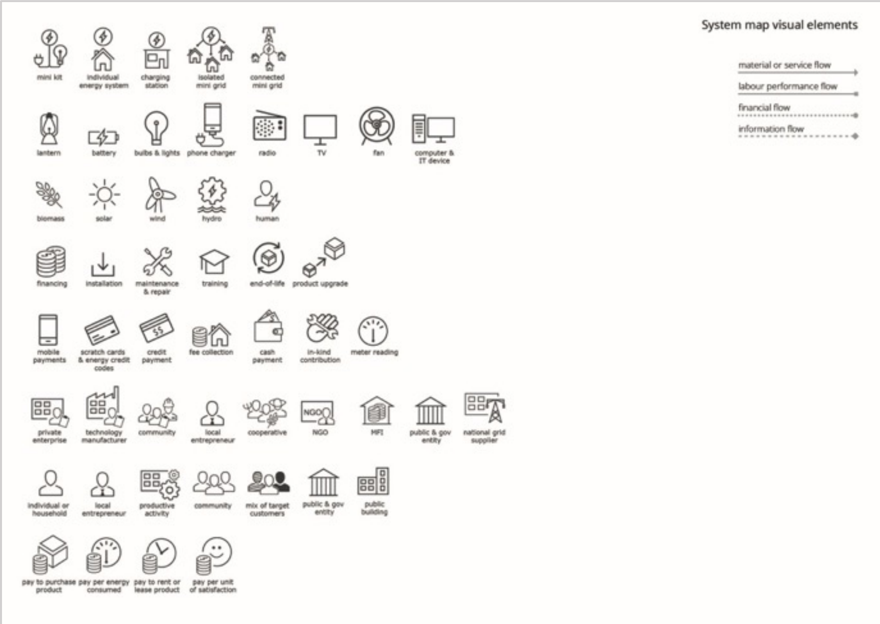


Figure 7.11 - Icons provided

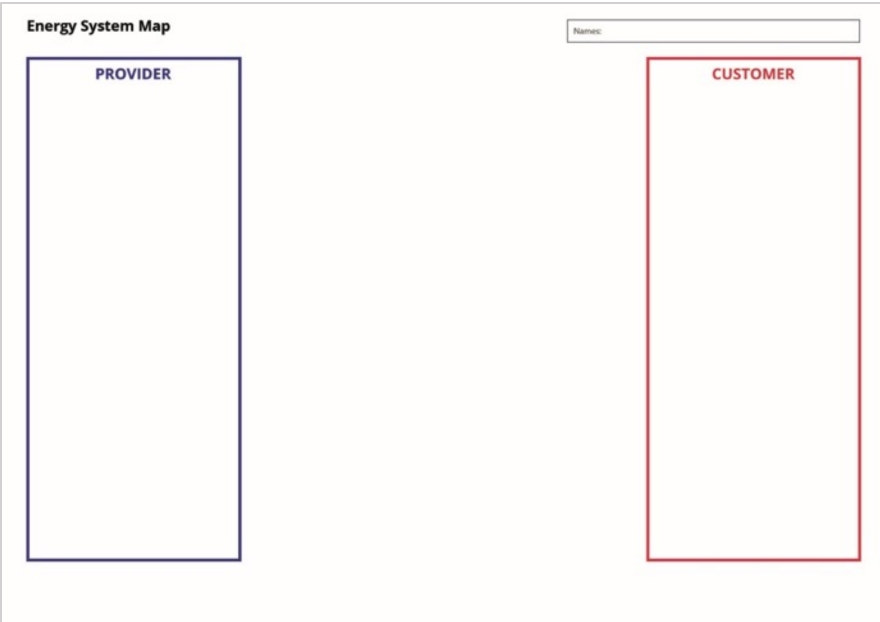


Figure 7.12 - Template for designing the Energy System Map

7.3 Descriptive Study II: testing activities in Kenya and UK

The Energy System Map (or Visualisation System 1.0) was empirically tested through a workshop with companies and practitioners in Kenya, in combination with the Innovation Map and Design Framework & Cards DS-III (see also sections 5.5 and 6.4). The testing activity took place in Nairobi during the LeNSes course, which involved eleven participants who used the tool for detailing their newly designed concepts of PSS+DRE. Participant observation and questionnaires were used to collect data in this study.

The DS-II includes also an evaluation of some aspects of the tool during the workshop with designers at Brunel University London (W6). Here the aim of the study was to rank the clearness of icons used in the Visualisation System. Data was collected through a questionnaire.

7.3.1 Workshop in Kenya

The workshop in Kenya, carried out in April 2016, was organised over four days of activities and engaged participants from local companies and consultancies involved in the renewable energy sector (Table 7.2). As described in sections 5.5.1 and 6.4.1, participants were selected through a partner organisation (KEREA).

Testing activities in Kenya (W5)		
Type of business	**Focus**	**Number of participants and position**
Consultancy (P13)	Energy access	1, HSE advisor
Consultancy (P14)	Energy (DRE design)	1, renewable energy engineer
Consultancy (P15)	Energy (DRE and business model)	1, consultant
Company (P16)	Solar systems: product-oriented	1, project engineer
SME (P17)	Cookstoves: product-oriented	1, director
NGO (P18)	Energy access and poverty alleviation	1, energy consultant
Company (P19)	Energy (renewable plants design)	1, chief engineer quality
SME (P20)	Energy/cookstoves: product-oriented	1, business unit director
SME (P21)	Training + cookstoves: product-oriented	1, managing director
Company (P22)	Solar systems: product-oriented	1, technical manager
Consultancy (P23)	Energy & women empowerment	1, consultant

Table 7.2 - Participants involved in Nairobi, DS-II

Participants worked in groups and they developed a new business concept of PSS applied to DRE using first the Innovation Map, then the Design Framework & Cards. Once the business model was defined, participants applied the Energy System Map tool for detailing and visualising their concepts. They were provided with a printed version of the tool (template + icons) and asked to design their own Energy System Map. At the end of the course they were asked to present their new business concept to the class and feedbacks was collected through questionnaires (Table 7.3). The workshop aimed at testing the clarity, ease of use and usefulness of the tool, as well as its completeness.

Rating: 1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT						
Questions	**1**	**2**	**3**	**4**	**5**	**Avg**
1. To what extent was the association of system map with the case study easy to be done?	-	-	18% (2)[24]	54% (6)	28% (3)	**4.0**
2. To what extent the system map helped you getting a better understanding of the case studies?	-	-	-	63% (7)	37% (4)	**4.3**
3. To what extent the system map helped you to clarify your final concept?	-	-	10% (1)	40% (4)	50% (5)	**4.0**
4. Would you use the system map to visualise your business concept in the future?	Yes: 9 No: 2					

Table 7.3 - Questionnaires' results from Nairobi, DS-II

7.3.1.1 Testing the clarity and ease of use

The first assumption was that the Visualisation System would help companies and practitioners in better understanding models of PSS and DRE compared to case studies described only with text. In fact, due to the high complexity of these models, the Energy System Map appears as an effective tool for clarifying the PSS offer, actors involved, ownership structure and payment modalities. In order to validate this hypothesis, participants were given a set of four case studies and four system maps and they were asked to match the right case with the corresponding system map. Cases were very similar to each other and presented differences in payment modalities, ownership structure or actors involved (example in Fig. 7.13 and 7.14). This session was carried out in about 15 minutes and, at the end of the exercise, all groups paired the cases with their relative system map correctly.

CASE STUDY 1

A company provides communities with mini grid systems that can be connected to the main electricity grid. The community becomes owner of the system and receives training in operation, maintenance and management of the mini grid. A community committee is responsible for collecting payments from households according to the agreed tariff.

Thanks to the grid-connected system, the committee is able to sell extra generated electricity to the national grid supplier.

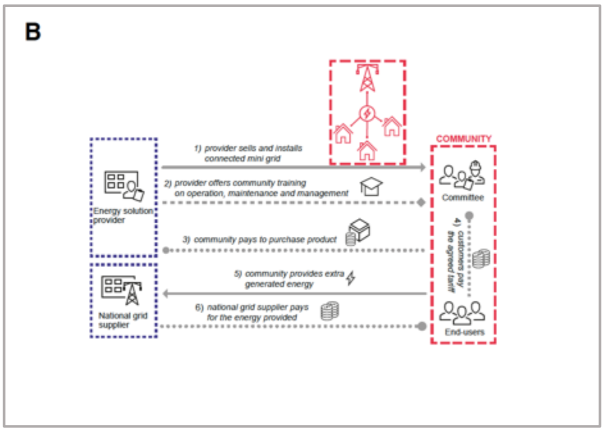


Figure 7.13 - An example of matching case description and system map

Participants were asked to rate the ease of this activity and most of them agreed that the exercise was easy to be done (average rating 4) and commented that it was "*clear to use*" (P22). This exercise helped to clarify the usefulness of Energy System Map for visualising and communicating PSS applied to DRE.

[24] Percentage of responses (number of respondents)

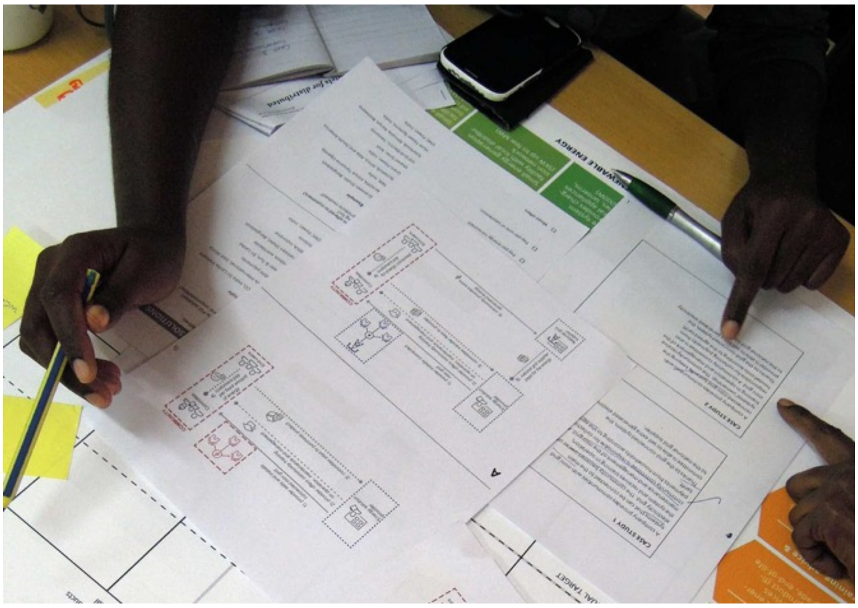


Figure 7.14 - Participant during the exercise of matching cases and system map

7.3.1.2 Testing the usefulness

1. Communicate case studies of PSS applied to DRE in a clear and effective way.

The first application of the Energy System Map is for visualising and communicating PSS applied to DRE in a simple and effective way. Participants were asked to rate the use of the tool for better understanding case studies and most of them (63%) rated 4=good and 5=very good (37%), highlighting that "*the system map gives you a visual picture of how the case study looks like. It gives you an overview of the whole business model*" (P20). Some particularly commended the fact that the tool gave a single visualisation of a complex model ("*it enabled visualisation of the entire business model in a single snapshot. Helped refine and define interrelationships between actors in a simple way*", P14) and that it helped clarifying relationships amongst actors and stakeholders ("*I can more clearly understand the important relationship and interrelationships between key stakeholders, products and services, value proposition and the customers*" P17; "*the system map clarifies synergies among player for each case study*", P15).

2. Design and detail new concepts of PSS applied to DRE.

In a second phase of the workshop, companies designed a new business concept and were asked to visualise their model using the Energy System Map. Participants were given the set of icons, the template and they were explained rules on how to describe flows and interactions. The activity, which lasted about two hours, resulted in a detailed PSS concept (see example Fig. 7.16).

In the evaluation session, participants rated the usefulness of the Energy System Map for clarifying business concepts with an average of 4.0 and most of them highlighted how the tool helped them in refining their concept ("*using the system map you are able to put together concepts or ideas that might be elusive during the brainstorming session*", P20). Furthermore, participants commented that the tool was helpful to clarify roles and relationships of stakeholders ("*[the system map is] a great deal on clarification of the concept*", P19; "*it helped in mapping the stakeholders and players*" P15; "*enables all actors to be given a role with clear relationships*", P14). Another participant highlighted that comparing case studies' maps with their own was useful in the concept generation ("*by comparing with other case studies system maps and understanding them it was easy to develop our final concept*", P16).

Most participants stated that they would use the tool for visualising their business concept in the future, however two participants responded negatively. They expressed their doubts in the usefulness of the tool, highlighting that "*it added more complexity*" (P14) and "*seemed too time consuming*" (P23). It was in fact observed that some groups struggled to use the tool in very complex concepts and when a high number of stakeholders was involved. This aspect may have influenced the perception of usefulness in the design process.

7.3.1.3 Design considerations

The workshop highlighted that the Energy System Map was not considered complete in terms of icons provided. Six participants suggested the need for more icons and these included hybrid sources, biofuels and biogas, icons for public institutions such as hospitals and schools, cookstoves. The aim of the tool was also to provide a framework for visualising PSS applied to DRE, however it cannot necessarily include all icons. On this aspect, P5 affirmed that the tool "*needs to have the flexibility to add other icons in a unique case*", while P4 stated that the Energy System Map "*it's good but over time can be refined*". In fact, suggestions for improvements included the creation of a software version (P22, P14) and this aspect has been implemented in the final version of the tool.

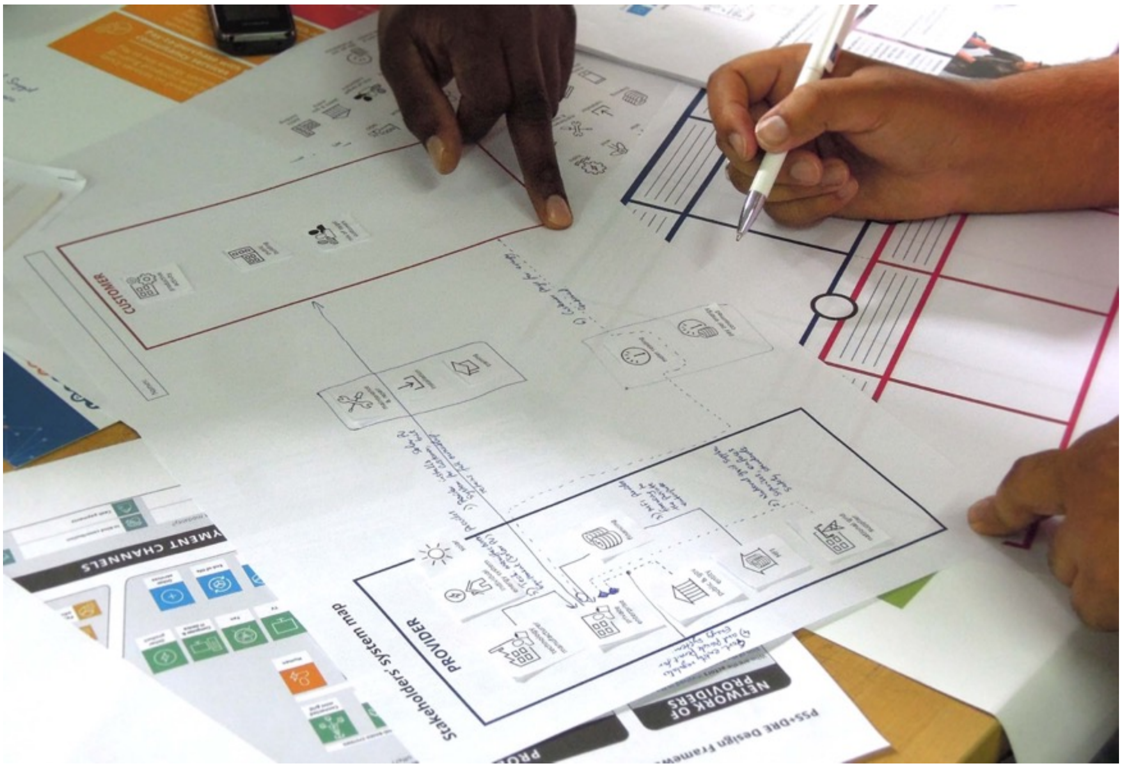


Figure 7.15 - Participants designing their system map

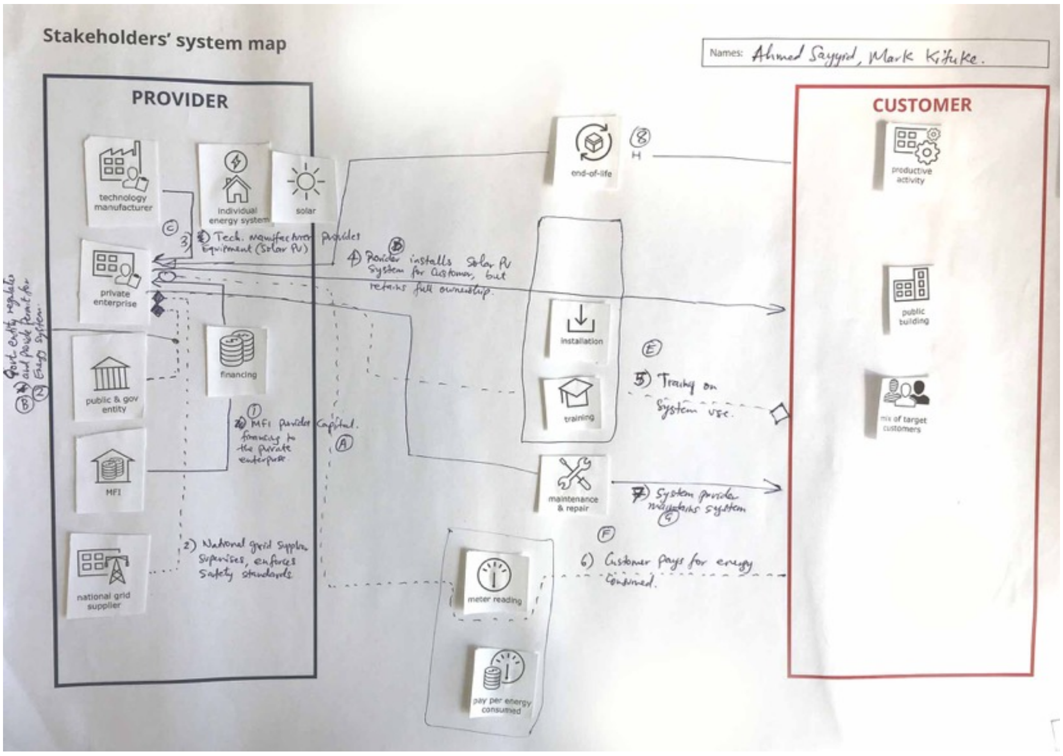


Figure 7.16 - An example of system map completed

Some interesting considerations emerged from the testing activities, not only in terms of graphic design improvements (such as icons) but also about the overall communication system and its use.

In particular, from the observations during the workshop and the feedbacks collected from participants, the following points can be considered:

- A set of rules and indications on how to design the Energy System Map should be provided in order to avoid first-time users to get confused about system barriers, types of flows etc. This aspect has been addressed in the next version of the tool.
- The use of 'provider' and 'customer' frames might limit the design process and system barriers were not clear in terms of which actors should be included within the frame. For example, some participants located 'government entities' in the providers' square even though their role was only to provide legislations and policy advice, therefore they should not be included in the main offer but only considered as secondary stakeholders. This aspect could be addressed by suggesting that main stakeholders need to be positioned within a "main offer barrier", while secondary actors should be visualised outside this area. This improvement has been considered in version 1.1 of the tool. Despite this modification, further developments could explore different ways of placing providers and customers. These considerations have not been covered within this PhD but they are discussed in regards to future research activities (see Chapter 9).
- In the current visualisation, flows of products and services are located in the upper-central space of the map. This created some confusion in more complicated systems, for example when a local entrepreneur is involved. Some design considerations should focus on whether the present structure is the best option for visualising PSS+DRE models or others should be explored. For the purpose of this PhD these considerations have not been developed, however they are discussed in future research activities (Chapter 9). It should be also mentioned that the Energy System Map was developed with the aim of being open source and available online for others to modify and improve. The final version of the tool was uploaded on a web platform (www.se4alldesigntoolkit.com) and on the LeNSes website (www.lenses.polimi.it).
- An assessment of icons and their clearness/effectiveness should be considered. This aspect was considered for the evaluation with designers (see next section).

The testing activities demonstrated that the Energy System Map can be used to clearly and effectively understand models of PSS and DRE and for (co)designing these types of business models. The feedback collected during the course in Nairobi helped to clarify needs for improvements of the tool and further testing activities with a wider range of companies and practitioners.

7.3.2 Evaluation with designers in the UK

After the workshop in Nairobi, a brief assessment of the Visualisation System' icons was undertaken. The icons were evaluated with designers during the workshop organised at Brunel University London in May 2016 (W6). As described in Section 6.5.2, this workshop principally aimed at evaluating the format, layout and usability of Design Framework & Cards 1.0, and additionally at rating clearness of the icons used in the Visualisation System. The study involved twelve participants including design researchers and master students selected initially following a purposive strategy but also involving convenience sampling to reach a certain number of participants.

Participants were provided with an updated list of icons, prepared from the feedback collected in Nairobi (Fig. 7.17). This included some additional icons such as computer & IT device in energy-using products, hybrid in renewable sources, public building and government entity amongst customers.

Figure 7.17 - Updated icons used in the workshop at Brunel University London

Participants were then given a document to rate the clearness of icons (Appendix III), and this assessment led to the identification of those that were not represented clearly. Ranging from 1=not clear to 5=very clear, those icons that scored lowest points (1 or 2) were considered for future improvements (Table 7.4).

Icon	Number of votes (1 or 2 rating)
Human power	4
Pay to purchase	4
Installation	4
Micro Finance Institution	4
Fee collection	4
Hybrid system	3
End-of-life	3
Charging station	3
Mini kit	3
Pay to lease or rent	3
Cooperative	2
NGO	2
Isolated mini grid	1
In-kind contribution	1
Local entrepreneur	1
Individual energy system	1
Cash payment	1
Pay per energy consumption	1

Table 7.4 - Ratings of icons

7.4 Prescriptive Study II: Visualisation System 1.1

A second version of the tool was then developed drawing conclusions from the data collected in DS-II. Main changes in this version included the following:

- Redesign and addition of some icons:

  - Energy systems: change of icons for mini kit, individual energy system, isolated mini grid, connected mini grid. Icons were changed to better describe different types of systems and their use, for example an individual system may also be applied on a large building and not only a household (it was not make explicit in the previous version).

  - Energy-using products: addition of cooling/heating device icon.

  - Services: (installation, financing, training). Icons were changed with the aim of representing services in a descriptive way, for example by describing 'training' with a book (in the previous version it was depicted with a graduation hat).

  - Offer: (pay to purchase). The icon was illustrated with a shopping cart (previous version was described with a package, which represented a product to be purchased).

- Payment channels (fee collection). Here again a more descriptive representation was chosen, describing fee collection through a hand holding coins.

- Change of colour-coding for each PSS+DRE design element (which matched Design Framework & Cards version 1.1).
- Change of template for designing the Energy System Map (Fig. 7.19): a framework for "main offer boundary" was added to distinguish main and secondary stakeholders, as for example illustrated in Fig. 7.20.
- Addition of a short guide to use the tool (fig. 7.21), explaining the set of rules to be followed.

Figure 7.18 - Icons developed in PS-II

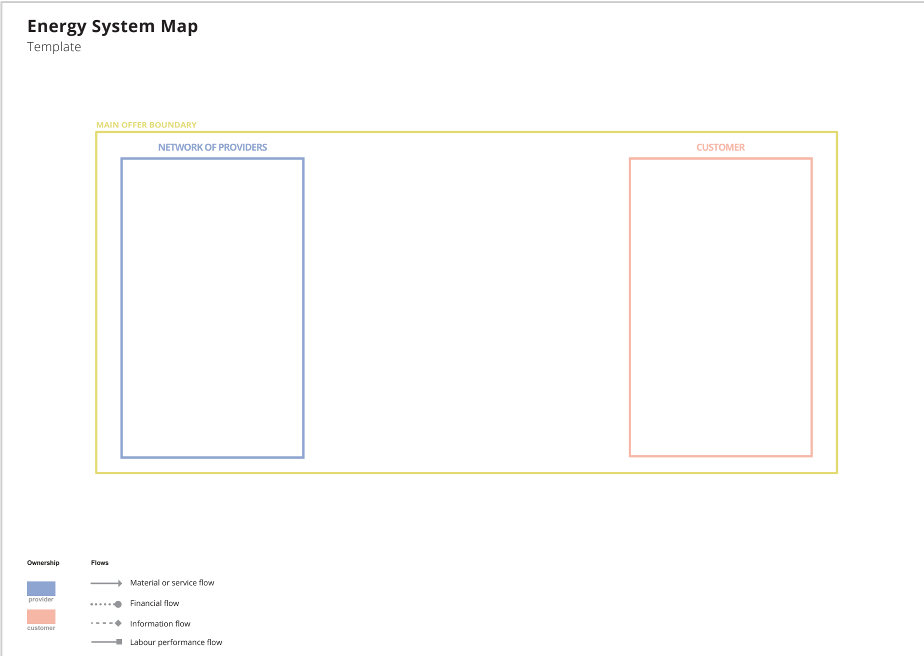


Figure 7.19 - Template for the map, PS-II

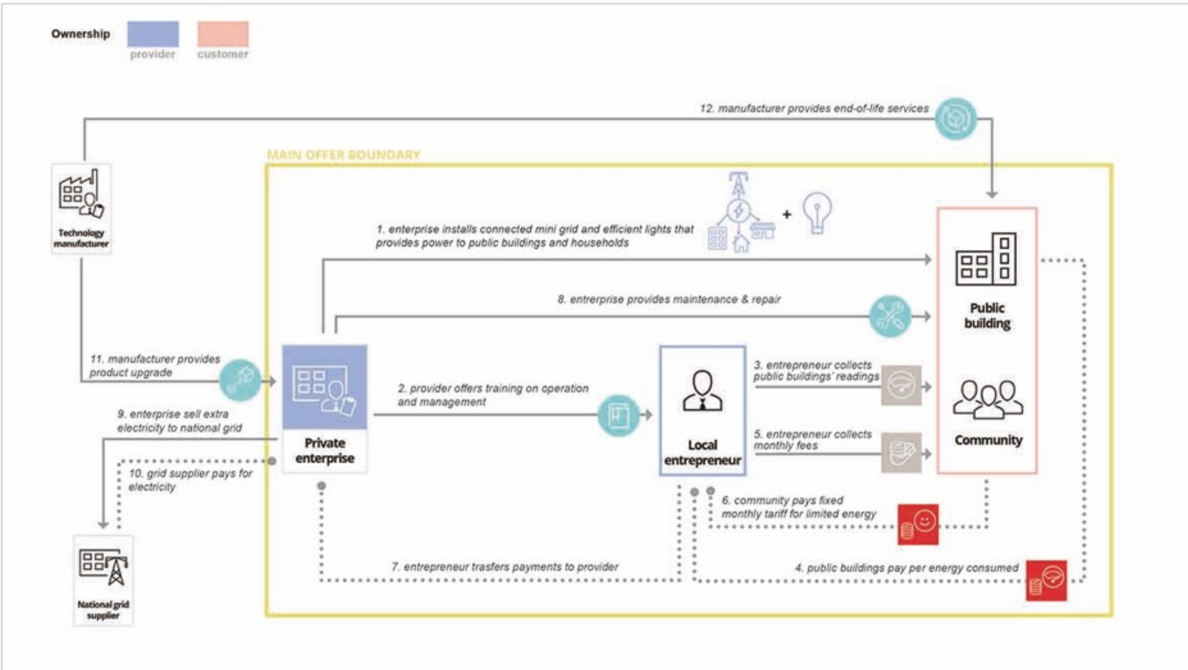
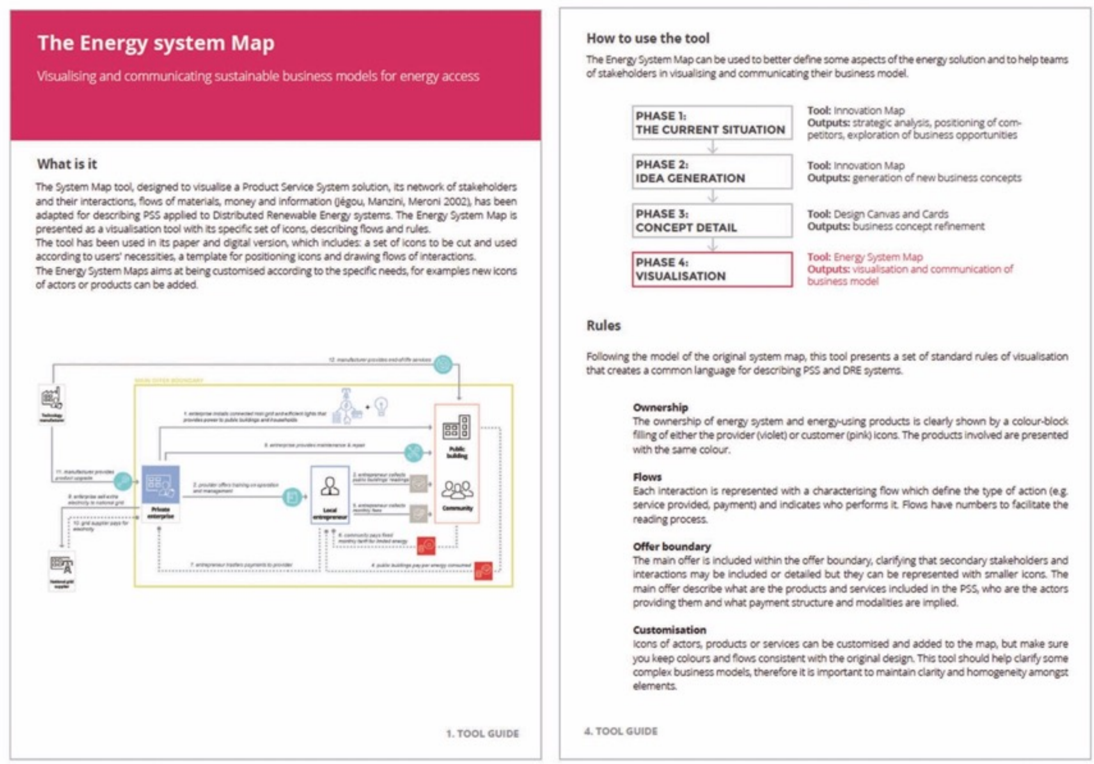


Figure 7.20 - An example of Visualisation System 1.1



The Energy system Map

Visualising and communicating sustainable business models for energy access

What is it

The System Map tool, designed to visualise a Product Service System solution, its network of stakeholders and their interactions, flows of materials, money and information (Jégou, Manzini, Meroni 2002), has been adapted for describing PSS applied to Distributed Renewable Energy systems. The Energy System Map is presented as a visualisation tool with its specific set of icons, describing flows and rules.
The tool has been used in its paper and digital version, which includes: a set of icons to be cut and used according to users' necessities, a template for positioning icons and drawing flows of interactions.
The Energy System Maps aims at being customised according to the specific needs, for examples new icons of actors or products can be added.

1. TOOL GUIDE

How to use the tool

The Energy System Map can be used to better define some aspects of the energy solution and to help teams of stakeholders in visualising and communicating their business model.

PHASE 1: THE CURRENT SITUATION	**Tool:** Innovation Map **Outputs:** strategic analysis, positioning of competitors, exploration of business opportunities
PHASE 2: IDEA GENERATION	**Tool:** Innovation Map **Outputs:** generation of new business concepts
PHASE 3: CONCEPT DETAIL	**Tool:** Design Canvas and Cards **Outputs:** business concept refinement
PHASE 4: VISUALISATION	**Tool:** Energy System Map **Outputs:** visualisation and communication of business model

Rules

Following the model of the original system map, this tool presents a set of standard rules of visualisation that creates a common language for describing PSS and DRE systems.

Ownership
The ownership of energy system and energy-using products is clearly shown by a colour-block filling of either the provider (violet) or customer (pink) icons. The products involved are presented with the same colour.

Flows
Each interaction is represented with a characterising flow which define the type of action (e.g. service provided, payment) and indicates who performs it. Flows have numbers to facilitate the reading process.

Offer boundary
The main offer is included within the offer boundary, clarifying that secondary stakeholders and interactions may be included or detailed but they can be represented with smaller icons. The main offer describe what are the products and services included in the PSS, who are the actors providing them and what payment structure and modalities are implied.

Customisation
Icons of actors, products or services can be customised and added to the map, but make sure you keep colours and flows consistent with the original design. This tool should help clarify some complex business models, therefore it is important to maintain clarity and homogeneity amongst elements.

4. TOOL GUIDE

Figure 7.21 - Guide for the use of the tool

7.5 Descriptive Study III: testing activities in Kenya and Botswana

The Visualisation System 1.0 was then applied in two workshops in Kenya and Botswana. These activities were organised as part of the EPSRC-funded project "Design and innovation tools to support SMEs in developing sustainable Product-Service Systems for energy access in African contexts". These workshops, described also in Sections 5.7 and 6.6, involved a small number or companies and practitioners (Table 7.5) and aimed at collecting qualitative data on the PSS+DRE tools. Questionnaires, participant observation and a discussion with participants were used to collect feedback.

Testing activities in Kenya and Botswana		
Type of business	**Focus**	**Number of participants and position**
Workshop at University of Nairobi (W7)		
NGO and consultancy (P1)	Energy access and poverty alleviation	1, energy management engineer
SME (P2)	Biomass: product-oriented	1, founder and CEO
Workshop at University of Botswana (W9)		
SME (P3)	Solar: product-oriented	1, DRE manager
SME (P4)	Biomass: product-oriented	1, technical advisor /managing partner

Table 7.5 - List of participants involved in DS-III

7.5.1 Description of activities

After a first introduction to the topic, participants were introduced to the Innovation Map and used the tool for mapping case studies, for positioning company's offers and competitors in the contexts, and for a first idea generation using the Concept Cards (see 5.7.2). The second day of the workshop focused on detailing the concepts generated using the Design Framework & Cards (see 6.6.1.2). In the third day, participants used the Visualisation System 1.1 to detail and visualise their concepts. They were provided with a printed version of the tool, including the template, set of icons and instructions with rules to follow (Fig. 7.22).

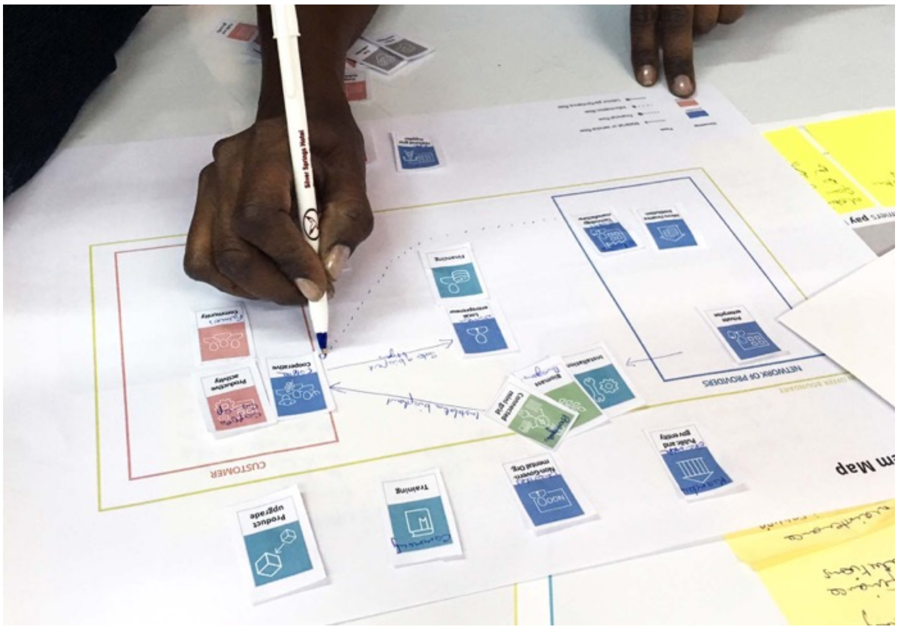


Figure 7.22 - A participant designing the Energy System Map in Nairobi

7.5.2 Data analysis

During the concept detailing, participant's observation was particularly helpful to highlight issues in using the tool. It was observed that some of them experienced initial difficulties with familiarising with the tool. However, once they understood how to work with the template and especially keeping the system map example as a reference, they easily designed their own Energy System Map ("*as time went by, it became more familiar*", P2). In Botswana, participants needed further clarification on differentiating the types of flow and in including the main providers within the template.

Participants were asked to rate the application of the Energy System Map to clarify their concepts (50% rated 4=good and 50% rated 5=very good) and they affirmed that "*it was very easy to clarify my initial concept*" (P2), that the "*map is very well thought out*" and "*clear enough*" (P1). In Botswana, participants stated that *"it makes you think of the financial side and to clarify payments"* (P3) and that "*help streamline ideas and define needs of the project versus the hopes/wants of where it is to be, thus helping to tackle things systematically and methodically"* (P4). All participants affirmed that they will use the tool in the future.

Some additional features have been suggested: to include an icon for distributors of products, to provide a bigger size canvas as a template and to possibly have a software version.

7.5.3 Discussion of results

Clearness and ease of use

Participants did not express any particular concerns in using the tool. However, by observing them during the workshop, some considerations have been made. The main difficulty emerged from using the template, which was too small (A3) for the exercise and not flexible enough to include all actors and flows among them. This resulted in 'crowded' and somehow confusing system maps (see Fig. 7.23-7.27). This aspect can be solved with larger templates (A2) and with a software version of the tool. On the other hand, participants often enquired on which stakeholders can be considered secondary and eventually which services may fall out of the 'main offer boundary'. This issue can be solved by integrating this information in the guide for using the tool.

It should be noted that the Energy System Maps generated during the workshops can be considered as work in progress and not as the final visualisation system. For example, the system map created by P1 during the workshop (Fig. 7.23) can be further improved (Fig. 7.24), resulting in a clearer visualisation.

Usefulness

During the workshop, P2 noted that the 'cooperative' icon was required as target customer, while P1 highlighted that suppliers/distributors icons was missing and that other products such as cook stoves should be integrated as energy-using products. In order to be exhaustive, the Energy System Map should provide icons describing all actors, products and services for PSS applied to DRE, however, this tool was developed to be flexible and adapted to each specific situation. Users should be able to create their own icons and to generate their own Energy System Map. For these reasons, a digital version may be useful where icons and elements can be easily added and positioned according to the specific needs.

Participants highlighted that the tool helped in clarifying their concepts, especially for payments (*"sort out how payment flows would work", P3).* One application of the system map is to visualise the PSS model in all its elements and interactions, but also to help detailing parts of the concepts that were not perhaps defined. This aspect was validated through the analysis of concepts generated with the Design Framework & Cards in the previous session (see 6.6.1.4). In was noted that a deeper level of detail was produced. This is visible, for example, in the work produced by P4, where clear relationships among stakeholders in the network of providers and clear flows of payments are shown (Fig. 7.25). Similarly, in the workshop in Kenya, both P1 and P2 clarified the flows and relationships among actors. For example, P2 highlighted which actor is 'paying per unit of satisfaction': a flow of mobile payments is visible from farmers to local entrepreneur (see Fig. 7.25) Similarly, P1 detailed that local women entrepreneurs lease solar products from Micro Finance Institution (Fig. 7.23). These aspects were not previously clarified using the Design Framework & Cards.

In conclusion, it can be affirmed that the Energy System Map has helped companies and practitioners in visualising their concepts and in better detailing their new solutions.

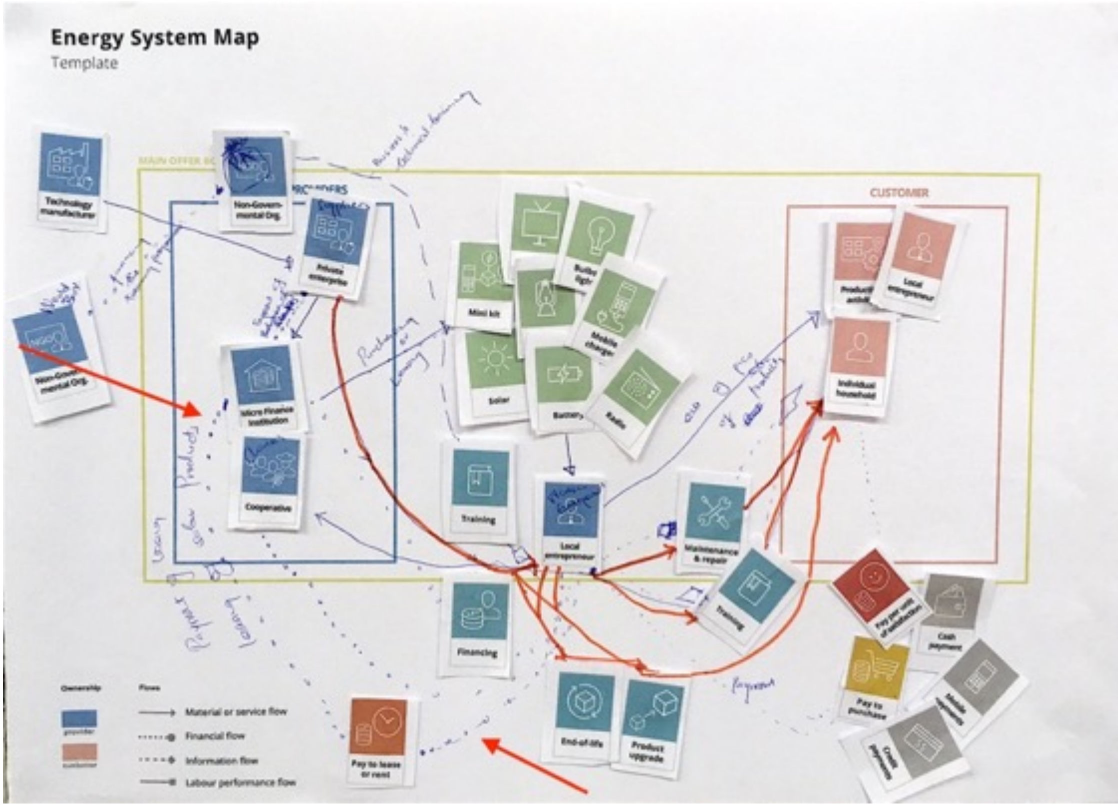


Figure 7.23 - Energy System Map, P1

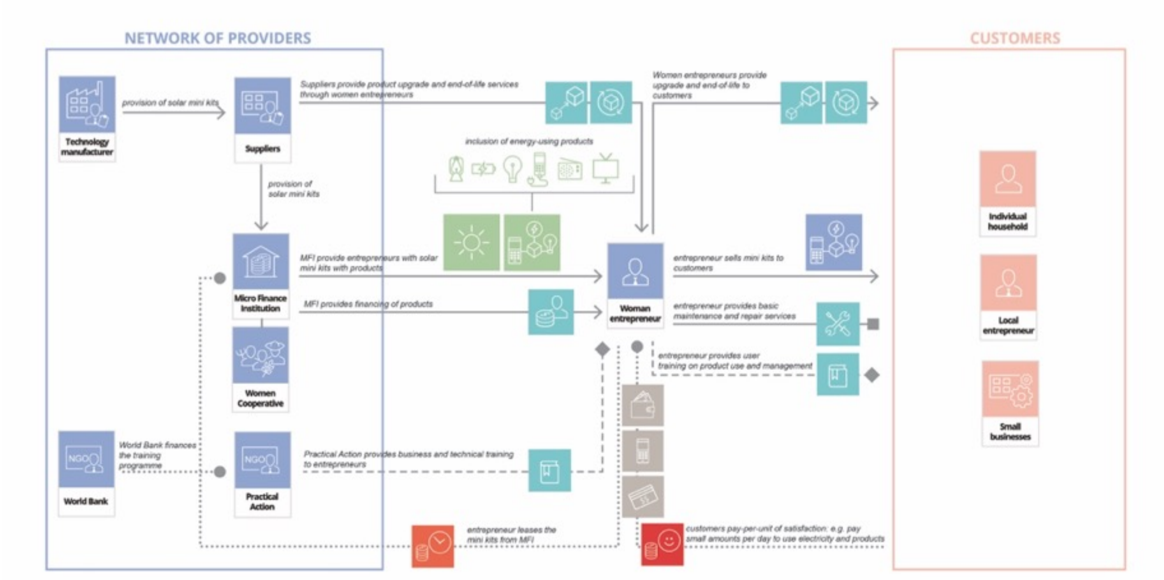


Figure 7.24 - Energy System Map designed by P1, prepared by the author

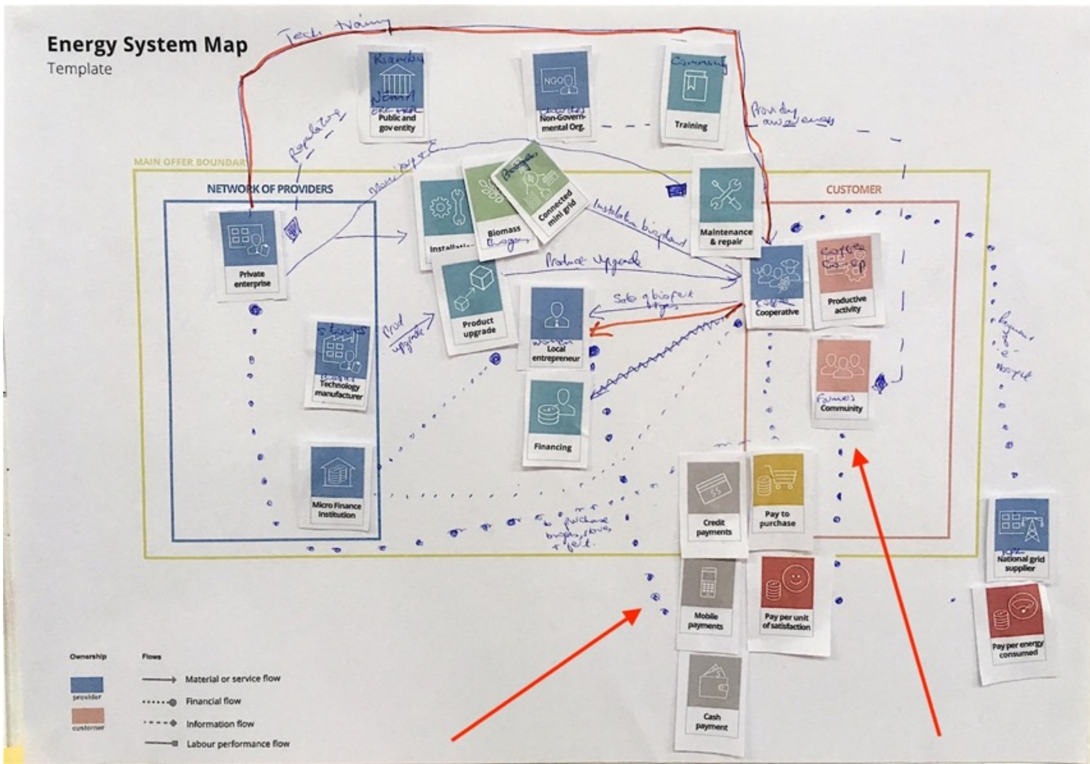


Figure 7.25 - Energy System Map, P2

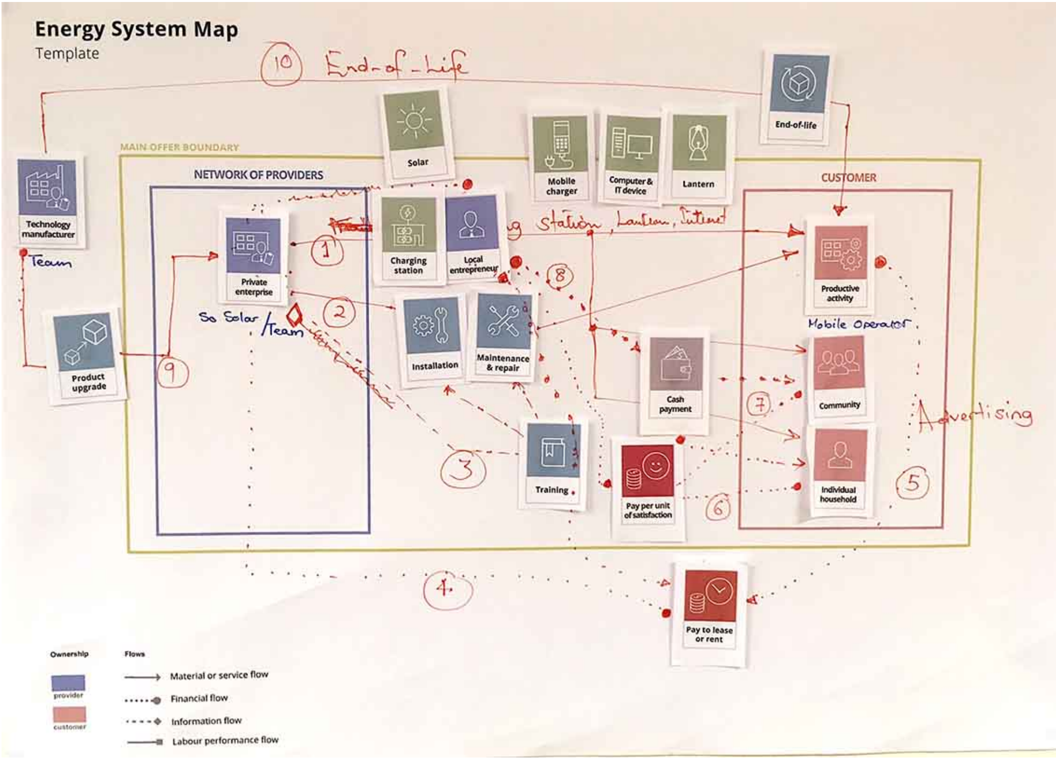


Figure 7.26 - Energy System Map, P3

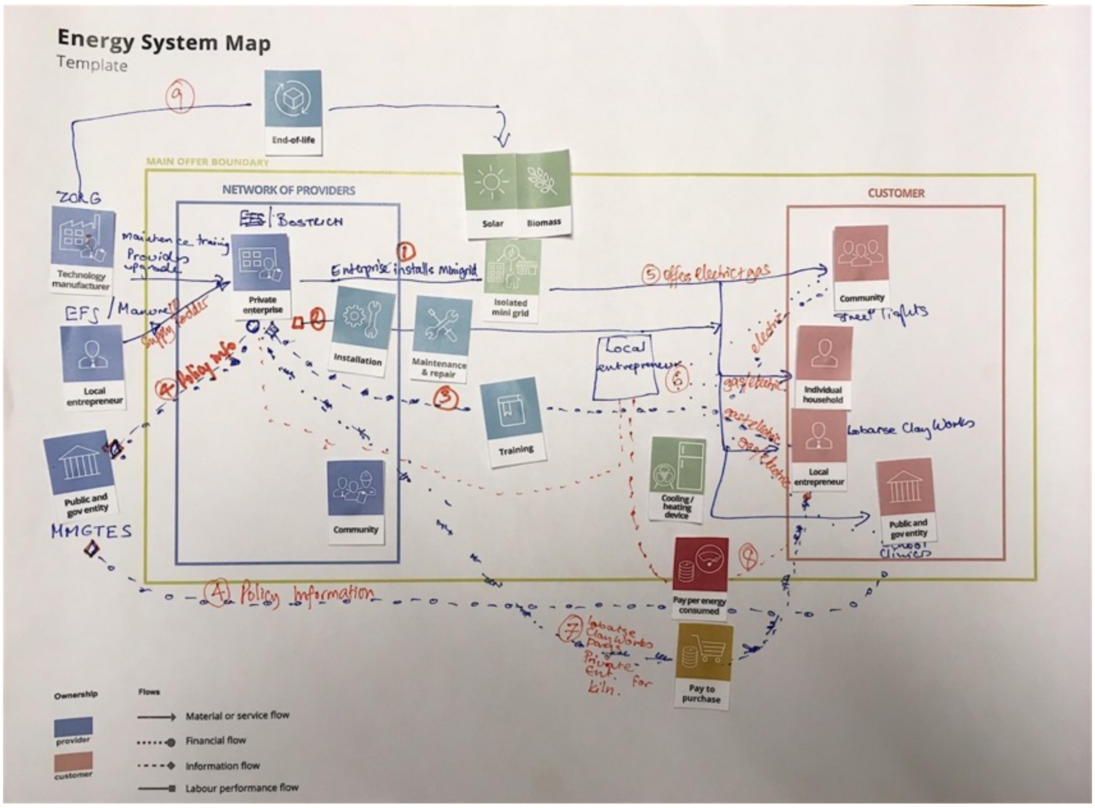


Figure 7.27 - Energy System Map, P4

7.6 Visualisation System final version

Drawing conclusions from the testing activities in Kenya and Botswana, the latest version of the Visualisation System was prepared. This version was developed in digital (PowerPoint) and printed version. The printed version included:

- A customisation section: blank icons for each design element were included to personalise and add customised elements in the Energy System Map (Fig. 7.26).
- A template for designing the system map was prepared in a bigger size A2.

The final version was also prepared in a digital form in PowerPoint, which allows users to add their own icons and position them on the template. This version was used in order to allow, in participatory processes, people with a non-professional design background to easily use the tool.

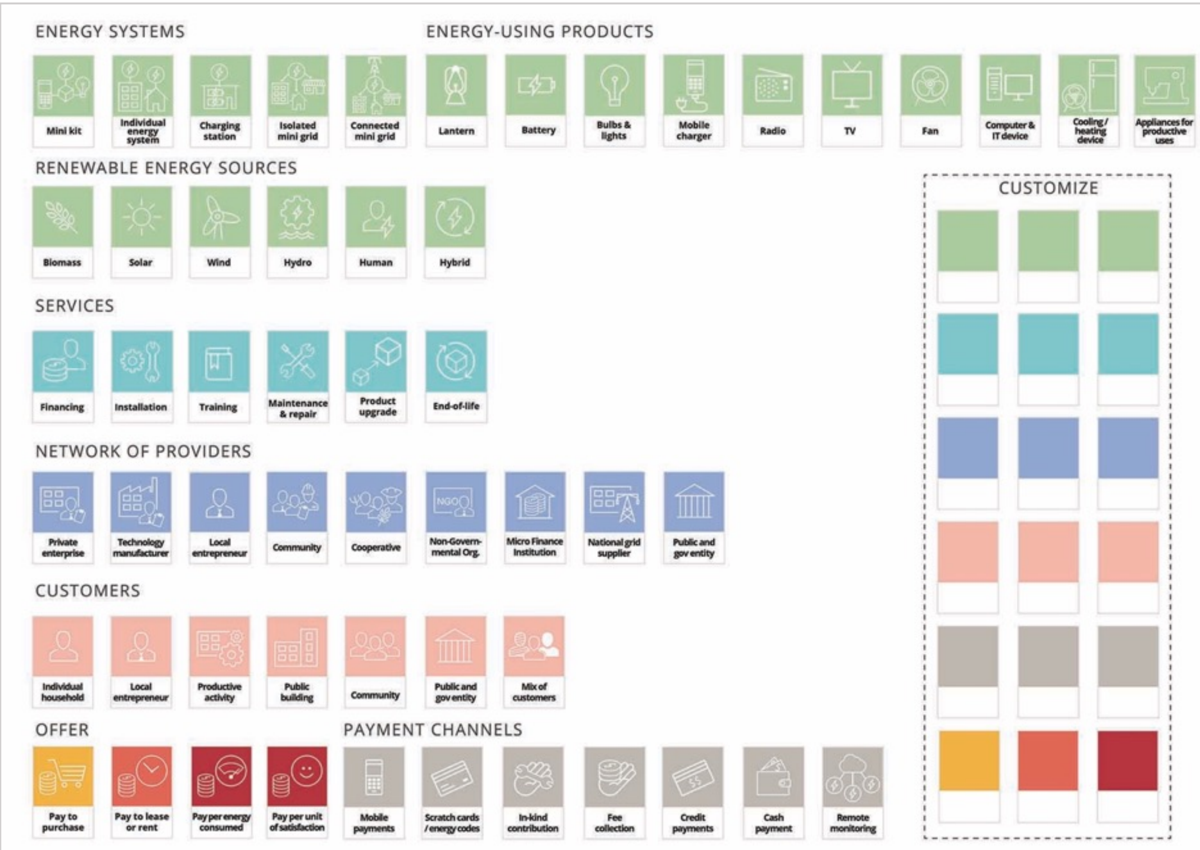


Figure 7.28 - Icons developed for Visualisation System final version (2.0)

7.7 Chapter summary

This chapter discussed the development and testing of the PSS+DRE Visualisation System. Starting from the outcomes of the first phase of this research, elements of PSS applied to DRE and their variables were illustrated through a set of icons. These were used firstly to described PSS+DRE

Archetypal Models, where a set of rules was set to standardise their description. The aim was to develop an appropriate visualisation system that would describe PSS+DRE models that would somehow facilitate their understanding and designing.

Later, the Visualisation System was employed as a design tool: the Energy System Map. This tool was tested and evaluated through workshops in Kenya and Botswana and its usefulness in the design process was demonstrated. A second round of designing (PS-II) and evaluating activities (DS-III) contributed to the refinement and testing of the Visualisation System, confirming the hypothesis that this tool can be used to describe PSS+DRE models and to support companies and practitioners in the visualisation and design process.

In summary, the Visualisation System of PSS+DRE has been presented as a third outcome of this PhD, which, combined with the other two strategic design tools, contributes to the creation of a toolkit for designing PSS+DRE solutions for BoP contexts.

Chapter 8

Discussion

8: Discussion

This chapter discusses additional findings emerging from the tools development and testing. Building upon the results obtained in the several testing activities (of all design tools), this chapters aims at making some considerations in terms of flexibility and adaptability of tools. In particular, this chapter discussed how different users (e.g. NGOs, SMEs) can apply the tools in their organisations.

8.1 The need to support companies and practitioners in designing PSS+DRE in BoP contexts

8.1.1 Needs and requirements for designing PSS applied to DRE

This research aimed at exploring the applications of PSS and DRE in BoP contexts and at developing tools to support the ideation process for these solutions. The literature review illustrated that the combination of PSS, DRE and design approaches for the BoP required academic research. In particular, previous approaches were limited to exploring selected dimensions (e.g. technology, type of offer) and to country-specific applications. Consequently, the review on design tools highlighted that existing approaches for PSS design, business models for DRE and design approaches for BoP-targeted solutions are not appropriate to encompasses all characteristics of PSS+DRE.

As discussed in Section 2.1.5, standard business models need to be modified to provide energy solutions in the BoP. Thus, it can be argued that business models tools are not appropriate to depict the complexity of DRE systems and the multi-dimensionality of PSS models. In addition, standard business models tools, such as the Business Model Canvas, do not include sustainability dimensions. On the other side, PSS literature is mature enough in regards to tools and methods for different fields of application. However, these appear to be limited when applied to DRE systems and when considering the complexity of BoP design projects.

The study with DRE companies and practitioners described in DS-I (see Section 4.6) provided additional supporting evidence that new tools were needed in this field. This study confirmed some of the literature's findings: existing tools are not widely adopted by practitioners and they present limitations, i.e. they do not include lessons learned in the past (critical factors) and case studies. Another point was provided by the lack of tools that can be applied in idea generation sessions. In fact, most DRE resources are in the form of manuals or books and do not fit for brainstorming.

In addition, needs and requirements for practitioners were outlined with this study, providing an understanding of how new tools may be adopted and used. For example, most companies look at competitors in the selected context to benchmark their offer and existing business models and DRE tools do not allow users to map competitors and classify types of offers. Another interesting insight

emerging from this study is related to how new tools may be applied in the design process and for which purposes. Interviewees responded that their offer was designed around a specific product, a target customers or in some cases looking at gaps in the market. This information, built upon the results from different testing activities, led to the identification of scenarios of applications of the toolkit (see 8.4).
In conclusion, this research has found that companies and practitioners need new tools for designing PSS applied to DRE in BoP contexts, and that these new tools should be flexible enough to be applied by users with different set of skills and for different purposes. These tools also needed to be relevant for different contexts and be applicable in idea generation sessions. Considering these requirements, this PhD aimed at filling the knowledge gap by providing three tools for designing PSS applied to DRE and by reflecting on the lessons learned in this process.

8.1.2 Filling the knowledge gap

While the three design tools represent the obvious outcome of this PhD in terms of practical contributions to the PSS+DRE field, this chapter discusses how the development and testing of the tools produced new knowledge. In particular, considerations can be made in regards to how the tools can be applied according to the identified purposes of applications and how they can be relevant to different contexts and types of users.
The literature review and the DS-I provided a clear picture of the knowledge gap present in this field and the need to produce new research. This aspect was addresses in the first part of the research by collecting case studies, critical factors and by developing a classification system for PSS applied to DRE. These findings constitute the theoretical contribution of this research in the field of PSS applied to DRE (see Section 9.2).
On the other side, the lack of tools and methods for designing these solutions was addressed in the second part of this PhD, by developing and testing three tools. The three tools fill the knowledge gap by providing a support for companies and practitioners that want to design PSS applied to DRE in BoP contexts. In particular, the tools support users in the idea generation and concept development phase of solutions for these markets. The Innovation Map enables the exploration of different types of PSS+DRE, their current applications (with Archetypal Models), and allows companies to map their offers and their competitors in a selected context. The tool also supports the idea generation of new solutions. The Design Framework and Cards supports the concept generation by visualising all elements of PSS+DRE and by providing guidelines and successful examples. The Energy System Map allows users to visualise and detail their concept and to communicate it within the team or other stakeholders.

The process of applying the tools and gathering data on their usefulness, usability and completeness, led to producing new insights in terms of design process for developing PSS+DRE solutions. For example, the feedback collected during the testing activities demonstrated that companies and practitioners have different approaches during the process: a company may want to start looking at competitors in the same context that provide a specific technology and then focus on detailing the new offer; an NGO may want to look into customers' needs and preferences and then design a solution around a specific energy demand. These insights helped drawing conclusions from the testing activities and at defining scenarios of applications of the toolkit. The following sections illustrate how the tools can be applied in a proposed design process and how this can be flexibly adapted to users' needs and requirements.

8.2 The Sustainable Energy for All Design Toolkit

Having discussed the design and evaluation of the three tools (Innovation Map, the Design Framework & Cards, the Energy System Map) in the respective chapters, here some considerations are made on the tools altogether. The three tools for designing sustainable PSS applied to DRE in BoP contexts constitute the *Sustainable Energy for All Design Toolkit*. The toolkit, named in line with the UN initiative Sustainable Energy for All[25], aims at supporting companies, NGOs, practitioners, consultants and strategic designers working in the renewable energy sector.

In addition to the three tools, a guide for their use was produced to lead users in their applications (Fig. 8.1). The need for a guide to the use of the toolkit emerged during the testing activities (see 6.5.2.3 and 6.6.2.1) and was produced to enable users to use the tools without training or introduction and to consequently facilitate dissemination amongst practitioners and companies. The structure of the guide is summarised here, while its content is discussed in the following sections.

- *Preface about the research background*: introduction on PSS applied to DRE, benefits emerging from combining these models and the purpose of having a guide for practitioners.
- *Introduction to the toolkit*: includes a short description of the three tools and how they can fit in a proposed design process (see 8.2).
- *Description of the tools*: a section that illustrates how each tool has been designed, how it works and how to apply it in the different phases of the design process.
- *Scenarios of use*: description of the toolkit applications with examples for different types of users: company / SMEs, consultant / designer / NGO, or academics/educators (see 8.3).

[25] Initiative promoted by the United Nations (SE4All, 2015), part of the Sustainable Development Goals (see Section 1.1)

The testing activities have demonstrated tools' usability, usefulness and completeness. In the following sections the applications of the three tools are discussed with a proposed design process, highlighting different scenarios of use and making consideration on their applications.

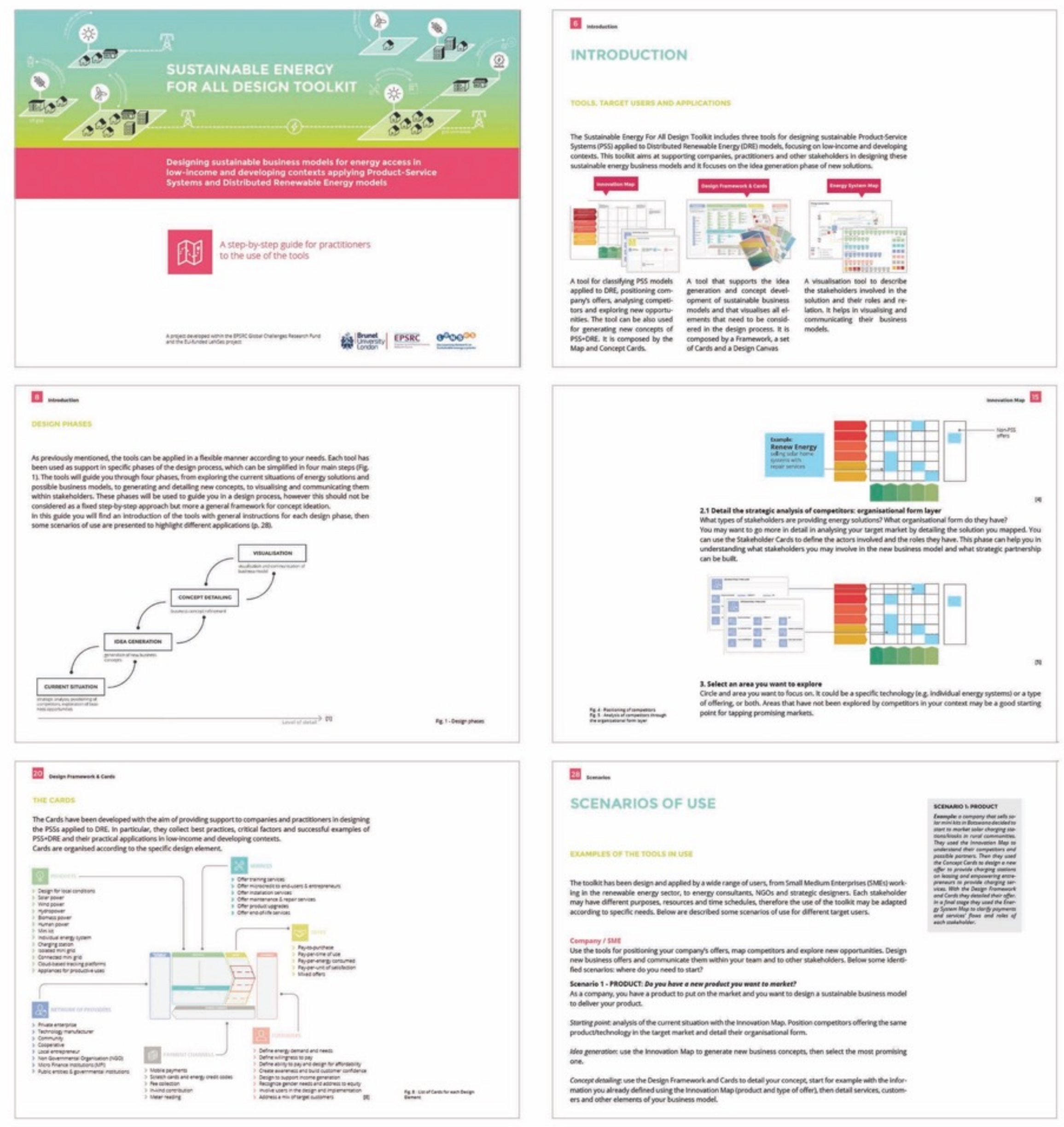


Figure 8.1 - Extracts from the guide to the use of the tools

8.3 A proposed design process

The PSS+DRE design tools were developed and tested with the purpose of being flexibly applied according to users' needs. However, in the several testing activities, the toolkit was applied following a proposed step-by-step approach. This design process evolved through the various activities with companies and practitioners. In fact, the data collected during workshops through participant observation and questionnaires contributed to the development of a step-by-step design process that would provide a structure for concept generation.

A suggested design process was applied in the first iteration of tools' testing, carried out through a pilot workshop with students at University of Botswana (described in 5.3.1 and 6.2.1). Users firstly used the Innovation Map to position existing cases of PSS applied to DRE and understand different types of PSS+DRE models. In a second phase, they used the Design Framework & Cards for idea generation, resulting in the creation of multiple concepts. These concepts were then mapped on the Innovation Map, with the purpose of exploring concepts' variations and selecting the most promising one. As discussed in Sections 5.3.1.2 and 6.2.1.3, by following this design process, users had difficulties in using the Innovation Map to explore concepts' variations and to select a final solution, failing also to choose most appropriate ideas generated with the Design Framework. Therefore, it has been argued that an inverted process would have been more effective. These conclusions led to develop new design features in the version 1.0 of the Innovation Map.

In the following iteration of testing activities, starting with the other two pilots in Botswana (see Section 6.2.2) and later with the workshops organised in South Africa and Kenya as part of DS-III, a refined design process was adopted. In these workshops the proposed design process was structured as follows: first the Innovation Map was applied to explore PSS+DRE models, map companies and competitors, explore areas for opportunities and then generate new concepts. Then, a selected concept was refined using the Design Framework and Cards, which supported a detailed idea generation. Lastly, the Energy System Map was used to visualise the new solution. This design process was considered appropriate especially for first time users and companies or practitioners that were not familiar with the concepts of PSS applied to DRE in BoP contexts or with the design toolkit. As most companies affirmed in DS-I, the starting point for designing a business model is often inspired by competitors operating in the same market. This aspect was covered through the first phase of the design process, which enabled users to get a deep understanding of PSS+DRE models, visualising competitors, opportunities for innovation and generating concepts based on their understanding of the energy scenario. In a second stage, they were able to detail each aspect of the new solution and to visualise it.

During PS-III, a further test with designers at Brunel University London (see 6.5.2) helped clarifying issues about the adopted design process and particularly regarding the composition of the Design Framework & Cards for supporting idea generation activities. Participants involved in the study had no background in PSS or DRE and they were provided with a short amount of time for familiarising with the tools. For this reason, the discussion about the design process and especially for first-time users led to the identification of issues related to navigation. Suggestions for improvements included the provision of a structured step-by-step approach that could guide users through the idea generation process.

For this reason, the following development of the tools included introductory cards and a step-by-step final design process. This was applied in DS-IV in Kenya and Botswana and distinguishes four main steps for applying the toolkit (Fig. 8.2). These phases can be carried out in an iterative way.

1. **Current situation**. Analyse the energy context, the companies operating and their offers, the actors providing energy solutions in a specific area, the technologies adopted. In this phase the aim is to draw a picture of the existing energy scenario for a specific context or a selection of geographical areas.

   Tool: Innovation Map

   Output: strategic analysis, positioning of competitors, exploration of business opportunities
2. **Idea generation**. Generate new sustainable business models by defining type of offer, actors involved, target customer, products and services offered, payment modalities. In this phase the aim is to brainstorm new concepts and select the most promising ones.

   Tool: Innovation Map

   Output: generation of new business concepts
3. **Concept detailing**. Refine the selected business offer by following design guidelines, tips and getting inspiration by successful cases. Detail all aspects of the new sustainable PSS. In this phase the aim is to generate a detailed energy solution, inclusive of all design elements.

   Tool: Design Framework and Cards

   Output: business concept refinement
4. **Visualisation**. Visualise and detail the PSS concept by mapping stakeholders and their interactions, flows of goods, services and financial transactions. This phase can be carried out at the end of the design process, for detailing a new concept, or during the design phase, for analysing existing models and detailing processes and interactions.

   Tool: Energy System Map

   Output: visualisation and communication of a business model.

The proposed design process represents a way to use the toolkit for generating new PSS applied to DRE starting from scratch and it is particularly useful for users that want to design a new business model. However, this process does not represent all possible applications of the tools. Some considerations can be made in terms of type of users and the different needs they may have when applying the toolkit.

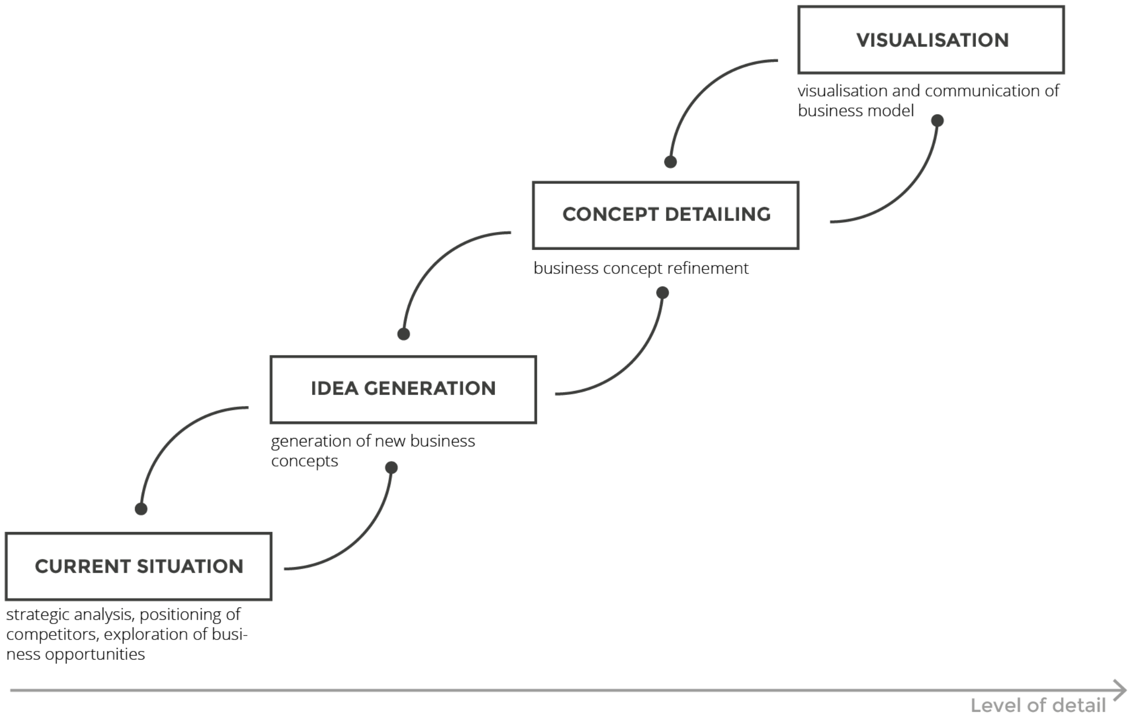


Figure 8.2 - the proposed design process for Sustainable Energy for All Design Toolkit

8.4 Scenarios of applications of the toolkit

The tools were designed to be applied by different type of users, such as companies/SMEs working in the renewable energy sector, energy consultants, NGOs and strategic designers. The testing activities led to the identification of some scenarios of use according to different type of users.

8.4.1 Needs of target users and purposes of applications of the toolkit

Drawing conclusions from the different types of participants involved in this research, both in the exploratory study in DS-I and in the tools' testing activities, three main types of users can be defined to describe different purposes and needs for using the toolkit.

- **Company/SME**
  Purposes: to position the company's offer(s), to map competitors in a selected market, for example focusing on a selected technology or on a type of target customer. To explore new business opportunities, with the aim of designing new offers or re-orient and refine existing models.
- **Consultant / Designer / NGO**
  Purposes: to map companies/projects in a selected context or targeting a specific customer base. To identify key stakeholders and their roles, types of PSS models and to identify opportunities. Differently from a company, a consultant, NGO or designer could use the tools

without a specific product in mind but for example by looking at providing energy solutions in a selected context. This type of user can aim at designing a new offer or refining an existing one.

- **Academics and educators**

  Purposes: to use the tools to teach about PSS applied to DRE models, facilitating the understanding of models applied and their characteristics. To support students in developing their practical projects.

8.4.2 Scenarios of applications

Different target users may apply the toolkit in different ways, according to the purpose of application. Drawing conclusions from how participants used the tools in the testing activities and from the feedback collected during the various Descriptive Studies, the toolkit can be used for the following purposes:

Start-up: the Sustainable Energy for All Design Toolkit can be used in early stages of a project/business design. In the interviews and questionnaires with DRE companies (DS-I) various starting points for a new venture or project were identified (see 4.6.2). An example is to design a new business by establishing the target users and designing a solution starting from a specific customer's need. Another option is to look at stakeholders involved in the selected context and then generating a new offer based on gaps in the market. Other companies have a product to market and design a business model based on the specific technology.

> *An example from the testing activities*: this application has been commended by companies participating in the DS-IV in Botswana and Kenya, where most participants used the tools to design a whole new business model (see 5.7.1 and 6.6.1). P3, a Botswanan SME that sells solar products, used the Innovation Map to define the area of intervention and design three new offers, which were then detailed through the Design Framework & Cards and the Energy System Map. P3 affirmed that "*once you see where your position is in the market as well as your competitors, you are able to take advantage of opportunities not being explored*" and that "*I found the tools very useful to start a business*".

Refine and re-orient: another way to apply the toolkit is for supporting companies and practitioners in focusing on specific aspects of a business model or project. The study in DS-I (see 4.6) highlighted that companies modify their business offer for different reasons: a change or upgrade of technology, changes in the market conditions or in customers' preferences. According to these results, it can be affirmed that the tools can be used for a specific need to re-design or re-orient an existing solution, therefore starting from the identified driver (e.g. customer's needs) and designing a new offer around it.

Another option is to use the tools, and especially the Design Framework & Cards, to generate ideas on a specific aspect of the business model, such as payment modality or services. In this way only some elements can be refined (*"it helps to focus on specific ideas*" P1, DS-IV).

> *An example from the testing activities*: a solar company from South Africa (DS-III) sells solar individual energy systems to large commercial customers, providing some services such as installation, training on product use, energy management and consultancy services. They aimed at exploring new business opportunities for their existing customer base and at extending product offer towards mini grids, adopting new payment structures. The company concluded the workshop by designing a new result-oriented PSS, offering energy services on a pay-per-consumption basis. Their new business model included the use of a new technology, connected mini grids, and a new configuration of stakeholders, involving manufacturer and local service providers.
>
> In addition, the use of the toolkit supported innovation by enabling the design of solutions that were not provided in the chosen context, therefore enhancing competitiveness of companies adopting the PSS+DRE approach.

Review or monitor solutions: similarly to the previous application, the tools can be used with the purpose of analysing and refining models. For example, existing business models can be mapped amongst competitors in the market (Innovation Map) and then detailed on a Design Canvas to understand whether some areas have not been defined. Another option is to use the toolkit to review concepts after some time from their ideation, in order to understand whether changes need to be made or to evaluate success/failure factors. Despite not having been practically applied in the testing activities, this application of the tools has been highlighted by some participants and during experts' interviews (*"[use] to continuously evaluate my model and identifying opportunities*" P17, DS-III; "*to review when you have your ideas and the looking at it again in 6 months or two years-time*" P3, DS-IV; "*for the review and monitoring phase and you can just concentrate on one aspect*" E3, DS-IV).

Inspiration mode: the tools can be used in inspiration mode, for example by mapping Archetypal Models on the Innovation Map and looking at which PSS types have been implemented, or by browsing the Cards to get inspiration from the case studies or the guidelines.

This application has not been implemented during the tools' testing activities, however interviews with experts in DS-IV (see 6.6.2.1) highlighted how the Design Framework & Cards can be used as "*a discussion template*" (E8) and "*for product brainstorming*" (E3). In addition, over the different testing activities, participants have affirmed that case studies and examples were a great source of inspiration (“*the examples have been very inspiring*” P4, DS-III).

The following section illustrates some scenarios of implementation of the toolkit according to the three types of target users. Each scenario is described according the four phases of the proposed design process.

8.4.2.1 Applications for company / SME

A company can use the tools for positioning their offers, mapping competitors and exploring new opportunities. A company can design new business offers and communicate them within their team and to other stakeholders. Four scenarios have been identified and discussed below.

<u>Scenario 1 - PRODUCT: Do you have a new product you want to market?</u>

As emerged in the primary study with DRE companies (DS-I), most respondents affirmed that their business model was designed around a product they wanted to offer. For example, a company has a new product to market and they want to design a sustainable business model to deliver their product.

Starting point: analysis of the current situation with the Innovation Map. Positioning of competitors offering the same product/technology in the target market and detailing of their organisational form.

Idea generation: use of the Innovation Map to generate new business concepts, then selection of the most promising one.

Concept detailing: use of the Design Framework and Cards to detail the new concept, starting for example, with the information already defined through the Innovation Map (product and type of offer), then detailing services, customers and other elements of their business model.

Visualisation: use of the Energy System Map to clarify roles and responsibilities of each stakeholder, flows of goods, information and money.

> **Example**: as described in the “start-up” applications, a company that sells solar products in Botswana decided to market solar charging stations/kiosk in rural communities (DS-IV). They used the Innovation Map to understand their competitors and possible partners. Then, they used the Concept Cards to design a new offer to provide charging stations on leasing and

empowering local entrepreneurs to provide charging services. With the Design Framework and Cards they detailed this offer, clarifying payments and services' flows with the Energy System Map.

Scenario 2 - CONTEXT: Do you want to expand/operate in a new context or geographic area?

A company that wants to provide services in a new geographic area, where they need to define appropriate product-service offer, customer segment etc.

Starting point: analysis of the current situation with the Innovation Map. Positioning all competitors operating in the chosen context, ranging from different technology options and different customer segments. Selection of an area on the map to explore, for example, a specific technology (isolated mini grid) or a type of offer (renting models).

Idea generation: use of the Innovation Map to generate new business concepts, then selection of the most promising one.

Concept detailing: use of the Design Framework and Cards to detail the new concept, starting for example, with the characteristics of target customers, matching appropriate combination of energy system and energy-using products according to the context specifications. Detailing of services provided and stakeholders responsible, then concluding with the payment structure and payment channels.

Visualisation: use of the Energy System Map to clarify roles and responsibilities of each stakeholder, flows of goods, information and money.

Example: a company from Kenya (DS-III) used the toolkit to expand its area of intervention to rural refugees' camps in Kenya. They first used the Innovation Map to explore competitors offering energy services in the determined geographic area (e.g. kerosene, charcoal and diesel distributors). Then they designed a new offer by matching the appropriate energy system and products (clean cookstoves, ethanol fuels and cooking kiosks) with specific customer's needs and habits (e.g. need for employment and training, women's roles, community cooking in the camp). They then proceeded with detailing services included in the offer (e.g. training, repair of spare parts) and a network of stakeholders to provide these solutions (e.g. manufacturers, Micro Finance Institution, UNHCR and partners). In a final stage they clarify and visualise their new concepts with the Energy System Map.

Scenario 3 - CUSTOMER: Do you want to reach a new customer base?

A company wants to provide their products and services to a new target customer, for example, a rural community or urban slums.

Starting point: analysis of the current situation with the Innovation Map. Positioning all competitors targeting the same type of customers they want to include in their offer. Selection of an area on the map to consider, for example, using a specific technology (isolated mini grid) or a type of offer (renting models), or both.

Idea generation: use of the Innovation Map to generate new business concepts, then selection the most promising one.

Concept detailing: use of the Design Framework and Cards to detail the concept, starting for example, with the characteristics of target customers, then detailing the type of offer, payment structure and modalities. Continue by matching technology option and services provided to conclude with the network of stakeholders.

Visualisation: use of the Energy System Map to clarify roles and responsibilities of each stakeholder, flows of goods, information and money.

Example: as described in the "refine and re-orient" application, a South African SME used the tools to focus on their existing customer base

Scenario 4: INSPIRATION: get insights and suggestions for your business. Do you want to introduce a new service? Or are you looking for options for payment modalities?

Here the suggestion is to browse the tools in a 'inspiration mode', for example, using the Archetypal Models to explore different PSS types, or picking some of the Cards the company would like to focus on, in order to get insights for their business/project. They may find interesting ideas on payment modalities, services or stakeholders to involved.

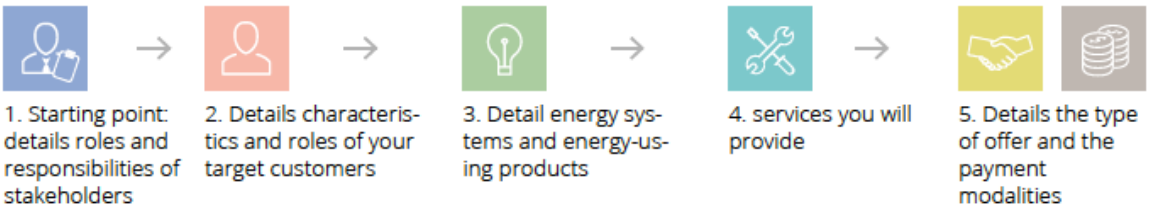
8.4.2.2 Applications for consultant / designer / NGO

A consultant, NGO, designer or other actor involved in designing energy solutions may explore sustainable business models and map companies operating in a specific context.

Starting point: analysis of the current situation with the Innovation Map. Positioning of the stakeholders operating in the selected context/s, distinguishing the actors and roles using the Stakeholders Cards. This may lead to identify technology providers, training institutions and distribution channels.

Idea generation: use of the Innovation Map to generate new concepts, then selection of the most promising one.

Concept detailing: use of the Design Framework and Cards to detail the concept. Starting, for example, by detailing roles and responsibilities of the stakeholders involved. Then, proceeding to the detail of other elements, such as customers, products and services and offer.



Visualisation: use of the Energy System Map to clarify roles and responsibilities of each stakeholder, flows of goods, information and money.

> **Example**: an NGO that participated in a workshop in Nairobi (DS-IV) was involved in a multi-stakeholder project to empower women entrepreneurs by providing them with solar mini kits and training them for setting up an energy business. The project was already defined in terms of stakeholders involved and the NGO had identified contexts of implementation, however products, services and payment structures were not yet established. The initial idea the NGO wanted to develop was to provide mini kits and financing services to entrepreneurs who would in turn sell products to end users.

The NGO used the Innovation Map to position the initial idea and the other projects/businesses operating in their selected target market. They mapped the involved stakeholders and selected the most promising area of intervention. The team proceeded to detail the new concept by defining roles and responsibilities of each stakeholder and then detailing customers' characteristics and roles in the PSS. The other elements of the solution (product, services, type of offer, payment) were then defined.

The main outcome of the workshop was the generation of concepts that were new compared to the existing solutions in the selected context of interest. In addition, the design activities allowed the NGO to move away from their initial business offer ("*through the tool I adopted a new offer compared to the initial one*" P1). Furthermore, it is very interesting to note that the NGO designed a solution that falls outside of the Archetypal Models, meaning that the combination of tools enabled users in developing innovative business models.

Another interesting aspect is that, differently from previous examples, the NGO was more focused on detailing the stakeholders' roles and the types of offer to women entrepreneurs and end-users rather than designing a business model around a product. The purpose of application of the tools was in fact to understand the context of implementation for their project (analysing competitors and existing solutions) and to provide a solution aimed at empowering women in the solar industry.

8.4.2.3 Applications for academics and educators

The tools can be used in an academic context to teach about how PSS can be applied to DRE models and to support students in developing their practical projects.

Learning about PSS+DRE models: use of the Innovation Map and Archetypal Models to provide examples of different types of PSS offers and their classification. Use of the case studies to position types of offerings and facilitate understanding of business models.

Supporting design exercises: use of the toolkit in practical design exercises, providing a brief for students and suggesting paths to follow. The examples previously discussed can be used for indications on the design process.

It has to be noted that students that are not familiar with renewable energy technologies, design for the Base of the Pyramid, Product-Service Systems or design processes may need an exhaustive introduction on these topics. Therefore, it is recommended to include the toolkit within a module or course that includes theory.

Example: the first pilot workshop with students at University of Botswana was carried out as part of the LeNSes project and involved theory and practice on PSS, DRE, human-centred design. The students used the toolkit in combination with other tools for measuring energy requirements, calculating sized and characteristics of DRE, as well as understanding users' needs through interviews and focus groups.

8.4.2.4 Application for business-supporting organisations

Business-supporting organisations can apply the toolkit for mentoring start-ups and companies operating in the renewable energy sector. This application has been discussed through the experts' interviews in DS-IV and most of participants involved expressed their interest in applying the tools in their organisations (such as Chendaria Business Incubation Centre, Botswana Innovation Technology and Research Institute, Botswana Innovation Hub and Kenyan Renewable Energy Association).
In particular, the aim of the EPSRC-funded project "Design and innovation tools to support SMEs in developing sustainable Product-Service Systems for energy access in African contexts" was to set up the ground for a close collaboration with the partner universities in Kenya and Botswana, allowing knowledge exchange and equipping African partners with expertise on how to apply the tools and how to disseminate the project outcomes. Local universities can play a role in facilitating training for business-supporting organisations, which engage with a wide network of companies and practitioners. The applications and diffusion of the toolkit can be facilitated by local academics in collaboration with these organisations[26].

8.5 Considerations on flexibility and adaptability

The previous sections discussed how the tools can benefit users with different purposes of applications and how the toolkit can be flexibly used in different scenarios of application. This section aims at discussing some of the concepts generated during the various testing activities, highlighting how the tools have supported users in achieving their purposes.

8.5.1 Flexibility across different purposes of applications

While each Descriptive Study (DS-II, DS-III and DS-IV) highlighted how the tools have been validated from a usability, completeness and usefulness point of view, some considerations can be made on the overall usefulness of the toolkit for different purposes of application.
In order to discuss the tools' applications for companies and practitioners, this section draws conclusions from those testing activities where companies or practitioners used the toolkit to develop a solution to addressing their chosen brief. Some considerations can be made by discussing the concepts generated during the various testing activities and how the tools supported users in different ways, generating innovative outcomes.

[26] As part of the LeNSes project's objectives, African universities can facilitate knowledge exchange and dissemination with local actors, applying the toolkit as part of a set of resources and tools to design sustainable energy systems.

Example 1:

In the pilot workshop with experts and practitioners in Botswana (DS-II, described in 6.2.2), participants generated two business models for the Mmokolodi project, a grid-connected and community-managed mini grid in Botswana. Although the idea generation session was carried out in a short timeframe and solutions were not explored in great detail, both concepts generated represented a new model not applied until then in the country. In terms of stakeholders involved and community's roles and responsibilities, the workshop resulted in the proposal of an innovative combination of actors and services provided by mixing private and public partnerships.

Example 2:

During the testing activities in South Africa and Kenya (DS-III), a wide range of practitioners and companies were engaged. Most of them used the toolkit in groups and generated 'fictional' business models. However, one company in South Africa and one in Kenya used the tools for their own design brief. The South African SME, which sells individual solar systems to productive activities, concluded the workshop by changing their offers to result-oriented PSS offering energy services on a pay-per-consumption basis. Their comments about the usefulness of the design tools included that *"[they] have changed [our] thinking of the offering in South Africa. This has opened the thinking into more ideas we can offer to our customers".*

Example 3:

In Kenya, an SME that sells efficient cookstoves and ethanol gas used the toolkit to generate a new model for refugee camps. In the newly-designed solutions, products were offered on a pay-to-purchase and pay-to-rent basis, resulting in an innovative business model which integrates two types of offer. This type of solution was not provided by other stakeholders in the chosen context and the SME affirmed that *"[through] a combination of different business models and with a bit of creativity I can play around with the options*", thus resulting in innovative solutions.

Example 4:

With the last iteration of testing activities (DS-IV), all participants in the workshops in Kenya and Botswana generated new business models that were different from the initial business offer or idea. In particular, P1 designed a solution that falls outside the PSS+DRE Archetypal Models, suggesting that the toolkit supported the design of an innovative business model.

These examples highlight that the toolkit supports the design of innovative solutions that were not provided in the chosen context, therefore enhancing competitiveness of companies adopting the PSS+DRE approach. Considering the different purposes that participants had when started the workshops, e.g. to provide solutions for an existing customer base or to venture in new markets, the toolkit demonstrated its flexibility across different reasons for applications.

In addition, most participants started with a sale-based offer (traditional business model) in mind and were able to shift their focus towards a PSS-based solution, in some cases resulting in innovative mixing of different offers.
It should be also highlighted that The Sustainable Energy for All Design Toolkit can be applied within a comprehensive design process and in conjunction with other tools, such as those proposed by the LeNSes project (www.lenses.polimi.it section Tools). In fact, as previously discussed, their focus lies in the idea generation phase of new solutions, which means that concepts generated with the toolkit may need to be further detailed, in terms of technical and financial aspects, in order to be implemented.

8.5.2 Flexibility across different types of users

The testing activities involved a total of 40 DRE companies' representatives and practitioners, 18 experts on PSS, DRE and design, 15 designers, 47 students (design and DRE) demonstrating that the toolkit can been used by a wide range of users with different backgrounds. The tools' flexibility across different types of users was also demonstrated by the fact that feedback collected did not reveal issues about clarity or usability for a specific type of target user over another one, thus confirming that people with different backgrounds and expertise can easily apply the toolkit.
Differences in knowledge and expertise were considered in the introduction of the tools. In some cases, for example with BA students in Botswana, longer introductory presentations were delivered including characteristics, benefits and barriers of PSSs, definition of sustainable development, energy access and characteristics of DRE technologies. In other cases, such as the workshop at Kenyatta University or the other workshops of DS-IV, a shorter introduction to the topic and on how to use tools was sufficient.
As discussed with experts on the applications of the Design Framework and Cards (6.6.2.1), it can be concluded that a short introduction to the toolkit may be necessary. Training and consultancy services may be preferred to assist users during the process and to facilitate workshops, according to the type of participants. For example, it was observed that some DRE companies were not familiar with brainstorming activities and for this reason had more difficulties in discussing ideas and writing them down on post-its. This aspect reflects the findings of DS-I, where most interviewees affirmed they did not use any tool for designing their business model. On the other side, workshops with designers showed that when participants are already familiar with idea generation tools or other strategic design tools they have less difficulties in applying the toolkit.

8.5.3 Adaptability to different geographical contexts

Testing activities took place in four countries. The African countries represent different examples of socio-economic development: while Botswana and South Africa are considered upper-middle income countries, Kenya falls under the low-income countries category (see 1.1). Additionally, the toolkit has been applied in other dissemination activities in Ghana, China, and The Netherlands, thus demonstrating its relevance to other contexts (see 8.5).

In line with the purpose of this research to support companies and practitioners in designing PSS+DRE for BoP contexts, the toolkit was designed to be applied for any low-income and developing context. For this reason, the case studies and critical factors collected during DS-I were selected with the aim of achieving a maximum variation in terms of covered contexts. Obviously some countries present a higher number of companies and ventures operating in the DRE field, such as Kenya, India, Tanzania or Bangladesh, and therefore the case studies reflect the maturity of certain markets.

It was observed during the testing activities that some participants paid particular attention to case studies from their own geographical context, or from similar African countries. It must be highlighted that the toolkit is open for future developments. It can be updated in terms of guidelines, case studies and other features that support the design of PSS+DRE in a selected context, such as Kenya or Brasil. Further developments can include the addition of case studies for specific context applications and the customisation of tools according to a selected area. For example, the Innovation Map could include additional layers to analyse the enabling environment for PSS+DRE in Kenya, while the Cards could include specific case studies from the Kenyan context and guidelines that summarise critical factors for targeting a specific area.

Future developments and research activities are further discussed in Section 9.4.

8.5.4 Lessons learned and conclusions

The previous sections illustrate how the design toolkit can be applied in a versatile fashion according to different users, requirements and contexts of applications. The scenarios illustrate how the testing activities generated insights on the purposes and needs of different types of target users (e.g. SMEs, designers or NGOs). This newly developed knowledge is important not only for the purpose of this research, which aimed at developing tools for PSS applied to DRE in BoP contexts. These findings can be used to develop other tools and methods, for example by focusing on the concept development and engineering phase of new solutions. In addition, highlighted needs and requirements of companies and practitioners and their purposes when applying the tools could lead to future research activities that look into other types of energy or other contexts of implementation (see 9.4.2).

8.6 Dissemination activities and other applications of the toolkit

In order to maximise diffusion and adoption of the Sustainable Energy for All Design Toolkit, an online platform with the outcomes of this PhD was created. The main purpose of the website is to enable users to download and freely use the tools, allowing the researchers to monitor downloads and their diffusion (singular views dated 20 July 2017: 1,024 views). The website is: www.se4alldesigntoolkit.com.

Besides the testing activities in Kenya, Botswana, South Africa and the UK, the toolkit has been applied in three other workshops in The Netherlands, China and Ghana. These other applications of the tools contribute to this research impact and demonstrated the usefulness of the tools in other contexts of applications.

1. Workshop at TU Delft, The Netherlands – February 2016

50 BA Industrial Design students participated in the workshop, which was carried out by a LeNSes partner from TU Delft.

2. Workshop at Tsinghua University, Beijing, China – May/June 2017

The workshop was organised as part of the 10-days LeNSin project[27] course at Tsinghua University and involved 45 students from 9 universities in China, and some exchange students from the RCA (Fig. 8.3).

3. Workshop at IEEE Power Africa Conference, Ghana – June 2017

The researcher was invited to deliver a training session on "Sustainable business models for energy access in Africa" at the IEEE Power Africa conference in Accra (Fig. 8.4). The tutorial involved 7 participants from 7 different countries and included companies, researchers and people involved in rural electrification projects.

[27] International Learning Network of networks on Sustainability, EU-supported (ERASMUS+ 2015-2018) project involving 36 universities from Europe, Asia, Africa, South America and Central America http://www.lens-international.org

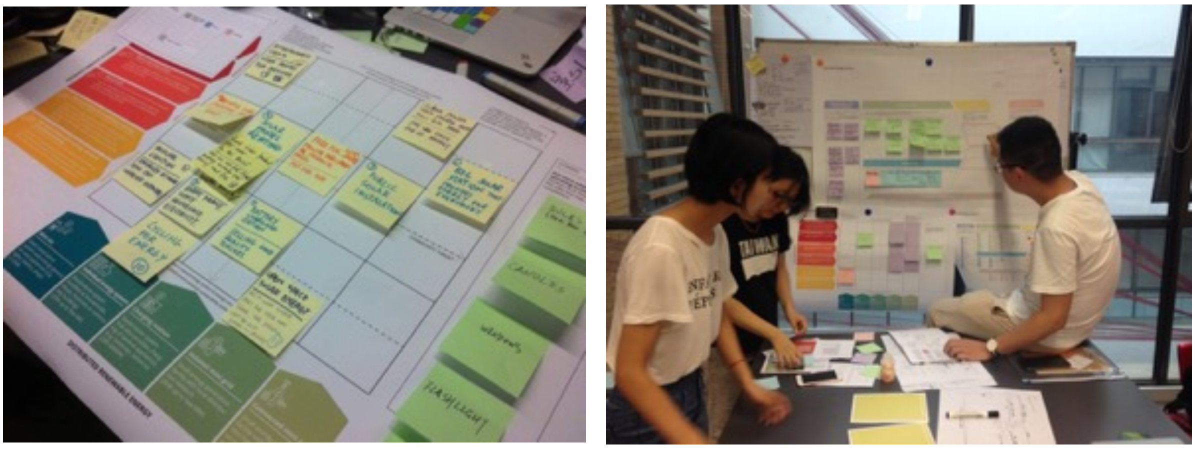


Figure 8.3 – Students using the toolkit during the workshop in Beijing, May/June 2017

Figure 8.4 – Companies and practitioners using the toolkit during the workshop in Ghana, June 2017

8.7 Summary and conclusions

This chapter discusses how the tools' development and testing generated insights for the applications of the Sustainable Energy for All Design Toolkit. In particular, needs and requirements of companies and practitioners, highlighted by the study in DS-I, were considered to develop a proposed design process. The tools are presented within a design process which has been developed during the various testing iterations and which suggests a flexible step-by-step approach to the use of the three tools, from strategic analysis to concept generation and detailing.

This chapter also discusses different purposes of applications for the toolkit: to start a new business model, to steer and refine existing models, to review existing solutions or in an inspiration mode. Each type of target user can apply the tools according to their specific purpose and these have been illustrated through scenarios of applications.

In terms of flexibility and adaptability of the tools, their resilience across different types of users and contexts of applications has been discussed considering the range of participants involved in the testing activities and the several countries where the tools have demonstrated their relevance.

Chapter 9

Conclusions

9: Conclusions

This chapter aims at providing a summary of the outcomes of this research, highlighting the contributions to knowledge, research limitations, and discussing further research activities.

9.1 Research overview: objectives and outcomes

The overall aim of this research was to explore the applications of PSS and DRE in low-income and developing contexts, thus defining characteristics of these models, their variables and critical factors. Additionally, this research aimed at developing a support for companies, practitioners and other stakeholders for designing sustainable PSS applied to DRE in BoP contexts, with a specific focus on the idea generation phase of new solutions.

Two main Research Questions were identified in the first part of this PhD (Research Clarification phase, see 3.6), which led to setting a list of objectives for this thesis. This section illustrates how the research objectives have been met and how the research questions have been answered. An index of objectives and corresponding thesis chapters is presented in Table 9.1.

Questions	Objectives	Chapters	Phase
RQ1	A To review literature on DRE systems, PSS, design approaches for the BoP and to explore the combination of these models, identifying their characteristics.	2. LITERATURE REVIEW 4. PRIMARY STUDIES	EXPLORATORY PHASE
	B To develop a classification system for PSS+DRE models.	4. PRIMARY STUDIES	EXPLORATORY PHASE
	C To investigate the applications of PSS and DRE in BoP contexts, identifying characteristics of these models.	4. PRIMARY STUDIES	EXPLORATORY PHASE
	D To identify critical factors for designing PSS and DRE.	4. PRIMARY STUDIES	EXPLORATORY PHASE
RQ2	E To review existing design approaches and tools for PSS, DRE and design for the BoP and to understand how these are applied by the research recipients (companies and practitioners)	2. LITERATURE REVIEW 4. PRIMARY STUDIES	DEVELOPMENT PHASE
	F To translate the outcomes of the primary studies in supports for companies, practitioners and designers.	5. PSS+DRE INNOVATION MAP 6. PSS+DRE DESIGN FRAMEWORK & CARDS 7. PSS+DRE VISUALISATION SYSTEM	DEVELOPMENT PHASE
	G To evaluate the outcomes of this research through a series of iterative testing activities, involving a wide range of stakeholders from different contexts and fields of expertise.	5. PSS+DRE INNOVATION MAP 6. PSS+DRE DESIGN FRAMEWORK & CARDS 7. PSS+DRE VISUALISATION SYSTEM	EVALUATION & REFINEMENT PHASE
	H To discuss implications of this research for the field of PSS and DRE, providing guidelines for different types of recipients (e.g. SMEs, NGOs).	8. DISCUSSION	CONCLUSION PHASE

Table 9.1 - Thesis chapters addressing the research questions and objectives

9.1.1 Meeting the objectives set to answer RQ1

The first part of this research aimed at exploring PSS applied to DRE in low-income and developing contexts. Research Question 1 included four sub-questions:

RQ1: What are the characteristics and applications of PSS and DRE in BoP contexts?

1.1 What are the characteristics of PSS applied to DRE?

1.2 How can these models be classified?

1.3 What are the applications of these models in BoP contexts?

1.4 What are the critical factors to successfully implement these models?

Objectives:

To review literature on DRE systems, PSS, design approaches for the BoP and to explore the combination of these models, identifying their characteristics (Fig. 9.1, activity A)

A first literature review (Chapter 2) discussed characterising dimensions and classification systems respectively for DRE (2.1.3) and PSS models (2.2.4). The review highlighted that a number of approaches are used to describe and classify DRE models, but multi-dimensional and cross-country studies were missing. On the other hand, the PSS literature provides a widely accepted classification system which is generic and, because of this reason, applicable to various domains. However, the literature review highlighted that combining PSS and DRE models requires the identification of characterising dimensions of PSS+DRE and therefore the current PSS classification system did not appear to be appropriate to exhaustively cover DRE characteristics.

A first phase of this research aimed at identifying characteristics of PSS applied to DRE (question 1.1). In DS-I, the dimensions used in PSS and DRE literature were combined using a theory-building approach which led to defining **nine characterising dimensions of PSS applied to DRE** (Section 4.1). These are: *value proposition/payment structure, energy system, target customer, ownership, energy system operation, capital financing, organisational form, provider/customer relationship,* and *environmental sustainability potential*. These dimensions were then detailed and illustrated on polarities (Fig. 4.1, p.112).

To develop a classification system for PSS applied to DRE (Fig. 9.1, activity B)

The DS-I presented a **new classification system for PSS applied to DRE** which was built combining the majority of dimensions describing these models. The classification system is a polarity diagram that distinguishes two axes and encompasses seven dimensions of PSS+DRE (*value proposition/payment structure, energy system, target customer, ownership, energy system operation, provider/customer relationship, environmental sustainability potential)*.

Compared to existing classifications of respectively PSS and DRE models, this system represents a multi-dimensional approach and therefore a more comprehensive way to describe PSS applied to DRE solutions (question 1.2).

To investigate the applications of PSS and DRE in low-income and developing contexts, identifying characteristics of these models (Fig. 9.1, activity B and C)

A **case study analysis** was conducted to explore applications of PSS+DRE in BoP contexts (question 1.3). 56 cases were collected and categorised according to the previously identified dimensions. Cases were mapped on the classification system and this process resulted in the **identification of 15 Archetypal Models of PSS applied to DRE**. The 15 models have been described in terms of offer provided, type of energy system, ownership and payment structures. Each model was also represented through a system map, a visualisation of actors and their relationships in the system.

To identify critical factors for designing PSS and DRE (Fig. 9.1, activity D)

Previously identified PSS+DRE dimensions were used to define **elements of PSS applied to DRE**: *products, services, offer, customers, network of stakeholders* and *payment modality*.

A second literature review, focused on **extracting critical factors** for each of the identified PSS+DRE elements and their variables, was carried out. In addition, case studies were used to provide successful examples and to integrate critical factors emerging from literature. These critical factors, summarised in Appendix II, aimed at answering question 1.4 and constitute the body of knowledge for implementing PSS applied to DRE in BoP contexts.

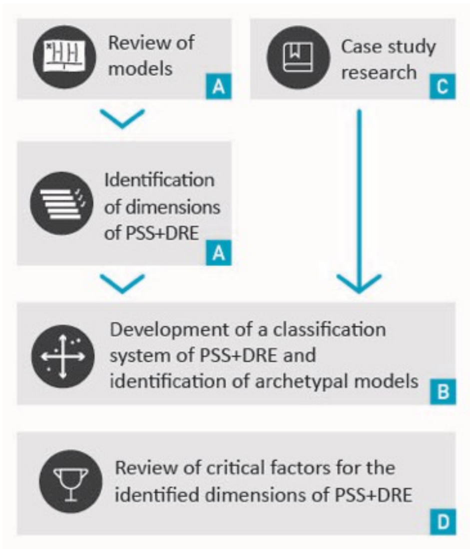


Figure 9.1 – Schematic of activities carried out to answer RQ1

9.1.2 Meeting the objectives set to answer RQ2

RQ2: How companies and practitioners might be supported in designing PSS applied to DRE for BoP contexts?

2.1 How can the identified critical factors and successful cases be translated to support the design of PSS applied to DRE?

2.2 What tools can be developed for designing these models?

Objectives:

<u>To review existing design approaches and tools for PSS, DRE and design for the BoP and to understand how these are applied by the research recipients (companies and practitioners)</u> (Fig.9.2 Activity E)

A second purpose of the literature review was to identify required design approaches and tools for designing PSS applied to DRE in BoP contexts. The review highlighted existing approaches and tools for designing PSSs, DRE's business models and PSS models in BoP contexts. It emerged that existing tools are not appropriate to support the design of PSS applied to DRE and there was a **need to develop new approaches for designing PSS+DRE models**. In particular, new tools should take into consideration the multi-dimensional characteristics of PSS applied to DRE.

While the literature review highlighted strengths and weaknesses of existing tools and provided requirements for developing new ones, it was also necessary to understand how the research recipients (i.e. companies and practitioners working in the DRE sector) would apply these new tools. An exploratory study was carried out to confirm the literature's findings and to understand more in depth the recipients of this research. In DS-I (Section 4.6), a series of **interviews and questionnaires with DRE companies and practitioners** helped defining characteristics of the target users of this research, it confirmed the need for specific tools to design PSS applied to DRE and it shed light on scenarios of applications of the tools.

<u>To translate the outcomes of the primary studies in supports for companies, practitioners and designers</u> (Fig. 9.2, activity E)

Drawing conclusions from the review on design tools and approaches and from the exploratory study with companies and practitioners, the outcomes of the first part of this research were then used to develop **three design tools** which aimed at supporting companies and practitioners to design PSS applied to DRE in BoP contexts (question 2.1 and 2.2).

- **PSS+DRE Innovation Map**: The tool was developed building upon some of the outcomes of the primary studies: the classification system of PSS+DRE and the identified Archetypal Models. The Innovation Map (Emili et al., 2016 (a); Emili et al., 2016 (d); Emili et al., 2016 (e)). is composed by a polarity diagram (classification system) that encompasses dimensions of PSS+DRE models, a set of Archetypal Models Cards that aim at providing inspiration for applied examples of these models, a set of Concept Cards to support the generation of new models. The tool can be used not only to classify PSS+DRE models, but also to map company's offerings, classify competitors in a selected market and to generate new solutions. The final version of the tool includes a set of Stakeholders Cards that supports the analysis of the organisational form of competitors active in a determined context.

- **PSS+DRE Design Framework & Cards:** The tool was developed from the identified dimensions of PSS+DRE and their variables, the collection of critical factors and case studies of PSS+DRE in BoP contexts.
  The Design Framework and Cards (Emili et al., 2016 (b)) aims at supporting the generation of PSS applied to DRE in BoP contexts by visualising all elements to consider in the design process, through the Design Framework, and by providing guidelines and successful examples, through a set of Cards. The Framework and Cards are thought to be used in combination with an empty Design Canvas to be filled during idea generation sessions.
- **PSS+DRE Visualisation System:** A Visualisation System was firstly developed to described PSS+DRE Archetypal Models, where a set of rules was set to standardise their description. The Visualisation System (Emili et al., 2016 (c)) features stakeholders involved in the solution, their interactions and flows of goods, services and information. It is composed by a specific set of icons designed to describe PSS+DRE dimensions and variables, and a set of rules for describing flows and positioning elements. The Visualisation System was then applied as a design tool, the Energy System Map, with the aim of supporting companies and practitioners in (co)designing and visualisation of PSS applied to DRE models.

<u>To evaluate the outcomes of this research through a series of iterative testing activities, involving a wide range of stakeholders from different contexts and fields of expertise</u> (Fig. 9.2, activity F)

- **Evaluation of the PSS+DRE Innovation Map**: The tool was tested through three series of iterations (DS-II, DS-III, DS-IV) adopting different methods: semi-structured interviews and questionnaires were used to test the tool's clearness and completeness; six workshops, where data was collected through questionnaires, participant observation and content analysis, were used to test the tool in use and to evaluate its clarity, usability and usefulness.
  In addition to the pilot evaluation with 39 design students, the tool has been tested with a wide range of practitioners from different disciplines: 40 people from companies, consultancies and NGOs, 6 experts of PSS and DRE, 8 DRE students and practitioners. Therefore, with 93 participants involved in the evaluation of the tool over its several iterations, it can be concluded that the Innovation Map has been empirically tested from a qualitative and quantitative perspective. These studies were carried out in three different countries, Botswana, South Africa and Kenya, contributing to results' validity and reliability.
- **Evaluation of the PSS+DRE Design Framework & Cards**: The tool was tested through four series of iterations (DS-II, DS-III, PS-III, DS-IV) and involved different research methods: eight workshops were organised to test the tool's usability and usefulness and data was collected through questionnaires, participant observation and content analysis. Semi-structured

interviews with experts and practitioners were employed to evaluate the tool's content and its completeness.

The tool was firstly tested through pilot workshops with 39 design students, 4 DRE and PSS experts and 3 design practitioners. A more refined version of the Design Framework & Cards was then tested with a wide range of practitioners from different disciplines: 23 people from companies, consultancies and NGOs, 12 designers, 8 DRE students and practitioners, 12 experts of design and DRE. Therefore, with 101 participants involved in the evaluation of the tool over its several iterations, it can be concluded that the tool has been empirically tested from a qualitative and quantitative perspective. These studies were carried out different countries, Botswana, South Africa, Kenya and the UK, contributing to results' validity and reliability.

- **Evaluation of the PSS+DRE Visualisation System**: The tool was tested through two iterations (DS-II, DS-III): four workshops were organised to evaluate the tool in use, its completeness and usability. A range of practitioners from different disciplines were involved in the testing activities: 16 people from companies, NGOs and consultancies and 12 designers. These studies were organised in Kenya, Botswana and the UK.

<u>To discuss implications of this research for the field of PSS and DRE, providing guidelines for different types of recipients (e.g. SMEs, NGOs)</u> (Fig. 9.2, activity G)

Drawing conclusions from the testing activities, some considerations were made in terms of a **proposed design process** to use the tools (Section 8.2). The identified phases were: Current Situation (analysis of existing solutions and identification of opportunities with the Innovation Map), Idea Generation (generation of concepts with the Innovation Map), Concept Detailing (concept detailing using the Design Framework & Cards) and Visualisation (concept detailing and visualisation using the Energy System Map). Then, the applications of the tools were discussed in terms of flexibility across different types of users and purposes of applications. The tools can be used to support the start-up of a new business, to refine and re-orient existing solutions, to monitor business models or in inspiration mode. The testing activities carried out in four countries, summed to the dissemination activities in three other countries, provided proof of the tools' flexibility and usefulness across different contexts of use.

Figure 9.2 – Schematic of activities carried out to answer RQ2

9.2 Contributions to knowledge

The overall aim of this research was to explore the combination of PSS models to DRE systems in low-income and developing contexts and to provide design supports for companies and practitioners venturing in these fields. This research contributes from a theoretical perspective to the academic literature on PSS with specific applications of these models in the DRE sector. Then, this PhD provides practical contributions to this field by presenting three design tools, their applications in the design process and by illustrating how different recipients can benefit from applying them.

Theoretical contributions

As discussed in Chapter 2, aside from some limited explorations of PSS in providing sustainable energy access in BoP contexts, the application of PSS and DRE presented limited research. In fact, studies that encompass different DRE technologies, a cross-country analysis and that consider design implications for these models were missing. This PhD contributes to the academic knowledge on PSS applied to DRE by providing a first multi-dimensional approach to describe, classify and design these models. In particular, three main theoretical contributions can be outlined:

1. *The identification of PSS+DRE characterising dimensions and the development of a classification system for PSS applied to DRE*. This research identified dimensions that describes these models and provided a new classification system that encompasses most of these dimensions. The classification system was built on a polarity diagram, resulting in the identification of *six types of PSS applied to DRE*. Differently from previous approaches, the

classification system provided a comprehensive way to distinguish value proposition/payment structure, energy system, target customer, ownership, energy system operation, provider/customer relationship, and environmental sustainability potential.

The new classification system provides a contribution to this field by supporting academics, researchers and experts in this field to understand characteristics of these models and to consequently classify them.

2. *The case study collection of examples of PSS applied to DRE in BoP contexts and the identification of 15 Archetypal Models*. This research explored practical applications of PSS applied to DRE in BoP contexts, by providing a first cross-country and multi-technology approach. Cases were described and classified according to their characterising dimensions, providing a first catalogue for PSS applied to DRE examples. The collection of case studies represents an important contribution to knowledge by highlighting which PSS+DRE models have been applied and what their characteristics are. In addition, the population of the classification system with case studies led to the identification of 'empty areas', i.e. models that have not yet been explored. In this way, this research provides an understanding of the current scenario for PSS and DRE, but it also pictures opportunities for future research activities.
3. *The extraction of critical factors to design PSS applied to DRE in BoP contexts*. Having identified PSS+DRE models and their characteristics, critical factors from literature and case studies were collected, organised and classified in a systematic way. This process resulted in the development of design guidelines for successfully implementing PSS applied to DRE in BoP contexts. Differently from previous approaches which focused on one technology or on a selected country of implementation, this research provides a first categorisation of critical factors developed from previous successful experiences. In other words, this research contributes to building theory for designing PSS applied to DRE by providing a collection of learned lessons from case studies and literature which span across technologies and contexts of implementation.

Practical contributions

This research contributes to the design of PSS applied to DRE in BoP contexts by providing companies and practitioners with three design-supporting tools. As discussed in Chapter 2, existing tools for DRE business model design and PSS tools presented limitations with regards to the particular application of PSS and DRE. The interviews with DRE companies and practitioners in DS-I confirmed these findings and the need to develop appropriate tools.

This research provided a first set of PSS+DRE tools to support companies and practitioners in the design process, particularly focusing on the idea generation phase of new solutions. The contributions to design practice can be summarised into three main points:

1. *Development of three design tools to support the generation and visualisation of PSS+DRE models*. The three tools developed in this PhD, which constitute the Sustainable Energy for All Design Toolkit, aimed at supporting practitioners in understanding types of PSS applied to DRE, mapping companies and competitors in a selected context, exploring new opportunities and designing new models with a great level of detail.
   Their several iterations of testing and refining the tools demonstrated their clarity, usefulness and usability in the design process.
2. *This research provides recommendations for using the tools through scenarios of applications and expected outcomes for different types of users.* Drawing conclusions from the testing activities, this research discussed how different users can benefit from applying the tools for different purposes. Companies and practitioners (NGO, consultants, and designers) used the tools for a range of purposes ranging from understanding the market in a given geographic area to exploring new sustainable business opportunities to design concepts of PSS applied to DRE. This research provides a contribution to design practice by illustrating examples of design processes according to different users' needs, and outline how using the tools supported companies and practitioners in achieving their outcomes.
3. *This PhD also provides insights for design researchers by illustrating an example of tools' development and testing* and by depicting how the Design Research Methodology has been applied and modified for this research. This approach could be used by future researchers who are interested in developing and evaluating design tools.

9.3 Limitations of this research

This research presents some limitations in terms of the topic under investigation and the data collection and analysis.

9.3.1 The topic

A first aspect is related to the rapidly changing research focus, the application of PSS and DRE in low-income and developing contexts. The activities carried out in the DS-I stage aimed at building theory on PSS applied to DRE in BoP contexts. In particular, the collection of case studies and critical factors aimed at providing an understanding of what models have been applied, what were their characteristics and what factors influenced a successful implementation. This phase had to be concluded within a certain timeframe and, although theoretical saturation was reached and data collected satisfied the requirements set for the study, this process can be still considered ongoing. In fact, during this PhD, it was necessary to carry out continuous updates on case studies and to look for publications regarding the implementation of these models. They highlighted that this sector is rapidly growing and, within the past three years, business models changed and new ones have emerged.

An example of how the energy scenario is evolving is provided by mobile money technologies and payment structures. While three years ago only few companies had tried to implement this option, nowadays the number of companies that adopted this technology has widespread. This has led to the adoption of product-oriented PSS that offer credit payments through mobile money, as well as result-oriented ones that provide pay-per-unit solutions. This scenario may be changing in the next five or ten years as new technologies emerge and policy regulation may favour the adoption of some models instead of others. In the near future, new cases could be added and it may be necessary to update the Archetypal Models within a certain time from the end of this PhD. Despite this, the classification system will remain the same and it will still provide a framework for mapping new cases. The same can be affirmed for the collection of critical factors. These can be integrated according to emerging successful cases, requiring to update the tools. In addition, many PSS+DRE models found in the literature and in the case studies have been implemented in recent years, thus it may be interesting to evaluate which factors have been successful in the long term and which lessons have been learnt from these recent ventures.

In order to avoid the tools to quickly become obsolete or not relevant for their purposes, they have been made available online in an open-source and copy-left format, enabling anyone to add or modify archetypes, cards, guidelines and case studies.

9.3.2 Data collection and analysis

Some limitations are related to the type of research methods used in this PhD. These are related to the data collection and analysis carried out during DS-I (case study analysis and extraction of critical factors) and to the testing activities.

9.3.2.1 Data collection for DS-I

Limitations of data collection in the DS-I are related to the use of secondary sources in the case study analysis. Secondary data triangulation (minimum of three sources for each case) ensured reliability and validity of the study, however the use of primary sources such as interviews and questionnaires with the companies' managers or directors would have perhaps provided a more in-depth analysis of cases. It would have been interesting to explore how these companies designed their business model and if their offers changed over time, as well as what factors influenced the successful implementation of their business model. These types of information would have provided a comprehensive overview of cases and may have led to the identification of new critical factors.

However, due to the high amount of cases (56), this approach could have not been implemented within the timeframe of this PhD. In fact, the purpose of the case study analysis was to provide an overview of what models have been implemented and what their characteristics were, hence the amount of cases selected had to reach theoretical saturation and satisfy the maximum variation strategy.

Another limitation of the data collection in the DS-I is related to the extraction of critical factors. This process aimed at collecting data on the different dimensions and variables identified in the literature. With the purpose of identifying critical factors for implementing PSS applied to DRE in low-income and developing contexts, case studies and literature from different countries were selected. This process led to a generalisation of factors, based on the principle that lessons learnt from a specific case could be successfully implemented in another context. However, this approach may present limitations as context specificities, such as regulatory frameworks, cultural preferences and financing options, might differ from one country to another. Thus, in order to avoid an ambiguous interpretation of guidelines, all participants of testing activities were informed (through the toolkit introduction and in the tools' guide) that guidelines and case studies provided by the tools should be used as inspiration to generate ideas, but what worked in a specific context does not necessary apply to others. However, it must be highlighted that this represents a common problem for all design guidelines, which provide generic recommendations that are not always applicable. An example of this can be found in relation to product eco-design guidelines. Depending on the type of product they are applied to, these guidelines they can be considered more or less relevant. Similar considerations can be made for other guidelines such as those found in the HCD toolkit (IDEO, 2009).

9.3.2.2 Tools' testing

Another limitation of this research is related to the type of testing activities. The testing activities were carried out using workshops, participant observation, interviews and questionnaires as data collection methods. The main purpose was to test the tools in practice and gather feedback directly from participants. The tools have been tested mostly through workshops with a large number of people, not allowing the author to gather data on the process of idea generation. This choice was made to enhance reliability of feedback collected and to enable users to brainstorm in a setting that is more similar to a 'real-life' idea generation. On the other hand, a more 'controlled' workshop activity would have provided insights on what types of conversations emerge when using the tools and how the process of idea generation takes place. This aspect might be implemented in further research activities with the aim of understanding how the tools trigger conversations and their impact in the idea generation process.

In addition, the collection of comments from participants after having used the tools (through questionnaires) may have resulted in a limited analysis of the tools' usefulness. This aspect was partially tackled by observing participants during the workshops activities, aimed in particular at understanding issues in the tools' use. On the other hand, the analysis of the outputs of the tools (content analysis) was carried out only in the two workshops organised in Kenya (W7) and Botswana (W8) where the amount of participants was limited (two companies for each workshop).

Another limitation of the tools' testing activities can be found in the interviews with experts aimed at evaluating the Design Framework & Cards (6.6.2). Here a different data collection method might have been more effective to gather feedback on the Cards. In fact, due to the high amount of Cards and consequently the high amount of guidelines and case studies, each participant provided feedback on a selected number of Cards. Other methods, such as a one-day focus group may have been more effective to evaluate the content of the Cards.

9.3.2.3 The researcher's role

Another aspect is related to the role of the researcher. The author was directly involved in delivering workshops and facilitating sessions, however her role was limited to explaining how tools work and in providing assistance where necessary (i.e. explaining expected outcomes of each session, providing explanations on how to use the tools). This choice was made to verify if companies and practitioners could successfully apply the tools without further guidance. A more involved role would have probably influenced the outcome of the workshop and would not have allowed a fair evaluation of the tools in use. On the other side, a more active role in the ideation process might have provided a benefit to participants by steering the design process and by maximising the use of the tools. Future research activities may focus on actively follow companies' ideation and implementation process, for example by selecting a small number of participants and exploring how tools are used within the company's managerial team and how these fit in their own design processes (see next section).

9.4 Recommendations for further work

This research explored the applications of Product-Service Systems and Distributed Renewable Energy models in low-income and developing contexts, providing a support for companies and practitioners to design these models. As mentioned before, this is an emerging field and it has only been partially explored, thus providing several opportunities for future research activities.

Some considerations can be made in terms of improvements for the tools, resonating on the comments collected during the testing activities that were not implemented in this PhD.
Other reflections can address emerging areas of research to expanding knowledge on PSS applied to DRE in BoP contexts.

9.4.1 Improvements and further developments of the toolkit

Considerations for improving the toolkit are mostly related to additional features and applications based on what emerged during the testing activities. In addition, as mentioned in the previous section, future research activities could focus on addressing the limitations of data collection an analysis of tools' testing, i.e. analysing the outputs of the tools in use, monitoring the concept generation process to understand how the tools stimulate ideas and trigger conversations. Another improvement would be to evaluate the tools' usefulness and usability in a real design and implementation process, for example by selecting one or two companies and monitoring how they use the tools in their design process.

<u>PSS+DRE Innovation Map</u>

Most of the suggestions for implementation of the Innovation Map require further research activities (see next section). For example, some companies highlighted that financial viability and sustainability of each PSS+DRE model should be assessed, thus supporting the selection of a concept over another. This could be developed by researching into what type of financing mechanisms are relevant for each type of PSS applied to DRE, and by developing guidelines to address this aspect. Further improvements could also include regulatory and policy components that influence specific models according to the context of implementation (see next section).
Future developments could include the addition of case studies for specific applications and the customisation of the tool according to a selected context. For example, the Innovation Map could include additional layers to analyse the enabling environment for PSS+DRE in Kenya. Following the same criteria of the Stakeholders Cards, this aspect could be developed by designing new sets of cards that support the analysis of regulatory frameworks and financing options for each model.

<u>PSS+DRE Design Framework & Cards</u>

Some of the companies involved in the testing activities suggested to implement the Framework and Cards in a software tool, perhaps an online version, that could be used, updated and shared among stakeholders. It would be interesting to transform the guidelines and case studies in a sort of 'guided design process' where users could browse all Cards and link them with ideas generated on the Canvas. Similarly to the Energy Delivery Model tool (Practical Action Consulting, see 2.1.6), the Design Framework and Cards could support a step-by-step process where users are provided with suggestions of best options and can then review or modify their models.

Other improvements that emerged in the testing activities were related to the need to cover other types of energy besides electricity (e.g. energy for cooking) and the need to consider the enabling environment in the design of a business model. At this current version, the Design Framework and Cards do not include Cards on other types of energy and it does not cover regulations, policies and capital financing aspects, which fall out of the scope of this PhD. Nevertheless, these elements are crucial for the implementation of PSS applied to DRE and future development of the tool may include context-specific information such as regulatory and financing frameworks (see next section).

PSS+DRE Visualisation System

The Visualisation System aimed firstly at communicating PSS+DRE models in a simplified way. For this reason, some rules of visualisation were developed, providing a template to design the Energy System Map and a guide on how to position elements. Some design considerations should focus on whether the present structure is the best option for visualising PSS+DRE models or others should be explored. Further developments could explore different ways of placing providers and customers, for example when detailing more complicated systems of stakeholders and interactions.

9.4.2 Emerging opportunities for research in the field of PSS applied to DRE in BoP contexts

Drawing conclusions from this PhD's activities, considering both the knowledge developed in the DS-I and through tools' evaluation, some opportunities emerged for research in this field. These can be summarised in the following points:

1. Research into the enabling environment necessary to implement PSS applied to DRE in a selected context: regulations and capital financing

   A first opportunity for further investigations could explore the financing and regulatory dimensions of PSS applied to DRE in specific contexts of application. For example, future research could look into what models can be implemented in Kenya according to the existing policy framework and what capital financing mechanisms exist to venture in this area. Results from this research may lead to the addition of layers on the Innovation Map, the inclusion of design elements on the Design Framework and the preparation of appropriate guidelines for additional Cards. Results emerging from a research into policy and financing frameworks could lead to the identification of most appropriate models of PSS applied to DRE for a specific context.

   1.1 Explore which regulations and financing mechanisms are necessary to implement models in different contexts

Following these considerations, a research that looks into the enabling environment for PSS applied to DRE could be used to generalise to other contexts. For example, the case studies collected in this research highlighted that models that are widely implemented in one context are not applied in others. This is the case of all pay-per-unit models using connected mini grid which are located in India or South Asia. On the other side, mobile payments and product-oriented models with financing services are widely used in many African countries, but they present limited applications in Asia. It could be interesting to explore what enabling environment is present in these regions and generate guidelines for regulations and implementations in other contexts. In an interview with a renewable energy policy expert (E12) in Botswana it emerged that the existing tools could be used to generate discussions on what models are available and which regulations need to be designed to implement them. These further developments would broaden the applications of the design tools for policy makers and investors.

In conclusion, future research activities could first look at specific regulations and financing models that enable PSS models in a selected context, in order to then generalise these results to other countries and provide guidelines for policy makers to design appropriate regulation for implementing these models.

1.2 Explore how companies might be supported in evaluating PSS business models

In relation to the financial and regulatory dimensions, future research activities could look at supporting the evaluation of PSS models and concepts generated with the toolkit in terms of financial sustainability and availability of appropriate regulations. In other words, research findings on regulatory and financial aspects could be used to improve the existing tools or to design additional tools.

2. Evaluate the proposed design process and explore the implementation and concept engineering phases

   With regards to the tools' limited applications, this PhD focused on the idea generation phase of new solutions. A proposed design process has been discussed in this thesis (8.2), however this requires validation and further research to evaluate its effectiveness. In addition, future research could address the concept engineering and implementation phase, by looking for example into capabilities and requirements that companies need to have to implement PSS applied to DRE or to shift their current business model towards a PSS+DRE approach. This may lead to reviewing existing tools to support this phase or by developing new ones to overcome barriers of implementation.

3. Exploring how the results of this research can be used for teaching about PSS applied to DRE
   The applications of the toolkit within academia (e.g. workshop with students in Botswana) highlighted the usefulness of the tools for understanding different types of PSS applied to DRE, as well to understand their characteristics. In fact, one of the main contributions of the tools was to simplify the understanding of these complex models. Future research could address this particular aspect and explore how the tools can be used for teaching purposes and how the outcomes of this research can be applied in higher education activities in different contexts.

9.4.3 Results generalisations

This research results could be generalised to other fields of applications. One option would be to apply the same approach and methodology to explore a different research focus, for example PSS applied to DRE in industrialised contexts. In this case, the collection of case studies would focus on developed countries, perhaps even targeting a specific context such as the UK. This would result in understanding (using the Innovation Map) which models have been implemented, what characteristics they have and consequently how they can be designed and implemented.

Similarly, critical factors could be collected focusing on the specific cultural, economic and policy frameworks present in the selected context.

Another approach could look at expanding the research focus to other types of energy besides electricity, such as thermal energy or cooking solutions. In this case, the same approach could be used to map cases where PSS-based solutions are applied to specific DRE products such as clean cookstoves or solar-water heaters. Future research activities could be then integrated with the results of this research, providing a complete overview of energy-related solutions in low-income and developing contexts and picturing a comprehensive map of models, technologies and actors involved.

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Appendix I: Case study analysis

In alphabetical order

Angaza Design, Tanzania, Kenya and Zambia		**Case description**
Value proposition / payment structure	Selling mini kits with additional services. Products are distributed through a network of women entrepreneurs. SERVICES: training, financing	Angaza Design provides solar mini kits with a pay-as-you-go technology which allows customer to pay small amounts to buy the solar system on credit. A local network of women entrepreneurs (Solar Sisters NGO) sells the products and customers own the product at the end of the credit period. Users receive training on product use and maintenance by the women entrepreneurs.
Energy system	Solar mini kits ENERGY-USING PRODUCTS: lights and mobile charger	
Ownership	End user	
Organisational form	Private enterprise, local entrepreneur (Solar Sisters NGO)	
Energy system operation	End user	
Target customer	Individual households, small businesses	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Low/medium	
Sources	Albi, E., Liebermarn, A. E. (2013). Bringing clean energy to the base of the pyramid. The interplay of business models, technology and local context. Journal of Management for Global Sustainability 2, 141–156 https://energypedia.info/wiki/Fee-For-Service_or_Pay-As-You-Go_Concepts_for_Photovoltaic_Systems#Rent-To-Own_vs._Service_Concepts http://energymap-scu.org/angaza-design/ https://wbi.worldbank.org/wbdm/ready-to-scale/angaza-design?destination=&page=6&viewall=all& www.angaza.com	

Avani, India		**Case description**
Value proposition / payment structure	Offering access to energy on a pay-per-consumption basis through connected mini grids SERVICES: installation, training	Avani works in the Indian Himalayan mountains where firewood is scarce and pine needles are a fire hazard and inhibitor for agriculture. The NGO developed a system that gasifies pine needles and produce energy. The community collects the needles and bring them to the power plant. The connected households pay a fixed fee for electricity.
Energy system	Biomass-based mini grids ENERGY-USING PRODUCTS: LED lanterns	
Ownership	Avani	
Organisational form	NGO, community	
Energy system operation	Community	
Target customer	Community	
Provider / customer relationship	Relationship-based	

Environmental sustainability potential	High	
Sources	http://energymap-scu.org/avani/ http://businesstoday.intoday.in/story/uttarakhand-company-producing-power-with-pineneedles/1/190360.html http://acumen.org/investment/avani-bio-energy/ http://thealternative.in/social-business/rural-innovation-series-turning-thorns-opportunity/ http://www.energynext.in/powering-progress/	

Azuri Technologies, Sub-Saharan Africa		**Case description**
Value proposition / payment structure	Selling mini kits with additional services. Customer pay with credit installments. SERVICES: installation, micro credit, maintenance	Azuri sells small solar kits on a PAYG- model where customer pay small installments until they own the product. Mini kits can include several lights, phone charger and other appliances such as radio and sewing machine. The company provides installation and maintenance services. Customers pay through scratch cards and energy-credit codes.
Energy system	Solar mini kits ENERGY-USING PRODUCTS: lights, mobile charger, radio, TV, sewing machine	
Ownership	End user	
Organisational form	Private enterprise	
Energy system operation	End user	
Target customer	Individual households and small businesses	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Low/medium	
Sources	IFC (2013). Lighting Africa Market Trends Report http://eight19.com/overview/indigo-pay-you-go-solar https://energypedia.info/wiki/Fee-For-Service_or_Pay-As-You-Go_Concepts_for_Photovoltaic_Systems#cite_note-35 http://www.youtube.com/watch?v=TNRZa9fGp3E	

Bboxx 1, Africa		**Case description**
Value proposition / payment structure	Offering recharging services through entrepreneur-owned and managed charging stations. Customers pay to recharge their products. SERVICES: installation and training	The company designs, manufactures, distributes and finances solar charging stations across Africa. The offer targets local entrepreneurs who buy the system (with financing services) and set up a charging business in their communities. Bboxx trains the entrepreneur in management and operation of the power station. End-users pay per unit of satisfaction, in this case to get their phones charged.
Energy system	Solar charging station ENERGY-USING PRODUCTS: battery, USB charger, fuses	
Ownership	Local entrepreneur	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Individual households, small businesses	

Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://www.bboxx.co.uk/energy-kiosk-2/ http://www.ft.com/cms/s/0/e49fc980-68a2-11e3-996a-00144feabdc0.html#axzz2yy3DniJ9 http://bennu-solar.com/wp-content/uploads/2013/05/Social-Impact-Assessment-of-Bboxxin-Uganda.pdf	

Bboxx 2, Africa		**Case description**
Value proposition / payment structure	Offering renting services through entrepreneur-owned and managed charging stations. SERVICES: installation and training	The company designs, manufactures, distributes and finances solar charging stations across Africa. The offer targets local entrepreneurs who buy the system (with financing services) and set up a renting business in their communities. Customers pay a deposit and a recharge fee to rent the solar products (lanterns, batteries).
Energy system	Solar charging station ENERGY-USING PRODUCTS: lanterns and batteries	
Ownership	Local entrepreneur	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Individuals	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://www.bboxx.co.uk/energy-kiosk-2/ http://www.ft.com/cms/s/0/e49fc980-68a2-11e3-996a-00144feabdc0.html#axzz2yy3DniJ9 http://bennu-solar.com/wp-content/uploads/2013/05/Social-Impact-Assessment-of-Bboxxin-Uganda.pdf	

CRERAL, Brasil		**Case description**
Value proposition / payment structure	Offering advice and training for community owned and managed connected mini grids. Customers pay per energy consumed. SERVICES: maintenance and repair, training	CRERAL is a Brazilian cooperative active in the district of Rio Grande do Sul that owns and manages the local electricity grid and two grid-connected hydro systems. The cooperative provides energy to the community, who pays for the energy consumed. Communities get training for operation and maintenance of the power plants and fee collection.
Energy system	Hydro mini grids connected to main grid (up to 120kW) ENERGY-USING PRODUCTS: -	
Ownership	Community	
Organisational form	Cooperative, community, private enterprise	
Energy system operation	Cooperative	
Target customer	Community	
Provider / customer relationship	Relationship-based	

Environmental sustainability potential	Medium/high	
Sources	Prado, J. (2008). Cooperative uses mini-hydro to increase electricity supply on local grid. Ashden Awards report. 2008 http://www.creral.com.br/index.php?id_menu=consumidor http://www.ashden.org/winners/creral08 http://vimeo.com/groups/hedon/videos/8597278	

CRELUZ, Brasil		**Case description**
Value proposition / payment structure	Offering advice and training services for community-owned and managed isolated mini grids. SERVICES: design, installation, training	CRELUZ provides Brasilian communities with hydropower plants. The mini grids are managed and owned by the cooperatives which count 20.000 members. Customers pay for the electricity they consume according to tariffs set with the cooperative. CRELUZ engineers train local people to operate the system and they encourage them to participate in its social and environmental activities.
Energy system	Isolated hydro mini grids ENERGY-USING PRODUCTS: -	
Ownership	Community	
Organisational form	Cooperative, community	
Energy system operation	Cooperative	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	
Sources	Pedo, M., Battisti, E. (2010). Cooperativa de Energia e Desenvolvimento Rural do Médio Uruguai Ltda (CRELUZ), Brazil Case study. Ashden Awards Bardouille P. (2012) From gap to opportunity: business models for scaling up energy access. World Bank http://www.creluz.com.br/ http://www.youtube.com/watch?v=BSWaqN0IoXk	

Coho Solar, Guatemala and Philippines		**Case description**
Value proposition / payment structure	Renting energy-using products through entrepreneur-owned and managed charging stations. SERVICES: maintenance and repair	Coho Solar target low-income families by providing solar batteries on a renting model through local entrepreneurs. Local shops get provided with an all-in-one charging station and provide a renting service to end users. For 15 cents, customers rent a solar recharged battery from the local grocery store. The customer transforms her/his battery powered device into a solar powered device. Coho's solar-recharged batteries are 4x the performance (energy per dollar) of existing disposable batteries.
Energy system	Solar charging services ENERGY-USING PRODUCTS: batteries, lights, mobile charger	
Ownership	Local entrepreneur	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Households	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	

Sources	http://energymap-scu.org/coho-solar/ https://www.crunchbase.com/organization/coho-solar#/entity http://prezi.com/nm5uaysmt55e/coho-solar-bottling-the-sun-the-blue-economy/

Deng Ltd., Ghana		**Case description**
Value proposition / payment structure	Selling individual energy systems with advice and training services. SERVICES: installation and training	Deng provides solar home systems to rural communities in Ghana. The company established a training centre for local entrepreneurs who then provide installation, training on product use to end users. Customers pay cash or credit and own the products.
Energy system	Solar individual systems ENERGY-USING PRODUCTS: -	
Ownership	End user	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	End user	
Target customer	Individual households	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Low	
Sources	Bosteen, F., Buabeng, H. (2009). Deng Ltd. Ashden Case Study Report http://www.ashden.org/winners/deng http://www.deng-ghana.com/index.php?option=com_content&view=article&id=7:dstc-offers-pv. http://www.dstcafrica.com/	

DESI Power, India		**Case description**
Value proposition / payment structure	Offering access to energy on a pay-per-consumption basis through isolated mini grids SERVICES: installation, maintenance and repair, training	DESI provides rural electrification in India by designing, installing and managing isolated mini grids. The company trains local entrepreneurs for plant operation and fee collection and in some cases sets up micro enterprises to manage the system. Customers that gets connected to the mini grid pay on a consumption basis.
Energy system	Biomass-based mini grids ENERGY-USING PRODUCTS: LED lanterns	
Ownership	DESI Power	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Palit, D., Chaurey, A. (2011) Off-grid rural electrification experiences from South Asia: Status and best practices. Energy for Sustainable Development 15 266–276 http://energymap-scu.org/desi-power/ http://www.desipower.com/Activities.aspx	

	http://www.entrepreneurstoolkit.org/index.php?title=DESI_Power,India-_A_case_study http://www.desipower.com

Devergy, Tanzania		**Case description**
Value proposition / payment structure	Offering access to energy on a pay-per-consumption basis through isolated mini grids. SERVICES: installation, operation and maintenance	Devergy provides energy in rural Tanzania through solar mini grids. The company installs PV panels and connects households and small businesses. Customers pay through mobile money according to the energy consumed. Devergy's solution is scalable as more PV panels can be added according to the village energy needs.
Energy system	Solar mini grid ENERGY-USING PRODUCTS: lights	
Ownership	Devergy	
Organisational form	Private enterprise	
Energy system operation	Devergy	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://www.devergy.com/ https://cleanenergysolutions.org/training/role-micro-grids-promoting-access-energy http://acumen.org/investment/devergy/ https://www.gsma.com/mobilefordevelopment/grantee/devergy-east-africa-ltd	

Econet Solar, Zimbabwe		**Case description**
Value proposition / payment structure	Selling mini kits with additional services SERVICES: installation, financing	Econet Solar is part of a larger company, Econet Renewable Energy that operates in Africa. In Zimbabwe, the company provides solar mini kits to customers with additional services. End users pay with mobile money an installation fee and then small installments over the credit period. They eventually own the product.
Energy system	Solar mini kits ENERGY-USING PRODUCTS: four lights, mobile charger	
Ownership	Customer	
Organisational form	Private enterprise	
Energy system operation	Customer	
Target customer	Individual	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Low	

Sources	http://www.econetwireless.com https://www.econet.co.zw/products/econet-solar http://www.go-green.ae/greenstory_view.php?storyid=1927 https://en.wikipedia.org/wiki/Econet_Wireless#Econet_Renewable_Energy

ESCO, Zambia		**Case description**
Value proposition / payment structure	Offering access to energy and energy using products on a pay-per-unit of satisfaction basis through individual systems. SERVICES: installation, training, maintenance and repair	The government of Zambia is involved in the creation of an Energy Service Company (ESCO), usually as subsidiary of an existing business by providing technical and business training. The government maintain the ownership of the systems and the ESCO performs installation, maintenance and repair, fee collection. Customers pay a fixed fee to receive the agreed amount of energy.
Energy system	Solar individual systems ENERGY-USING PRODUCTS: lights	
Ownership	ESCO	
Organisational form	ESCO (public utility)	
Energy system operation	ESCO	
Target customer	Individual households and small shops	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Gustavsson, M., Ellegard, A. (2004). The impact of solar home systems on rural livelihoods. Experiences from the Nyimba Energy Service Company in Zambia. Renewable Energy 29, 1059–1072 Lemaire, X. (2009). Fee-for-service companies for rural electrification with photovoltaic systems: the case of Zambia. Energy for Sustainable Development 13, 18–23	

Fenix International, Uganda and Rwanda		**Case description**
Value proposition / payment structure	Selling of solar mini kits with additional services. Customers pay through mobile installments for the credit period and then own the product. SERVICES: microcredit, warranty	The company sells solar mini kits with micro credit services through PAYG mobile. After an initial deposit, the user can pay daily, weekly or monthly instalments over the credit period, then he/she becomes owner of the system. A warranty for maintenance and repair is included.
Energy system	Solar mini kit ENERGY-USING PRODUCTS: phone charger, light	
Ownership	End user	
Organisational form	Private enterprise	
Energy system operation	End user	
Target customer	Individual households and small businesses	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Low/medium	
Sources	Collings, S. (2011). Phone charging micro businesses in Tanzania and Uganda. GVEP International, London	

	http://www.fenixintl.com/uganda/ http://singularityhub.com/2012/08/20/readyset-solar-charger-successful-in-africa-nowheaded-to-us/ http://greenfrog.typepad.com/weblog/2013/08/social-enterprises-choosing-for-profitbusiness-model-to-light-the-world.html

Gram Power 1, India		**Case description**
Value proposition / payment structure	Offering access to energy on a pay-per-consumption basis through isolated mini grids. SERVICES: installation, training, maintenance.	Gram Power provides energy services in rural India through the installation and operation of mini grids. Target customers are rural communities who gets connected to the mini grid and pre-pay for the energy they consume. Households gets smart meters installed at their home and have the possibility to prepay electricity through local entrepreneurs. The entrepreneur, in fact, purchases in bulk energy credit from Gram Power, who keeps ownership of the system, and transfer the recharge into the consumer's smart meter through a wireless technology.
Energy system	Mini grids running on solar, biomass, wind or hybrid ENERGY-USING PRODUCTS: -	
Ownership	Gram Power	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://www.grampower.com/about-us/ http://www.climatesolver.org/innovations/energy-access/gram-power-india http://articles.economictimes.indiatimes.com/2012-07-06/news/32566187_1_renewableenergy-innovation-pilferage http://www.theguardian.com/world/2012/sep/10/india-hamlet-where-power-stayed-on	

Gram Power 2, India		**Case description**
Value proposition / payment structure	Offering access to energy on a pay-per-unit of satisfaction basis through isolated mini grids. SERVICES: installation, training, maintenance.	Gram Power provides energy services in rural India through the installation and operation of mini grids. Target customers are rural communities who gets connected to the mini grid and pre-pay a fixed amount per month (pay-per-unit of satisfaction). A local entrepreneur is responsible for fee collection.
Energy system	Mini grids running on solar, biomass, wind or hybrid ENERGY-USING PRODUCTS: -	
Ownership	Gram Power	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Community	
Provider / customer relationship	Relationship-based	

Environmental sustainability potential	High	
Sources	http://www.grampower.com/about-us/ http://www.climatesolver.org/innovations/energy-access/gram-power-india http://articles.economictimes.indiatimes.com/2012-07-06/news/32566187_1_renewableenergy-innovation-pilferage http://www.theguardian.com/world/2012/sep/10/india-hamlet-where-power-stayed-on	

Grameen Shakti, Bangladesh		**Case description**
Value proposition / payment structure	Selling of individual energy systems with additional services – selling individual systems with training services SERVICES: installation, financing, maintenance and repair, training	The company offers solar home systems with a service package inclusive of end-user credit, installation, maintenance and repair, take-back services. In addition, Grameen Shakti offer training services targeted to training women as local technicians for repairs and maintenance of systems and for assemble solar accessories such as lamps, inverters, charge controllers. Grameen Shakti extended microcredit services to low-income people originated as an outgrowth of the pioneer in microcredit institution, Grameen Bank. GS model in Bangladesh shows the effective-ness of a "one stop shop" that markets PV systems, provides in-house financing and extends product-related services. End-users, low-income households and small businesses, can purchase the product with microcredit services and be able to repay the loan in 3-4 years.
Energy system	Solar individual systems (10-130Wp) ENERGY-USING PRODUCTS: batteries, lamps, TV, mobile charger	
Ownership	End user	
Organisational form	Private enterprise, women entrepreneurs	
Energy system operation	End user	
Target customer	Individual households and small businesses	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	
Sources	Wimmer, N. (2013). The art of rural business. Journal of Management for Global Sustainability 2 107–119 Biswas,W.K., Bryce, P., Diesendorf, M. (2001). Model for empowering rural poor through renewable energy technologies in Bangladesh. Environmental Science and Policy 4, 333–344 Gunaratne, L. (2002). Rural Energy Services Best Practices. USAIS/SARI http://energymap-scu.org/grameen-shakti/	

<table>
<tr><th colspan="2">Husk Power Systems, India</th><th>Case description</th></tr>
<tr><td>Value proposition / payment structure</td><td>Offering access to energy and energy-using products through mini grids. Customers pay a fixed monthly fee for using lamps and mobile chargers. Pay per unit of satisfaction.
SERVICES: installation, maintenance and repair, training.</td><td rowspan="8">The company provides energy solutions by designing and installing 25 kW to 100 kW isolated or connected mini grids based on biomass power plants. A partnership with local farmers is established to provide rice husk to power the plant. Households pre-pay a fixed monthly fee, ranging from 2 to 3 USD, to light up two fluorescent lamps and one mobile charging station. The company retains ownership and it employs local agents for operation, maintenance and fee collection. In the case of grid-connected systems, Husk Power sells electricity to the grid.</td></tr>
<tr><td>Energy system</td><td>Isolated and connected mini grids running on biomass</td></tr>
<tr><td>Ownership</td><td>Husk Power Systems</td></tr>
<tr><td>Organisational form</td><td>Private enterprise, local entrepreneurs</td></tr>
<tr><td>Energy system operation</td><td>Husk Power Systems</td></tr>
<tr><td>Target customer</td><td>Communities</td></tr>
<tr><td>Provider / customer relationship</td><td>Relationship-based</td></tr>
<tr><td>Environmental sustainability potential</td><td>High</td></tr>
<tr><td>Sources</td><td colspan="2">http://www.ashden.org/files/Husk%20winner.pdf
http://www.huskpowersystems.com/index.php?pageT=Home&page_id=1
http://acumen.org/investment/husk-power-systems/
http://energymap-scu.org/husk-power-systems/</td></tr>
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<table>
<tr><th colspan="2">IBEKA, Indonesia</th><th>Case description</th></tr>
<tr><td>Value proposition / payment structure</td><td>Offering advice and training for community owned and managed connected mini grids. Customers pay per unit of satisfaction, according to the agreed tariff.
SERVICES: installation and training</td><td rowspan="8">IBEKA is a non-profit organisation that provides hydro mini grids to communities with design, installation and community organisation. IBEKA sets up a community-managed enterprise to run the system and trains it for operation, maintenance and management. The grid connected system allows communities to sell to the national grid supplier and revenues cover operation, maintenance, loan repayments and a community fund. End-users pay according to the agreed tariff: pay per energy consumed (meter) or an agreed amount of energy per day.</td></tr>
<tr><td>Energy system</td><td>Hydro mini grids connected to main grid (up to 120kW)
ENERGY-USING PRODUCTS: -</td></tr>
<tr><td>Ownership</td><td>Community</td></tr>
<tr><td>Organisational form</td><td>NGO, community</td></tr>
<tr><td>Energy system operation</td><td>Community</td></tr>
<tr><td>Target customer</td><td>Community</td></tr>
<tr><td>Provider / customer relationship</td><td>Relationship-based</td></tr>
<tr><td>Environmental sustainability potential</td><td>Medium/high</td></tr>
<tr><td>Sources</td><td colspan="2">Mumpuni, T. (2012) Ashden case study | IBEKA, Indonesia, Report
http://www.ashden.org/winners/ibeka12
http://www.unescap.org/sites/default/files/23.%20Indonesia-Micro-Hydropower-Projects.pdf</td></tr>
</table>

	http://www.planetedentrepreneurs.com/planete/?p=2611&lang=en http://www.youtube.com/watch?v=Xm-PaJNlRp8

Juabar, Tanzania		**Case description**
Value proposition / payment structure	Offering access to energy-using products through entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis SERVICES: financing, training, maintenance	Juabar provides solar charging stations to local entrepreneurs in Tanzania. Using a high quality 50W solar-PV system, Juabar can charge either 10 or 20 phones or a variation of other small electronic devices at once. Entrepreneurs lease the charging station and get training on operation and management. Customers pay per unit (pay per recharge).
Energy system	Solar mobile charging station ENERGY-USING PRODUCTS: mobile chargers, battery	
Ownership	Juabar	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://juabar.com https://www.indiegogo.com/projects/juabar-solar-charging-kiosks-that-mean-business#/ https://www.energy4impact.org/news/juabar-crowdfund-support-solar-phone-charging-tanzania https://vc4a.com/ventures/juabar-design-1961654582/	

Kamworks 1, Cambodia		**Case description**
Value proposition / payment structure	Renting energy-using products through entrepreneur or community-managed charging stations. SERVICES: training, maintenance and repair	Kamworks set up a renting model for its charging station and lanterns in rural Cambodia. Local entrepreneurs receive training and lease the charging station from Kamworks, then offering renting of lanterns to customers. For each rented lantern Kamworks collect a fee. Entrepreneurs are responsible for maintenance of the station and lanterns.
Energy system	Solar charging stations ENERGY-USING PRODUCTS: lanterns	
Ownership	Kamworks	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	

Sources	http://www.kamworks.com/uploads/tx_news/Solar_Lantern_development_and_implementation_LQ__final__november_2010_01.pdf http://contourmagazine.com/2011/09/12/cambodia-by-moonlight-solar-powered-lanternby-kamworks/ http://nexus-scu.org/energymap/kamworks/ http://www.ease-web.org/wp-content/uploads/2011/07/20110630-Final-report-EASE-Pico-Sol-Cambodia.2.pdf http://www.picosol.org/en/countries/cambodia/181-business-in-a-box http://www.renewableenergyworld.com/rea/news/article/2011/04/off-grid-solar-solutionsshine-in-low-income-rural-cambodia	

Kamworks 2, Cambodia		**Case description**
Value proposition / payment structure	Leasing solar home systems SERVICES: training, maintenance and repair	Kamworks provide solar home systems on a leasing basis. Customers gets the systems installed and pay a deposit and a monthly fee through mobile money, according to the system size. Kamworks retains ownership and responsibility for repair and maintenance and take-back at the end of the contract. Mobile money and remote monitoring allows the company to retrieve real time data on systems' consumption and performances.
Energy system	Solar home systems (20W-160W) ENERGY-USING PRODUCTS: battery and plugs	
Ownership	Kamworks	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	End user	
Target customer	Individuals (households and businesses)	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	
Sources	http://www.kamworks.com/uploads/tx_news/Solar_Lantern_development_and_implementation_LQ__final__november_2010_01.pdf http://contourmagazine.com/2011/09/12/cambodia-by-moonlight-solar-powered-lanternby-kamworks/ http://nexus-scu.org/energymap/kamworks/ http://www.ease-web.org/wp-content/uploads/2011/07/20110630-Final-report-EASE-Pico-Sol-Cambodia.2.pdf http://www.picosol.org/en/countries/cambodia/181-business-in-a-box http://www.renewableenergyworld.com/rea/news/article/2011/04/off-grid-solar-solutionsshine-in-low-income-rural-cambodia	

KES, South Africa		**Case description**
Value proposition / payment structure	Offering access to energy on a pay per-unit of satisfaction through individual energy systems SERVICES: installation, maintenance and repair	A private-public partnership between KES and the public utility in South Africa provided rural households with electricity from solar home systems. KES installs the system at the customer house. The customer
Energy system	Solar individual systems (50 Wp)	

<table>
<tr><td></td><td>ENERGY-USING PRODUCTS: mobile charger, lights</td><td rowspan="7">pays an installation fee (R110) and a cellular phone charger was offered for an additional R20. Customers would then pay a monthly fee for a limited amount of electricity per day. KES retains ownership and responsibilities of all products.</td></tr>
<tr><td>Ownership</td><td>KES</td></tr>
<tr><td>Organisational form</td><td>Public utility, Private enterprise (EDF-Total)</td></tr>
<tr><td>Energy system operation</td><td>KES</td></tr>
<tr><td>Target customer</td><td>Individual households</td></tr>
<tr><td>Provider / customer relationship</td><td>Relationship-based</td></tr>
<tr><td>Environmental sustainability potential</td><td>High</td></tr>
<tr><td>Sources</td><td colspan="2">Prasad, G. (2007). Electricity from solar home systems in South Africa. Energy Research Centre UCT, South Africa
http://total.com/en/energies-expertise/renewableenergies/solar/photovoltaic-solar-energy/projects-achievements/kes-1
http://www.engineeringnews.co.za/article/kwazulu-energy-services-expands-ruralelectrification-programme-to-e-cape-2009-05-06</td></tr>
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<table>
<tr><th colspan="2">Khimti Rural Electrification Cooperative (KREC), Nepal</th><th>Case description</th></tr>
<tr><td>Value proposition / payment structure</td><td>Offering advice and training for community-owned and managed isolated mini grids.
SERVICES: installation and training</td><td rowspan="8">KREC was established in 2004 to operate and run a hydropower plant that connects 400 households in Nepal. The community owns the system and has been trained to operate it and to run the energy business through the cooperative.</td></tr>
<tr><td>Energy system</td><td>Isolated mini grids
ENERGY-USING PRODUCTS: -</td></tr>
<tr><td>Ownership</td><td>Community</td></tr>
<tr><td>Organisational form</td><td>Cooperative</td></tr>
<tr><td>Energy system operation</td><td>Cooperative</td></tr>
<tr><td>Target customer</td><td>Community</td></tr>
<tr><td>Provider / customer relationship</td><td>Relationship-based</td></tr>
<tr><td>Environmental sustainability potential</td><td>Medium/high</td></tr>
<tr><td>Sources</td><td colspan="2">http://www.gorkhapatra.org.np/rising.detail.php?article_id=32509&cat_id=27
https://www.ekantipur.com/the-kathmandu-post/2010/04/19/Business/HPL-ruralelectrification-improves-lives-in-Khimti/207397/
http://www.dmu.ac.uk/documents/technology-documents/research-faculties/oasys/project-activities/decentralised-off-grid-electricity-generation/experiences-from-nepal---mr-dilli-prasad-ghimire.pdf
http://hpl.com.np/about-hpl/fact-sheets/</td></tr>
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<table>
<tr><th>Mera Gao Power, India</th><th>Case description</th></tr>
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Value proposition / payment structure	Offering access to energy on a pay-per-unit of satisfaction through isolated mini grids. SERVICES: installation, training, maintenance.	Mera Gao Power provides rural villages in India with solar mini grids. The systems are easy to be installed and distribute electricity to off-grid villages. Customers receive two lights and a mobile charger and pay for using energy for a limited amount of time a day. Mera Gao retains ownership and responsibility of all products involved.
Energy system	Isolated mini grids ENERGY-USING PRODUCTS: lights and mobile charger	
Ownership	Mera Gao Power	
Organisational form	Private enterprise (installation, maintenance and repair)	
Energy system operation	Mera Gao Power	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://meragaopower.com/gallery/ http://www.ashden.org/awards/2014/international http://www.theguardian.com/sustainable-business/selling-energy-service-meetingneeds-of-poor https://www.forbes.com/sites/suparnadutt/2017/01/17/solar-energy-entrepreneurs-in-india-are-finding-faster-cleaner-and-economical-route-to-power/#79eabda86eb8	

M-Kopa, Kenya		**Case description**
Value proposition / payment structure	Selling of solar mini kits with additional services. Customers pay through mobile installments for the credit period and then own the product. SERVICES: microcredit, warranty	M-Kopa provides energy by selling solar mini kits with lights, radio, phone charging and enabling customers to pay small, flexible installments over time. By partnering with a technology provider (d.Light) and using the existing network of mobile money M-PESA, the company allows customers to pay an initial deposit and then process payments via mobile money-transfer. If the payment does not occur the system gets blocked. After the credit period, the customer owns the system and benefits from free and sustainable energy provision.
Energy system	Solar mini kits ENERGY-USING PRODUCTS: lights, torch, phone charging, radio	
Ownership	End user	
Organisational form	Private enterprise	
Energy system operation	End user	
Target customer	Individual households and small businesses	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Low/medium	
Sources	Nique, M., Arab, F. (2012). Sustainable Energy and Water Access through M2M Connectivity. GSMA	

	http://gigaom.com/2014/04/10/how-m-kopa-unlocked-pay-as-you-go-solar-in-rural-kenya/ http://acumen.org/investment/m-kopa/ http://www.m-kopa.com/

Mobisol, Tanzania, Kenya and Ghana		**Case description**
Value proposition / payment structure	Selling individual energy systems with additional services – Selling individual energy systems with training services SERVICES: financing, maintenance and repair, training	The company sells solar home systems with some additional services (financing, maintenance) and integrated mobile payment modality. Customers buy the chosen system and pay through mobile installments over the credit period. In addition, Mobisol provides training services through the Mobisol Akademie, a training institution for staff, local entrepreneurs and contractors who wants to specialise in sales and technical support of solar home systems. The aim is to create local employment and capacity building and ensure that local expertise and assistance is provided.
Energy system	Solar home systems ENERGY-USING PRODUCTS: lights, mobile charger, TV etc.	
Ownership	End user	
Organisational form	Private enterprise	
Energy system operation	End user	
Target customer	Individual households, small businesses	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Low/medium	
Sources	Nique, M., Arab, F. (2012). Sustainable Energy andWater Access through M2MConnectivity.GSMA http://microenergy-project.de/index.php?id=637 http://www.plugintheworld.com/mobisol/impact/ http://www.aecfafrica.org/windows/react/projects/mobisol-gmbh http://vimeo.com/56383921 http://prezi.com/cyrhpc3tmi10/mobisol-a-green-inclusive-business/ http://www.arushatimes.co.tz/Local%20News_5.html	

NuRa, South Africa		**Case description**
Value proposition / payment structure	Offering access to energy and energy-using products through solar home systems on a pay-per-unit of satisfaction basis. Customers pay a fixed monthly fee to use the chosen system. SERVICES: installation, maintenance and repair, upgrade	NuRa provides energy through solar home systems. The company sets up an Energy Store where an entrepreneur is responsible for service provision and installation of the SHS. End-users pay an initial fee (500R) and pre-pay a monthly fee of 61R that enables the connection of four fluorescent lamps and an outlet for a small black and white TV or a radio, operated on direct current (50W panel) for four hours a day. Fees, based on the unit of satisfaction agreed (X
Energy system	Solar individual systems, ENERGY-USING PRODUCTS: fluorescent lights	
Ownership	NuRa	
Organisational form	Private enterprise	
Energy system operation	NuRa	
Target customer	Individual households	

Provider / customer relationship	Relationship-based	amount of electricity for X hours a day), are collected through local businesses and shops. The ownership stays with NuRa, who is also in charge of maintenance and repairs.
Environmental sustainability potential	High	
Sources	Winrock International forWorld Bank (2008). Final Report Policy and Governance Framework for Off-grid Rural Electrification with Renewable Energy Sources Lemaire, X. (2011). Off-grid electrification with solar home systems: The experience of a fee-for-service concession in South Africa. Energy for Sustainable Development 15, 277–283	

Nuru Energy, Rwanda and Kenya		**Case description**
Value proposition / payment structure	Offering pay-per-unit services (charging) through charging stations. Customers pay to get their lanterns recharged. SERVICES: maintenance and repair, training	Nuru Energy provides pedal-powered charging stations to local entrepreneur who buy the station and the lanterns (with credit services). The entrepreneur then offers recharging services for the lanterns and customers pay-per-recharge. Nuru Energy receive a franchise fee for each recharge.
Energy system	Pedal-powered charging station ENERGY-USING PRODUCTS: portable lanterns	
Ownership	Local entrepreneur, end user (lanterns)	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Individual households	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Dish, D., Bronkaers, J. (2012). An analysis of the off-grid lighting market in Rwanda: sales, distribution and marketing. GVEP International, London http://www.kiva.org/partners/271 http://www.se4all.org/commitment/expanding-rural-energy-entrepreneurship-andaccess-to-clean-lighting-in-east-africa/ http://nuruenergy.com/nuru-africa/the-solution/powercycle/ http://www.forbes.com/sites/csr/2011/10/10/how-sameer-hajee-has-shed-reallight-in-africa/	

Off Grid Electric, Tanzania		**Case description**
Value proposition / payment structure	Offering access to energy and energy-using products through solar mini kits. Customers pay daily fees to use the mini kit for a certain amount of time per day (e.g. 8h) - Pay-per-unit of satisfaction. SERVICES: installation, maintenance and repair, product upgrade, basic customer's training	The company provides electricity services through solar mini-kits installed at customer's home. Customers can choose the size of the kit according to the appliances they need (starting kit includes two lights and a phone charger for eight hours a day) and upgrade with
Energy system	Solar mini kit (5-10 Wp),	

	ENERGY-USING PRODUCTS: lights, phone chargers and radio	additional appliances (more lights, radio, TV). Off Grid Electric retains ownership of systems and appliances and trains a network of local dealers for installation and customer support. Customers pay an initial deposit and pre-pay the energy service through mobile money. When the payment is received, the customer receives an SMS with a code to unlock the system and start using it.
Ownership	Off Grid Electric	
Organisational form	Private enterprise	
Energy system operation	Off Grid Electric	
Target customer	Individual households, small businesses	
Provider / customer relationship	Relationship-based: customers are assisted with 18h-day call centre and agents provide customers' training and assistance	
Environmental sustainability potential	High	
Sources	Ashden Case study report: Off Grid Electric, Ashden International Winner 2014 http://offgrid-electric.com/ http://venturebeat.com/2014/03/21/off-grid-electric-gets-7m-to-light-africa-in-a-decade-exclusive/ http://www.jasmine.org.nz/ventures/off-grid-electric/ http://www.fastcoexist.com/1681724/how-to-power-10-million-off-grid-african-homes-in-10-years	

OMC Power 1, India		**Case description**
Value proposition / payment structure	Offering access to energy on a pay-per-consumption basis through individual energy systems. Renting energy-using products through entrepreneur or community managed charging stations. SERVICES: installation, training, maintenance.	The company offers energy solutions to productive activities (telecom tower companies) through large stand-alone power plants running on solar, hydro, wind or hybrid, according to the specific conditions. Mobile network operators get the power plant installed on site and pay according to the energy consumed (kWh). OMC Power retains the ownership of system and provide operation and maintenance.
Energy system	Individual systems running on solar, biomass, wind or hybrid ENERGY-USING PRODUCTS: lanterns, fans, batteries	
Ownership	OMC Power	
Organisational form	Private enterprise	
Energy system operation	OMC Power	
Target customer	Industrial customers	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	www.omcpower.com http://articles.economictimes.indiatimes.com/2012-11-01/news/34857689_1_uninterrupted-power-solar-power-conventional-power-lines http://www.gsma.com/mobilefordevelopment/one-mobile-tower-and-lantern-at-a-time	

	https://mobiledevelopmentintelligence.com/insight/MDI_Case_Study_-_OMC_Power From the Bottom Up - How small power producers and mini-grids can deliver electrification and renewable energy in Africa.

OMC Power 2, India		**Case description**
Value proposition / payment structure	Renting energy-using products through entrepreneur or community managed charging stations. SERVICES: installation, training, maintenance.	The company offers energy solutions to off grid villages through charging stations. OMC Power retains the ownership of system and provide operation and maintenance. The company provides charging services through entrepreneur or community-managed stations. Customers can rent lanterns or batteries and pay for the time of use.
Energy system	Charging stations ENERGY-USING PRODUCTS: lanterns, fans, batteries	
Ownership	OMC Power	
Organisational form	Private enterprise, local entrepreneur	
Energy system operation	OMC Power	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	www.omcpower.com http://articles.economictimes.indiatimes.com/2012-11-01/news/34857689_1_uninterrupted-power-solar-power-conventional-power-lines http://www.gsma.com/mobilefordevelopment/one-mobile-tower-and-lantern-at-a-time https://mobiledevelopmentintelligence.com/insight/MDI_Case_Study_-_OMC_Power From the Bottom Up - How small power producers and mini-grids can deliver electrification and renewable energy in Africa.	

Persistent Energy (PEG), Ghana		**Case description**
Value proposition / payment structure	Offering access to energy and energy-using products on a pay-per-unit of satisfaction through mini kits SERVICES: financing,	The company offers solar mini kits with lights, radio and mobile chargers on a pay-per-unit of satisfaction basis. Customers get the kits installed and pay daily or weekly fees to activate the system. If payments do not occur the system gets shut down. The company monitors energy needs and usage through mobile money technology.
Energy system	Solar mini kits ENERGY-USING PRODUCTS: -	
Ownership	Persistent Energy	
Organisational form	Private enterprises (PEG and M-Kopa)	

Energy system operation	Persistent Energy	
Target customer	Individual households	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	https://www.pegafrica.com http://www.triplepundit.com/2013/12/persistent-energy-ghana-brings-solar-need-light/ http://www.ietp.com/en/company/peg-africa https://www.businessghana.com/site/directory/utilities/397646/PEG-Ghana-Solar-Limited	

PowerGen Renewable Energy, Kenya		**Case description**
Value proposition / payment structure	Offering access to energy on a pay-per-consumption basis through isolated mini grids. SERVICES: installation, training, maintenance.	PowerGen Renewable Energy provide reliable and clean energy supply to the township of Remba Island with a wind and solar powered micro grid. The technology is locally built and installed, a local entrepreneur is trained to provide operation and maintenance while customer pay for the energy consumed through mobile phones.
Energy system	Solar and wind isolated mini grid ENERGY-USING PRODUCTS: smart meters	
Ownership	PowerGen	
Organisational form	PowerGen, local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://powergen-renewable-energy.com/micro-grids/ http://accessenergy.org/ http://www.youtube.com/watch?v=rvSAX8Uwn4k http://www.kiva.org/partners/340 http://www.wired.co.uk/news/archive/2013-08/29/remba-micro-grid http://inhabitat.com/accessenergy-aims-to-bring-life-changing-clean-energy-to-kenyasslum-island/	

Practical Action, Peru		**Case description**
Value proposition / payment structure	Offering advice and training services for community-owned and managed mini grids. Customers pay per energy consumed with tariffs structured according to the type of user SERVICES: training, operation and maintenance	The NGO helps communities in the Andes region in installing and setting-up mini grids running on hydropower. Practical Action partners with local manufacturers to design

Energy system	Hydro mini grids, isolated ENERGY-USING PRODUCTS: -	the system, then involves the communities by setting up a village committee that will take care of fee collection and trains some technicians who will perform daily operation and maintenance. The community participates in the system installation with construction labour and becomes owner of the energy system. End-users pay for the electricity they consume with tariffs that differ between the type of customers.
Ownership	Community	
Organisational form	NGO, community	
Energy system operation	Community	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	
Sources	Albi, E., Liebermarn, A. E. (2013). Bringing clean energy to the base of the pyramid. The interplay of business models, technology and local context. Journal of Management for Global Sustainability 2, 141–156 http://energymap-scu.org/practical-action-peru/ http://practicalaction.org/peru-1 http://www.ashden.org/winners/practicalaction	

Quetsol/Kingo, Guatemala and South Africa		**Case description**
Value proposition / payment structure	Offering access to energy and energy-using products on a pay-per-unit of satisfaction through mini kits. SERVICES: installation, maintenance and repair, upgrade	Kingo (previously Quetsol) provides energy services through small solar systems to customers who flexibly pay daily, weekly or monthly installments. Users pay per unit when they need the energy. The company provides installation and full service of their systems and upgrades them according to the growing energy demand.
Energy system	Solar mini kits ENERGY-USING PRODUCTS: lights, USB charger	
Ownership	Kingo	
Organisational form	Private enterprise	
Energy system operation	Kingo	
Target customer	Individual households and small businesses	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://www.quetsol.com/ http://kingoenergy.com/about/ http://latincorrespondent.com/tag/quetsol/ http://agorapartnerships.org/accelerator-2/for-entrepreneurs/by-class/quetsol https://www.bcorporation.net/community/quetsol http://magazine.good.is/articles/how-pay-as-you-go-solar-is-bringing-light-to-rural-guatemala http://www.fastcoexist.com/3016109/change-generation/bringing-solar-to-impoverished-towns-with-a-model-straight-from-the-corpor#1fckLR	

Redavia, Tanzania		**Case description**
Value proposition / payment structure	Offering individual energy systems in leasing to productive activities. SERVICES: installation, maintenance and repair	Redavia provides pre-assembled PV blocks that can be shipped and easily installed in remote locations. The stand-alone systems can run with hybrid diesel generators. Redavia is responsible for installation, operation and maintenance and provides flexible contracts for mining companies or other industrial customers. Customers pay according to the length of the contract and the size of the system installed.
Energy system	Individual energy systems, PV and hybrid ENERGY-USING PRODUCTS: -	
Ownership	Redavia	
Organisational form	Private enterprise (installation, maintenance)	
Energy system operation	Redavia	
Target customer	Productive activities	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://unfccc.int/secretariat/momentum_for_change/items/7850.php http://www.redaviasolar.com/ http://www.pidg.org/impact/case-studies/tanzania-redavia-off-grid-solar-project http://www.infracoafrica.com/project/redavia-2/	

REPRO, Rwanda		**Case description**
Value proposition / payment structure	Offering access to energy on a pay-per-unit of satisfaction basis through mini grids. SERVICES: installation, operation and maintenance	REPRO (Rwanda Renewable Energy Promotions) provides hydro mini grids to off-grid communities in Rwanda. The company builds and operate the mini grid and connects villagers who pay according to their consumption rate. REPRO trains local technicians to provide maintenance.
Energy system	Biomass-based mini grids ENERGY-USING PRODUCTS: LED lanterns	
Ownership	REPRO	
Organisational form	Private enterprise	
Energy system operation	REPRO	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	

Sources	Mirunda Micro Hydro (n.d.) Rural energy promotion, the Africa-EU Energy Partnership Bardouille P. (2012) From Gap to opportunity Business Models for Scaling Up Energy Access. The World Bank http://reprorwanda.com http://www.bbc.co.uk/news/world-africa-15695207

SELCO, Sri Lanka		**Case description**
Value proposition / payment structure	Selling of individual energy systems with additional services – selling individual energy systems with training, advice and consultancy services. SERVICES: financing, installation, maintenance and repair, training	SELCO sells energy home systems and products with an inclusive service package. SELCO offers tailored products and financing services to its clients by facilitating customers getting financed through its partners. In Sri Lanka, SELCO partners with SEEDS (Sarvodaya Economic Enterprise Development Services) and therefore focuses its expertise in providing high quality services in installation and maintenance of systems, while the MFI takes care of loans and repayments. In addition, in order to prevent users from misuse or damage the solar systems, the company provides user training during installation of systems. Technicians, qualified by in-house training programs, explain clearly what the user should expect from the system and how to use it.
Energy system	Solar individual systems ENERGY-USING PRODUCTS: batteries, lamps, TV, mobile charger	
Ownership	End user	
Organisational form	Private enterprise, MFI	
Energy system operation	End user	
Target customer	Individual households and small businesses	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	
Sources	Gunaratne, L. (2002). Rural Energy Services Best Practices. USAIS/SARI http://energymap-scu.org/selco/ http://www.selco-india.com/ http://www.ashden.org/winners/selco07	

Shared Solar, Mali		**Case description**
Value proposition / payment structure	Offering access to energy and energy-using products through isolated mini grids. Customers pre-pay for the electricity they consume. SERVICES: installation, training, maintenance and repair	Shared Solar provides energy services to rural communities by installing solar mini grids with a local distribution network. Households gets connected and provided with smart meters to measure consumption. Customers pre-pay for the electricity through a local entrepreneur that collects mobile payments and provide energy codes through scratch
Energy system	Solar isolated mini grids ENERGY-USING PRODUCTS: lights, smart meters	
Ownership	Shared Solar	
Organisational form	Private enterprise, local entrepreneur	

Energy system operation	End user	cards. The entrepreneur is trained for operation and maintenance of the grid, while Shared Solar retain ownership.
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Roach, M., Ward, C. (2011). Harnessing The Full Potential of Mobile for Off-Grid Energy. IFC, London http://sharedsolar.org/ http://blogs.ei.columbia.edu/2012/02/09/solar-power-lights-up-new-business/ http://www.greentechmedia.com/articles/read/can-microgrids-electrifyone-billion-people	

Simpa Networks, India		**Case description**
Value proposition / payment structure	Selling individual energy systems with additional services. SERVICES: installation (through partners SELCO), micro credit, maintenance and repair	Simpa Networks sells solar home systems and appliances with additional services in India. The company provides installation (through their partner SELCO), when the customer pays an installation fee (10-30% of the price). After that users pay small installments over the credit period. Servicing and maintenance of the systems is also included.
Energy system	Solar home systems ENERGY-USING PRODUCTS: lights, phone charger, fan	
Ownership	End user	
Organisational form	Private enterprise	
Energy system operation	End user	
Target customer	Individual households	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Low/medium	
Sources	IFC (2013). Lighting Africa Market Trends Report https://energypedia.info/wiki/Fee-For-Service_or_Pay-As-You-Go_Concepts_for_Photovoltaic_Systems#Rent-To-Own_vs._Service_Concepts http://simpanetworks.com/	

Solarkiosk, Africa and Asia		**Case description**
Value proposition / payment structure	Offering access to energy-using products through community or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis SERVICES: installation, training	The company targets local entrepreneurs, especially women, for the provision of energy services through charging stations. Solarkiosk design and installs the E-Hubb,

Energy system	Charging station (solar) ENERGY-USING PRODUCTS: lights, laptop, printer, water purifier etc.	a charging station provided with solar panels and energy using products and recruits a local entrepreneur who manages the system and appliances. Due to the modular configuration of the station, he/she can provide a wide range of energy services such as internet connectivity, water purification, copying, printing and scanning etc. Customers pay for the agreed unit of satisfaction: pay to print, pay to get purified water, pay for internet access etc.
Ownership	Solarkiosk	
Organisational form	Solarkiosk, entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Community/individual	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	http://solarkiosk.eu/ http://www.gvepinternational.org/en/business/news/versatile-solarkiosksproviding-much-needed-energy-services-grid-communities http://www.sustainablebusinesstoolkit.com/solarkiosk/	

Solar Now, Uganda and Kenya		**Case description**
Value proposition / payment structure	Selling individual energy systems with additional services SERVICES: financing, installation, maintenance and repair	Solar Now offers individual systems and products targeted at households and businesses. Customers chose the system and energy-using products they need and pay with the options of financing over a credit period. Solar Now provides installation and maintenance and repair for five years. Customers own the products after the credit period.
Energy system	Solar home systems starting from 50 Wp ENERGY-USING PRODUCTS: radio, light, iron, fridge, TV, chargers etc.	
Ownership	Customer	
Organisational form	Private enterprise	
Energy system operation	Customer	
Target customer	Households and businesses	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Low-medium	

Sources	UDNP (2013) Breaking Through: Inclusive Business and the Business Call to Action Today. Mapping challenges, progress and the way ahead. UNDP, NY http://acumen.org/investment/solarnow/ https://www.solarnow.eu

Solar Transition 1, Kenya		**Case description**
Value proposition / payment structure	Renting energy using products through entrepreneur-managed charging stations. SERVICES: training, maintenance and repair	The Solar Transition project targets off grid communities with energy services provided through solar charging station. The energy centre is operated and maintained by a local entrepreneur. Services offered include renting of lanterns and batteries. Customers pay to rent products.
Energy system	Solar charging station ENERGY-USING PRODUCTS: lanterns and batteries	
Ownership	Solar Transition	
Organisational form	Local entrepreneur	
Energy system operation	Local entrepreneur	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Ulsrud, K., Winther, T., Palit, D., Rohracher, H., Sandgren, J. (2011). The Solar Transitions research on solar mini-grids in India: learning from local cases of innovative socio-technical systems. Energy for Sustainable Development 15 293–303 http://www.sv.uio.no/iss/english/research/projects/solar-transitions/energy-centre/index.pdf http://south-south.connect.teriin.org/files/Ikisaya-brochure.pdf http://www.sv.uio.no/iss/english/research/projects/solar-transitions/ http://www.ifz.tugraz.at/eng/Research/Energy-and-Climate/Current-projects/Solar-Transitions	

Solar Transition 2, Kenya		**Case description**
Value proposition / payment structure	Providing energy on a pay-per-unit of satisfaction basis through entrepreneur-managed charging stations. SERVICES: training, maintenance and repair	The Solar Transition project targets off grid communities with energy services provided through solar charging station. The energy centre is operated and maintained by a local entrepreneur. Services offered include mobile charging, IT and photocopying. Customers pay
Energy system	Solar charging station ENERGY-USING PRODUCTS: lanterns	
Ownership	Solar Transition	

Organisational form	Local entrepreneur	according to the service needed on a pay-per-unit basis.
Energy system operation	Local entrepreneur	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Ulsrud, K., Winther, T., Palit, D., Rohracher, H., Sandgren, J. (2011).The Solar Transitions research on solar mini-grids in India: learning from local cases of innovative socio-technical systems. Energy for Sustainable Development 15 293–303 http://www.sv.uio.no/iss/english/research/projects/solar-transitions/energy-centre/index.pdf http://south-south.connect.teriin.org/files/Ikisaya-brochure.pdf http://www.sv.uio.no/iss/english/research/projects/solar-transitions/ http://www.ifz.tugraz.at/eng/Research/Energy-and-Climate/Current-projects/Solar-Transitions	

Sunfarmer, Nepal		**Case description**
Value proposition / payment structure	Selling individual energy systems with additional services SERVICES: design, installation, maintenance, financing	Sunfarmer provides energy to health facilities, hospitals and schools by selling solar system with additional services. The company designs and installs the system according to the customers' needs and provides financing so that they can pay over a credit period. Maintenance is provided by local partners.
Energy system	Solar individual systems ENERGY-USING PRODUCTS: -	
Ownership	Customer	
Organisational form	Private enteprise	
Energy system operation	Customer	
Target customer	Health clinics, schools	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Medium-low	
Sources	http://www.sunfarmernepal.org https://www.fastcompany.com/3035841/bringing-solar-power-to-remote-hospitals-is-saving-lives https://www.theguardian.com/sustainable-business/2014/aug/18/solar-systems-blackout-nepal-hospital-energy	

Sustainable Energy Services, Afghanistan		**Case description**
Value proposition / payment structure	Offering advice and training for community-owned and managed isolated mini grids. SERVICES: installation and training	Sustainable Energy Afghanistan installs mini grid in off grid areas and trains local technicians for maintenance. The community takes ownership of the grid system and adopts pre-pay electricity meters for paying the energy they consume.
Energy system	Isolated mini grids ENERGY-USING PRODUCTS: -	
Ownership	Community	
Organisational form	Community, NGO	
Energy system operation	Community	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	
Sources	http://sesa.af/projects/sayed-karam-solar-pv-project/ http://www.sesinter.com/our-projects/afghanistan/bamyan-solar-project/ http://www.infrastructurenews.co.nz/node/728	

Suntransfer, Kenya and Ethiopia		**Case description**
Value proposition / payment structure	Selling individual energy systems with additional services SERVICES: financing, installation, maintenance	The company offers small solar home systems for households and businesses. Customers pay to purchase the product with a credit service and pre-pay through small installments. Suntransfer provides installation and maintenance through a network of energy centres and technicians.
Energy system	Solar home systems ENERGY-USING PRODUCTS: lights, mobile charger	
Ownership	Customer	
Organisational form	Private enterprise	
Energy system operation	Customer	
Target customer	Individual households and businesses	
Provider / customer relationship	Transaction-based	
Environmental sustainability potential	Low-medium	

Sources	https://aecfafrica.org/sites/default/files/one-pagers/Suntransfer%20Kenya.pdf http://suntransfer.com

Sunlabob 1, Laos		**Case description**
Value proposition / payment structure	Renting energy-using products through entrepreneur- or community-managed charging stations. Customers pay to rent the lanterns. SERVICES: installation, training, maintenance and repair	The company provides energy service through a renting model: it leases the charging station and energy-using products (lanterns) to a village committee who in turns rents the products to the individual households. The committee is in charge of setting prices, collecting rents and perform basic maintenance. Sunlabob retains ownership, maintenance responsibilities and offers training services. End-users can rent the recharged lantern for $0.25 and it will last for 15 hours of light, while the committee pays to rent the charging station ($1.75-8 per month).
Energy system	Solar charging stations | isolated mini grids ENERGY-USING PRODUCTS: lanterns	
Ownership	Sunlabob	
Organisational form	Private enterprise, community or local entrepreneur	
Energy system operation	Community / local entrepreneur	
Target customer	Communities	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Flotow, P., Friebe, C. (2013). Scaling up Successful Micro-Utilities for Rural Electrification. SBI, Burgstrasse http://www.ashden.org/winners/sunlabob http://energymap-scu.org/sunlabob/ http://www.youtube.com/watch?v=wXCdreDNDC0	

Sunlabob 2, Laos		**Case description**
Value proposition / payment structure	Providing energy services on a pay per consumption basis through isolated mini grids. SERVICES: installation, training, maintenance and repair	Sunlabob targets off grid communities in Laos by installing isolated mini grids. Communities that get connected pay according to their KWh consumption. Sunlabob trains a local entrepreneur to provide operation and maintenance and the company retains responsibilities for major repairs.
Energy system	Isolated mini grids ENERGY-USING PRODUCTS: -	
Ownership	Sunlabob	
Organisational form	Private enterprise	
Energy system operation	Local entrepreneur	
Target customer	Communities	

Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Flotow, P., Friebe, C. (2013). Scaling up Successful Micro-Utilities for Rural Electrification. SBI, Burgstrasse http://www.ashden.org/winners/sunlabob http://energymap-scu.org/sunlabob/ http://www.youtube.com/watch?v=wXCdreDNDC0	

Temasol, Morocco		**Case description**
Value proposition / payment structure	Offering access to energy on a pay per-unit of satisfaction through individual energy systems SERVICES: installation, operation and maintenance	Temasol (joint venture between EDF and Total) provides energy through solar home systems. The company installs, operates and maintains the systems while customers pay a fee according to the size of the system chosen.
Energy system	Solar individual systems (50-200 Wp) ENERGY-USING PRODUCTS: lights, plugs, refrigerator	
Ownership	Temasol	
Organisational form	Private enterprise	
Energy system operation	Temasol	
Target customer	Individual households	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Allalli, N., 2011. TEMASOL: Providing Energy Access to Remote Rural Households in Morocco. Temasol (2010) An introduction to Temasol's activities (https://www.oecd.org/mena/competitiveness/46769870.pdf) http://www.pickar.caltech.edu/me105/materials/casestudies/temasol_full_case_final_web.pdf https://www.globalhand.org/en/browse/regions/Middle+East/success+story/document/33676	

TERI, India		**Case description**
Value proposition / payment structure	Renting energy-using products through entrepreneur-owned and managed charging stations. Customers pay to rent lanterns. SERVICES: maintenance and repair, training and financing to entrepreneur	TERI provides charging stations for renting lanterns to rural customers in India through an entrepreneur-led model. TERI sets up micro solar enterprises in un-electrified or poorly electrified villages. A local
Energy system	Solar charging services	

	ENERGY-USING PRODUCTS: LED lanterns	entrepreneur, who receives training and financing, buys and manages the charging station by renting the solar lamps every evening, for an affordable fee, to the rural populace. Every household pays a nominal charge (Rs. 2–4 approx.) per day per lantern for getting it charged.
Ownership	Local entrepreneur	
Organisational form	Private enterprise, local entrepreneur, NGO, MFI	
Energy system operation	Local entrepreneur	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	
Sources	http://www.sv.uio.no/iss/english/research/projects/solar-transitions/announcements/TERI-Lighting_a_BillionLives_Palit.pdf http://cdkn.org/2013/05/feature-lighting-a-billion-lives-in-india/ http://www.theguardian.com/global-development/poverty-matters/2013/mar/06/-india-solar-electricity http://india.blogs.nytimes.com/2012/08/06/alternate-energy-practices-at-the-grassroots/?_php=true&_type=blogs&_r=0 http://www.hedon.info/LightingBillionLives+TERI	

Tiny Pipes, Philippines		**Case description**
Value proposition / payment structure	Offering individual energy system and energy using products on leasing. SERVICES: installation, maintenance	TinyPipes designed their own smart solar panels that they can meter and control over a cellular network. The company installs the solar system which is connected to a battery. Users pre-pay for energy by texting in a payment via mobile money, or by paying in cash at a local store. Once the payment is made, the system gets unlocked and recharge the battery. Customers pay according to different contracts, with weekly or daily plans. Tinypipes retains ownership and responsibilities of products.
Energy system	Solar individual systems (60 Wp) ENERGY-USING PRODUCTS: battery	
Ownership	Tinypipes	
Organisational form	Private enterprise	
Energy system operation	Customer	
Target customer	Households	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium-high	
Sources	https://www.fastcompany.com/3020376/to-bring-power-to-15-billion-living-off-the-grid-a-cellphone-enabled-mini-solar-panel https://e27.co/tiny-pipes-project-to-power-off-the-grid-households-in-the-philippines/ https://d-lab.mit.edu/scale-ups/tiny-pipes	

The Sun Shines for All (TSSFA), Brazil		**Case description**
Value proposition / payment structure	Offering solar individual systems on lease. Customers pay an installation fee and a monthly payment to lease the system. SERVICES: installation, maintenance and repair, training, take back.	The company offers a solar home systems package (with energy-using products) on leasing by providing customers with a contract that includes installation, maintenance, battery replacement after 3 years and take-back services. Users pay an initial deposit and a monthly leasing fee according to the system size and number of lights implied. The provider, who retains the ownership of systems and appliances, trains and employs local technicians who perform maintenance, repair and take-back services.
Energy system	Solar individual energy system ENERGY-USING PRODUCTS: lights	
Ownership	TSSFA	
Organisational form	Private enterprise	
Energy system operation	Customer	
Target customer	Individual households	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	Medium/high	
Sources	C. Vezzoli. (2014) System design for sustainability: a promising approach for emerging and low-income contexts. Y. Mugica (undated) Distributed Solar Energy in Brazil: Fabio Rosa's Approach to Social Entrepreneurship. UNC Kenan-Flager Business School Cases, University of North Carolina, p. 27 C. Sutton (2007) The Role of the Utilities Sector in Expanding Economic Opportunity. Harvard University. http://energymap-scu.org/ideaas/	

WBREDA Sagar Island, India		**Case description**
Value proposition / payment structure	Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini-grids. SERVICES:	The West Bengal Renewable Energy Development Agency (WBREDA) provided Sagar Island with 11 small solar PV power mini grids. The systems distribute electric power to the surrounding villages. The grids are switched on for six hours a day, from 6pm to midnight, and are managed by cooperative societies formed by the villagers that use the power. WBREDA retains ownership and responsibilities over major repairs while the community takes care of fee collection and daily operations.
Energy system	ENERGY-USING PRODUCTS: l	
Ownership	WBREDA	
Organisational form	WBREDA (management, installation, major repairs), community for daily operation and maintenance and fee collection	
Energy system operation	Community	
Target customer	Community	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	

Sources	Chakrabarti, S., Chakrabarti, S (2000). Rural electrification programme with solar energy in remote region—a case study in an island. Energy Policy 30 33–42 Ulsrud, K., Winther, T., Palit, D., Rohracher, H., Sandgren, J. (2011). The Solar Transitions research on solar mini-grids in India: learning from local cases of innovative socio-technical systems. Energy for Sustainable Development 15 293–303 http://www.ashden.org/winners/wbreda http://www.wbreda.org/

Yeleen Kura, Mali		**Case description**
Value proposition / payment structure	Offering access to energy (and energy using-products) on a pay-per-unit of satisfaction basis through individual energy systems. Customers pay a fixed fee for the service chosen. SERVICES: installation, maintenance and repair	In Mali EDF (France) partnered with NUON (Dutch) to form an energy company, Yeleen Kura. The company provides electricity through solar home systems in rural Mali. Customers gets their systems installed and pay for the service once a month (farmers can pay annually). Yeleen Kura sets up energy stores where local technicians is responsible for installation, maintenance and repair services as well as fee collection.
Energy system	Solar home systems ENERGY-USING PRODUCTS: battery, controller, radio, mobile charger	
Ownership	Yeleen Kura	
Organisational form	Private enterprises	
Energy system operation	Yeleen Kura	
Target customer	Households	
Provider / customer relationship	Relationship-based	
Environmental sustainability potential	High	
Sources	Sutton, C. (2007). The Role of the Utilities Sector in Expanding Economic Opportunity. Harvard University. http://www.naruc.org/international/Documents/15%20MALI-%20Toure%20and%20Kassambara%20Presentation%20March%202011.pdf http://ec.europa.eu/energy/idae_site/deploy/prj058/prj058_1.html	

Other cases: (used for Critical factors and Cards)

Title	Description
Trama Tecno Ambiental (Morocco)	The company provides community-owned and managed mini grids and established training and capacity building services in two stages: first, during preparation and implementation, end-users, committee and technicians are trained for operation, maintenance, fee collection and uses of energy. Secondly, after 6 months, feedbacks are collected and a second level of training is provided, targeting specific issues and problems encountered.
Rolland S., Glania G. (2011). Hybrid mini grids for rural electrification: lesson learned. USAID/ARE www.tta.com.es	
Solar Sisters (Tanzania, Uganda, Nigeria)	Solar Sisters partners with manufacturers such as d.Light and Angaza Design and empowers women by distributing solar technology through a network of franchisees. Solar Sister provides the women with a 'business in a bag', a start-up kit of inventory, training and marketing support. Manufacturer companies benefits by building a robust distribution channels that reaches rural customers.
Lucey K. (2014) Solar Sister are doing it for themselves. UN Women – Knowledge Getaway for Women's Economic Empowerment. Empower Women. NY, 2014 www.solarsisters.org Ballati S., Bird J., Hegedus (2013) Accelerating widespread adoption of distributed energy: solutions targeting small and medium-sized enterprises. Centre for Science, Technology and Society - Santa Clara University	
Cooperatives (Nepal)	In Nepal community-based organisations successfully work in hydro mini grids management. These groups have been legalised into cooperatives that diversify local activities and started to use the profits generated from energy sales to offer microfinancing for income-generation activities to their members. Improving productive uses of electricity aims to increase daytime demand and the capacity to invest in new businesses
Gunaratne L. (2002) Rural energy services best practices. USAID-SARI Energy Program Yadoo A., Cruickshank H. (2010) The value of cooperatives in rural electrification. Energy Policy 38, pp. 2941-2947	
SKDRDP (India)	Shri Kshethra Dharmasthala Rural Development Project (SKDRDP) is an NGO that promotes financing through a network of self-help-groups. They have developed expertise in renewable energy technologies, by building a list of reliable suppliers who must provide technology and after-sale services for members who want to have

	loans. SKDRDP officers provide information on the different technologies at village meetings and then create a group loan accordingly.
Winrock International (2008) Policy and governance framework for off-grid rural electrification with renewable energy sources. Final report submitted to The World Bank. UNEP (2005) Indian solar loan programme. Programme overview and performance report.	
Phaesun (Somalia)	The BOSS-programme (Business Opportunities with Solar Systems) of Phaesun and its local partner company Horn Renewables aims at supporting small businesses with specific solar systems to increase their productivity. The BOSS-systems include solar powered charging stations, fridges for kiosks and mobile fridges for fish transportation. The project has been implemented in Somaliland and targeted small businesses, fishermen and local entrepreneur.
Lecoque D., Wiemann M. (2015). The productive use of renewable energy in Africa. Alliance for Rural Electrification – Africa-EU Energy Partnership report. http://www.phaesun.com/references/rural-electrification/boss-in-somaliland.html	
ONergy (India)	ONergy offers, as part of their energy portfolio, a solar irrigation system for smallholder farmers. The water pump has remote monitoring capability, allowing farmers to control their own water supply via GSM. ONergy offers a pay-as-you-go model to finance its product.
http://switchon.org.in/India/ http://switchon.org.in/India/projects-2/agriculture/solar-irrigation/	
Kitonyoni solar mini grid project (Kenya)	The project was set up as part of the Energy for Development initiative, where engineers, local contractors and villagers worked together to set up a solar mini grid. The size of the plant has been established to cover the energy needs of the community, differentiating between types of customers: a school, medical centre and 50 businesses are connected to the mini grid, while individuals with lower energy needs can benefit from recharging services of batteries and lanterns.
Practical Action (2016) Poor people's energy outlook 2016. Practical Action Publishing, UK GVEP International (2012) Accelerating access to energy - GVEP Annual Review	
Sparkmeter (worldwide)	The company targets mini grids providers by selling a metering system that enables them to customise and limit load energy and monitor remotely and in real time the electricity usage, avoiding risks of theft and overuse. End-users can prepay for the energy they consume, for hourly consumption, or for a fixed monthly amount of energy, according to the unit of satisfaction agreed with providers.

http://www.sparkmeter.io
http://www.shellfoundation.org/Our-Focus/Partner-Profiles/SparkMeter/Summary
http://energyaccess.org/news/recent-news/sparkmeter-brings-smart-grid-functionality-to-underserved-utility-customers/

Appendix II: Critical factors of PSS applied to DRE in BoP contexts

1. Summary of factors and case studies.

1.1 Customer

Designing PSS+DRE models for BoP customers requires taking into considerations several aspects of the socio-cultural context where these solutions are implemented, such as customers' needs and energy demand, awareness of technology, community organisation, customers' ability to pay etc. (Wilson et al., 2012).

Define energy demand and needs

In the design of the energy solution, first factors to be defined are the energy demand and needs of customers, which depends on the types of customers and their current uses of electricity (Zerriffi, 2011). In other words, defining customers' demand means detailing the level of peak demand, how many hours electricity is used and the types of appliances run (Zerriffi 2011). A first consideration can be made on what type of appliances users have and how much they are spending for the energy provision and then choose an appropriate technology that satisfies the existing energy consumption (Hankins & Banks, 2004). Energy provision has also effects on expectations on how energy is going to improve customers' living standards in terms of employment and income generation, therefore it is important to predict future increases of demand. To meet future increase of demand a general common practice is to build a system in 30% extra capacity (Rolland & Glania, 2011).

Several authors (Chaurey et al., 2012; Terrado et al., 2008; Zerriffi, 2011) agree on the importance of customising solutions and technology packages for the specific needs of the identified target customer. In order to do so, different needs and requirements for types of target customers can be considered. For example, energy for individual household is intended to satisfy lighting, cooking, heating and cooling, information and communication services (phone charging, radio, TV). Productive activities, on the other hand, can be defined as agricultural, commercial and industrial activities (Brüderle et al., 2011) and they require a reliable energy supply (Zerriffi, 2011). Communities may have medium-high energy demand according to the size and density of the population, and they would need energy for various applications including community buildings (schools, hospitals) and public spaces.

Define willingness to pay

A key factor to be considered in designing a PSS offer for BoP customers is to ensure that the solution is affordable and matches customers' willingness to pay. Willingness to pay is directly related to customer awareness, expectations and the perceived value of energy solutions (Bardouille, 2012). One option is to enhance confidence in the technology through education and training on product use and benefits (Bardouille, 2012). In fact, some studies (Iyer et al., 2010) affirm that rural customers are generally willing to pay a higher price for a better electricity service as they already pay a large amount of their income for expensive and dangerous fuels such as kerosene and diesel. Another key factor is related to provide PSS solutions that add perceived value of the technology and therefore improve willingness to pay. For example, adding extra appealing features, such as mobile charging sockets, incentivizes users in setting up small income generation activities (IFC, 2011). A good example of this practice is provided by Fenix International. The company developed a solar mini kit with phone charging plugs that allow local entrepreneurs to set up a small charging business. They report that entrepreneurs are more willing to invest in the up-front cost of the technology as they can recover the investment within few months[1].

Ability to pay and design for affordability

Another critical factor is to define ability to pay and to design a solution that is affordable for low-income customers. In fact, some customers, despite being willing to pay a high price for clean and reliable energy, in some cases still cannot have access to most solutions and technologies. A common practice is to adapt payment structures that mirror existing spending patterns of the target customer (Bardouille, 2012). Offers that allow flexible payments according to seasonality of income and cash availability are an example of how solutions can be designed according to the type of customer (Hankins & Banks, 2004). The last few years have seen a high increase of organisations leveraging mobile payments technologies. These solutions enable providers to tackle one of the main barriers for DRE implementation, affordability. Through mobile payments customers can pay small incremental amounts according to their income availability, mimicking existing spending patterns for non-renewable sources (kerosene, charcoal). Several cases of companies succeeding in applying this technology have been found in the literature (M-Kopa, Azuri Technologies, Off Grid Electric, Mobisol, Bbooxx, Shared Solar etc.).

Another common approach is to partner with microfinance institutions (MFI) and provide financing services to end users and entrepreneurs (Bardouille, 2012). Affordability is also tackled by adopting use and result-oriented PSS models, where customers do not pay the full value of products but instead pay to get access to energy or energy using products (see Offer, Section 4.5.5).

Create awareness and build customer confidence

One of the barriers of introducing DRE technologies in BoP contexts is related to the unfamiliarity or lack of awareness for renewable energy products, often caused by market distortion due to poor quality products (IFC, 2011). Therefore, it is important to build confidence and trust in renewable energy systems and in particular to communicate benefits of introducing these technologies. Marketing campaigns operating at different levels (word of mouth, radio, roadshows, partnering with

[1] For references to the complete list of case studies discussed in this section see Appendix II.

existing brands) can help reaching BoP customers (Bardouille, 2012). The introduction of PSS models, and especially of ownerless solutions, can also encounter cultural barriers (Ceschin, 2013). This is due to the cultural shift required in adopting new habits and behaviours which contradict the established norm of ownership (Ceschin, 2013; Goedkoop et al., 1999; Manzini et al., 2001; Mont, 2002; UNEP, 2002). It is therefore critical to educate customers on economic and environmental benefits derived from PSS innovations.

Design to support income generation

Implementing PSS+DRE solution may support income-generating activities in several ways. One approach is to support productive activities by targeting them with machinery, irrigation systems or other appliances for productive uses of energy (Gradl & Knobloch, 2011). In this way energy provision can improve productivity and reduce production costs. Another option is to target enterprises to install their own generating unit and earn additional income by providing energy to nearby customers or communities (Zerriffi, 2011). Supporting the growth of productive activities may require targeted services such as financing and training on product use (Cu Tran, 2013).

Recognise gender needs and address to equity

Designing energy services for BoP customers requires understanding how energy impacts women and men differently and how their daily tasks, responsibilities and needs influence their electricity needs (Modi et al., 2005; Terrado et al., 2008). This means designing PSS solutions that address the different uses of energy for men and women and that favour the integration of women in the energy solutions. This can be achieved for example by including women in the PSS management or in some roles such as technicians or entrepreneurs (Adams et al., 2006). One approach is to enhance their income generating skills through training activities. In fact, women are more likely to afford energy services if they can be used to generate income, such as water pumping, husking and milling or home-based enterprises (Adams et al., 2006).

Involve users in the design and implementation process

A key success factor for DRE projects is to involve users and communities as early as possible in the design and implementation process (Cu Tran, 2013; Gradl & Knobloch, 2011; Chaurey et al., 2012). An option is to involve target customers in the design of the solution, for example organising focus groups and adopting participatory approaches (Gradl & Knobloch, 2011). This is particularly valid when the solution involves community-managed systems, such as mini grids, where users can be also involved in the customization of payments and in the tariffs set up. A good example of community involvement is provided by IBEKA, an Indonesian NGO that develops community-run mini grid projects. The NGO works closely with the community in designing a tariff structure that covers operation and maintenance and helps setting up a community fund. This process ensures customers involvement and support which is vital for the success of a project (Cu Tran, 2013).

Differentiate the offer and address a mix of target customers

Ensuring financial sustainability can be a complex matter when targeting BoP customers, therefore addressing a mix of customers including households, commercial and productive activities may be a recipe for success (Chaurey et al., 2012). Mixing targets can in fact ensure a more stable customer base, for example by addressing the needs of productive activities which will act as anchor customer and simultaneously making electricity more affordable for lower-income users (Martinot et al., 2002). An example of this approach is provided by OMC Power, which supplies energy to telecom tower companies in rural India and installs charging stations to provide energy services to nearby communities. It is also important to consider different payment structures according to the different targets. An option is to provide energy services to productive activities (e.g. commercial farm) which use the energy during the day on a pay-per-consumption basis and which provide nearby households with basic electricity supply (pay-per-unit) at night (Zerriffi, 2011).

1.2 Products

This section provides a summary of factors for the Products dimension, including considerations on renewable sources, DRE technologies and their applications.

Design for local conditions

Choosing the right DRE technology is complex and several factors need to be considered, from environmental, socio-ethical, economic, resource and regulatory perspectives (Kishore et al., 2013). Several authors highlight the importance to choose a technology that reflects resource availability and that is site specific (Zerriffi, 2011; Terrado et al., 2008; Barnet, 1990; Lemaire, n.d.). The technology should be also flexible and robust for a number of users, in terms of energy capacity and should consider energy demand changes and seasonality of resources (Barnet, 1990; Biswas et al., 2001). Another point is that technology and relative services must be customised to specific needs of communities (Chaurey et al., 2012).

Renewable sources

DRE systems use renewable sources to provide energy. Each renewable source and respective technology has specific benefits, barriers and applications. Main strengths and weaknesses of each type of renewable are discussed here in general terms (for a detailed list of factors see Appendix II, Products). *Solar power*, obtained converting solar radiation through the photovoltaic effect, is widely available much of the year and in most areas. This technology is modular and can be adapted to specific energy requirements and PV systems have a long life-span (Terrado et al., 2008; Bardouille, 2013, Kishore et al., 2013). Weaknesses of solar PV include high initial costs, the need for battery storage, required installation and maintenance by skilled technicians.

Wind power is generated through turbines and this technology presents low running costs, little maintenance and parts can be produced and assembled locally (Noble & Sanchez, 2008; Practical Action, n.d.). However, generation through wind power is site specific and subjected by seasonality, therefore resource studies must be carried out before installation (Terrado et al., 2008; Rolland, 2011). Another weakness is represented by high capital costs and low state of maturity for DRE using wind resource (Kishore et al., 2013). On the other side, DRE systems using *hydropower* are highly efficient, well understood technologies and present low capital costs (Rolland, 2011). However, the use of hydropower is site specific and cannot be adapted to energy demand.

Another well diffused DRE resource is *biomass*, in the form of gasification or combustion of natural resources. Biomass has the advantage of being a reliable and low-cost fuel, especially when it involves crop waste (Bardouille, 2012). DRE using biomass are also well-understood and mature technologies, however they require constant supply of raw material, which is subjected to changes in costs and availability (Kishore et al., 2013). Another renewable considered for DRE systems is *human power*. It involves the human body as producer of energy in form of mechanical, thermal and electrical energy (Jansen & Stevels, 1999). DRE systems using human power can generate power on demand, do not depend on site specification and can be designed and produced according to specific requirements (Mechtenberg et al., 2012). However, human power is limited in terms of capacity, it depends on health and age of individuals and it requires battery storage (Mechtenberg et al., 2012).

Mini kits

Mini kits are small plug-and-play systems that include a small generator, lights, battery and other appliances such as radio or phone chargers (Rolland, 2011). Their strengths include easy installation, little maintenance required and low costs (Rolland, 2011). Due to its limited capacity, this technology is appropriate for households or small businesses, especially for scattered customers living in rural areas with a low-energy demand (Cu Tran., 2013). These types of systems are widely used with mobile payments technologies, either providing microcredit or enabling pay-per-unit payments. Several examples are provided by companies such as M-Kopa, Azuri Technologies, Off Grid Electric, Fenix International etc.

Individual energy systems

Individual systems are stand-alone technologies that can be powered by solar, wind, hydro or biomass power and can target individual households, businesses or larger customers such as schools and productive activities. This type of technology suits especially off-grid customers and it is particularly convenient for the lack of transmission and distribution costs and for the flexibility to adapt to customers' needs (Rolland, 2011). However, individual systems require storage for extra-generated electricity and provides higher capital costs for customers. Applications of this technology span from smaller solar home systems (e.g. Mobisol, Grameen Shakti, SELCO), to larger systems for productive activities (e.g. Redavia, OMC Power).

Charging stations

The type of technology is a stand-alone system that can provide charging services (batteries, lanterns) and other services such as ICT or water purification. The main advantages of using charging stations are related to their mobility and flexibility, which makes them suitable for off grid or emerging settings (Rolland, 2011). This technology has been applied in use-oriented PSS (pay-to-rent/share/pool) and for pay-per-unit of satisfaction models, enabling even lower income customers to have access to lanterns and batteries without paying up-front costs (Chaurey & Kandpal, 2009). Larger charging stations can provide power simultaneously to productive activities (as an individual energy system) and to nearby communities, through renting of appliances. This model has been implemented by an Indian company, OMC Power, which targets telecom tower companies in rural areas and villages nearby (see Appendix I).

Isolated mini grids

A mini grid is a small generation facility that provides power through a local distribution network and it is not connected to the grid (Rolland, 2011). This technology varies in applications, sizes and renewable sources used and presents several advantages: it is flexible and can be adapted to customers' demand; it is suitable for productive uses of energy and for multiple types of customers; it contributes to local development and employment as it can be managed and maintained by communities (World Bank, 2008; Lemaire, n.d.). Isolated mini grids suits communities that are densely populated as they require enough demand for power to be profitable (Terrado et al., 2008). Main barriers for this technology are the need for skilled personnel for operation and maintenance, management and monitoring; they require specific regulatory frameworks and high capital financing (World Bank, 2008). Several players are providing energy through mini grids, adopting different types of PSS models. Most of them involves community-owned and managed mini grids (pay-to-purchase with training and advice) and result-oriented PSS, where customers are paying per energy consumed or per unit of satisfaction.

Connected mini grids

Connected mini grids present a further advantage compared to the isolated ones. They allow providers to sell electricity to the main grid and can operate at higher load factors, thus enhancing economic sustainability (Martinot et al., 2002). This DRE system is particularly convenient for communities that live close to the national electricity grid or that may be connected in the near future, allowing the integration of the two energy supply (AFREA, 2011). PSSs involving connected mini grids allow providers to have an anchor customer (national grid supplier) and distribute power to communities.

Some examples can be found in community-owned and managed systems (e.g. IBEKA and CRERAL) and in pay-per-unit of satisfaction models (e.g. Avani and Husk Power Systems).

1.3 Services

The service package provided in the PSS solution can include training and consultancy services for product use and management; financing and microcredit services; services that aim at extending the life span of products (installation, maintenance, repair, upgrade); end-of-life services such as recycling or take-back.

Training services

Coupling the energy solution with training, consultancy and advice services is a key factor for ensuring success of a PSS+DRE solution (Schillebeeckx et al., 2012). Different target users can be recipients of training services: communities who will be responsible for management of the energy system, end-users who need to learn about product use, local entrepreneurs to be involved in the PSS solution and local technicians for providing maintenance and repair services.

Community training refers to providing training in operation, maintenance and management for communities to successfully run energy systems, such as mini grids or charging stations (Jain & Koch, 2009). It is important to respect community's structure and its existing organisation by identifying respected individuals and relevant stakeholders (Cu Tran, 2013). A good approach is to involve local partners to provide training, such as NGOs or cooperatives that can deliver training in the local language and help in reaching customers (Gradl & Knobloch, 2011; Cu Tran, 2013).

On the other side, end-user training is a key service to ensure customers understand capabilities and limitations of energy systems and can support wise consumption of electricity, prevent blackouts and system failures. These also create a lasting relationship between provider and customer (May, 2002; Terrado et al., 2008). In fact, technical problems are often related to systems' overuse related to the lack of understanding of their limitations (Lemaire, 2009; Chaurey et al., 2012). In order to avoid these, training can be provided during system installation or through regular visits of technicians (Lemaire, 2009).

Training services can also be focused on empowering local entrepreneurs by including them in some aspects of the energy solution. Coupling technical and business training with technologies that allow income generation can help fostering local economies and economic sustainability (Albi & Lieberman, 2013; Practical Action, 2012).

A key aspect for ensuring good after-sale service is to establish a network of local technicians who can provide prompt maintenance and repair services (Gradl & Knobloch, 2011). Training programs can focus on most recurring technical challenges, training technicians to carry out basic maintenance services (Gradl & Knobloch, 2011). A good example is provided by Bangladeshi company Grameen Shakti. The company trains women for performing repairs, maintenance and assembling of solar accessories. Their ties with rural customers and the established network in their communities ensure that these women provide and effective after-sale service (maintenance and repair, spare parts management).

Microcredit to end-users and entrepreneurs

Financing customers and entrepreneur is an essential element for a solution that targets BoP markets (Koch & Hammond, 2013). Microcredit can help reaching customers with low or irregular income and can support entrepreneurs who want to set up an energy business. Offering microcredit services is an option when a company has good knowledge of their existing customer base (Lemaire, 2007) and partnering with a Micro Finance Institution (MFI) or other credit facilities can facilitate this process. It is crucial to define willingness and ability to borrow taking into consideration long term ability to pay, size of the down payment and monthly payments and also paying attention to credit history and financing environment of target customers (ESMAP, 2001). For example, SELCO, a company operating in South East Asia, partners with SEWA (Self Employed Women's Association), an Indian bank that specializes in supporting women's empowerment. SELCO and SEWA conjunctly design solutions that couple solar products with microcredit services targeted to women entrepreneurs.

Installation

Providing installation as part of the PSS package can avoid that systems are installed improperly or wrong components are used (ISES, 2001). Offering installation services also provides an opportunity to train local technicians (Da Silva et al., 2015).

Maintenance and repair

When providing a PSS solution, manufacturers have an economic interest to reduce as much as possible maintenance and repair of products, and keep their costs low. Thus, ensuring products long life-time is essential to avoid system failures and improper repairs by end-users, but also to reduce costs incurred by the provider. According to Foley (1992), maintenance and repair are the main factors which influence success or failure of community managed systems.

Providing maintenance and repair in rural and sparsely populated areas can be particularly expensive and difficult to deliver (Bardouille, 2012). Using existing infrastructures to keep spare parts (May, 2002) and training local technicians in order to optimize services can be a recipe for success. DESI Power, an Indian provider of energy services through biomass-based mini grids, trains local enterprises and entrepreneurs to operate and maintain power plants and uses a standardized technology that does not require specialized skills. It is in fact important to design products that minimize and facilitate maintenance and repair (Gradl & Knobloch, 2011).

Product upgrades

Product upgrading can be provided by offering modular and upgradable solutions, for example allowing users to add elements over time (e.g. more lights, TV or radio). Instead of new products manufacturing, modifying or upgrading systems with more efficient/novel technologies can offer possibilities to satisfy consumers' wants and needs and at the same time reduce material consumption (Niinimäki, 2014). This is especially relevant for those PSSs in which the provider keeps the ownership and responsibility over the products part of the solution. Also, replacing technologically obsolete components and products (e.g. batteries) can help reducing energy consumption. A good practical example is provided by the company Azuri Technologies, which sells solar systems with additional services. Azuri's vision is an 'energy escalator' where customers can gradually increase their uses of electricity through trading up to successively larger systems and novel components. For example, the company introduced new generation LED lamps and a new control system which adapts output according to weather conditions, providing a technological upgrade to their previous version. Customers are encouraged to upgrade their old systems without buying a new one but simply adapting their payment structure.

End-of-life services

Providing services to ensure that products are collected to be re-used or remanufactured at the end of their life span is a key factor to ensure environmental sustainability (Mont, 2002). In addition, as said before, when providing PSS solutions manufacturer are incentivised to do that, since they keep ownership of the equipment/products involved. End-of-life services can be provided through strategic partnerships with local actors which can collect broken equipment or expired batteries (Gradl & Knobloch, 2011). A key factor also relates to the design of the products involved in the PSS, which should be easily disassembled or designed to facilitate re-use and re-manufacturing. Few examples of companies providing these services have been found in the literature. A good case is provided by Laos-based company Sunlabob. Sunlabob ensure that components are recycled by establishing a take-back service of batteries and other products. The company also provides mini grids and rehabilitates broken hydropower plants into functioning hybrid systems.

1.4 Network of providers

The providers involved in the PSS solution, also referred as the organisational form of DRE systems (Zerriffi, 2011), indicates the types of actors involved in providing the solution.

Private enterprise

Private enterprises can cover a variety of roles and be directly involved in the design, manufacturing and in the provision of product-related services. Small-scale companies have the advantages in terms of proximity to customers, while larger-scale enterprises may be more likely to ensure financial viability (Lemaire, 2009). Despite the size and structure of private companies, a key success factor is related to ensuring a strong local representation (Asian Development Bank; Gradl & Knobloch, 2011).

In fact, involving agents that are part of the target communities and building a network of dealers and service personnel at a local context is an important feature for success. Existing networks related to other products (e.g. farms machinery, generators, telecommunications etc.) can be also used in the delivery of the energy solution (May, 2002). The Kenyan company M-Kopa, for example, uses existing infrastructures of shops and retailers from its partner Safaricom, the mobile network provider.

Technology manufacturer

A key role in PSS solutions is covered by manufacturers. Manufacturing companies can provide energy services coupled with the products they manufacture, thus adding value through servicing components (Mont, 2002). Manufacturers can provide services aimed to add value to the product life-cycle, coupling with the energy systems or energy-using products they produce (Mont, 2004). When manufacturers retain ownership or responsibility energy systems and/or products, their economic interest is to postpone the disposal costs and the costs of manufacturing new products (Ceschin, 2014; Mont, 2004). Kamworks, a Cambodian company, designs and manufactures solar home systems and lanterns, providing a range of additional services. The company provides energy through different offers: product-related services (maintenance, training) or advice and consultancy are offered when products are sold; in the use-oriented offer, energy systems and energy-using products are provided on renting or leasing.

Community

The involvement of communities is a key factor in the success of an energy solution in the BoP, not only as consumers but also as partners in development and provision of the energy solution (Wilson et al., 2009). In fact, when directly involved in providing their own energy, communities have a strong incentive in operating and maintaining systems in a sustainable way (Cu Tran, 2013). Communities need to be involved as soon and as much as possible from project implementation to the organisation of the energy solution (Rolland & Glania, 2011). One approach is to consider established cooperatives or organisations at a village level and plan the energy solution according to the existing local organisational structure (May, 2002). Then, in order to overcome the lack of technical and business skills, communities, or their representatives, need to be properly trained if they are involved in managing/delivering some aspects of the energy solution (Cu Tran, 2013). The training activities can be facilitated by strategic partners such as NGOs. For example, IBEKA is a non-for-profit organisation that promotes community development via the provision of local energy. Communities are involved at early stages of implementing hydro mini grids and they receive training in operation and maintenance. The community becomes owner of the system and it's responsible for day-to-day operations, tariffs structure and collection fees.

Local entrepreneur

Local entrepreneurs are individuals, either with existing business activities or not, who can be involved in providing energy solutions or who can perform specific tasks such as maintenance services or fee collection. If involved as service providers, usually local entrepreneurs need to be assisted with access to financing and microcredit (Iyer et al. 2010; Terrado et al., 2008). In fact, entrepreneurs may not be able to cover initial investments for setting up an energy business. Another option is to involve local entrepreneurs in performing some services related to the energy solution, such as maintenance and repair or supporting product distribution. Depending on the activities he/she has to perform, entrepreneurs should be provided with training on energy system operation, maintenance, repair, and business management (Terrado et al., 2008).

Cooperative

Cooperatives are organisations composed by members that come together for a common purpose and can operate in various sectors (e.g. agriculture). They can provide energy solutions or play a role in partnership with the energy provider. The involvement of cooperatives is strategic because they have direct relationships with their members, they are characterised by self-regulatory forces and promote equal participation (Yadoo & Cruickshank, 2010). Successful examples in Nepal and Brasil are found in the literature, where cooperatives manage connected mini grids and provide powers to communities (e.g. CRERAL). Cooperatives can also be involved to support users' financing (Neupane, 2009; Subedi, 2009), as partners for the distribution of energy products or to support training, awareness campaigns and promotion of DRE (Gradl & Knobloch, 2011).

Non-Governmental Organisation (NGO)

NGOs can be defined as mission-driven organisations that aim to achieve social or environmental objectives and may have a direct focus on energy provision (Gradl & Knobloch, 2011; Zerriffi, 2011). The role of non-profit organisations can be crucial in delivering PSS applied to DRE as they can be directly involved in providing solutions or can represent a strategic partner. For example some NGOs, such as Practical Action in Peru and Avani in India, design and implement energy solutions at a community level and train villages on operation and maintenance of mini grids. Their knowledge of local characteristics and their strong relationships with communities suits NGOs for providing energy services (May, 2002; Gunaratne, 2002).

Another option is to involve these organisations to support some activities such as raising awareness, market research, or assisting in the distribution of products (Gradl & Knobloch, 2011; Bairiganjan et al. (2010). NGOs can also be strategic partners for selecting and training local entrepreneurs that will deliver energy solutions. Solar Sisters, an African NGO, partners with manufacturers such as d.Light and Angaza Design and empowers women by distributing solar technology through a network of franchisees. Solar Sister provides the women with a 'business in a bag', a start-up kit of inventory, training and marketing support.

Through their network of donors funding and access to subsidies, NGOs can also facilitate customers' financing (Martinot, 2002). For example Shri Kshethra Dharmasthala Rural Development Project (SKDRDP) is an NGO that promotes financing through a network of self-help-groups. They have developed expertise in renewable energy technologies, by building a list of reliable suppliers who must provide technology and after-sale services for members who want to have loans.

Micro Finance Institution (MFI)

Micro Finance Institutions (MFI) are credit organisations that can play a key role in the provision of energy services, either by adding energy products to their portfolio or as a strategic partner for financing customers and entrepreneurs. In some cases, MFIs can provide energy systems coupled with their financing services, thus diversifying their business revenues (Gradl & Knobloch, 2011). A successful example is provided by Grameen Shakti, a Bangladeshi MFI that effectively represents a "one stop shop", marketing PV systems, providing in-house financing and services that add value to the product life-cycle (maintenance, repair, take back).

Some key aspects must be considered when involving a MFI as financing partner. Training and awareness must be provided to MFI staff in order to understand technology options and design credit offers accordingly (Gradl & Knobloch, 2011). In Sri Lanka, SELCO offers tailored products and financing services to its clients by facilitating customers getting financed through its partners. SELCO partners with SEED (Sarvodaya Economic Enterprise Development Services) and while it focuses its expertise in providing high quality services in installation and maintenance of systems, the MFI takes care of loans and repayments. Good communication and cooperation between MFIs and technology providers is also essential in order to ensure fee collection and continuation of payments (Lemaire, 2011).

Public entities and governmental institutions

Other actors from the public sector might be involved in providing energy solutions (e.g. public utilities) or can be engaged as partners to cover some aspects of the PSS offer, such as financing or regulatory support. When large scale utilities or ESCOs (Energy Service Companies) are responsible for providing energy services, they can cover all aspects from financing to marketing, to customer education and maintenance services (Hankins & Banks, 2004). The advantage is related to their extensive experience, financial resources and technical capabilities (Lemaire, 2009; Rolland & Glania, 2011). A key factor that should be considered in these cases is to ensure local presence and assistance to customers, for example by training local entrepreneurs and technicians to provide maintenance and collect fees (Lemaire, 2009; Rolland & Glania, 2011). In a case in Zambia (Lemaire, 2009), the government is involved in the creation of an Energy Service Company, usually as subsidiary to an existing business (e.g. farms implements, waste management) by providing technical and business training. The government maintains the ownership of systems (Solar Home Systems) and the ESCO performs installation, maintenance and repairs, fee collection. In other cases, public entities can be partners for the project's financing, the provision of subsidies to customers or the creation of supporting policies. In fact, regulatory support is a key aspect of sustainable energy solutions and governmental entities can create protective policies and regulations (Modi et al., 2005).

1.5 Offer

As described in Section 4.2, six types of PSS applied to DRE can be defined, and 15 Archetypal Models distinguish different types of PSS+DRE offers. In this section, main critical factors for each type of PSS offer are discussed.

Product-oriented: Pay-to-purchase

In this type of PSS+DRE, the ownership of energy system and appliances is transferred to the customer and additional services are provided. Two PSS types are defined: customers pay to purchase systems with consultancy and training on product use and management; and customers pay to buy systems with additional services for the use phase of the products. This payment structure (pay-to-purchase) is usually adopted for small individual energy systems and mini kits as investment costs are not so high and the purchase include the additional services provided (Cu Tran, 2013). In fact, access to financing is crucial when customers pay to purchase systems, as affordability is a critical aspect to be tackled (Bardouille, 2012; Chaurey et al., 2012). Companies offering microfinancing options (e.g. M-Kopa, Mobisol, Grameen Shakti, SELCo, Azuri Technologies, Fenix International etc.) have addressed this issue by spreading payments over a credit period and customers own the products at the end of the financing contract.

When this model is applied to mini grids, the PSS solution involves community-owned and managed systems and it usually implies in-kind contributions from the community or the involvement of subsidies/donations. In product-oriented PSS+DRE, the ownership dimension is considered key to a successful implementation for community-based models. In fact, when community-based organisations are both owners and the users of the energy solution, they present a strong interest in the quality of the service and its management (Gunaratne, 2002).

In terms of environmental sustainability, product-oriented PSSs present in general a lower potential compared to use and result-oriented offers (Tukker, 2004; Tukker & Tischner, 2006). As highlighted before, PSS models must be properly designed to be a sustainable alternative to traditional business models. In this case, providers can offer advice on product use and training on energy system operation, aiming at optimizing energy consumption. Additional services that aim at extending life-span of products such as maintenance, and repair should be provided. Additionally, end-of-life services are crucial to ensure safe disposal of polluting and dangerous components, such as batteries (Terrado et al., 2008; Adams et al., 2006). Companies such as Grameen Shakti and SELCO, are succeeding in providing a complete service package, from installation to financing, maintenance and recycling of individual energy systems.

<u>Use-oriented: Pay-per-time of use</u>

In use-oriented PSSs two types can be distinguished: pay-to-lease and pay-to-rent/share/pool. With leasing, customers pay a regular fee (e.g. pay-per-month) for an individual and unique access to products. Leasing models should consider the ability to pay of customers, as users with unstable income may not be willing to sign for monthly payments if they are not sure they can afford it.

With renting, customers pay for the use of products for shorter periods of time (e.g. pay-per-hour, pay-per-day) and sometimes simultaneously with other users (pooling and sharing models). The ownership of equipment/products (and the responsibility for maintenance, repair, disposal etc.) is retained by providers. This model mimics the existing spending patterns of lower income customers (with kerosene) and customers pay only when they need or when they can afford the product (Chaurey & Kandpal, 2009).

Successful examples of renting models can be found especially in South East Asia, such as TERI India and Sunlabob in Laos. TERI offers renting of solar lanterns through an entrepreneur-owned charging station. It is critical that the daily rental is chosen by the entrepreneur and the community together in order to match customers' ability to pay (Chaurey et al., 2012). Another important aspect is provided by the collaboration between TERI and product manufacturers in developing efficient and cost-effective products that have been designed appropriately for renting. Sunlabob, on the other hand, leases charging stations to community committees, which perform operation and maintenance and rent charged lanterns to end users. Sunlabob retains ownership and responsibilities of products involved in the offer.

These types of PSSs can trigger some rebound effects (Ceschin, 2014). The impact on customers' behaviour should be considered when introducing ownerless solutions such as leasing and renting models. In fact, if the user does not own the product, he/she may adopt careless behaviours and misuse and mishandle of products can reduce their life-span. Thus, products should be properly designed to be used and shared amongst different users (Niinimäki 2014). In fact, since providers retain the products ownership, it is in their economic interest to have products that are long-lasting (easy to be maintained, repaired, upgraded), easy to remanufacture, and easy to recycle.

Another aspect is related to the awareness of economic benefit emerging from adopting a use-oriented PSS. Customers may lack understanding about life cycle costs (White et al., 1999) and therefore prefer solutions where they become owners of the products.

Result-oriented: Pay-per-energy consumed

In result-oriented PSSs, consumption-based offers involve the provider retaining ownership of products (energy systems and energy-using products) and the customer paying to get energy on a kWh basis. This model has been applied to individual energy systems targeted at productive activities (e.g. OMC Power) and to mini grid-based PSSs.

Some issues related to this type of payment structure are related to the ability to pay of lower income customers and the process of fee collection (Lemaire, 2009; Roach & Ward, 2011). An effective approach is to monitor customers and conduct daily/weekly visits to ensure payments, such as DESI India and Gram Power solutions which involve local entrepreneurs working in villages and regularly visiting households. Another option is to use pre-payment technologies to limit demand and avoid overconsumption (Lemaire, 2009). However, when adopting this type of PSS, limited capacity of DRE systems must be considered. In fact, this type of offer may result in overconsumption and system failures, especially if customers are not aware of limits of renewable energy sources and technologies. Some technologies allow extra capacity to be added according to energy demand. Shared Solar, for example, provides solar-based isolated mini grids in Mali. When demand grows, additional PV panels are added to the generator and customers pre-pay for the energy they consume using mobile payments. When extra capacity can be added, specific payment structures can be designed to encourage productive activities to be set up. An example is provided by Practical Action, an NGO operating in Peru which designed a tariff structure with the community, according to their priorities. Low rates for consumption over 60kWh were designed to encourage people to create businesses and get connected to the mini grid.

Result-oriented: Pay-per-unit of satisfaction

Another type of PSS applied to DRE has been defined as "Pay-per-unit of satisfaction" and encompasses those models where customers pay to get access to energy and energy-using products according to the agreed satisfaction unit. This PSS include several payment structures:

- *pay per recharge*: pay a fixed cost for recharging an energy-using product (e.g. a lantern or a phone).
- *pay per lux*: pay a fixed cost for an agreed level of luminance of a building.
- *pay per print or internet connectivity*: pay a fixed amount to use energy-using product/s.
- *pay per energy service package*: pay a fixed fee to have access to energy-using products and a limited amount of energy.

In the case of pay per energy service package, customers might pay a fixed tariff according to the agreed result or according to the limits of the power generation (Cu Tran, 2013). In the first case, fees can be set according to different levels of consumption, determined on existing or desired appliances and the regularity of their use (IRENA, 2012). For example, customers pay to use few lights, a mobile charger and TV for a certain amount of time per day. In the second case, customers pay to have a limited agreed amount of energy per day. Here limiting devices such as smart meters can be used to ensure the energy provision is fixed and to avoid system overload. Some companies such as Off Grid Electric in Tanzania are providing these unlocking systems to ensure payments are met. Others, such as Mera Gao Power in India, involve local entrepreneurs to collect weekly fees and ensure that the system automatically locks according to its generation capacity.

The inclusion of energy-efficient products is particularly crucial for this type pf PSS and its application in low-income contexts (Rolland, 2011). Some studies highlighted that it is necessary to include energy-efficient components with the energy systems and ensure that users are lifted from the responsibility of replacing them (Rolland, 2011). The provider retains responsibilities for managing and operating on the products involved, avoiding that customers influence efficiency and capacity of the energy system. It has been argued that fixed tariffs do not encourage customers in conserving energy and avoiding overconsumption (AFREA, 2011). For this reason, it is crucial to ensure this aspect is tackled through technology (e.g. use of locking meters, inclusion of efficient energy-using products) and through customer education and training. As discussed for use-oriented PSSs, solutions must be properly designed to deliver the sustainability potential and to provide a more environmentally friendly alternative to traditional business models (Tukker & Tischner, 2006).

Some barriers are also related to the applications of this type of PSS. The main cultural barrier is related to the adoption of ownerless solutions (Goedkoop et al., 1999; Manzini et al., 2001; Mont, 2002; UNEP, 2002). In addition, in pay per unit/result models the final user may feel less responsible for the good use of the system (Lemaire 2009) and may tend to adopt careless behaviours (Ceschin, 2014). In addition, as mentioned for use-oriented PSS, lacking of understanding about life cycle costs may steer the choice towards solutions where they become owners of the products.

<u>Mixed offers</u>

Combining PSS offers can strategically mix payment structures for different customer segments. For example, lower income households can pay a fixed amount for a limited service (pay per unit of satisfaction) whereas productive activities or higher income customers can pay per energy consumed (kWh). This approach can ensure financial viability of PSSs (Chaurey et al., 2012) and provide customer's satisfaction according to specific needs of each target group. An example is provided by OMC Power, an Indian company that targets productive activities (telecom tower companies) on a pay-per-consumption basis and communities through a use-oriented model (renting of appliances).

1.6 Payment modality

Different payment methods and channels can be adopted in PSS+DRE models. These include cash and credit, mobile payments, scratch cards and energy codes, in-kind contribution, fee collection and remote monitoring as an activity supporting payment.

Mobile payments

The wide adoption of mobile services and the great diffusion of mobile phones provides an opportunity to use this technology for payment purposes. In fact, the mobile phone penetration in rural areas has created demand for power while supplying infrastructure and innovative approaches to energy service provision (Craine et al., 2014). The use of mobile payments tackles some of the main barriers of energy solutions at the BoP: revenue collection and affordability for customers (Nique & Arab., 2012). The integration of mobile payments represents an innovative way for low-income people to have access and pay for energy services, and simultaneously offer remote control of products' performances and consumption (Nique & Arab., 2012). Several companies have adopted mobile payments in their channels (M-Kopa, Azuri Technologies, Mobisol, Shared Solar etc.).

Scratch cards and energy credit codes

Similarly to mobile payments, scratch cards can be used to deploy energy credits in forms of unique codes that allow customers to prepay the electricity provision and unlock the energy system. This payment method can be very convenient for pre-payment of systems and enable flexibility of payments, allowing users to mimic the patterns of airtime purchases (Bardouille, 2012; Gradl & Knobloch, 2011). A good practice is to involve local vendors and entrepreneurs in distributing pre-paid cards. Azuri Technologies, for example, sells mini kits with a mobile credit service: after paying an installation fee, users purchase a scratch card at local vendors each week and adds credit to their unit via mobile phone. They send the code via SMS and receive a number that has to be entered in the control unit. The system then unlocks for a week.

Fee collection

A suitable fee collection scheme should be set up as it can influence customers' willingness to pay (Cu Tran, 2013). This means adapting collection schemes to local income patterns. For example, farmers and rural customers may have seasonal income (Lemaire, 2009). Another key factor is to ensure local representation for the collection of payments, for example involving local technicians who can perform regular visits to customers (Gradl & Knobloch, 2011). Following this principle, Mera Gao Power, an Indian provider of mini grids, involves local technicians who have existing relationships with customers and who visit households weekly to collect payments.

In-kind contribution

Another type of payment method can be in-kind contribution in the form of labour or support for managing the energy system. Communities may be involved in providing labour for mini grids works and construction (Gunaratne, 2002). This approach increases the sense of ownership from the end-users and is it critical to ensure a sustainable operation and maintenance (Rolland & Glania, 2011).

Another example of including end users is to involve farmers who can provide biomass to generate power and have a reduction on their tariff (Iyer et al., 2010).

Remote monitoring

Remote monitoring and meter reading are activities that support payment. Meters can be used to monitor energy consumption, disconnect non-paying customers and load supply according to the contract agreement. Meters are also useful to incentivize energy conservation and efficiency by allowing customers to have accurate record of their consumption.

If normal meters are installed, then reading must be considered and performed periodically by technicians (Rolland & Glania, 2011). Another option is to use smart meters and pre-payment. With this system, customers purchase in advance units of electricity and the supply shuts down when the credit is exhausted. The management of energy loads and payments can then be done remotely so that the problem of reading, billing, and collecting can be solved (Bardouille, 2012; Nique & Arab, 2012). Sparkmeter, for example, targets mini grids providers by selling a metering system that enables them to customise and limit load energy and monitor remotely and in real time the electricity usage, avoiding risks of theft and overuse.

Appendix II: critical factors

Organised in the following order: 1. Services, 2. Customer, 3. Network of providers, 4. Payment modality, 5. Product, 6. Offer

SERVICES				
Variable	**Extract**	**Reference**	**Guideline**	**Case study/example**
Offer training to communities	*Community training: training in operation, maintenance, management and support is essential for communities who will run power systems.*	Jain & Koch, 2009	A comprehensive training in operation, maintenance, and management is essential for communities to successfully run energy systems.	Practical Action Peru: The NGO provides hydro mini grids for rural communities in the Andes region. Practical Action trains a community committee through courses and during installation on technology operation and management. The community, who becomes owner of power system, is also trained to handle tariffs and manage finances in order to cover operation and maintenance costs and loan repayments.
	The community involved in project implementation should be kept small and functional. It includes a group of respected individuals with a good standing and reputation in the village. The participation of all relevant stakeholders and groups has to be ensured	Cu Tran (2013)	Are you respecting community's structure? You should provide training in order to create a community organisation that reflects the existing structure and leadership of the community in terms or roles and responsibilities	
	Train via partners. Training sessions can also be conducted by local implementation partners such as NGOs or local companies; Unlike international trainers who usually require interpreter, local trainers can deliver the training contents directly in the local language, hence limiting risks of misunderstanding	Gradl and Knobloch (2011); Cu Tran (2013)	Have you taken into consideration cooperatives, financing institutions, consumer groups? Partner with existing organisations that could help you in delivering your training offer (for example delivering contents in the local language, reaching customers, using community facilities etc.).	
Offer training to end users	*It is important that customers learn capabilities and limitations of systems. User training also creates a lasting relationship between provider and customer.* *Education of end-users on the uses of electricity is important. Wise consumption can help prevent system blackouts*	Gunaratne (2002); Terrado et al. (2008)	Providing information on optimal use and limitations of the system is essential to build an enduring provider/customer relationship and educate end-users on sustainable behaviour.	SELCO sells energy home systems and products with an inclusive service package. In order to prevent users from misuse or damage the solar systems, the company provides user training during installation of systems. Technicians, qualified by in-house

	Training for technicians and users through manuals and guide books should be provided in their language and should be adapted to users' and technicians' prior belief structures and knowledge	Tillmans & Schweizer-Ries (2011)	Are you communicating in the right way? Training through manuals and guide books should be provided in the users' language and should be adapted to their prior knowledge and background. Use illustrations.	training programs, explain clearly what the user should expect from the system and how to use it. A manual is provided.
	It is important that customers learn capabilities and limitations of systems. The technical education of consumers to help them to make the best out of their systems and to ensure the project sustainability is fundamental	Gunaratne (2002); Rolland and Glania (2011)	Can you educate or provide tools to end-users to enable them in reducing energy consumption? Wise consumption can prevent system blackouts and help end-users to save money.	
	Technical problems tend to be linked to overuse of systems and this happens because of a lack of understanding of the limits of the system. Regular visits of technicians would facilitate the learning process. […] This learning process among people who previously had no experience of solar electricity can be accelerated by interactions with the technician. *User training is conducted immediately after installation to ensure that the users are not only made aware about proper usage but are also trained on the institutional pattern to enable them to seek proper after- sales.*	Lemaire (2009), Chaurey et al. (2012)	Why not coupling installation with training services? You can provide end-user training about product use, limitations and care during the installation of the system. If a maintenance service is provided, technicians can also train end users during regular visits.	
Offer training to local entrepreneurs	*[TERI program] it also tries to enhance their income and afford- ability by extending additional income generating opportunities like mobile phone charging, to bridge the gap from both ends. LaBL also provides an option to the operators to start solar enterprises by facilitating loans and subsidizing partial cost of the enterprise.* *[…] to start and run a business, it is highly valuable for budding entrepreneurs to have some business and management training. The companies installing the renewable energy systems, NGOs, academia and local associations can play a crucial role in this regard.*	Chaurey et al. (2012); Lecoque & Wiemann (2015)	Can you offer training to local entrepreneurs to become local energy providers? Coupling technical and business training services with technologies that allow income generation, such as charging stations for phone charging business, can foster local economies and economic sustainability.	Mobisol: The company sells solar home systems with a focus on training services. It established a training centre in partnership with a technical university a PV-specialised consultancy to develop training material. The training courses are targeted to local entrepreneurs and focus on design, installation and assembly of solar systems and include a business training course.
	SDO toolkit	Vezzoli & Tischner (2005) www.sdo-lens.polimi.it)	Can you offer training to marginalised and weaker social strata (unemployed, women, youth) to become local energy providers?	

Offer training to local technicians	*Train local representatives to perform common service tasks*	Gradl and Knobloch (2011)	Establish a network of trained technicians who can provide prompt maintenance and repair services to local customers.	Grameen Shakti: The company offers solar home systems with an inclusive service package. In order to ensure an effective after-sale service (maintenance and repair, spare parts management), Grameen Shakti trains women as local technicians for repairs and maintenance of systems and for assemble solar accessories such as lamps, inverters, charge controllers.
	Explain handling and maintenance and outline common issues and solutions. Simple tasks can be carried out by the customers themselves, more complex ones by local staff, and unusual ones by specialists.	Gradl and Knobloch (2011)	Can you identify the most recurring technical problems challenges? Develop training programs focused on the most common maintenance and repair needs and tailor them to the local context.	
	Technicians and managers should share information as technicians deal directly with households in isolated areas and management supervision is essential to monitor the work	Dornan (2011)	Can you differentiate your training programs? Local technicians can be trained to tackle common issues and provide prompt maintenance when needed but specialists could take care of unusual and more specific challenges.	
Offer microcredit to end users and entrepreneurs	*Providing financing to customers and/or suppliers is an essential element of a successful BoP energy venture business model.*	Koch and Hammond (2013)	Offering microcredit solutions can allow providers to reach clients with lower or irregular incomes and to target local entrepreneurs who want to set up energy businesses.	SEWA and SELCO: Self Employed Women's Association (SEWA) is an indian bank that provides credit, counseling and insurance and it established a partnership with SELCO in order to support women empowerment. Together they design solar products and deliver comprehensive energy solutions, enabling lower income customers to get access to microcredit and clean power generation.
	micro credit is a good solution when companies have a good knowledge of their customers and allows them to adjust their offer to the demand in order to be more flexible.	Lemaire (2007)	Can you develop strategic partnerships with Micro Finance Institutions or other credit facilities? Offering microcredit can be challenging if you don't have an existing customer base and a good knowledge of your target users	
	the willingness to borrow for a solar home system is influenced by the size of the down payment and the monthly payment relative to the perceived value of the services and the ability to pay. Borrowing is also influenced by concerns about long-term ability to pay. This is particularly true among farmers and others with seasonal or uneven income streams.	ESMAP (2001)	Can you define willingness and ability to borrow? Long term ability to pay, size of the down payment and monthly payments are influencing factors especially for customers with seasonal incomes (such as farmers). Pay attention to the their credit history and the financing environment of customers	

		TERI case study (Chaurey et al., 2012)	Can you offer microcredit to entrepreneurs? Helping them in covering capital costs to set up energy businesses (such as charging stations for renting of products).	
Offer installation service	*Systems may be installed improperly or wrong components or appliances may be used if training is only provided through manuals.* *Offering installation services in addition to the technology reduces failure rate of systems and provides an opportunity to build local technical capacity.*	ISES (2001); Da Silva et al. (2015)	Installation services are necessary to avoid that energy systems are installed improperly, wrong components or inappropriate electric appliances are used.	TSSFA: The company offers solar home systems on leasing, allowing customers to use energy and products at a monthly fee with a comprehensive service package. Installation is provided by trained local technicians who already had related businesses (electrical store). Users pay the installation fee, which covers the technician labor (2-3 hours) and travel. The monthly fees cover maintenance and repair services.
	Due to lack of information transfer between producers and technicians or users, it is often not assured that the components of a technical system like Solar Home Systems will be installed properly.	Schäfer et al. (2011)	Can you provide energy systems installation? Can you involve strategic partners to undertake this activity? It is important that skilled technicians perform installation in order to avoid that systems are installed improperly	
	Train customers how to use and maintain the equipment when they receive it. When customers know how to handle the equipment properly, damage can be avoided, service costs reduced and the reliability of the equipment improved.	Gradl and Knobloch (2013)	Have you taken into consideration providing manuals and training if your energy system doesn't require professional installation? Mini kits, for example, can be easily installed by customers and they don't require technical assistance. It is important to provide sufficient user know-how in form of a clear installation manual and components should be designed with error protection to prevent problems	
Offer maintenance and repair	*Prolong product lifetime by providing warranties and regular maintenance service, and ensuring the availability of spare parts.*	Gradl & Knobloch (2011)	Maintenance and repair services are important to avoid system failure (e.g. due to unaffordability of spare parts) and improper repairs by end-users.	DESI Power provides energy through biomass mini grids in rural India. The company uses standardised gasifiers that are produced by its sister company Netpro. By using a standard technology, maintenance of plants doesn't require

	Comprehensive after-sale service can be expensive especially in sparsely populated areas. Companies can offer warranties and train local dealers on how to service systems and providing them with a stock of replacement parts and only taking products back to the factory if they are beyond repair. This system keeps costs down.	Bardouille (2012)	Can you ensure the local presence of technicians for prompt assistance to customers? Comprehensive after-sale service can be expensive in sparsely populated areas: train local technicians in order to optimise long distance activities and reduce transportation	specialized skills but can be easily performed by a local entrepreneur after a basic training. By targeting local enterprises to operate plants, DESI ensure an effective and inexpensive maintenance services.
	Companies should establish infrastructure in the area to keep in stock parts and items needed to repair and maintain the systems and in order to respond to after-sales requirements as quickly as possible. *Components for repairs should be purchased and provided by the same energy company in order to avoid delays of maintenance.*	Gunaratne (2002); Dornan (2011)	Can you use existing infrastructure for maintenance, repair and to ensure local availability of spare parts? Local retail stores or NGOs can help in providing these services and respond quickly to customers' needs.	
	Standardise the product for mass production. Reduce the variety of parts to facilitate product upgrades and spare parts management.	Gradl & Knobloch (2011)	Are your products designed to minimise and facilitate maintenance and repair? If you offer a PSS solution it is your economic interest to extend products' life span as much as possible.	
Offer product upgrades	*Each client can choose to upgrade his system to have more lighting or even an inverter and pay a higher fee. This financial cost could be reduced if upgraded systems were more systematically proposed or even considered as the basic system.*	Winrock International (2008)	Upgrading services can prevent technological obsolescence and allow end-users to add elements (e.g. more lights) to their offer.	Azuri Technologies: The company sells solar mini kits with installation and credit services. Azuri's vision is an 'energy escalator' where customers can gradually increase their uses of electricity through trading up to successively larger systems. Customers can in fact decide to upgrade their system at the end of the credit period and continue with instalments payments.
	Substitute obsolete products with new and more efficient ones, if the cost of these new products can be more than offset by reduced operative costs (e.g. less costs in the use phase due to energy savings)	Ceschin (2014); Vezzoli (2007); IFC (2011)	Can you offer a service to technologically upgrade the products of your system? Replacing technologically obsolete components and products (e.g. batteries) can help reducing energy consumption.	

	Services, such as upgrading or modifying, can also offer service possibilities in place of new product manufacturing, thus dematerialising the satisfaction of consumer's wants and needs	Niinimäki (2014)	Can you offer modular and upgradable solutions? For example you can allow end-users to add elements over time (e.g. more lights) depending on the changing in their needs.	
Offer end-of-life services	*At the end of a product's life, PSS providers have the potential economic interest to re-use or re-manufacture the product/s and their components, in order to save on disposal costs and on the costs to manufacture new products.3 For the same reason, providers are economically motivated to look into other ways to extend materials life, through recycling, energy recovery or composting.*	Ceschin (2014)	Products and equipment should be collected, at the end of their life span or at the end of the contract period, to be re-used or re-manufactured.	Steama: Steama implemented a hybrid mini grid in a slum island in Kenya. The technology is composed by a locally manufactured wind turbine (1kW) and solar panels (2kW). The turbine, designed according to the required energy demand, uses recycled materials as it is built from scrap metal and car parts.
	Local service providers can collect broken equipment or parts, especially batteries, at local collection points or during regular maintenance visits.	Gradl and Knobloch (2011)	Can you establish a take-back service? Which actors can help you in this activity? For example local technicians can collect broken products/components during customer visits and deliver it at a local collection point	Sunlabob: The company implements a rental system through charging stations managed by a community committee. Sunlabob ensure that components are recycled by establishing a take-back service of batteries and other products. The company also provides mini grids and rehabilitate broken hydropower plants into functioning hybrid systems.
	Collaborate with external recycling services. Companies can co-operate with other organisations that collect expired batteries or other valuable material.	Gradl and Knobloch (2013)	Can you develop strategic partnerships (e.g. with manufacturers) aimed at re-using and or re-manufacturing products/components?	
	Use a limited variety of parts. Using few and standardised parts in products wherever possible makes it easier to maintain a supply of spare parts.	Gradl and Knobloch (2011)	Are your products designed to facilitate components' re-use and re-manufacturing? For example, can they be easily disassembled? If you offer a PSS solution it is your economic interest to provide products whose components can be easily re-used and or re-manufactured	
	Batteries are dangerous to health and pollute if disposed inappropriately. Correct recycling is strongly recommended. *Replace harmful material. Harmful, polluting, resource- and energy-intensive materials can be replaced by more environmentally friendly ones*	Adams et al (2006), Gradl and Knobloch (201)	Can you establish services to take-back potentially harmful products or components such as batteries? Which actors can help you in this activity? For example local technicians can collect these products/components during customer visits and deliver it at a local collection point.	

	Collaborate with external recycling services. Companies can co-operate with other organisations that collect expired batteries or other valuable material. These will often pay customers or the business for the scrap value	Gradl and Knobloch (2011)	Can you establish partnerships with manufacturers or local recycling centres to allow them to properly recycle/dispose products and components?	
	Extend materials' life, in order to valorise materials from scrapped products. Rather than ending up in landfills, these materials can be re-processed to obtain new secondary raw materials or incinerated (burned) to recover their energy content	Ceschin (2014); Vezzoli (2007); Mont (2004)	Are your products designed to facilitate recycling? Can their materials be easily separated? If you offer a PSS solution it is your economic interest to provide products whose materials can be easily recycled.	
CUSTOMER				
Variable	**Extract**	**Reference**	**Guideline**	**Case study**
Define energy demand and needs	*From a technical perspective, the nature of the demand depends on the types of customers and their uses of electricity*	Zerriffi (2011)	Design an energy solution that respond to an existing needs (and related demand of energy) and choose the appropriate technology accordingly	SELCO: SELCO creates the energy offer according to the specific needs of its customers. The company works with end-users to define type and size of technology needed (e.g. small energy home systems for low-consume households, charging stations with lanterns for entrepreneurs) and design an all-inclusive offer with tailored credit, installation and after-sale services.
	The starting point to look at what appliances people already have and how much they are already spending on energy for them.	Hankins & Banks (2004)	Can you detail the needs of the customer? Can you estimate the related energy demand (e.g. household needs: lighting, TV and radio, phone charging, small appliances, cooling, heating, refrigeration, productive use)?	
	Customization of technology packages and services to specific needs of the communities	Chaurey et al. (2012)	Does your offer adapt to different customers' needs? Design a solution that allows users to customise the offer in relation to their specific needs.	

	To meet the increase of the demand without compromising the service quality, some components of the system need to be oversized. One common practice to avoid sharp increases in system costs is to build in 30% extra capacity, mainly in wiring and batteries. *A capacity margin of around 20% was considered to be sufficient to provide adequate generation security*	Rolland and Glania (2011); Strbac (2008)	Are you taking into consideration future increases of demand? Energy provision has effects on expectations and living standards associated with improvements in employment and income generation. Be sure your energy supply can adapt to changing rates of consumption. One common practice is to allow a 30% extra capacity.	
	Characteristics of different target customers: nature of demand for rural households in low, at peak times.	Zerriffi (2011)	Individuals and households require a low power generation, usually at peak times (only for few hours a day).	
	Multi-tier energy framework (p. 6)	ESMAP (2015)	Energy for individual use is intended to satisfy, individually or altogether, household and small businesses needs (lighting, cooking, heating and cooling, information and communication -TV, radio, phone, IT-)	
	Shops and other micro businesses providing local services (e.g. cell phone shops, internet cafés, grocery shops) […] usually have much less electricity demand than workshops with their electrical machines.	Flotow & Friebe (2013)	Local entrepreneurs require low-medium constant electricity to support their activities (e.g. phone charging).	
	Entrepreneurs can earn extra income charging mobile telephone batteries	Morris et al. (2007)	Local entrepreneurs need electricity to provide energy services or charging several appliances simultaneously	
	Supply reliability and quality should also be higher when productive activity is included in the target customer base due to higher reliability and quality power demands of most productive activities. *Anchor loads like telecom towers or industry loads usually have a reliable high and usually quite constant electricity demand which*	Zerriffi (2011); Flotow & Friebe (2013)	Productive activities' energy demand can be high depending on the activity and require constant power supply.	
	productive uses of electricity are defined as agricultural, commercial and industrial activities involving electricity services as a direct input to the production of goods or provision of services.	Brüderle et al. (2011)	Productive activities need electricity for agro-processing activities, manufacturing industries, commercial activities	

			Communities have medium-high energy demand according to the size and density of the population.	
	For the community facilities locale, five sub-locales need to be considered: health facilities, educational facilities, street lighting, government buildings, and public buildings.	ESMAP (2015)	Communities would need energy for various applications: household uses, public buildings (schools and clinics), productive activities and public spaces.	
Define willingness to pay	*A customer's willingness to pay for a good or service is the second key driver for the addressable market estimate, and is based on customer awareness, expectations, and, critically, the perceived value of energy solutions.*	Bardouille (2012)	Willingness to pay is based on customer awareness, expectations, and the perceived value of energy solutions	Fenix International: The company has developed a mini kit with battery box that can provide phone charging services. Many customers in Uganda are using the energy system to set up a charging business and they earn up to $48 per month. The local entrepreneurs are willing to invest the up-front costs of an energy system as they can cover the investment within few months.
	Customer education on the benefits of modern technologies, valued extra features (like phone charging), product performance guarantees, and social recognition can all increase willingness to pay.	Bardouille (2012)	Have you considered educating and building customer confidence? By providing customer education on technology's benefits you may increase willingness to pay for your offer.	
			Can you provide product performance guarantees? It is important to build customer confidence in technology.	
	Solar recharging is perceived to add to the overall cost of the device. This could mean that consumers assume such devices are expensive, even if in fact they are not.	IFC (2011); Fenix International case study	Can you enhance willingness to pay by offering a solution that enable customers to set up a small business? Adding extra appealing features (such as phone charging sockets) adds perceived value to products and users may create small income generation activities.	
	Consumers are generally willing to pay significantly more for shorter outages and better-quality supply […]. This is also confirmed by observations that in remote and off -grid areas consumers are willing to pay a premium for electricity connections.	Iyer et al. (2010)	Individuals and households can be willing to pay higher prices for replacing kerosene or other expensive and dangerous fuels.	

		Fenix International case study	Local entrepreneurs may have high willingness to pay when the technology enables income generation activities.	
	If electricity generation and sup- ply is directly tied to income generation activity, the community's ability to pay for electricity services are further enhanced.	Iyer et al. (2010)	Productive activities have high willingness to pay for energy supply as it directly affects their income.	
	Characteristics of different target customers: willingness to pay of communities is mostly low.	Zerriffi (2011)	Communities may have low-medium willingness to pay.	
Define ability to pay and design for affordability	*[…] making it possible to fold capital costs into the monthly fee and reduce up-front costs to the end-user, thereby increasing affordability.* *Tariffs always have to be high enough to cover O&M as well as replacement costs.*	Zerriffi (2011); Rolland & Glania (2011)	The amount that customers are able to pay should cover capital and running costs of energy provision.	Mobile payments: An increasing number of organisations are leveraging mobile payments technology to enable a pay-as-you-go energy. This model tackle one of the main barrier of off grid energy distribution: affordability. Customers can in fact pay in small incremental amounts, for the energy they consume or to repay credit and eventually own products. This mimics existing spending patterns of other energy sources (kerosene) and allow users to adapt payments according to income availability
	Another tactic for maximizing affordability is to adopt a payment profile that mirrors the traditional spending profile of customers who would otherwise use kerosene for lighting or charcoal for cooking.	Bardouille (2012)	What is the existing spending profile of your customers? Adopt a payment structure that that mirrors the amount and frequency of the existing spending profile of your customers (who would otherwise use kerosene, charcoal or other non-renewable energy sources).	
	Consumer financing should have flexible repayment terms taking into account the seasonality of the incomes of the consumers.	Hankins & Banks (2004)	Does your offer allow flexible payments? Consider seasonality of income of your target customers, such as annual or semi-annual payments for farmers who have cash availability according to the harvest schedule.	
	A common approach is to partner with microfinance institutions and rural banks that already provide financing in target markets.	Bardouille (2012)	Can you provide financing services to your customer? If your end-users don't have access to credit you could design an offer that enable microcredit financing.	
	The lack of disposable income may prevent otherwise willing households from adopting solar systems (in India). *It is also important to take into account the fact that for some groups of customers like farmers, income can vary considerably during the year. Therefore, payment of the debt by ESCOs could be made on a basis other than monthly, - e.g. quarterly or annually. For instance, CHESCO accept payments with interest by farmers after harvest.*	Urpelainen & Joon (2015); Lemaire (2009)	Individuals and households can vary in ability to pay, but in most cases is low and it is subjected to seasonality of income availability.	

		Nuru Energy, Bboxx, TERI case studies	Local entrepreneurs may have low ability to pay, especially if they don't have an existing business activity.	
	Communities usually have low ability to pay. Financial sustainability is worst when the target customer is only community structures (schools, clinics, etc.). The collective action problem of having community members pay for such electrification can be large.	Zerriffi (2011)	Communities may have low-medium ability to pay.	
	facilitating the development of productive activities, local customers may have a relatively high ability and willingness to pay for electricity tariffs. *In general, commercial enterprises that use electricity to generate income have a greater ability and willingness to pay for electricity than households.*	Cu Tran (2013); Zerriffi (2011)	Productive activities have higher ability to pay.	
Create awareness and build customer confidence	*Consumers tend to be very skeptical for lighting products that they have limited exposure to. This could be due to early market spoiling by low quality torches, based on inherent skepticism of new technology, or reflect a general lack of understanding about the benefits from improved lighting technology.*	IFC (2011)	Build trust about product reliability and quality. Address the need of consciousness about renewable energy benefits and uses of electricity especially if the customer is going to be actively involved in the energy solution.	Solar Sisters is a non-profit organisation that empowers women in becoming solar entrepreneurs in rural communities. Thanks to their ties in their communities, these women entrepreneurs use their network of families, friends and neighbors to sell solar products and to create awareness in terms of benefits from using clean energy products. Solar Sisters provide in this way a customised and close relationship with customers, by advising them on product choice and best uses. *For instance, village community centre or religious centre can have systems installed for demonstration. Power and Sun in Sri Lanka first installed systems in buddhist temples. Often the community participates in purchasing the systems which gives a form of ownership (Gunaratne 2002).*
	Marketing: Roadshows and other traditional media are popular at the BOP, word of mouth and relationships at a local level, extensive radio campaigns do a good job at leveraging local knowledge and executing effective grassroots outreach campaigns	Bardouille (2012)	Have you considered educating, creating awareness and building trust by intervening at different levels? Word of mouth, leveraging marketing campaigns and partnering with existing consumer brands, organising community-based meetings are all necessary to build customer confidence in the technology.	
	the main barrier is the cultural shift necessary to value an ownerless way of having a satisfaction fulfilled, as opposed to owning a product	Ceschin (2013); Goedkoop et al., (1999); Manzini et al., (2001); Mont, (2002); UNEP, (2002).	In particular, can you educate customer on the economic and environmental benefits derived by PSS-based innovations (e.g. reduced responsibility on maintenance, repair, disposal)?	

Design to support income generation	*Introduce income-generation solutions: Provide productive inputs such as machinery for local crafts, seeds and live-stock, or irrigation systems as part of the business' product offering. Create new market opportunities by initiating new local activities such as sewing or food processing, or enabling access to markets for agricultural products or fabricated goods*	Gradl and Knobloch (2011)	Providing electricity for local productive uses (agricultural, commercial and industrial activities) can increase income generation by improving productivity or reducing production costs in an existing production process.	REDAVIA: The company offers solar powered stations to rent for productive activities in the mining and agricultural sectors. The solution involves pre-assembled and modular solar systems (up to 1MW) that are installed, operated and maintained by Redavia on a flexible 24 months renting contract.
	For enterprises that install their own generating unit, they can potentially earn additional income by supplying the community with electricity when not using the power for their primary activity.	Zerriffi (2011)	Have you thought about targeting enterprises that could supply extra energy produced to communities? By installing their own generating unit, small enterprises can potentially earn additional income by supplying the community with energy when not using it for their primary activity	
	Facilitating the development of productive activities, local customers may have a relatively high ability and willingness to pay for electricity tariffs	Cu Tran (2013)	Have you considered supporting the growth of local productive activities with collateral services (such as training and financing)? Provide an energy solution that support local development, for example offering energy services with training or microfinance to enable business growth	
Recognise gender needs and address to equity	*Access to energy services affects men and women differently, and the specific energy services used by men and women differ based on the economic and social division of labor in the workplace and at home.* *it is important to understand the role of men and women and their use of electricity depending on their daily tasks*	Modi et al. (2005); Terrado et al. (2008)	Understand the differences in how men and women use energy and promote gender equity by designing an offer that favour the integration of women and improve their social and economic situation	Grameen shakti: Grameen Shakti employs women as in the Bangladesh society most families feel uncomfortable in allowing men to enter the house for installation or maintenances of solar home systems. By training women and empowering them with jobs and skills for installation and repairs, GS has helped in bringing them a new level of recognition in society.
	Interventions to improve status of women ca be either through enhancing their production and income generating skills, through improving their education or through including women in planning the project	Adams et al. 2006	Can you enable women in support productive activities undertaken by women? Women in developing countries are more likely to afford energy if it can be used to generate income or to improve their activities (water pumping, husking and milling, home based enterprises).	

	Women often know families' needs best, also regarding electricity use. In some rural villages, women head the households and are responsible for household energy expenditures. In this case, the voice of women about their ability and willingness to pay for electricity is important for project planning	Cu Tran (2013)	Have you considered how introducing electricity in households affects women and men differently? Provide a technology choice that adapts to requirements of both genders. For example if you do not provide energy for cooking, women, who are mostly in charge of food preparation, may still have to rely on traditional and dangerous fuels.	
	In many cases, the provision of electricity without attention to the provision of modern cooking fuels or appliances has resulted in rural electrification that in fact increases the hardships of women because the working day is prolonged while traditional fuel use patterns remain in place	ENERGIA/UNDP (2004)	Women are usually in charge for food preparation and require energy for cooking together with other household needs.	
	Women in developing countries generally cannot afford to pay for new equipment unless it somehow can be used to generate income. Therefore, projects to address women's energy needs must take into account the types of value-added productive activities typically undertaken by women.	ENERGIA/UNDP (2004)	Local entrepreneurs may be women or previously unemployed people who set up an energy business.	
	Men and women have different energy needs: energy for cooking, cleaning and child care are the obvious examples for women's needs but also water pumping, energy for husking and milling, energy for home based enterprises	Adams et al. (2006)	Productive activities undertaken by women (agriculture or home based enterprises) can benefit from energy provision.	
Involve users in the design and implementation process	*Early in the project planning stage, the target community needs to be reached for example via awareness campaigns, regular meetings with community leaders and community-based meetings*	Cu Tran (2013)	Customers involvement and support is vital for the project success and they must be early reached via promotional programs and meetings with community leaders.	IBEKA develops hydro mini grids (connected or not) together with the community, based on its specific needs. IBEKA works with end-users to agree a tariff structure that covers operation and maintenance and a community fund. Simultaneously training is provided and a community committee is established to own and manage the mini grid.
	Involve the target group in the product design, through means such as idea competitions or focus groups in which users can design their own models. *community buy- in and their active involvement right from the planning stage is pivotal to ensure the success of any project.*	Gradl & Knobloch; Chaurey et al. 2012	Can you provide an offer that enable active participation of the end-users? In a community-managed system, for example, customers are also involved in the energy provision. Participatory approaches during project planning and implementation are necessary for users involvement.	

	IBEKA works with the community to agree a tariff structure that brings sufficient revenue to cover the day-to-day cost of operation; a maintenance fund; and a community fund.	IBEKA case study, Ashden (2012)	Can you involve the end-user in the customisation of payment? Tariffs for example can be set up with the help of community and be based on financial availability of target customers.	
Address a mix of target customers	*Productive uses of electricity increase incomes and provide development benefits to rural areas. As income increase, rural populations are better able to afford greater levels of energy services, which can allow even greater use of renewable energy*	Martinot et al. (2002)	Mixing targets can ensure a more stable customer base by addressing the needs of productive activities who act as anchor customers and, at the same time, making electricity services more affordable to lower income customers (e.g. individual households).	OMC power: The company offers energy solutions to productive activities (telecom tower companies) and communities through charging stations. Mobile network operators get the power plant installed on site and pay per energy consumed (kWh) while nearby communities pay to rent energy-using products (batteries, lights, fans).
	Productive activities can provide a solid customer base with the potential to recover more of the costs of providing electricity. *These commercial customers can also act as an anchor consumer for the electrification project, allowing more of the capital costs to be recovered. For example, an agricultural producer can use the electricity during the day to process agricultural produce and in the evenings the unit can supply a basic amount of electricity (enough for lights or perhaps a radio) to domestic users.*	Etcheverry (2003); Zerriffi (2011)	Can you design an offer that addresses simultaneously different target customers? Coupling an offer to productive activities with an offer to communities or individual end-users might be a good strategy to have a more stable customer base.	
	One option to explore could be the "anchor client" model. Here, a mini-utility would partner with mobile network operators (to manage the power needs of off-grid base stations) or other businesses, such as commercial farms or extractive industries, and in parallel, sell electricity to close-by communities.	OMC Power case study; Bardouille (2012)	Have you considered different payment structures according to different targets?	
NETWORK OF PROVIDERS				
Variable	**Extract**	**Reference**	**Guideline**	**Case study**
Private enterprise		From case studies: M-KOPA, Kamworks, Azuri Technologies etc.	Private enterprises can be involved in providing energy solutions by covering a variety of roles, from technology design and manufacturing to providing product-related services.	M-KOPA is a private enterprise that sells mini kits with additional services and uses mobile money transaction for credit services. The company partners with the

		-	Can you involve a private enterprise for the provision of technology (energy systems and products)?	technology provider (d.Light) and uses the existing infrastructure of mobile transactions, shops and retailers of Safaricom, the mobile network provider (M-PESA).
		-	Can you involve a private enterprise for PSS management and collection of payments?	
		-	Can you involve a private enterprise to provide services to add value to the product life-cycle (installation, maintenance, upgrade, take-back etc.)?	
	Small-scale companies bring advantages in terms of proximity to costumers […] Larger-scale companies (ESCO) are more likely to be financially viable but then they have to rely on local shops to maintain links with customers	Lemaire (2009)	Energy solutions can be provided by small private companies, with advantages in terms of proximity to customers, or bigger-scale enterprises who have the advantage of ensuring financial viability.	
	It is important to have agents who are part of the community, someone people trust and who can respond to their concerns	Asian Development Bank (n.d.)	Can you ensure a strong local representation? Agents who are part of the community are essential to build trust and responsive services, local shops and retailers can create links with customers.	
	If the energy company is originally dealing other products or services (farm machinery, fertilizers, pumps, generators, batteries, electronics, telecommunication etc) can use their existing networks of sales, outlets, dealer and service personnel	Martinot et al. (2002)	Can you use an existing network of sales, outlets, dealers and service personnel to deliver your offer? If the company was involved in the offering of other products or services before introducing an energy portfolio, existing infrastructures can be used for the energy solution delivery.	
Technology manufacturer	Manufacturing companies can attach additional value to a product, for example with financial schemes or refurbishing or upgrading. To improve the total value for the customer because of increased servicing and service components […]	Mont (2002)	Manufacturers can provide energy solutions by offering services coupled with the products they manufacture, or they can be involved as partners for performing specific tasks (e.g. training, maintenance).	Kamworks designs and manufactures solar home systems and lanterns, providing a range of additional services. The company provides energy through different offers: product-related services (maintenance, training) or advice and consultancy are offered

		-	Can you involve the technology manufacturer for the provision of technology (energy systems and products)?	when products are sold; in the use-oriented offer, energy systems and energy-using products are provided on renting or leasing.
		-	Can you involve it for training on products use, maintenance or management?	
		-	Can you involve it to provide product-related services (installation, maintenance, upgrade, take-back etc.)?	
	As the provider owns and maintains the product during the use phase, and thus controls maintenance and repair, this may facilitate the reuse and refurbishment (remanufacturing) of products.	Mont (2004)	Manufacturers can provide services aimed to add value to the product life-cycle, coupling with the energy systems or energy-using products they produce.	
	In this way producers need to manufacture fewer products and components, and this leads to reducing raw material and energy consumption. *Producers become more responsible for their product–services in case material cycles are closed. Producers are encouraged to take back their products, upgrade and refurbish them and use them again. In the end, less waste is incinerated or landfilled*	Ceschin (2014); Mont (2002)	Can the manufacturer provide services aimed at extending the product life-cycle? When the manufacturer retains ownership or responsibility of energy systems and/or products, it's in his economic interest to postpone the disposal costs and the costs of manufacturing new products.	
Community	*A strong advantage of the community-based entities is that the owners are also the customers and have a strong incentive to operate and maintain the system sustainably.* *The involvement of communities is often key, not only as consumers and producers or subcontractors, but also as partners in development*	Cu Tran (2013); Wilson et al. (2009)	Communities can play a wide variety of roles in your energy solution. They are not only the customers. They can be involved in managing and delivering (some aspects of) the energy solution.	IBEKA is an non-for-profit organisation that promotes community development via the provision of local energy. Communities are involved at early stages of implementing hydro mini grids and they receive training in operation and maintenance. The community becomes owner of the system and it's responsible for day-to-day operations, tariffs structure and collection fees.
		-	Can you involve the community (or some of its members) in PSS management and payments collection?	Trama Tecnoambiental: The company provides community-owned and managed mini grids and established training and capacity building services

		-	Can you involve the community (or some of its members) in the installation of energy systems and products?	in two stages: first, during preparation and implementation, end-users, committee and technicians are trained for operation, maintenance, fee collection and uses of energy. Secondly, after 6 months, feedbacks are collected and a second level of training is provided, targeting specific issues and problems encountered.
		-	Can you involve the community (or some of its members) in providing maintenance and repair services?	
	Involve the local community as much as possible and as soon as possible through financial or in-kind participation, connection fees, and the village committee.	Rolland & Glania (2011)	Communities need to be involved as soon and as much as possible from project implementation to organisation of the energy solution.	
	It is easier to build a community organisation based on the actual level of organisation at the village level	Gunaratne (2002)	Have you considered already established cooperatives or village organisations? Coordinate and plan the energy solution accordingly to the existing local organisational structure.	
	Very early on, in the assessment phase, some efforts must be made to maximize community awareness, involvement, and support, which are vital to project success. From project inception, target communities must be reached via promotional programs and regular meetings with community leaders	Rolland & Glania (2011)	Can you involve the community in the decision process? A key success factor is the participation and cooperation of the community from early stages of the implementation process.	
	A weak point of the community-based entities is that they often lack the technical skills to operate and maintain the power systems and the business skills to implement a sustainable business plan. It therefore requires substantial capacity building and training	Cu Tran (2013)	Communities need to be properly trained if they are involved in managing/ delivering some aspects of the energy solution	
	Successful projects illustrate that rural communities can organise themselves with capacity building and financial support from external facilitators	Gunaratne (2002)	Have you considered providing capacity building and technical training to communities? Especially if they own and manage the energy system, they may need assistance in terms of training on electricity and uses, accounting procedures, technical operation and maintenance of the system.	

	[...] this approach also needs a long preparation period and much technical and social capacity building to compensate the lack of skills and the potential for social conflicts. Therefore, the introduction of another partner – either private or public – to take over some aspects is preferable.	Rolland & Glania (2011)	Can you involve strategic partners in delivering capacity building and training activities? For example NGOs can assist communities by providing training on financial, technical and organisational aspects	
Local entrepreneur	*[…] small local entrepreneurs who have access to a distribution chain and can become a primary provider of electricity for several households (e.g. shop-owners on the central market)* *Market-based mechanisms build on public-private partnerships where a network of local entrepreneurs contributes to the maintenance of systems.*	Groh et al. (2015); Lemaire (2011)	Local entrepreneurs are individuals, with existing business activities or not, who can be involved in providing energy solutions or can be engaged as partners and cover specific tasks (e.g. maintenance and repair services).	Kamworks: The company has implemented a charging station for entrepreneurs to rent out lanterns to individuals. Initially the systems were purchased by entrepreneurs with loans from MFIs, but instead of having to repay the capital investment, they preferred to rent the energy system and products from Kamworks and be in charge of management and maintenance of the charging station.
		-	Can you involve the entrepreneur in the PSS management and payment collection?	
		-	Can you involve the entrepreneur in providing services that add value to the product life-cycle (installation or maintenance and repair)?	
	Big international companies can sell their products through third-party channels village entrepreneurs who have long-lasting and extensive networks in villages.	Bardouille (2012)	Local entrepreneurs can be involved in various roles in the provision of energy solutions as they have close relationships with communities.	
	Small-scale local entrepreneurs may also need to be provided with initial assistance in market research and development. In order to encourage such innovation and ownership, micro-credit schemes have supported the development of local capacities.	Iyer et al. (2010)	Have you considered assistance in capital financing? Local entrepreneurs usually lack of finance availability to afford the capital costs of energy systems and products. Consider subsidies and microcredit to allow him/her to cover initial investment.	

	The key ingredients are providing small private entrepreneurs technical assistance and financing. *Involvement of new actors is often needed for provision of functional sales and PSSs. However, middlemen also need to be educated and trained to solicit the customers.*	Terrado et al. (2008); Mont (2004)	Have you considered providing technical and business training to entrepreneurs? Depending on the activities he/she has to perform, entrepreneurs should be provided with training on energy system operation, maintenance, repair, and business management.	
	Favour/integrate the weaker and marginalized: a system design promoting and favouring (in order to integrate) people such as children, the elderly, the differently abled, the unemployed, the illiterate or any other minority or marginalised social group.	SDO Toolkit (Vezzoli & TIschner, 2005)	Can you involve women, youths or unemployed as entrepreneurs?	
Cooperative	*Cooperatives are organisations in which members have come together for a common purpose such as the purchase or sale of goods and services. Farmers' co-operatives are a widely used model in developing countries that facilitate access to markets.*	Gradl and Knobloch (2011)	Cooperatives are organisations composed by members that come together for a common purpose and can be involved in various sectors (e.g. agriculture). They can provide energy solutions or play a role in partnership with the energy provider.	CRERAL is a brasilian cooperative active in the district of Rio Grande do Sul that owns and manages the local electricity grid and two grid connected hydro systems, built to ensure reliable power for its members/customers. The cooperative used to buy bulk electricity from the grid and sell it to its customers, but with the connected mini grids it can ensure a continuous power supply.
		CRERAL case study	Can you involve the cooperative for providing technology?	
	Operation and maintenance costs have been lowered and distribution losses (particularly non-technical losses derived from pilferage) have been significantly reduced where cooperatives have taken over management from public utilities.	Yadoo & Cruickshank (2010)	Can you involve the cooperative in the PSS management and payment collection?	
		CRERAL case study	Can you involve the cooperative in providing services to add value to the product life-cycle (installation, maintenance, upgrade etc.)?	
	Cooperatives often function on a one member, one vote basis, thereby promoting equal participation and empowering rural people to shape the course of local development. Cooperatives can also benefit from the self-regulatory forces derived from this direct accountability to their customer base	Yadoo & Cruickshank (2010)	Cooperatives, with the appropriate financial and institutional support, can provide efficient and effective energy solutions due to their direct relationships with members, equal participation and self-regulating forces.	

	In India Rural Electric Cooperative Societies purchase electricity in bulk from the grid supplier and operate independently and successfully. *Generally, a cooperative rural distribution company purchases bulk-power supply from national or regional transmission companies*	Gunaratne (2002); Barnes (2011)	Have you considered engaging cooperatives in the management of energy systems? They can also manage sales of extra generated electricity to the national supplier (in the case of grid-connected systems) and divide the income among members or create a community found.	In Nepal community-based organisations successfully work in hydro mini grids management. These groups have been legalised into cooperatives that diversify local activities and started to use the profits generated from energy sales to offer microfinancing for income-generation activities to their members. Improving productive uses of electricity aims to increase daytime demand and the capacity to invest in new businesses.
	Many of the cooperatives offer micro-financing loans to their members to promote productive end uses of electricity and other income-generating activities	Yadoo & Cruickshank (2010)	Cooperatives active in different sectors (e.g. farmers) are interested in providing members with ways to improve productivity and they can be a strategic partner for financing services.	
	Newly formed cooperatives began to use the profits generated from electricity sales to offer their members micro-financing for small-scale income generation activities	Yadoo & Cruickshank (2010)	Have you considered involving cooperatives as partners for financing services? Cooperatives are usually interested in increasing productivity and income of their members, therefore they can provide financing services to be couple with energy technologies	
	They can be used as a partner for the distribution and sale of solar home systems or appliances such as lanterns.	Gradl & Knobloch (2011)	Have you thought about using cooperatives for local distribution of products? They can be used as a partner for distribution of energy systems and products among their members.	
	Producers associations can create more economic value for their members by sharing the costs of certification or processing technology. Collaboration enables co-investments by partners through financing but also, crucially, through information-sharing. This is particularly important in developing countries where the informal sector dominates trade. *Cooperative usually provide training and certification to their members.*	Wilson et al. (2009); Barnes & Foley (2004)	Cooperatives have direct relationships with customers and they have interests in community development, therefore they can be involved in end-user training activities.	CRELUZ is a Brasilian cooperative with more than 20.000 members. It operates hydro mini grids and provides training to its members through different activities: local operators are trained on the technical aspects of the hydro plants and on the environmental component of their work. End users, who are required to participate in the cooperative activities, are involved in environmental awareness promoted through TV ads, seminars, magazines.

	Co-operatives usually ensure high and reliable product quality by providing training and certification to their members. *Farmer cooperatives or from other sectors are interested in providing members with ways to improve productivity*	Gradl & Knobloch (2011); Barnes & Foley (2004)	Can cooperatives be involved in providing training to customers? Cooperatives have existing relationships with their members and they can provide training and certifications to end-users, create awareness and promote renewable energy solutions.	
NGO	*NGOs are mission- driven organisations aiming to achieve social or ecological objectives. Many humanitarian and environmental NGOs in developing countries are involved in the energy business because it is so interlinked with topics such as health, education and climate change.* *A non-profit organization is the locus of the activity, sometimes with an explicit agenda of promoting development and/or environmental protection. In such cases rural electrification can be the main focus of the organization or simply a vehicle to achieve larger social welfare goals*	Gradl & Knobloch (2011); Zerriffi (2011)	NGOs are mission-driven organisations that aim to achieve social or environmental objectives and they can provide energy solutions or be a strategic partner	
		-	Can you involve the NGO in the management of the PSS?	
		-	Can you involve the NGO as partner to provide financing and training services?	
		-	Can you involve the NGO in providing services aimed at the product life-cycle (installation, maintenance, upgrade etc.)?	
	NGOs can help carry out market research, to raise awareness of the benefits of modern energy solutions, assist with the distribution of products, and train sales personnel.	Gradl & Knobloch (2011)	Can you involve the NGO for supporting activities, such as lobbying or market research?	
	NGOs are more suited in many ways to provide energy services to villages as they know the local characteristics best.	Gunaratne (2002)	NGOs can successfully provide energy solutions as they have strong relationships with communities and deep knowledge of the local realities where they operate	Avani: Avani is a NGO working in the Himalayan's region where households lack of reliable electricity access. Avani implemented a 120 kW power plant that converts pine needles into

		Practical Action Peru case study	Have you considered involving NGOs for energy solutions targeted to communities? NGOs can design and implement energy solutions at community level by managing energy systems. Communities can be involved in other activities, such as operation and fee collection	electricity which is fed directly into the existing grid. The local community is trained for operation and maintenance of the plant and women are able to earn extra income by collecting pine needles.
	Effective coordination can help leverage the strength and reach of each stakeholder, minimize market distortions, increase efficiency, and help to create a strong commercial market for modern energy.	Morris et al. (2007)	Can you ensure good coordination with other actors in the energy eco-system? Especially in cases where the NGO's primary goal is not related to energy (but health, education or agriculture) it is important that strategic partnerships with manufacturers and financing institutions are established	
	NGOs can help carry out market research, to raise awareness of the benefits of modern energy solutions, assist with the distribution of products, and train sales personnel. *Non-profit organisations can help raise awareness of products or sell them through their rural networks, thereby reducing companies' marketing and distribution costs.*	Gradl and Knobloch (2011); Bairiganjan et al. (2010)	NGOs can be involved to perform several tasks such as market research, raising awareness of energy solutions, assist in the distribution of products, provide training to customers and local entrepreneurs.	Solar Sisters partners with manufacturers such as d.Light and Angaza Design and empowers women by distributing solar technology through a network of franchisees. Solar Sister provides the women with a 'business in a bag', a start-up kit of inventory, training and marketing support. Manufacturer companies benefits by building a robust distribution channels that reaches rural customers.
	Community based NGOs are more suited in many ways to provide services in the village, as they know the village best	Gunaratne (2002)	Can you involve NGOs in providing training to communities or entrepreneurs? Due to their close relationships with local people, NGOs can act as facilitators for community development and empowerment	
	Governments and development partners have helped companies by providing training and support to energy access entrepreneurs.	Bardouille (2012)	Can you involve NGOs in reaching local entrepreneurs? NGOs can select, train and empower entrepreneurs that will deliver energy solutions.	

	Many NGOs and foundations purchase lanterns from THRIVE and distributes them. THRIVE also collaborates with NGOs to provide a consumer-financing scheme for end users, who pay INR 350 up front and approximately INR 30 per month over the term of the loan.	THRIVE case study, CDF-WRI field research, 2009.	NGOs can be involved in facilitating access to microcredit and support customer financing.	Shri Kshethra Dharmasthala Rural Development Project (SKDRDP) is an NGO that promotes financing through a network of self-help-groups. They have developed expertise in renewable energy technologies, by building a list of reliable suppliers who must provide technology and after-sale services for members who want to have loans. SKDRDP officers provide information on the different technologies at village meetings and then create a group loan accordingly.
	NGOs can act as Market Facilitation organisations (MFO) as public-private entities that support the growth of a particular market through a variety of means. In micro-hydro projects in Sri Lanka, Nepal, Peru, Zimbabwe and Mozambique NGOs led most of these programs driven by a committment to marginalized people and because commercial banks were unwilling to pay transaction costs	Martinot et al. (2002)	Have you thought about involving NGOs to help with customer financing? Having access to donors funding and government subsidies, NGOs can provide financing services and be involved in advice and consultancy of technology choice.	
MFI (Micro Finance Institution)	*Some MFIs have discovered energy solutions as a new stream of revenues, and as a way to support their own customers' generation of income*	Gradl & Knobloch (2011)	MFIs are credit organisations that offer loans to groups and individuals and they can provide energy solutions as part of their portfolio or act as strategic partner for financing services.	Grameen Shakti extended microcredit services to low-income people originated as an outgrowth of the pioneer in microcredit institution, Grameen Bank. GS model in Bangladesh shows the effectiveness of a "one stop shop" that markets PV systems, provides in-house financing and extends product-related services.
	Sometimes, MFIs take on other roles such as selling energy systems or providing after-sales service directly	Gradl & Knobloch (2011)	Can you involve the MFI for PSS management and payments collection?	
		Grameen Shakti case study	Can you involve the MFI to provide services that add value to the product life-cycle (installation, maintenance, upgrade etc.)?	
		SELCO case study	Can you involve the MFI as financing partner?	
	MFIs can introduce stoves, lanterns or solar home systems as complementary products into their portfolio, thus diversifying their business revenues	Gradl & Knobloch (2011)	MFI can diversify their revenues and support their customers' income generation by coupling financing services with energy provision. They have a big customer base and good knowledge of their customers	
	MFIs adding energy lending to the portfolio can result in more customers for the energy enterprises and the creation of energy entrepreneurs—resulting in improved productivity and quality-of-life	Morris et al. (2007)	Can the MFI target local entrepreneurs to facilitate access to capital?	

	MFI staff should review the effectiveness of each energy product model with the aim of continuously improving service delivery. Possible points of revision could include adjusting interest rates, loan repayment terms, and payment, revising processes to disburse equipment, and monitoring after-sale service.	Kabutha et al. (2007)	Have you taken into consideration adapting the financial offer to the provision of energy solutions? MFI should be flexible in designing energy loans, including terms of repayment schedule and eligibility criteria.	
	Address knowledge gaps and improve communication and co-ordination between the energy and microfinance sectors. Expanding energy access through microfinance loans is largely hindered by a lack of co-ordination and poor communication between the energy and microfinance sectors. *Field demonstrations can let clients actually see how the energy product works and can benefit them. This was shown to be very important to the SEWA and SELCO partnership.*	Kabutha et al. (2007); Morris et al. (2007)	Have you considered training the MFI staff on energy and technologies? If the MFI uses partners for products manufacturing, ensure that training and awareness is provided to staff in order to avoid the use of low quality equipment	
	Diversify technology and loan product option. MFIs and energy companies have an opportunity to expand energy lending even further by offering loans for income-generating activities, productive use, and electricity grid connection, or combining energy loans with housing, sanitation, and rural enterprise development programs.	Kabutha et al. (2007)	MFIs can expand access to energy for poor clients by offering credit and/or loans for energy products.	SELCO and SEED: SELCO offers tailored products and financing services to its clients by facilitating customers getting financed through its partners. In Sri Lanka, SELCO partners with SEED (Sarvodaya Economic Enterprise Development Services) and therefore focuses its expertise in providing high quality services in installation and maintenance of systems, while the MFI takes care of loans and repayments.
	Forge links to local MFIs. Most energy companies work with existing microfinance providers in what has been called the "two-handed" model: The energy company handles the technical aspects and the MFI the financial aspects of the contract.	Gradl & Knobloch (2011)	How can you involve a MFI as financing partner? Create awareness on modern energy technologies in order to understand their potential and adapt the credit offer accordingly as key activity to bridge the knowledge gap between stakeholders	
	mutual cooperation between micro-finance institutions and technology providers is needed to avoid purchasers stop paying their installments when electricity is not provided.	Lemaire (2011)	Have you thought about coordinating monitoring and fee collection? Ensure communication and coordination among energy provider and MFI in order to ensure payment collection especially in remote areas and to avoid customers (e.g. local entrepreneurs) to repay loans if technical issues occur	

Public entities and governmental institutions	*Utility mode: the utility – or service provider – is effectively responsible for the full chain of activities. This includes financing, marketing, delivery, customer education, revenue collection, and maintenance*	Hankins & Banks (2004)	The public sector can directly provide energy solutions or can be involved as a partner to cover some aspects of the PSS offer (e.g. financing, regulatory).	ESCO Zambia: In Zambia, the government is involved in the creation of an Energy Service Company, usually as subsidiary to an existing business (e.g. farms implements, waste management) by providing technical and business training. The government maintains the ownership of systems (Solar Home Systems) and the ESCO performs installation, maintenance and repairs, fee collection.
		-	Can you involve public entities for PSS management and payments collection?	
		-	Can you involve public entities as partners for financing services?	
		-	Can you involve public entities in supporting with regulations and laws?	
		-	Can you involve public utilities for providing services that add value to the product life-cycle (installation, upgrade etc.)?	
	Larger-scale ESCOs are more likely to be viable from a financial point of view, but need then to have relays with local shops to maintain links with their customers	Lemaire (2009)	Public sector entities (such as government utilities) can be involved in providing energy solutions as technical capabilities and financial resources are easily available.	
	Utilities generally have more experience, financial resources, and technical capabilities to carry out rural electrification projects. They can realize economies of scale and use their central position to take advantage of financing options, but many of them are also inefficient and lack commitment at the local level.	Rolland & Glania (2011); Lemaire (2009)	Have you considered involving government utilities for the provision of energy solutions? Utilities can own and manage the energy systems (and products) and provide installation and product-related services	NuRa is a private company that provides energy services through solar home systems on a pay-per-unit of satisfaction basis. The company works under a "concession model" where the government subsidies the capital costs of solar systems. NuRa provides a full service package with installation, maintenance and repair services and the fixed fees paid by end-users covers these services.
			Have you considered local presence and assistance to customers? With a central management remote areas could left out from public sector's priorities therefore it's important to provide maintenance and repair services by ensuring local assistance and avoiding system deterioration	

	Utility model in South Africa: Ongoing regulation by government is usually necessary, since some sort of subsidy is usually involved. The National Electricity Regulator plays a key auditing role, administering capital subsidies on behalf of the government. *Sustained political commitment is required to create a framework of market conditions amenable to energy-based approaches to poverty reduction*	Hankins & Banks (2004); Modi et al. (2005)	Public entities can be partners for the project's financing, the provision of subsidies to customers or the creation of supporting policies.	
	In Bangladesh, a quite successful off grid rural electrification program is administered by the Infrastructure Development Company Limited (IDCOL), a public financial institution [20].a The project offers participating organizations—generally microfinance organizations, nongovernmental organizations, municipalities, and private- sector institutions—both credit and grants with which to purchase solar home systems	Barnes (2011)	Can you involve government in the provision of capital financing? The low interest loans can help businesses growth and subsidies can be used enhance affordability	
	National governments can assist by reducing import duties on energy-generation technologies and equipment for electricity generation, transmission, and distribution.	Modi et al. (2005)	Have you considered involving public entities to create protective policies and regulations? Governmental entities can play a secondary supporting role through policies and regulations (such as tariffs adjustments when connected mini grids sell electricity to national grid distributor).	
PAYMENT MODALITY				
Variable	**Extract**	**Reference**	**Guideline**	**Case study**
Mobile payments	*Pay-as-you-go pricing innovation uses cell phone SMS messaging for transmitting "top up" prepayments. Combined solar/IT systems could thus make energy more widely accessible via telecom networks.* *This mobile phone penetration in rural areas has simultaneously created the demand for power to keep phones charged, and the supply infrastructure backbone innovative approaches to off-grid energy service provision.*	Koch & Hammond (2013); Craine et al. (2014)	The wide adoption of mobile services and the great diffusion of mobile phones provides an opportunity to use this technology for payment purposes.	M-KOPA provides mini kits that are connected directly through the cellular network and allow customers to pay via mobile money. The system works "on-network", meaning that products are integrated on a software platform and can track information such as battery status and customer usage. Daily payments unlock the system and are transferred via the M-PESA mobile money transfer

	As revenue collection is a challenge for off-grid business sustainability, the integration of mobile money services, such as M-PESA in Kenya, to the energy service, represents a clear disruption in the way low income people have access and pay for affordable energy.	Nique & Arab (2012); M-Kopa case study	Can you develop strategic partnerships with mobile money operators (such as Safaricom/M-PESA in Kenya)? Transactions through mobile phones allow lower-income customers who wouldn't be able to afford formal bank accounts.	
	The development of "Pay As You Go" solutions combining the use of M2M technology to mobile money services, provides a microfinance element where the credit on a user's account can be checked remotely. *The information is driving institutional change and new business models to improve maintenance responses to handpump failures at scale.*	Nique & Arab (2012); Shared Solar, M-Kopa, Mobisol, Azuri Technologies case studies	Have you thought about using mobile networks to track information on consumption and products' performances? You can use the network to get information about customer usage, products' status (e.g. battery performance) and at the same time manage payments and customers' accounts	
Scratch cards and energy credit codes	*Electricity companies could partner with phone companies to accept their scratch cards. This has the potential to further reduce costs and increase the convenience of the prepayment system*	Bardouille (2012)	Cards can be used to deploy energy credits in forms of unique codes that allow customers to prepay the electricity provision and unlock the energy system.	Azuri Technologies: The company sells mini kits with a mobile credit service: after paying an installation fee, users purchase a scratch card at local vendors each week and adds credit to their unit via mobile phone. They send the code via SMS and receive a number that has to be entered in the control unit. The system then unlocks for a week and after a period of 18 months customers become owner of systems and can freely enjoy solar power.
	Pre-paid cards enable flexibility for the customer, while eliminating financial risk for the business. Small amounts make purchasing credit affordable even for poorer customers.	Gradl & Knobloch (2011)	Can you involve a local entrepreneur or an existing network of vendors and partners to distribute prepaid cards? Electricity provision can be paid through cards sold at local vendors or through local entrepreneurs.	
		OMC Power case study	Can you mimic the patterns of airtime purchases according to the context of use? In India, for example, energy prepaid credits are sold through entrepreneurs with an SMS-based model. Customers can pay in cash transaction the entrepreneur and get the prepaid energy "recharge" code via SMS.	
Fee collection	*Ensure a suitable fee-collection scheme. As methods of payment can influence the willingness to pay, it is advisable to make it easy for the rural villagers to pay for the electricity use*	Cu Tran (2013)	Fee collection can influence customers' willingness to pay and therefore it should be organised to be easy and practically feasible for them.	Mera Gao Power sets up and runs solar powered mini grids in small rural Indian communities. The company provides low voltage energy and has installed circuit

	Task local representatives with collecting payments. Regular visits by representatives to the customer's house make payment more convenient, and enables equipment to be maintained. *Monthly visits to collect fees appear to be preferable to a scheme where clients themselves have to go to ESCOs' stores to pay, as it gives the opportunity of constant monitoring of each system by technicians during their visits.*	Gradl & Knobloch (2011); Lemaire (2009) ESCO Zambia	Can you involve local representatives or technicians in the collection of fees? People who have existing relationships with customers, such as technicians who perform regular visits to customers, can be engaged in the fee collection and ensure constant monitoring.	breakers in order to control overloading and customers pay to get 7 hours of power per day for Rs 25 a week. In order to keep customers paying, the fee collection is carried out by a local technician who visits houses weekly.
	It is advisable to make it easy for the rural villagers to pay for the electricity use, both by making it practically feasible and by allowing the customers to pay when they have cash. A fee-collection scheme can be based on monthly payments, but also on larger down-payments for example in the harvesting season. *for some groups of customers like farmers, income can vary considerably during the year. Therefore, payment could be made on a basis other than monthly, - e.g. quarterly or annually. For instance, CHESCO accept payments with interest by farmers after harvest.*	Cu Tran (2013); Lemaire (2009)	Are you adapting collection schemes to local incomes patterns? Customers may not have regular cash income all year round due to agricultural cycles and seasonal labour migration to cities. Especially In rural areas it is better to adapt collection schemes to local harvest schedule	
In-kind contribution	*The farmers supplying biomass could be compensated by reduction of their electricity bills to that extent and the entrepreneur could be incentivized by ensuring adequate returns on the investment through fair tariffs*	Iyer et al. (2010)	Payments can be made through special contribution such as labour, support and management	Biomass mini grid India: In a community-own and managed mini grid in India the biomass power plants runs on extracted oil from pongamia seeds. Villagers pay by collecting the seeds needed for the electricity generation and this covers operation (performed by a women's self help group) and distribution. The community also sold carbon-dioxide equivalent verified emission reductions to Germany and spread the income generated across the families.
	[…] coordinates the in- kind and equity contribution from the community. They could supply the project with the labor for the civil work and construction, bricks, wood, cement etc. *Communities sometimes can pay up to 10-20% of the capital investment of renewable energy mini-grid systems upfront in the form of labor, material, and cash contributions.*	Gunaratne (2002); The World Bank (2008)	Can you cover parts of the capital costs with in-kind contributions? This can be done for example by partnering with governments or public agencies who can help with support staff, or in case of mini grids with companies who can provide distribution grid management.	

	financial or other contributions from the end-users are a technique often used to ensure and increase the sense of project ownership that is critical to the sustainable operation of a system. Communities sometimes can pay up to 10-20% of the capital investment of renewable energy mini-grid systems upfront in the form of labor, materials, and cash contributions. *Greater customer flexibility can be facilitated by allowing in-kind payments, such as marketable livestock or agricultural products.*	Rolland & Glania (2011); The World Bank (2008)	Have you thought about using in-kind contributions from a community who wants to become owner of the energy system? When capital costs can't be covered by the community itself, it can participate in the installation and setting-up of the energy system (such as a mini grid) by providing labour.	
Remote monitoring	*[demand-side management] actions can be done through the consciousness of the consumers or with direct interference, by the installation of some kind of equipment that manages automatically the consumers' demand, such as situations of load interruption at given periods. […] Possibility of consumption management by real-time reading of the electrical data at the meter's display. Possibility of use of limited emergency credits, that are discounted after the introduction of new credits.* *The fee for service payment model is effective, and there is less abuse by consumers when meters are used instead of a flat fee per connection.*	Blasques & Pinho (2012): Chaurey & Kandpal (2010)	Meters can be used to monitor energy consumption, disconnect customers who don't meet payments and load supply according to the contract agreement. Meters are useful to incentivize energy conservation and efficiency by allowing customers to have accurate record of their consumption	Sparkmeter: The company targets mini grids providers by selling a metering system that enables them to customise and limit load energy and monitor remotely and in real time the electricity usage, avoiding risks of theft and overuse. End-users can prepay for the energy they consume, for hourly consumption, or for a fixed monthly amount of energy, according to the unit of satisfaction agreed with providers.
	Like prepayment for mobile phones, the customer buys widely available tokens, each with a unique code. The code is entered into the meter to credit the account and supply power. When credits run out, the account is not disconnected, but the electricity ceases, to be started again when the customer again has cash available. *The active monitoring of units (i.e. Solar Home Systems) allows ESCOs to have real time information about on-going operations. At regular intervals, an embedded microcontroller sends information to a central server about user's consumption, photovoltaic energy production, battery voltage and any operational problems that could result in the unit failure.*	Bardouille (2012); Nique & Arab (2012)	Can you introduce pre-payment and smart meters? With this system, the consumers need to purchase in advance units of electricity and supply shuts down when the credit is exhausted. The management of energy loads and payments can then be done remotely so that the problem of reading, billing, and collecting can be solved. It also helps avoiding overdue payments, especially in community-managed systems	
	Moreover, [meters] are not necessarily reliable and they might be hard to read for uneducated rural people. They also require the operator (or the regulator) to organize regular visits on site to control the meters.	Rolland & Glania, 2011	Who is in charge of meter reading? Customers can take their own reading but difficulties in meter reading must be considered and the provider should periodically organise visits to check meters. Technicians can also take care of meter reading and collect fees during the same visit	

PRODUCTS				
Variable	**Extract**	**Reference**	**Guideline**	**Case study**
Design for local conditions	*this is important as it reflects resource availability and suit-ability, including the human resources necessary for either installing individual units or running a small grid*	Zerriffi (2011)	The technology choice must be site specific and based on the location's characteristics in order to ensure reliable energy generation	Avani works in the Indian Himalayan mountains where firewood is scarce and pine needles are a fire hazard and inhibitor for agriculture. They developed a system that address environmental issues and provide clean energy at the same time: by gasifying pine needles the plant generates electricity for village use. The community is also involved in the pine needle collection.
	Implicit in the overall process is the upfront collection of baseline data on energy consumption, income, and willingness to pay among the various sectors in the community and information on the availability of local energy resources. *The technology choice should be based on location need and has to be site specific.*	Terrado et al. (2008); Lemaire (n.d.)	What is the local availability of energy sources? What is the best combination of energy sources to satisfy the customer demand? Adapt the technology choice on the local availability.	
	Adaptation of technology: necessary condition for their diffusion. The viability of many small-scale energy technologies depends on factors that are specific to a particular location. Such variability means that adaptation to meet local conditions is often essential	Barnett (1990)	Can you adapt your products to specific conditions? The viability of energy systems and products depends to the particular local factors, for example technology should be flexible and robust across a number of users and their different needs in terms of energy capacity and use.	
	Develop simple and reliable technology that is robust across a number of users, needs and locations. Build up a production, delivery and maintenance system that is willing to honestly monitor progress and can adapt to changing circumstances. *Technologies could be used for different purposes in different seasons. For example biogas technology could be used to generate electricity for irrigation in the dry season while it could supply thermal energy for paddy parboiling in the rainy season when other biomass fuels get wet.*	Barnett (1990); Biswas et al. (2001)	Can you adapt the energy system and products to contextual and environmental changes? Take into consideration energy demand growth, customer base changes and seasonality of energy sources	
Solar power	*PV technologies are broadly classified into crystalline silicon, thin Film, concentrating PV and emerging PV technologies. An SPV system usually consists of the following components: PV modules, battery, charge controller, inverter, interconnections and other devices.*	Kishore et al., (2013)	Electricity from solar power is obtained by converting solar radiation through the photovoltaic effect. The technology consists of solar panel (monocrystalline/ polycrystalline silicon), inverter, charge controller, battery, wires and cables for electric connections.	
	Solar energy is the most abundant and inexhaustible of all the renewable energy resources. *SPV technology can be used in a wide range of applications—from small solar lanterns up to kilo-watt sized mini-grids.*	Kishore et al., (2013); Terrado et al. (2008); Bardouille (2012)	Strengths: - Solar resource is widely available much of the year in most areas - PV systems are modular and can be easily adapted to energy requirements	

	PV is the only technology that can function virtually anywhere despite geographic variations in the resource (i.e., solar radiation intensity or number of days without sunshine). *Panels have the advantage of a 15-to-30-year life, with no operating costs as such,*		- Life span is long (20-25 years); technology is highly reliable	
	Panels must be installed by trained technicians and require regular maintenance. *Energy home systems such as PV are still expensive and present high initial costs for both providers and consumers.* *PV systems are modular and rugged; they require little maintenance (mainly periodic cleaning of the glass panel), although arrangements must be made to obtain spare parts and repair services.*	Bardouille (2012); Terrado et al. (2008)	Panels must be installed by trained technicians and require maintenance - Spare parts management and technical assistance must be provided with basic user training on operation - Initial costs can be high - Excepts in grid connected systems, solar power requires battery storage and can be characterised by intermittence - Conversion for DC/AC loads can result in inefficiency and storage capacity issues	
Wind power	*Although various designs do exist, most wind turbines are horizontal axis machines. They use either lift or drag forces to harness the wind.*	Noble & Sanchez (2008)	Wind turbines generates power from wind through rotor blades connected to a generator. Most wind turbines are horizontal axis machines and they are provided with battery storage, power conditioning unit and wiring.	
	Capital costs for wind power are high, but running costs are low. *The production of small- and medium-sized machines locally is generally much cheaper than imported machines.* *Blades can be made locally from laminated wood, steel, aluminum, fibre glass or combinations of these materials.*	Practical Action (n.d.)	- Wind can be cost competitive with other technologies - Parts (e.g. turbines) can be produced and assembled locally and adapted to site specifications	
	RETs that use wind, hydropower, and biomass face strict limitations imposed by site specificity and seasonality of resources. *The location of the turbine is very important and should be carefully studied to avoid wind interferences. Small wind turbines require a higher level of maintenance.* *Due to their low state of maturity and commercialization, current designs of SWT are relatively less efficient, more expensive to manufacture and produce lesser energy per kW when*	Terrado et al. (2008); Rolland (2011): Kishore et al. (2013)	- Wind is very site specific and power generation can be intermittent during the days or seasons therefore resource studies must be carried out before system installation; - Capital costs are high - Technology is still unfamiliar - Regular maintenance is required.	
Hydropower	*Hydro power is the power produced by harnessing energy from the flow or fall of water in rivers, streams or canals.* *Water pressure is converted using a hydro turbine into mechanical energy*	Kishore et al. (2013)	Hydropower uses the kinetic energy of a river fall, typically run-of-river but sometimes reservoir, to generate continuous electricity up to about 5 MW.	

	highly efficient (from 70% to 90%), have relatively low operation and maintenance costs, a lifespan up to 100 years and therefore an attractive energy pay-back ratio even for developing countries. Most of all, small hydro is a mature and reliable technology that has already been installed for more than 30 years all over the world. Cheapest technology for rural electrification over the lifetime of the system.	Rolland (2011)	- Continuous availability (runs for 24 h a day) does not require any power storage eliminating costs and maintenance of batteries; - Suitable for small and large-scale potential development; - Low average costs of electricity generated; - Well understood technology	
	small hydro plants (or run-of-river power plants) have little to no water storage capacity, so are best located on rivers with a consistent and steady flow	Rolland (2011)	- Right combination of flow and fall is required to meet the load and the river flow can be subject to seasonal and annual variations; - Technology is site specific and expansion not possible.	
Biomass power	*Biomass resources are highly versatile and can be used in a solid, liquid or a gaseous form for producing electrical power, heat, bio-fuels and other useful by-products.*	Kishore et al. (2013)	Biomass is obtained from a wide range of natural resources, (tree and grass crops and forestry, agricultural, and urban wastes) and can be used to produce electricity with direct combustion or converting the resources in liquid, gasified or solid fuel.	HPS buys rice husks from cooperatives or from centralized rice mills, which purchase them from local farmers in the mini-utility's service area. Indeed, the basis for establishing its plants in certain communities has been the availability of fuel and a good informal relationship with producers (Bardouille (2012)
	Generally considered mature/well-understood technology. Biomass can be a reliable, low-cost fuel, especially when it comes from crop waste. Where biomass fuel is available, thermal plants run on this resource can have distinctive cost advantages.	Bardouille (2012)	- Considered well-understood and mature technology - High availability of resources - Produces thermal energy at the same time as electricity (unlike wind, hydro and solar) that can suit productive activities	
	The cost of electricity generated too varies widely, depending on several factors such as the cost of feedstock, labour costs, capacity utilization factor of the plant and the distance over which the feedstock needs to be transported. Consistency had to be maintained in the feedstock supply. Biomass-based systems must be assured a constant supply of the appropriate type of biomass fuel over the project life.	Kishore et al. (2013); Terrado et al. (2008)	- Costs can be high due to collecting biomass feedstock - Good management of the whole supply chain is required - Raw material can be seasonal	
Human power	the human body acts as an energy producer in different ways. The amount of energy obtained from the human body depends on which body segments are used, the physical and mental condition the user and the design of the interface between the user and the generator.	Jansen & Stevels (1999)	The human body can act as energy producer in many ways (muscles, movement, skin potential, perspiration, body heat) and produce mechanical, electrical, thermal and chemical energy. The amount of energy obtained depends on which body segment is used, physical and mental condition of the user and the design of the interface between user and generator.	
	the devices can be built locally and therefore maintained locally, thus creating a new type of locally sustainable product. These HP devices can be maintained (and built) locally which is effective regardless of their energy efficiency (recall that for some populations they are more efficient as well)	Mechtenberg et al. (2012)	- Energy source does not depend on weather conditions or site specifications - Devices can be designed and produced locally and adapted to requirements - Power can be generated on demand - Economically convenient	

	Human power is only useful for small loads in rural areas, or to act as a back-up emergency system for critical loads. Power output will vary from person to person and depends on the health and age of the individual,	Mechtenberg et al. (2012)	- Limited capacity - Power output vary from person to person and depends on health and age of individuals - Battery storage is necessary	
Mini kit	*small SHS with a power output of 1 to 10W, mainly used for lighting and depending on the model, small ICT applications (e.g. mobile phone charger, radio) can also be added.* *Plug-and-play system including portable solar panel, batteries, multiple lights, and sockets for running small appliances*	Rolland (2011); Bardouille (2012)	Mini kits are plug-and-play systems that include a small energy generator, battery, 2-6 LED lights and socket for small appliances or phone charging with a power output from 1 to 25 W.	Azuri Quad: The system is composed by a 10W solar panel, four LED lights, a USB port for mobile phone charging, switches and the pay-as-you-go controller which enables user to top up their energy credit. The mini kit requires easy installation and basic maintenance
	offer a wide range of advantages: easy installation (Plug & Play), user-friendly application, low investment costs, little maintenance required, high degree of expandability and flexible use.	Rolland (2011)	Easy installation (plug and play); user friendly application; low investment costs; little maintenance required; high degree of expandability and flexible use.	
	Plug-and-play solar kits, which can provide sufficient power for the most basic services of essential lighting and cell phone charging […] for a minimum of 4 hours a day (Tier 1)	World Bank (2016)	Limited capacity (not suitable for complete electrification or productive uses); small battery size in mini kits can make it difficult for consumers to use all energy appliances simultaneously for long periods of time.	
	Stand-alone systems or pico systems are most suitable for villages where the customer base is small and/or ability-to-pay is low (i.e. scattered customers and little or no productive use of electricity, poor households)	Cu Tran (2013)	Target users can be individual households with low energy demand living in scattered populated areas.	
	these prices are generally within the payment capacity of most rural people in developing countries.	Rolland (2011)	Mini kits are relatively cheap systems and can be coupled with microcredit services through mobile payments	
Individual energy system	*Solar home systems are often found in predesigned combinations from 20 watts peak (Wp)12 to 150 Wp, with 50 Wp being a common size, they can also be designed according to specific users' needs.* *These include SHS, which range from household-sized systems of 30–100 watt peak10 capable of powering a few bulbs, a fan, and possibly a small television, to institutional sizes (100–500 watt peak) for use in small community centers, schools, or health centers.* *Where water resources are available, pico-hydro systems of less than 5 kW have also been used for individual homes, small farms. Most countries define micro-hydro, mini-hydro, and small-hydro capacities as up to 100 kW, 100–1,000 kW, and 1–10 or 30 MW, respectively.*	Bardouille (2012); World Bank (2016); Terrado et al. (2008); Rolland (2011)	This technology is a stand-alone system installed directly in homes, shops, factories or community buildings and it can generate a power from 20W up to few kW.	Mobisol: The company offers different sizes of solar home systems (30, 80, 100, 120, 200W) with energy-using products (LED light bulbs, portable lantern, mobile charger, wiring and switches) targeted to individuals with different energy needs. The smallest system can light up two lights and charge four phones per day, the biggest one powers multiple appliances simultaneously.

	Wind-home systems can deliver a monthly amount of energy comparable to a large SHS, depending on the average wind speed (capacity of 400W). *Small wind turbines have with a power output below 50kW.*			
	very energy efficient systems without any conversion losses.	Rolland (2011)	No transmission and distribution costs are involved as power generation is at the customer's site; flexibility in load requirements and resources available.	
	it requires good design and the use of an optimized charging technology.	Rolland (2011)	Initial costs can be high; limited capacity; high battery costs and limited capacity to store electricity forcing to throw away the extra energy generated.	
	Small stand-alone charging systems are suitable for remote households in developing countries.	Lemaire (n.d.)	This technology is the most cost effective for customer far from the national grid connection and in areas with low population density.	
	They usually provide electricity to large individual installations like hotels, hospitals, schools, factories etc. and offer a wide range of applicable loads.	Rolland (2011)	Larger systems can be installed at public buildings (schools, hospitals, governments etc) of for productive uses (e.g. 2kW systems) and also use a mix of complementary resources (e.g. solar and wind).	
Solar individual systems	*Classical Solar Home Systems generally cover a power output of up to 200W peak. Important advantages of classical SHS are the DC loads like DC energy saving lamps, radios, DC TV and special DC fridges directly usable by the system.*	Rolland (2011)	This technology is a fixed installed system (50-200W power), usually on a rooftop, that provides storage energy for a few days and can run several lights and appliances (TV, radio, mobile charging, fans, refrigerator).	
	Where customers are few and dispersed and their main electricity use is domestic lighting, individual systems, usually SHSs, are used	Terrado et al. (2008)	To be used in areas whose demand is too low for a grid-based system, or for a dispersed population	
	The maintenance and quality management of these components are key factors for a successful and sustainable operation of PV off-grid systems. Training of local operators and cooperation with service providers can guarantee long-term professional O&M.	Rolland (2011)	Panels must be installed by trained technicians and require regular maintenance, therefore spare parts management and technical assistance must be provided together with basic user training on operation.	
Wind individual system	*WHS consists of a turbine mounted on the rooftop or on a tower, a charge controller, deep-cycle batteries and optionally a power conditioning unit*	Kishore et al. (2013)	The system consists of a wind turbine with direct current generator, charge controller, battery, wiring and switches, lights and an outlet	**Wind for productive activities Madagascar:** A stand-alone wind-powered system has been installed to provide reliable electricity to a telecom tower company. The telecom antenna has an average electricity consumption of 1kW and, based on the wind speed of 7 m/s in that location, the expected power production is of 32 kW (Rolland, 2011)
		Rolland (2011): Wind for productive activities in Madagascar	Target customers can be local businesses and telecommunication centres in need of power reliability and autonomy because they are more likely able to cover the high investment costs.	
	Small wind turbines (50-150W) are suitable for household energy supply and they can power low-energy light bulbs,	Noble & Sanchez (2008)	Small wind turbines (50-150W) are suitable for household energy supply and they can power low-energy light bulbs, radios, mobile phone charging and	

	radios, mobile phone charging and occasional television use.		occasional television use. Bigger turbines (up to 500W) can be suitable also for battery charging.	
Charging station	*Some are developing an energy kiosk around ICT activities, hence addressing two main issues in developing countries: access to electricity and to new information and communication technologies.*	Rolland (2011)	Charging stations are big stand-alone systems that can provide power between 200 to 5000W for both batteries and phones charging, lanterns and offer electricity for other small productive uses or IT services.	**Bboox Malawi:** The charging station offers basic electricity services to local communities by renting charged Bboxx units to customers. Customers pay a deposit and fees between \$0.5 to \$10 a week to rent out a maintenance free battery that has plug for lights and mobile charging. Bboxx targets local entrepreneurs to set up the charging business.
	Health services, Information and Communication Technology based educational services, water purification services, etc. can be provided to the communities by expanding the capacity of the charging stations in future. *The main advantage of such systems is their mobility, which makes them especially suitable in situations where no other type of power is available and where there is a need for emergency access*	Chaurey & Kandpal (2009); Rolland (2011)	Charging stations have modular design that can be expanded according to capacity requirements and renewable energy choice; they can be easily installed and moved; maintenance costs are usually low.	
	A key lesson is that location is a key consideration when selecting the services to be provided and best way to deliver them. It is important to consider that the logistics of remittance or collection of payments from agents is difficult in areas with limited inter-village public transport and poor or limited mobile network coverage.	Muchunku & Ulsrud (2014)	Location is important: This system is suitable where customers live nearby the station as lanterns or batteries need to be carried and recharged often; limited capacity	
	The concept of Central Charging Station works on the model of fee-for-service or renting. Setting up of central charging stations would require identifying, selecting and training entrepreneurs to operate and manage a charging station. *This technology suits poorest consumers are it provides energy when they can afford to pay (renting lanterns). Market the energy service as an income generation activity (charging stations for entrepreneurs).*	Chaurey & Kandpal (2009); Gunaratne (2002)	This technology suits even lower income customers as allow them to pay when they can afford (renting model) and can be managed by communities or entrepreneurs.	
		OMC Power case study	Big charging stations can provide power as stand-alone systems for productive uses (e.g. communication towers) and at the same time offer renting of appliances (batteries and lanterns) to lower income customers.	

Solar charging station	*A large solar battery charging station (SCS) is typically set up at a central place in a village/hamlet. This station has battery bank charged from an array of PV modules. A DC-DC converter is used to charge batteries of individual solar lanterns*	Kishore et al. (2013)	This stand-alone power generation uses solar power to provide electricity to communities with 150-500 customers.	
	Users are not responsible for safety of PV modules. The consumer could either buy a lantern or pay fees of only charging or he can rent a charged lantern for a particular duration	Kishore et al. (2013); TERI case study	Charging station can be owned by a local entrepreneur who earns with renting the batteries, or can be leased to entrepreneurs or communities who shares charging fees with technology provider	
		OMC Power case study	Payments can be made through mobile money to reduce administrative challenges	
		TERI case study	Installation can be provided and training in maintenance and operation is required	
Human powered charging station	*the bicycle generator is optimal in multiple situations of low cost and low electricity consumption. When the bicycle generator is not optimal (in areas above $5/day and electrical energy consumption above 0.6 kWh/day) the best choice is the solar panel with a battery and a bicycle generator used as a backup system*	Nuru Energy case study	This system can recharge lanterns by using pedal power with an output of 50W. Twenty minutes of pedaling can recharge 5 lights simultaneously and no battery backup is needed.	**Nuru Energy:** The concept is to sell low-cost lanterns that can be charged using pedal power. Entrepreneurs purchase 50 lanterns ($5 each) and a POWERCycle ($150) from Nuru. Each franchise sells lights ($6) to local customers, mainly farmers without regular cash income, and then receives ongoing revenues by charging customers a fee of $0.25 to charge each lantern (Bardouille, 2012)
		Nuru Energy case study	The technology can fit renting and leasing models.	
		Nuru Energy case study	Charging station can be targeted to local entrepreneurs who could own the system or provide energy on a leasing contract with technology provider.	
Isolated mini grid	*A mini-grid (also sometimes referred to as a micro-grid or isolated-grid) provides electricity generation at the local level, using village-wide distribution networks not connected to the main national grid.*	Rolland (2011)	A mini grid is a small energy generation facility with a local distribution network that can provide loads capacity between 5kW up to few MW.	**Shared Solar Mali:** The company provides electricity to rural communities with solar mini grids built to match existing demand. If the demand grows over time solar panels can be added to increase system capacity. Customers prepay according to energy consumed, using mobile phones or cash transaction to a local entrepreneur. Smart metering is used to manage account and load information.
	they can provide economic benefits to the local population contributing to productive uses and; renewable energy mini-grids have high investment requirements but low energy costs. *one advantage of community-owned mini-grid systems is that the development of productive end uses for the power can be better planned into the development of the system*	The World Bank (2008); Lemaire (n.d.)	Modularity and adaptability to demand; reliability of energy supply can be improved by integrating different energy generators (hybrid); suitable for productive activities; contribute to local development by creating jobs in management and operation.	
	The most relevant barriers to mini-grid renewable energy systems are: institutional issues, high investments and transaction costs, uncertain customer demand, lack of technical skills for design, O&M, management and monitoring.	The World Bank (2008); Rolland (2011)	Adequate demand for power is required for sustainability; capital financing is high and bill collection approaches and payment structure are important to cover connection costs; institutional setup is needed; organizational structure for bills management, operation and maintenance are required.	

	Setting up O&M schemes, fee collection and local structures/regulation are the greatest barriers.			
	Mini-grids provide capacity for both domestic appliances and local businesses, and have the potential to become the most powerful technological approach for accelerated rural electrification	Rolland & Glania (2011)	This technology suits community use and it can address a mix of target customers (productive activities and households).	
	Mini grids require adequate demand for power and in order to operate efficiently and profitably. Several technical and non-technical factors that have to be considered including: distance from the utility grid, system power losses, load characteristics, demand-side management, base/peak load issues, economics and billing and ownership and management.	Lemaire (n.d.)	Optimum size of system is essential for technical and economical sustainability. Size depends on the load of demand, end-user types, the daily (and seasonal) variation in consumer demands, and the expected growth in consumer demand	
Solar mini grid	*The mini-grids are typically in the range of 2–150 kWp and provide AC electricity*	Kishore et al. (2013)	This technology has an electricity distribution network operating typically between 10-100 kW and it can provide electricity from a solar PV plant with its own storage (batteries) facility.	
	They usually supply for domestic power, commercial activities (e.g. shops, video centres, computer aided communication kiosks, small grinders), and community requirements such as drinking water supply, street lighting and vaccine refrigeration	Chaurey & Kandpal (2010)	Solar mini grids can target domestic use of power and commercial activities but also community use (e.g. street light, drinking water supply).	
	The mini-grids are typically in the range of 2–150 kWp and provide AC electricity.Limited availability of low wattage DC appliances is another factor that is currently restricting the technology to primarily lighting loads such as CFL and LED lamps.	Kishore et al. (2013)	Electricity is converted to AC power (same as centralized power supply) distributed to customers through a local grid usually for a limited number of hours.	
	The high cost of energy relative to the limited purchasing power of the rural households makes the electricity prohibitively expensive.	Kishore et al. (2013)	Cost effectiveness is related to high densely populated target areas and flat terrain.	
Wind mini grid	*most wind turbines are horizontal axis machines. They use either lift or drag forces to harness the wind.*	Noble & Sanchez (2008)	Wind turbines generates power from wind through rotor blades connected to a generator. Most wind turbines are horizontal axis machines with battery storage, power conditioning unit and wiring.	**Sustainable Energy Afghanistan:** the mini grid is installed in off grid areas by the New Zealand technology providers, who also trains local technicians for maintenance. The community takes ownership of the grid system and adopts pre-pay electricity meters for paying the energy they consume.
	Wind-power systems require average wind speeds of at least 4 m per second for small turbines.	Terrado et al. (2008)	The wind mini grid (require a speed of 4-5 m/s to be viable.	
	A turbine should be located wherever the highest constant wind speed can be captured, and with as little turbulence as possible. The wind turbine should be sited away from obstructions such as trees and buildings.	Noble & Sanchez (2008)	The turbines should be located wherever the highest constant wind speed can be captured and they should be sited away from obstructions such as trees and buildings.	

	due to the intermittent nature of the wind resource, SWTs are usually used in combination with other technologies such as Solar PV, diesel generators and energy storage systems.	Kishore et al. (2013)	In order to ensure a reliable power supply, a diesel generator set is often used as backup for when wind speeds	
Hydro mini grid	*Where water resources are available, pico-hydro systems of less than 5 kW have also been used for individual homes, small farms, or clustered households located near the river*	Terrado et al. (2008)	A mini-grid hydro system is an isolated water-driven power supply intended to provide a village with energy for households, productive uses and community buildings.	Practical Action Peru: The NGO has installed 47 mini hydro systems that provide an average electrical power of 33kW to about 5000 families and small businesses in the Andes. Most turbines are locally manufactured. Micro-enterprises are set up and trained to operate the systems and communities manage tariff structure and collection. Users pay per energy consumed.
	In case of hydropower generation the project should take into account water use rights and local needs regarding drinking water, fishing, irrigation.	Adams et al. (2006)	The system design should take into account water use rights and local needs regarding drinking water, fishing, irrigation.	
		Practical Action Peru case study	Community-managed hydro mini grids are successful due to easy operation and maintenance of systems.	
	Menyar pico is located downstream of Gwere along the same river. It provides power for 94 homesteads and a community-run battery charging station with a generation capacity of 500. *[…] unconnected households benefited by the possibility of hiring lights for special occasions*	Richard (2011); ESMAP (2000)	Battery charging can extend the effectiveness by using power in times of low demand (late night) and reaching customers too far to be grid connected.	
Biomass mini grid	*For systems operating on renewable sources like biomass there will be a high pressure on these renewable sources, as the system usually operates at high scales and need more biomass for its operation*	Kaundinya et al. (2009)	Biomass-fueled technologies (digesters and gasifiers) can be used in mini grid systems with high capacity and size (see also: connected mini grid)	
	The first consideration must be to review the feedstock available and hence to tailor the technology and system design to this. Long-term project viability requires the development of supply agreements with specific suppliers for amounts, prices and set time- frames. The significant costs for collection and transportation, storage and handling also need careful consideration.	Lemaire (n.d.)	Since large quantities of solid material are involved, system design must take into consideration collection, storage, preparation and processing of feedstock as well as disposal of residues	
	To manage both fuel supply chains and cost structures, biomass mini- utilities may need to enter into long-term guaranteed contracts with cooperatives or other third parties and build storage facilities to manage price volatility. Alternatively, developing proprietary plantations near their mini-utilities may also help to manage costs.	Bardouille (2012)	Partnering with cooperatives or other parties to manage fuel supply chain can be an option, or alternatively developing plantations near the mini grid can help to manage costs and transportation.	
Hybrid mini grid	*A hybrid system can use several renewable energy technologies (RETs) and balance the specific advantages and shortcoming of each resource.*	Rolland (2011)	This system can use several renewable energy technologies balancing the specific advantages and intermittency of each resource.	Sunlabob offers community electrification through hybrid mini grids. The company combines a 12 KW small hydro generator with a 2kWp PV system and a 15 kVA diesel generator. The different sources accommodate the fluctuating loads of village by allowing
	This subsystem includes the generation (RETs and genset), storage (batteries), converters (convertors, rectifiers, an d inverters to convert DC power to AC), and management (energy management systems) components.	Rolland & Glania (2011)	Hybrid systems consist of generator, battery bank for energy storage, control system and a particular system architecture that allows optimal use of all components.	

	Hybrid mini-grids ensure a continuous and reliable electricity supply equivalent to (and sometimes even better than) the one provided to grid users in developing countries	Rolland (2011)	Reliability and continuity of system is higher than other renewable options.	power to be generated 24 hours a day. The system is a financially alternative to grid connected systems.
	The reality is that designing a hybrid system is a complex task that should only be undertaken by true professionals with proven expertise and track records.	Rolland (2011)	This technology requires high initial investments and due to the complexity of systems, management and maintenance of different technologies is crucial.	
Connected mini grid	*A grid-connected energy system is an independent decentralized power system that is connected to an electricity transmission and distribution system (referred to as the electricity grid).*	Kaundinya et al. (2009)	A connected mini grid is a system that is connected to, and may exchange electricity with, the main national grid.	**Husk Power Systems:** The company sets up biomass gasification- based power plants with capacity ranging from 30 to 100 kW running on rice husk, abundantly available in rural India. Customers, low income people living in rural areas, pre-pay the electricity to light up two lights and one mobile charging station. Local technicians are trained to run the operation and maintenance.
	Mini grids connected allow providers to sell electricity at a good price to the national grid. This technology brings together public and private partners and allows the community to generate extra income.	Martinot et al. (2002)	Unlimited storage capacity due to grid connection can tackle seasonal load variations; larger-scale systems can be used hence they can operate at high load factors and improve economic viability; national grid supplier can be "anchor" customer that guarantees stable revenues and enables communities to earn income; communities can also purchase energy in bulk	
	To make grid connected systems competitive the right geographic resources must be chosen and the regional-specific costs of competing fuels must be analysed	Martinot et al. (2002)	Regulatory framework influences feasibility and tariffs; regional energy costs must be analysed and right technology must be chosen in order to make the system competitive.	
	They are ideal for locations close to grid. The connectivity to grid enables setting up relatively large-scale systems and hence they can operate at high plant load factors improving the economic viability of the operation.	Kaundinya et al. (2009)	This system fits high demand communities located close to the national electricity grid or that receive an unreliable grid supply.	
	This system can become a small power distributor that purchase bulk power from the national utility when the grid reaches the previously off-grid areas. In this way the risks are lower for private operators who would otherwise need to shut down systems	AFREA (2012)	When the national grid reaches previously off-grid areas, this system allows the integration of the two energy suppliers and avoids the otherwise fall into disuse.	
Appliances for productive uses of energy	*typical productive uses can be found in agro-processing (e.g. grain milling), various manufacturing industries such as carpentry, tailoring, welding and looming, and in the service sector, e.g. in bars and restaurants that use electricity for lighting, sound systems and refrigeration, as well as for charging mobile phones.*	Brüderle et al. (2011)	Productive uses of energy can be defined for use in agricultural, industrial and commercial activities that generate income and include powering machines for instance for pumps, drip irrigation, milk machines, mechanical workshops, food refrigeration, IT supply for businesses or processing and storage industries.	**Phaesun Somalia**: The BOSS-programme (Business Opportunities with Solar Systems) of Phaesun and its local partner company Horn Renewables aims at supporting small businesses with specific solar systems to increase their productivity. The BOSS-systems include solar powered charging stations, fridges for kiosks and mobile fridges for fish transportation. The project has been implemented in Somaliland and targeted small businesses, fishermen and local
	in addition to generating additional income, work loads can be reduced, time saved which can be used for education and other constructive activities and more sophisticated products can be produced through the productive use of energy.	Feibel et al., (2008); Rolland (2011)	Can you include appliances for productive activities in your PSS offer? This would benefit customers by extending businesses' operating hours, allowing mechanisation,product preservation, increasing productivity, improving working conditions and more in	

	The use of energy-efficient products is very important and should be promoted and even subsidised as part of any rural electrification project/programme, whatever the technology chosen		general creating sustainable local economy.	entrepreneur.
	Quantity of electricity supply: In the case of energy access programmes in off-grid areas, productive use promotion should obviously prioritise zones where electricity supply currently exceeds demand for household requirements, and with sufficient distribution capacities.	Brüderle et al. (2011)	Have you considered higher energy demand? Productive activities often require higher energy demand density and power can be supplied by a wide range of technologies and resources.	
	Financial service providers (formal and informal) provide loans for facilitating electricity connections and purchasing of off-grid equipment. *Inexperienced entrepreneurs-in-spe typically need strong hand-holding.* *Support local capacity building and training, especially to start and run a business, as well as to work with the renewable energy installation.*	Brüderle et al. (2011); Lecoque & Wiemann (2015)	Can you provide additional supporting services such as financing and training? Businesses and entrepreneurs require skills development and knowledge to profit from newly introduced DRE systems. Enhancing access to microcredit or other financing mechanisms may be required.	
Cloud-based tracking platforms	*Given that loads are difficult to estimate and manage in a small grid with little diversification, smart grid technologies can help manage loads more effectively and improve overall performance, such as by prioritizing certain loads or sequencing them in "waiting lists" so as not to overstress the grid*	Bardouille (2012)	Meters can be used to monitor energy consumption, disconnect customers who don't meet payments and load supply according to the contract agreement. Meters are useful to incentivize energy conservation and efficiency by allowing customers to have accurate record of their consumption	**Bboxx**: Smart Solar is an energy service offered by the company to provide remote monitoring and battery management. The software collects usage information and uses data analysis to extend the battery life and control the product (solar home systems & appliances). The provider has access to systems' location and can track problems and alerts service agents through a management dashboard.
		Sparkmeter case study	Management software are coupled with smart meter technologies and can be used in both stand-alone or grid-based systems.	
	Impact: Real time information on operations; improved payment processing and increase efficiency (no payment collector needed); customer data on energy usage increases knowledge on customer consumption patterns. […] The information is driving institutional change and new business models to improve maintenance responses to handpump failures at scale.	Nique & Arab (2012)	Cloud-management gives providers the possibility to track systems' performances and keep records of products usage. Maintenance and repair services can be scheduled accordingly.	
	Core technology is smart metering, enabling real time consumption monitoring and prepaid use.	Nique & Arab (2012)	Data can be collected and uploaded to the server via mobile networks. The system also allows mobile payments management and monitoring	
OFFER				
Variable	**Extract**	**Reference**	**Guideline**	**Case study**

PRODUCT-ORIENTED: Pay to purchase	*Giving local communities ownership will also increase sustainability.* *When community-based organisations are both owners and the users of the energy solution, they present a strong interest in the quality of the service and its management*	Schillebeckx et al. (2012); Gunaratne (2002)	The ownership of the energy system is transferred to the customer, but additional services, such as installation, maintenance and repair, are provided	**Grameen Shakti:** The company offers solar home systems with a service package inclusive of end-user credit, installation, maintenance and repair, take-back services. End-users, low-income households and small businesses living in rural isolated communities, can purchase the product with microcredit services and be able to repay the loan in 3-4 years. In order to ensure an effective after-sale service, Grameen Shakti trains women as local technicians for repairs and maintenance of systems and for assemble solar accessories such as lamps, inverters, charge controllers.
		-	Can you sell energy systems (e.g. mini kits, energy home systems, mini grids) or its components, together with additional services?	
		M-Kopa case study	Can you offer financing services?	
		Practical Action Peru	Can you offer services to support the optimal design of energy systems?	
			Can you offer installation services?	
			Can you offer maintenance and repair services?	
	Services, such as upgrading or modifying, can also offer service possibilities in place of new product manufacturing, thus dematerialising the satisfaction of consumer's wants and needs	Niinimäki (2014)	Can you offer service to upgrade energy systems?	
	Arrangements must be made to educate users and require project implementers to recycle and ensure safe disposal of any hazardous waste. *Batteries are dangerous to health and pollute if disposed inappropriately. Correct recycling is strongly recommended.* *With PSS, producers become more responsible for their product–services in case material cycles are closed. Producers are encouraged to take back their products, upgrade and refurbish them and use them again. In the end, less waste is incinerated or landfilled.*	Terrado et al. (2008); Adams et al. (2006); Mont (2002)	Can you offer take-back services for the re-manufacturing of energy systems? Can you offer take-back services for recycling of energy systems?	M-Kopa provides energy by selling solar mini kits with lights, radio, phone charging and enabling customers to pay small, flexible installments over time. By partnering with a technology provider (d.Light) and using the existing network of mobile money M-PESA, the company allows customers to pay an initial deposit and then process payments via mobile money-transfer. If the payment does not occur the system gets blocked. After the credit period, the customer owns the system and benefits from free and sustainable energy provision.
	Teaching users how the installed system works, and specifically what its limitations are, is of utmost importance in developing successful RE projects.	Krishnaswamy (2010) SELCO case study	Can you provide advices to the customer on the optimal use of equipment (e.g. to optimise energy consumption)?	

	Shifting responsibility to the service deliverer or increasing local competences by basic maintenance training and simple manuals could increase the needed support for installed technologies. *[…] to start and run a business, it is highly valuable for budding entrepreneurs to have some business and management training. The companies installing the renewable energy systems, NGOs, academia and local associations can play a crucial role in this regard.*	Wamukonya (2007); Lecoque & Wiemann (2015); IBEKA, Practical Action Peru case studies	Can you offer training services to enable the customer to install, maintain and repair the energy system? Who can you partner with to deliver those services? Think about the potential role of manufacturers, NGOs, local entrepreneurs and other stakeholders.	
	[…] when ownership is transferred. because the customer suddenly bears the operation and maintenance (O&M) risks and associated costs. However, there are business models that avoid this problem: in Bangladesh, the operational risk remained with Grameen Shakti, although ownership was immediately transferred to the customer. Importantly, the moment of payment can be adapted to local needs.	Schillebeeckx et al. (2012)	Have you considered customers' ability to purchase your product? Match the payment structure with spending patterns, willingness to pay and payment cultures.	
		Added after review with experts (DS-IV)	What technology/payment channel can facilitate your chosen payment structure?	
USE ORIENTED Pay per time of use	*The product stays in ownership with the provider, and is made available in a different form, and sometimes shared by a number of users.* *Product lease: […] The lessee pays a regular fee for the use of the product; in this case normally he/she has unlimited and individual access to the leased product.* *Product renting or sharing: The user pays for the use of the product. […] others can use the product at other times. The same product is sequentially used by different users.*	Tukker (2004)	Customers rent or lease energy systems and/or 'energy using products'. With renting, customers pay for the use of products (e.g. Pay-per-hour, Pay-per-day). With leasing, customers pay a regular fee (e.g. Pay-per-month) for an individual and unique access to products. The ownership of equipment/products (and the responsibility for maintenance, repair, disposal etc.) is retained by providers.	TERI provides charging stations for renting lanterns to rural customers in India through an entrepreneur-led model. TERI sets up micro solar enterprises in un-electrified or poorly electrified villages. A local entrepreneur, who receives training and financing, buys and manages the charging station by renting the solar lamps every evening, for an affordable fee, to the rural populace. Every household pays a nominal charge (Rs. 2–4 approx.) per day per lantern for getting it charged.
	the daily rental is decided by the operator and community jointly so that it is comparable to the average expenditure incurred on the current fuel for lighting	Chaurey et al. (2012)	Can you rent or lease energy systems (e.g. mini kits, energy home systems, mini grids etc.)?	
			Can you provide access to collective energy systems (e.g. charging station), on a Pay-per-time basis?	

		From case studies	Can you rent or lease 'energy using products' (e.g. lights, lanterns, appliances etc.)? Can you rent or lease charged 'energy using products' (e.g. charged lanterns)? Can you rent or lease energy systems in combination with 'energy using products'?	Sunlabob: The company provides energy service through a renting model: it leases the charging station and energy-using products (lanterns) to a village committee who in turns rents the products to the individual households. The committee is in charge of setting prices, collecting rents and perform basic maintenance. Sunlabob retains ownership, maintenance responsibilities and offers training services. End-users can rent the recharged lantern for $0.25 and it will last for 15 hours of light, while the committee pays to rent the charging station ($1.75-8 per month).
	TERI in collaboration with leading solar lamps manufacturers, lighting companies and PV manufacturers has developed cost-effective products with improved efficiency and quality. *For manufacturing companies a service component adds/allows: To improve the total value for the customer because of increased servicing and service components, which include activities and schemes that make the existing product last longer, extend its function (upgrading and refurbishment), and make the product and its materials useful after finishing its life cycle (recycling and reuse of parts or entire product).*	Chaurey et al. (2012); Mont (2002)	Can you partner with the manufacturers of energy systems and/or manufacturers of 'energy using products' to deliver renting/leasing solutions?	
	Teaching users how the installed system works, and specifically what its limitations are, is of utmost importance in developing successful RE projects. *[…] to start and run a business, it is highly valuable for budding entrepreneurs to have some business and management training. The companies installing the renewable energy systems, NGOs, academia and local associations can play a crucial role in this regard.*	Krishnaswamy (2010); Lecoque & Wiemann (2015)	Can you couple the offer with additional services (e.g. training, advice on the optimal use of equipment/products)? Who can provide those services? Who can you partner with? Think about the potential role of manufacturers, NGOs, local entrepreneurs and other stakeholders	
	Products should be properly designed to be used and shared amongst different users. *The company can potentially have an economic and competitive interest in improving resource productivity, e.g. long-lasting, reusable and recyclable products.*	Niinimäki (2014); Ceschin (2014); Vezzoli (2007)	Are the energy system and the 'energy using products' included in your offer designed to facilitate maintenance, repair, remanufacturing, recycling? In renting/leasing solutions you retain the products ownership, thus it is in your economic interest to have products that are long-lasting (easy to be maintained, repaired, upgraded), easy to remanufacture, and easy to recycle.	
		TERI case study	Have you considered customers' ability to rent/lease your product? Match the payment structure with spending patterns, willingness to pay and payment cultures.	
		Added after review with experts (DS-IV)	What technology/payment channel can facilitate your chosen payment structure?	
RESULT-ORIENTED		Gram Power, OMC Power, Practical	Customers pay to get access to energy and/or 'energy using products' (e.g. lights, lanterns, appliances) on a pay-per-energy consumed basis. The ownership of	Gram Power provides energy services in rural India through the installation and operation of mini grids. Target

Pay per energy consumed		Action Peru case studies	equipment/products (and the responsibility for maintenance, repair, disposal etc.) is retained by providers.	customers are rural communities who gets connected to the mini grid and pre-pay for the energy they consume. Households gets smart meters installed at their home and have the possibility to prepay electricity through local entrepreneurs. The entrepreneur, in fact, purchases in bulk energy credit from Gram Power, who keeps ownership of the system, and transfer the recharge into the consumer's smart meter through a wireless technology.
		-	Can you offer access to energy on a pay-per-energy consumed basis? Which energy system/s (e.g. mini kits, energy home systems, charging station, mini grids etc.) is the most appropriate?	Shared Solar Mali: The company provides electricity to rural communities with solar mini grids built to match existing demand. If the demand grows over time solar panels can be added to increase system capacity. Customers prepay according to the energy they consume, using mobile phones or cash transaction to a local entrepreneur. A smart meter is installed to each household and it is used to manage account and load information.
		-	Can you offer access to 'energy using products' (e.g. lights, lanterns, appliances etc.) on a pay-per-energy consumed basis?	
	Teaching users how the installed system works, and specifically what its limitations are, is of utmost importance in developing successful RE projects.	Krishnaswamy (2010)	Can you couple the offer with additional services (e.g. training, advice on the optimal use of equipment/products)? Who can provide those services? Who can you partner with? Think about the potential role of manufacturers, NGOs, local entrepreneurs and other stakeholders.	
	For manufacturing companies a service component adds/allows: To improve the total value for the customer because of increased servicing and service components, which include activities and schemes that make the existing product last longer, extend its function (upgrading and refurbishment), and make the product and its materials useful after finishing its life cycle (recycling and reuse of parts or entire product).	Mont (2002)	Can you partner with the manufacturers of energy systems and/or manufacturers of 'energy using products' to deliver these kind of solutions?	
			Can you partner with energy suppliers to deliver these kind of solutions?	
	The company can potentially have an economic and competitive interest in improving resource productivity, e.g. long-lasting, reusable and recyclable products.	Ceschin (2014); Vezzoli (2007)	Are the products included in your offer designed to facilitate maintenance, repair, remanufacturing, recycling? Since you retain the products ownership it is your economic interest to have products that are long-lasting (easy to be maintained, repaired, upgraded), easy to remanufacture, and easy to recycle.	

	An effective approach is to monitor customers and conduct daily/weekly visits to ensure payments, such as DESI India and Gram Power solutions which involve local entrepreneurs working in villages and regularly visiting households	DESI India, Gram Power case studies	Have you considered customers' ability to pay-per-energy consumed? Match the payment structure with spending patterns, willingness to pay and payment cultures	
		Added after review with experts (DS-IV)	What technology/payment channel can facilitate your chosen payment structure?	
Pay per unit of satisfaction	*The PSS still has a fairly common product as a basis, but the user no longer buys the product, only the output of the product according to the level of use.*	Tukker (2004)	Customers pay to get access to energy and/or 'energy using products' (e.g. lights, lanterns, appliances) on a pay-per-unit of satisfaction basis. The ownership of equipment/products (and the responsibility for maintenance, repair, disposal etc.) is retained by providers	Solarkiosk: The company targets local entrepreneurs, especially women, for the provision of energy services through charging stations. Solarkiosk design and installs the E-Hubb, a charging station provided with solar panels and energy using products and recruits a local entrepreneur who manages the system and appliances. Due to the modular configuration of the station, he/she can provide a wide range of energy services such as internet connectivity, water purification, copying, printing and scanning etc. Customers pay for the agreed unit of satisfaction: pay to print, pay to get purified water, pay for internet access etc.
	The most common approach to this challenge is to apply current limiting device to all customer connections that are sized to the level of service purchased by that customer.	The World Bank (2008) and from case studies	Can you offer access to energy and/or 'energy using products' on a Pay-per-unit of satisfaction basis (fixed payment on an agreed satisfaction)? Examples of Pay-per unit of satisfaction are: - Pay-per-recharge: pay a fixed cost for recharging a phone or a lantern. - Pay-per-lux: pay a fixed cost for an agreed level of luminance of a building. - Pay-per-print or internet connectivity: pay a fixed amount for use of the energy-using product - Pay-per-energy service package: pay a fixed fee to have access to 'energy-using-products' and a given amount of energy.	
			Which energy system/s (e.g. mini kits, individual energy systems, charging station, mini grids) is the most appropriate to provide your 'customer satisfaction'?	**Off Grid Electric:** The company provides electricity services through solar mini kits installed at customer's home. The service is tailored to users' needs and the satisfaction-based solution (two lights and a phone charger for tot hours/day) is paid by users with daily fees. Customers can choose the mini kits with energy-using products they want and upgrade with additional appliances. The starting kit includes two lights and a phone charger for 8 hours a day. Off Grid Electric retains ownership of systems and appliances and trains a network of local dealers for installation and customer support.
	For manufacturing companies a service component adds/allows: To improve the total value for the customer because of increased servicing and service components, which include activities and schemes that make the existing product last longer, extend its function (upgrading and refurbishment), and make the product and its materials useful after finishing its life cycle (recycling and reuse of parts or entire product).	Mont (2002)	Can you partner with the manufacturers of energy systems and/or manufacturers of 'energy using products' to deliver these kind of solutions?	
	Teaching users how the installed system works, and specifically what its limitations are, is of utmost importance in developing successful RE projects.	Krishnaswamy (2010)	Can you couple the offer with additional services (e.g. training, advice on the optimal use of equipment/products)? Who can provide those services? Who can you partner with? Think about the potential role of manufacturers, NGOs, local entrepreneurs and other stakeholders.	

	The company can potentially have an economic and competitive interest in improving resource productivity, e.g. long-lasting, reusable and recyclable products.	Ceschin (2014); Vezzoli (2007)	Are the energy system and the 'energy using products' included in your offer designed to facilitate maintenance, repair, remanufacturing, recycling? Since you retain the products ownership it is your economic interest to have products that are long-lasting (easy to be maintained, repaired, upgraded), easy to remanufacture, and easy to recycle.	
	The use of energy-efficient products is very important and should be promoted and even subsidised as part of any rural electrification project/programme, whatever the technology chosen. *if energy-saving bulbs (CFL) are part of the initial equipment, there is a strong tendency to replace broken ones with cheap, incandescent bulbs, so energy consumption may in- crease over time due to efficiency losses.*	Rolland (2011)	Are the energy system and the 'energy using products' included in your offer designed to optimise/reduce energy consumption? Since you are selling a performance, less energy you use to deliver that performance, lower will be your operational costs and higher your profits.	
	The seasonal distribution of rural incomes needs also to be taken into account when determining the ability of average customers to pay for the service that the system provides.	The World Bank (2008)	Have you considered customers' ability to pay-per-unit of satisfaction? Match the payment structure with spending patterns, willingness to pay and payment cultures	
		Added after review with experts (DS-IV)	What technology/payment channel can facilitate your chosen payment structure?	
Mixed offers		OMC Power, Gram Power case studies	Offers can be articulated mixing & matching different payment structures (e.g. pay-per-time of use + pay-per-unit of satisfaction). Modular/customisable offers should be considered when you target a mix of different customers.	OMC Power: The company offers energy solutions to productive activities (telecom tower companies) and communities through charging stations running on solar, hydro, wind or hybrid. Mobile network operators get the power plant installed on site and pay per energy consumed (kWh) while nearby communities benefit from basic electricity (phone charging, lighting and batteries) with a renting model. OMC establish and trains a network of local entrepreneurs who deliver and collect lanterns and boxes each day and take care of the renting system.
	The financial viability have been ensured through servicing a cluster of villages with mixed consumer profile such as domestic, commercial and agricultural	Chaurey et al. (2012)	Have you tried to mix & match various types of PSSs?	
	Allowing for different levels of service for different customer categories will improve affordability of the tariff for the poorer customers. […] Traditionally, the monthly fee consists of a fixed charge, which usually covers basic service to the lowest income group, and a variable charge based on the level of consumption. The monthly fees intend to recover the operational costs of the systems and partial equipment replacement costs.	The World Bank (2008)	Can you customise your offer to the specific needs of each customer group?	

Appendix III – Questionnaires employed in this research

Questionnaires and interviews completed are available at
https://figshare.com/s/ff57e1bbee93f241c4b2

Questionnaire A: used in DS-I with companies and practitioners

*questions included in the second phase of the study

SECTION A - Design of the business model

1. How did you design your business offer and who was involved in the process?
2. Have you supported the process of designing your business model with any tool (e.g. business model canvas)? If yes, which ones?*
3. How did you benchmark your offer? Did you take inspiration from other companies or case studies?
4. Did your offer(s) change over time? If yes, for which reasons?

SECTION B – Design of the distributed renewable energy system

1. Have you used manuals, guides or toolkits for distributed renewable energy systems? If yes, which ones?*

2. If you answered yes to the previous question, for what purposes have you used those manuals, guides or toolkits (e.g. informing about technology options)?*
3. Did you find those manuals, guides or toolkits useful for your purpose? Have you encountered issues with their use?*

Questionnaire B: used in DS-II with students at University of Botswana (W1) and with experts and practitioners (W2 and W3) to evaluate the Innovation Map and Design Framework & Cards

Evaluation of the Innovation Map

Please give an evaluation on the following aspects of the polarity diagram.

Please tick the relevant boxes according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

CHARACTERISTICS OF THE INNOVATION MAP

	1	**2**	**3**	**4**	**5**
1. To what extent is the innovation map easy to understand (i.e. the meaning of each axis is clear)	☐	☐	☐	☐	☐
1.1 If you answered from 1 to 3 please explain what was not clear to you.					

1.2 Do you have any suggestion to improve the clearness of the innovation map?					
2. To what extent is the positioning of case studies in the innovation map easy for you?	☐	☐	☐	☐	☐
2.1 If you answered from 1 to 3 please explain what problems you encountered during the positioning exercise.					
2.2 Do you have any suggestion to improve this aspect?					

APPLICATIONS OF THE INNOVATION MAP

	1	**2**	**3**	**4**	**5**
3. To what extent has the innovation map helped you to understand the different types of PSS+DRE offers?	☐	☐	☐	☐	☐
3.1 If you answered from 1 to 3 please explain what problems you encountered.					
4. To what extent has the positioning of your concept ideas in the innovation map been easy?	☐	☐	☐	☐	☐
4.1 If you answered from 1 to 3 please explain what problems you encountered.					
5. To what extent the innovation map helped you to explore different variations of your concept ideas (i.e. moving the concept from an area of the map to another one)?	☐	☐	☐	☐	☐
5.1 If you answered from 1 to 3 please explain what problems you encountered.					

6. To what extent the innovation map helped you to facilitate the discussion to select the most appropriate/promising concept idea?	☐	☐	☐	☐	☐
6.1 If you answered from 1 to 3 please explain what problems you encountered.					

General considerations:

Do you have any further comment about the innovation map? Do you have any suggestion to improve it?

Evaluation of the Design framework and guidelines

Framework

Please give an evaluation of the following aspects of the canvas.

Please tick the relevant boxes according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

CHARACTERISTICS OF THE FRAMEWORK

	1	2	3	4	5
1. To what extent is the framework clear (i.e. the various elements of the framework, and their relations, are clear)	☐	☐	☐	☐	☐
1.1 If you answered from 1 to 3 please explain what was not clear to you.					
1.2 Do you have any suggestion to improve the clearness of the framework?					
2. To what extent are the design questions (for each design element of the framework) clear?	☐	☐	☐	☐	☐

2.1 If you answered from 1 to 3 please explain what was not clear to you.
2.2 Do you have any suggestion to improve the usability this aspect?

General considerations:

Do you have any further comment about the framework? Do you have any suggestion to improve it?

Cards

Please give an evaluation of the following aspects of the cards.

Please tick the relevant boxes according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

CHARACTERISTICS OF THE CARDS

	1	2	3	4	5
1. To what extent is the content of the cards clear?	☐	☐	☐	☐	☐
1.1 If you answered from 1 to 3 please explain what was not clear to you.					
1.2 Do you have any suggestion to improve the clearness of the cards content?					
2. To what extent are the cards easy to be used?	☐	☐	☐	☐	☐
2.1 If you answered from 1 to 3 please explain why they are not easy to be used for you.					

2.2 Do you have any suggestion to improve the usability of the tool?					
3. To what extent are the guidelines easy to understand?	☐	☐	☐	☐	☐
3.1 If you answered from 1 to 3 please explain why the guidelines are not easy to understand.					
4. To what extent is the layout of the cards appropriate to its content?	☐	☐	☐	☐	☐
4.1 Do you have any suggestion to improve the cards layout?					
5. To what extent are the cards grouped in a clear way?	☐	☐	☐	☐	☐
5.1 Do you have any suggestion to group the cards in different ways?					
6. To what extent are the guidelines useful to stimulate the generation of ideas?	☐	☐	☐	☐	☐
6.1 If you answered from 1 to 3 please explain why the guidelines were not useful.					
7. To what extent are the case studies described in the cards useful in the generation of ideas?	☐	☐	☐	☐	☐
7.1 If you answered from 1 to 3 please explain why the case studies were not useful.					

General considerations:

Do you have any further comment about the cards? Do you have any suggestion to improve them?

Questionnaire C: used in DS-II to evaluate the Innovation Map with companies and practitioners in Botswana and South Africa

Please give an evaluation on the following aspects of the Innovation Map.

Please rate the innovation map according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

1| CHARACTERISTICS

	1	2	3	4	5
1. To what extent is the innovation map easy to understand (i.e. the meaning of each axis is clear)?	☐	☐	☐	☐	☐
1.1 Please explain what was not clear to you.					
2. To what extent is the innovation map easy to be used (e.g. positioning of case studies, positioning of your offer etc.)?	☐	☐	☐	☐	☐
2.1 Please explain what was not clear to you.					
3. Can you think of other types of offer or other examples/cases that are not included in the archetypal models? If yes, which ones?					

2| APPLICATIONS

Please rate the polarity diagram according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

	1	2	3	4	5
1. The innovation map is intended to be used for positioning a company's offer(s). **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
1.1 Please explain your answer.					
1.2 Would you use the innovation map for this purpose in the future?					
2. The innovation map is intended to be used for mapping the existing offers of PSS applied to DRE (competitors in the same business sector, other companies operating in the selected context etc.). **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
2.1 Please explain your answer.					
2.2 Would you use the innovation map for this purpose in the future?					
3. The innovation map is intended to be used for exploring new business opportunities (repositioning of offer, combination of different offers). **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
3.1 Please explain your answer.					

3.2 Would you use the innovation map for this purpose in the future?

4. The innovation map and archetypal models can be used for generating ideas. **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
4.1 Please explain your answer.					
4.2 Would you use the innovation map for this purpose in the future?					

General considerations:

5. Do you have any further comment about the innovation map? Do you have any suggestion to improve it?

Questionnaire D: used in DS-III with companies and practitioners (W4 and W5) to evaluate the Innovation Map and Design Framework & Cards in Kenya and Botswana

SECTION 1: Innovation Map

Please give an evaluation on the following aspects of the innovation map.

Please rate the innovation map according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

1| CHARACTERISTICS

	1	2	3	4	5

1. To what extent is the innovation map easy to understand (i.e. the meaning of each axis is clear)?	☐	☐	☐	☐	☐
1.1 Please explain what was not clear to you.					
2. To what extent is the innovation map easy to be used (e.g. positioning of case studies, positioning of your offer etc.)?	☐	☐	☐	☐	☐
2.1 Please explain what was not clear to you.					
3. Can you think of other types of offer or other examples/cases that are not included in the archetypal models? If yes, which ones?					

2| APPLICATIONS

Please rate the Innovation Map according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

	1	2	3	4	5
1. The innovation map is intended to be used for positioning a company's offer(s). **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
1.1 Please explain your answer.					
1.2 Would you use the innovation map for this purpose in the future?					
2. The innovation map is intended to be used for mapping the existing offers of PSS applied to DRE (competitors in the same business sector, other companies operating in the selected context etc.). **To**	☐	☐	☐	☐	☐

what extent is the innovation map contributing to the achievement of this objective?					
2.1 Please explain your answer.					
2.2 Would you use the innovation map for this purpose in the future?					
3. The innovation map is intended to be used for exploring new business opportunities (repositioning of offer, combination of different offers). **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
3.1 Please explain your answer.					
3.2 Would you use the innovation map for this purpose in the future?					
4. The innovation map and archetypal models are intended to be used for generating ideas. **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
4.1 Please explain your answer.					
4.2 Would you use the innovation map for this purpose in the future?					

General considerations:

5. Do you have any further comment about the innovation map? Do you have any suggestion to improve it?

SECTION 2: Design Framework

Please give an evaluation on the following aspects of the design framework.

Please rate the innovation map according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

CHARACTERISTICS OF THE FRAMEWORK

	1	2	3	4	5
1. To what extent is the framework clear (i.e. the various elements of the framework, and their relations, are clear)	☐	☐	☐	☐	☐
1.1 If you answered from 1 to 3 please explain what was not clear to you.					
1.2 Do you have any suggestion to improve the clearness of the framework?					
2. To what extent are the design questions (for each design element of the framework) clear?	☐	☐	☐	☐	☐
2.1 If you answered from 1 to 3 please explain what was not clear to you.					
2.2 Do you have any suggestion to improve the usability this aspect?					

General considerations:

Do you have any further comment about the framework? Do you have any suggestion to improve it?

SECTION 3: Cards

Please give an evaluation of the following aspects of the cards.

Please tick the relevant boxes according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

CHARACTERISTICS OF THE CARDS

	1	2	3	4	5
1. To what extent is the content of the cards clear, i.e. the guidelines and case studies are easy to understand?	☐	☐	☐	☐	☐
1.1 If you answered from 1 to 3 please explain what was not clear to you.					
1.2 Do you have any suggestion to improve the clearness of the cards content?					
2. To what extent are the cards easy to be used (e.g. looking for information, browsing cards etc.)?	☐	☐	☐	☐	☐
2.1 If you answered from 1 to 3 please explain why they are not easy to be used for you.					
2.2 Do you have any suggestion to improve the usability of the tool?					
4. To what extent is the layout of the cards appropriate to its content?	☐	☐	☐	☐	☐
4.1 Do you have any suggestion to improve the cards layout?					
6. The guidelines on the cards are intended to be used to support the generation of ideas. **To what extent are the guidelines contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
6.1 If you answered from 1 to 3 please explain why the guidelines were not useful.					
7. The case studies in the cards are intended to be used as inspiration for generating ideas. **To what extent are the case studies contributing to the achievement of this objective?**	☐	☐	☐	☐	☐

7.1 If you answered from 1 to 3 please explain why the case studies were not useful.
8.1 Would you use the cards for generating ideas for your business or for other projects in the future?

General considerations:

Do you have any further comment about the cards? Do you have any suggestion to improve them?

Questionnaire E: used in DS-III with companies and practitioners in Kenya (W5) to evaluate the Visualisation System

Visualisation tools

Please give an evaluation of the following aspects of the system map tool.

Please tick the relevant boxes according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

	1	2	3	4	5
1. To what extent was the association of system map with the case study easy to be done?	☐	☐	☐	☐	☐
1.1 If you answered from 1 to 3 please explain what was not clear to you.					
1.2 Do you have any suggestion improve the clearness of the system maps?					
2. To what extent the system map helped you get a better understanding of the case studies?	☐	☐	☐	☐	☐

2.1 Please comment your answer.					
3. To what extent the system map helped you to clarify your final concept?	☐	☐	☐	☐	☐
3.1 Please comment your answer.					
4. Do you think the system map tool exhaustively includes all types of icons and flows of PSS applied to DRE?					
4.1 Can you think of other types of icons or flows that have not been included in the system map? If yes, which ones?					
5. Would you use the system map tool in the future?					
Do you have any other comment about the system map? Do you have any suggestion for improvements?					

Questionnaire E: used with designers at Brunel University London to evaluate the Design Framework & Cards version 1.0 and the visualisation system

Please tick the correct boxes according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

	1	2	3	4	5
1. To what extent are the cards easy to be used (e.g. looking for information, browsing cards)?	☐	☐	☐	☐	☐

1.1 If you answered from 1 to 3 please explain why they are not easy to be used for you.
1.2 Do you have any suggestion to improve this aspect?

2. To what extent you think the current composition of framework + cards + empty framework is appropriate for the idea generation session?	☐	☐	☐	☐	☐
2.1 Do you have any suggestion to improve this aspect?					

5. Do you have any other comment or suggestion to improve the design process?

	1	**2**	**3**	**4**	**5**
1. To what extent is the size of the cards appropriate to its content and to its use?	☐	☐	☐	☐	☐
1.1 Do you have any suggestion to improve this aspect?					
2. To what extent is the layout of the cards appropriate to its content?	☐	☐	☐	☐	☐
2.1 Do you have any suggestion to improve the cards layout?					

3. To what extent are the cards grouped in a clear way?	☐	☐	☐	☐	☐
3.1 Do you have any suggestion to improve this aspect?					
4. The list of cards (presented with the design framework) is designed to facilitate the process of browsing cards and selecting them. To what extent do you think it contributes to this objective?	☐	☐	☐	☐	☐
4.1 Do you have any suggestion to improve this aspect?					

5. Do you have other comments about the cards? Do you have any suggestions for improvements?

SESSION TWO: DESIGNING THE TOOLKIT

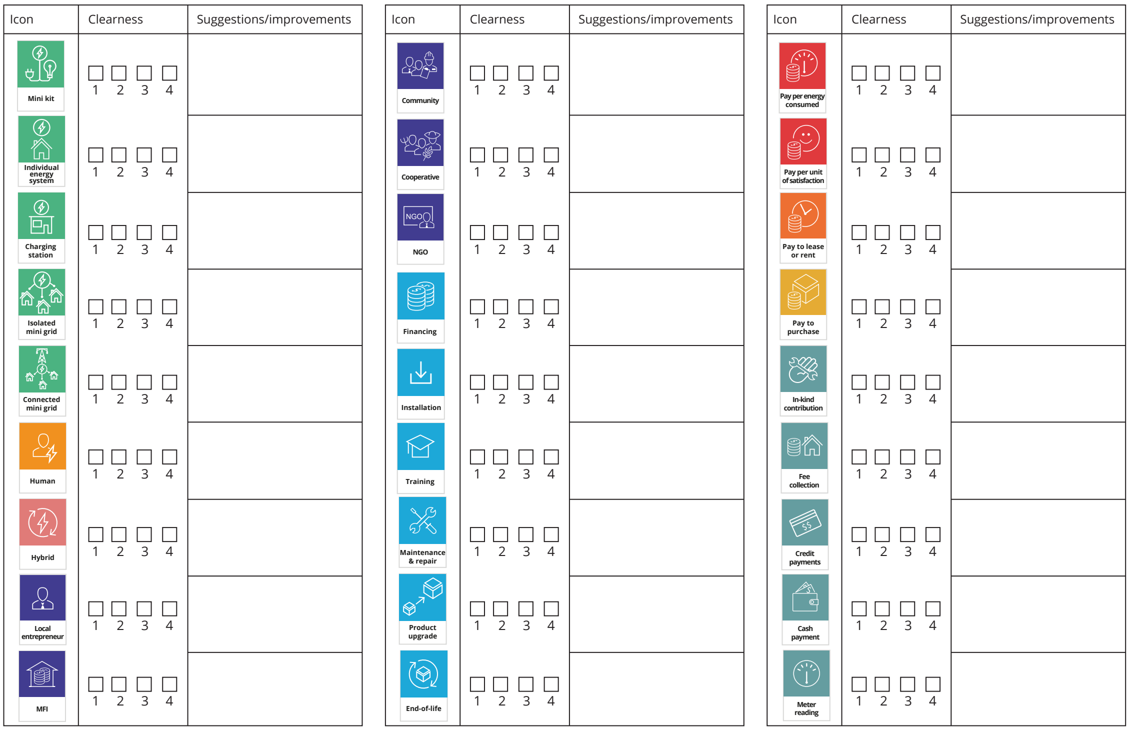
Please consider the following aspects of the toolkit:

<u>FORMAT</u>

- Most appropriate / most effective format
- Design process: framework + cards + empty framework canvas
- Size
- Cards grouping
- Transitions and connections amongst cards

LAYOUT

- Quantity of information on a single card
- Position of elements on a card (e.g. guidelines, case study, explanation)
- Proportion of elements in a single card
- Colours



GUIDELINES: IMPROVING THE LAYOUT AND COMMUNICATION
Please evaluate the clearness of the following icons

Icon	Clearness	Suggestions/improvements
Mini kit	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Individual energy system	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Charging station	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Isolated mini grid	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Connected mini grid	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Human	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Hybrid	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Local entrepreneur	☐ 1 ☐ 2 ☐ 3 ☐ 4	
MFI	☐ 1 ☐ 2 ☐ 3 ☐ 4	

Icon	Clearness	Suggestions/improvements
Community	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Cooperative	☐ 1 ☐ 2 ☐ 3 ☐ 4	
NGO	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Financing	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Installation	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Training	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Maintenance & repair	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Product upgrade	☐ 1 ☐ 2 ☐ 3 ☐ 4	
End-of-life	☐ 1 ☐ 2 ☐ 3 ☐ 4	

Icon	Clearness	Suggestions/improvements
Pay per energy consumed	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Pay per unit of satisfaction	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Pay to lease or rent	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Pay to purchase	☐ 1 ☐ 2 ☐ 3 ☐ 4	
In-kind contribution	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Fee collection	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Credit payments	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Cash payment	☐ 1 ☐ 2 ☐ 3 ☐ 4	
Meter reading	☐ 1 ☐ 2 ☐ 3 ☐ 4	

Questionnaire F: used in DS-IV with companies and practitioners in Kenya (W7) and Botswana (W8) to evaluate the three tools

SECTION 1: Innovation Map

Please give an evaluation on the following aspects of the innovation map.

Please rate the innovation map according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

1| CHARACTERISTICS

	1	2	3	4	5
1. To what extent is the innovation map easy to understand (i.e. the meaning of each axis is clear)?	☐	☐	☐	☐	☐

1.1 Please explain what was not clear to you.					
2. To what extent is the innovation map easy to be used (e.g. positioning of case studies, positioning of your offer etc.)?	☐	☐	☐	☐	☐
2.1 Please explain what was not clear to you.					
3. Can you think of other types of offer or other examples/cases that are not included in the archetypal models? If yes, which ones?					

2| APPLICATIONS

Please rate the polarity diagram according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

	1	2	3	4	5
1. The innovation map is intended to be used for positioning a company's offer(s). **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
1.1 Please explain your answer.					
1.2 Would you use the innovation map for this purpose in the future?					
2. The innovation map is intended to be used for mapping the existing offers of PSS applied to DRE (competitors in the same business sector, other companies operating in the selected context etc.). **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐

2.1 Please explain your answer.					
2.2 Would you use the innovation map for this purpose in the future?					
3. The innovation map is intended to be used for exploring new business opportunities (repositioning of offer, combination of different offers). **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
3.1 Please explain your answer.					
3.2 Would you use the innovation map for this purpose in the future?					
4. The innovation map and archetypal models are intended to be used for generating ideas. **To what extent is the innovation map contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
4.1 Please explain your answer.					
4.2 Would you use the innovation map for this purpose in the future?					

General considerations:

5. Do you have any further comment about the innovation map? Do you have any suggestion to improve it?

SECTION 2: Design Framework

Please give an evaluation on the following aspects of the design framework.

Please rate the innovation map according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

CHARACTERISTICS OF THE FRAMEWORK

	1	2	3	4	5
1. To what extent is the framework clear (i.e. the various elements of the framework, and their relations, are clear)	☐	☐	☐	☐	☐
1.1 If you answered from 1 to 3 please explain what was not clear to you.					
1.2 Do you have any suggestion to improve the clearness of the framework?					
2. To what extent are the design questions (for each design element of the framework) clear?	☐	☐	☐	☐	☐
2.1 If you answered from 1 to 3 please explain what was not clear to you.					
2.2 Do you have any suggestion to improve the usability this aspect?					

General considerations:

Do you have any further comment about the framework? Do you have any suggestion to improve it?

SECTION 3: Cards

Please give an evaluation of the following aspects of the cards.

Please tick the relevant boxes according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

CHARACTERISTICS OF THE CARDS

	1	2	3	4	5
1. To what extent is the content of the cards clear, i.e. the guidelines and case studies are easy to understand?	☐	☐	☐	☐	☐
1.1 If you answered from 1 to 3 please explain what was not clear to you.					
1.2 Do you have any suggestion to improve the clearness of the cards content?					
2. To what extent are the cards easy to be used (e.g. looking for information, browsing cards etc.)?	☐	☐	☐	☐	☐
2.1 If you answered from 1 to 3 please explain why they are not easy to be used for you.					
2.2 Do you have any suggestion to improve the usability of the tool?					
4. To what extent is the layout of the cards appropriate to its content?	☐	☐	☐	☐	☐
4.1 Do you have any suggestion to improve the cards layout?					
6. The guidelines on the cards are intended to be used to support the generation of ideas. **To what extent are the guidelines contributing to the achievement of this objective?**	☐	☐	☐	☐	☐
6.1 If you answered from 1 to 3 please explain why the guidelines were not useful.					
7. The case studies in the cards are intended to be used as inspiration for generating ideas. **To what extent are the case studies contributing to the achievement of this objective?**	☐	☐	☐	☐	☐

7.1 If you answered from 1 to 3 please explain why the case studies were not useful.
8.1 Would you use the cards for generating ideas for your business or for other projects in the future?

General considerations:

Do you have any further comment about the cards? Do you have any suggestion to improve them?

SECTION 4: Visualisation tools

Please give an evaluation of the following aspects of the system map tool.

Please tick the relevant boxes according to the following scale: **1=VERY POOR; 2=POOR; 3=SUFFICIENT; 4=GOOD; 5=VERY GOOD/EXCELLENT.**

	1	2	3	4	5
3. To what extent the system map helped you to clarify your final concept?	☐	☐	☐	☐	☐
3.1 Please comment your answer.					
4. Do you think the system map tool exhaustively includes all types of icons and flows o§f PSS applied to DRE?					
4.1 Can you think of other types of icons or flows that have not been included in the system map? If yes, which ones?					

5. Would you use the system map tool in the future?
Do you have any other comment about the system map? Do you have any suggestion for improvements?

Questionnaire G: used in DS-IV with experts and practitioners in Kenya and Botswana to evaluate the Design Framework & Cards

Information on the interviewee:
NAME:

POSITION:

FIELD OF EXPERTISE/EXPERIENCE:

On PSS applied to DRE in your specific context:

1. Looking at models of PSS applied to DRE, what are the most appropriate or promising in the Kenyan/Botswanan context?

2. Flexibility of tools: how can they be adapted to the local context? What characteristics need to be included?

Evaluation of Design Framework and Cards

	yes	no
1. The framework includes all element of a PSS applied to DRE offer.		
1.1 If you answered NO please indicate what is missing.		

1.2 Do you have any suggestion to improve framework?

Applications of the design framework

For each of the following statement indicate your response as outlined

1=strongly disagree; 2=disagree; 3=sort of agree; 4=agree; 5=strongly agree.

	1	2	3	4	5
1. The design framework aims is useful to give an overview of all design elements of the energy solution.					
1.2 If you answered between 1 and 3 please explain your answer.					
2. The design framework is useful to stimulate idea generation of the energy solution by suggesting elements to be considered.					
2.1 If you answered 1 or 2 please explain your answer.					

Cards

Please give an evaluation on the specific sections of the cards.

Please indicate the validity of the cards' content by indicating whether to **KEEP**, **ADJUST** or **REMOVE** its elements.

SECTION: SERVICES

For each of the following statement indicate your response as outlined:

1=strongly disagree; 2=disagree; 3=sort of agree; 4=agree; 5=strongly agree.

	1	2	3	4	5
1. The content of the cards is appropriate / useful					
1.2 If you answered between 1 and 3 please explain your answer.					

2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.					
2.1 If you answered between 1 and 3 please explain your answer.					

Card element	keep	adjust	remove	Comments/remarks
1. Offer training services				
Guidelines				
Case study				
2. Offer microcredit to end-users & entrepreneurs				
Guidelines				
Case study				
3. Offer installation services				
Guidelines				
Case study				
4. Offer maintenance & repair services				
Guidelines				
Case study				
5. Offer product upgrades				

Guidelines				
Case study				
6. Offer end-of-life services				
Guidelines				
Case study				

SECTION: CUSTOMER

For each of the following statement indicate your response as outlined:

1=strongly disagree; 2=disagree; 3=sort of agree; 4=agree; 5=strongly agree.

	1	2	3	4	5
1. The content of the cards is appropriate / useful					
1.2 If you answered between 1 and 3 please explain your answer.					
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.					
2.1 If you answered between 1 and 3 please explain your answer.					

Card element	keep	adjust	remove	Comments/remarks
1. Define energy demand and needs				
Guidelines				

Case study				
2. Define ability to pay and design for affordability				
Guidelines				
Case study				
3. Define willingness to pay				
Guidelines				
Case study				
4. Create awareness and build customer confidence				
Guidelines				
Case study				
5. Design to support income generation				
Guidelines				
Case study				
6. Involve users in the design and implementation process				
Guidelines				
Case study				
7. Recognise gender needs and address to equity				
Guidelines				
Case study				

8. Address a mix of target customers				
Guidelines				
Case study				

SECTION: PAYMENT

For each of the following statement indicate your response as outlined:

1=strongly disagree; 2=disagree; 3=sort of agree; 4=agree; 5=strongly agree.

	1	2	3	4	5
1. The content of the cards is appropriate / useful					
1.2 If you answered between 1 and 3 please explain your answer.					
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.					
2.1 If you answered between 1 and 3 please explain your answer.					

Card element	keep	adjust	remove	Comments/remarks
1. Fee collection				
Guidelines				
Case study				
2. Mobile payments				
Guidelines				

Case study				
3. Scratch cards and energy credit codes				
Guidelines				
Case study				
4. In-kind contribution				
Guidelines				
Case study				
5. Meter reading				
Guidelines				
Case study				

SECTION: NETWORK OF PROVIDERS

For each of the following statement indicate your response as outlined:

1=strongly disagree; 2=disagree; 3=sort of agree; 4=agree; 5=strongly agree.

	1	2	3	4	5
1. The content of the cards is appropriate / useful					
1.2 If you answered between 1 and 3 please explain your answer.					
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.					

2.1 If you answered between 1 and 3 please explain your answer.

Card element	keep	adjust	remove	Comments/remarks
1. Private enterprise				
Guidelines				
Case study				
2. Technology manufacturer				
Guidelines				
Case study				
3. Local entrepreneur				
Guidelines				
Case study				
4. Community				
Guidelines				
Case study				
5. Cooperative				
Guidelines				
Case study				
6. Non-Governmental Organisation				

Guidelines				
Case study				
7. Micro-Finance Institution				
Guidelines				
Case study				
8. Public entity and government utility				
Guidelines				
Case study				

SECTION: PRODUCTS

For each of the following statement indicate your response as outlined:

1=strongly disagree; 2=disagree; 3=sort of agree; 4=agree; 5=strongly agree.

	1	2	3	4	5
1. The content of the cards is appropriate / useful					
1.2 If you answered between 1 and 3 please explain your answer.					
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.					
2.1 If you answered between 1 and 3 please explain your answer.					

Card element	keep	adjust	remove	Comments/remarks

1. Design for local conditions				
Guidelines				
Case study				
2. Solar power				
Guidelines				
Case study				
3. Hydropower				
Guidelines				
Case study				
4. Wind power				
Guidelines				
Case study				
5. Biomass power				
Guidelines				
Case study				
6. Human power				
Guidelines				

Case study				
7. Mini kit				
Guidelines				
Case study				
8. Individual energy system				
Guidelines				
Case study				
9. Charging station				
Guidelines				
Case study				
10. Isolated mini grid				
Guidelines				
Case study				
11. Connected mini grid				
Guidelines				
Case study				
12. Cloud-based tracking platforms				

Guidelines				
Case study				

SECTION: OFFER

For each of the following statement indicate your response as outlined:

1=strongly disagree; 2=disagree; 3=sort of agree; 4=agree; 5=strongly agree.

	1	2	3	4	5
1. The content of the cards is appropriate / useful					
1.2 If you answered between 1 and 3 please explain your answer.					
2. The content of the cards reflect the state-of-the-art knowledge in the field of designing sustainable PSS applied to DRE for the specific section.					
2.1 If you answered between 1 and 3 please explain your answer.					

Card element	keep	adjust	remove	Comments/remarks
1. Pay to purchase				
Guidelines				
Case study				
2. Pay per time of use				
Guidelines				
Case study				
3. Pay per energy consumed				

Guidelines				
Case study				
4. Pay per unit of satisfaction				
Guidelines				
Case study				
5. Mixed offers				
Guidelines				
Case study				

Appendix IV – Concepts generated: workshops in Kenya (W7) and Botswana (W8) during DS-IV

Concepts generated with the Innovation Map

Participant	Concept: details from Concept Cards
P1	CONCEPT 1 **Concept description**: Light touch mentorship: Training and mentoring last mile women entrepreneurs to join and participate in the solar pico value chain. **Stakeholders**: IFC/World Bank - Lighting Africa Program, certified solar manufacturers, certified solar distributors, women entrepreneurs, Practical Action, financial institutions. **Products**: mini kit (solar lantern, with charging options) **Services**: training, maintenance and repair, upgrade, financing **Customers**: off grid households (for technical and economic reasons) mostly from rural areas, women entrepreneurs **Payment channels**: pay to buy, cash + credit option
	CONCEPT 2 **Concept description**: renting or pay per unit model. Rent to own (Pay As You Go) model **Stakeholders**: manufacturer, distributors, mobile money service provider, Practical Action, financial institutions **Products**: mini kits, possibility of product diversification **Services**: financing entrepreneurs and customers, training to end users, training to entrepreneurs, maintenance, repair, upgrade (optional) **Customers**: off grid (technical and economic reasons), entrepreneurs, rural areas **Payment channels**: mobile money
P2	CONCEPT 1 **Concept description:** electricity from coffee processing plants **Stakeholders:** coffee cooperative, private enterprise **Products:** biogas individual plants + high quality biofertilizer and biogas, connected mini grid to local households and main grid **Services:** installation, maintenance and repair, training **Customers:** coffee cooperative farms, rural areas **Payment channels:** cash and credit

Participant	Concept: details from Concept Cards
P3	CONCEPT 1 **Concept description**: pay to purchase and pay to lease of solar water pumps **Stakeholders**: german manufacturer, private enterprise (installation, training), local technicians **Products**: water pumps **Services**: installation, training **Customers**: farmers **Payment channels**: cash
	CONCEPT 2 **Concept description**: solar mini kits on a pay per unit of satisfaction **Stakeholders**: private company **Products**: solar kits and solar products **Services**: training on use, installation **Customers:** individuals **Payment channels**: cash
	CONCEPT 3 **Concept description**: leasing solar kiosk to mobile producers + offering charging services **Stakeholders**: TEAM (manufacturer), enterprise (management), local entrepreneur **Products**: solar kiosks **Services**: charging services, training, maintenance **Customers:** mobile company, communities **Payment channels**: cash
P4	CONCEPT 1 **Concept description:** pay per unit of satisfaction **Stakeholders:** private company, manufacturer **Products:** isolated mini grid **Services:** installation, management, maintenance **Customers:** farmers, community **Payment channels:** cash
	CONCEPT 2 **Concept description**: sale of electricity to end users through national grid – pay per consumption **Stakeholders**: private company, manufacturer **Products**: connected mini grids **Services**: installation, management, maintenance **Customers:** farmers, community **Payment channels**: cash

Idea generation with Design Framework and Cards

P1	
Network of providers	• **NGO**: Practical Action: training women entrepreneurs, linkage with finance institutions and suppliers, coordination among actors • **NGO**: World Bank / IFC: funding

	• **Women entrepreneurs**: sale of light products, customer training on product use. They receive assistance in financing, technical and business training • **Suppliers/manufacturers**: certified suppliers from WB/IFC. Responsible of carrying training on life and maintenance of products; available for major repairs and maintenance. Take back services • **Cooperative**: women Chama. Financing the service and facilitating recruiting • **MFI**: access to capital to entrepreneurs. Clarify that MFI have technology awareness. Coordination and responsibility of payback, payments collection
Products	• **Solar power mini kits**: payment option PAYG with charging option; more than one lantern, M-KOPA connectivity • Radio (efficient) and TV
Services	• **Manufacturers**: to ask for **end of life services** (take back) and **product upgrade** • **Basic maintenance and repair** (entrepreneurs) • **Major maintenance** service by suppliers/manufacturers • **Micro credit**: offer micro credit to consumers – how do entrepreneurs do that? • **Training** by entrepreneurs **to end users**: will manufacturers offer manuals? Videos from place to place? • Tools to end users – limits of kits • Practical Action to offer **training to entrepreneurs**
Offer	• **Pay per time of use**: small deposit and small daily fee _ manufacturer: do you have renting options? Lease products to entrepreneurs • Other options: pay to purchase • Pay per unit of satisfaction: daily? monthly?
Customers	• Spending profile of customers? • Offer allow flexible payments? PAYG? Microcredit financing? • **Target customers**: off-grid rural communities • **Design to increase income**: small businesses / kiosks • **Create awareness**: how will local entrepreneurs create awareness of the product? “word of mouth” – economic and environmental benefits • **Define willingness to pay**: will they produce product performance guarantees? Appealing features?

Payment channels	• Cash • **Mobile payments** – M-Kopa • **Credit: fee collection** from entrepreneurs – adopting collection schemes to local patterns

Table 1 - Ideas generated with the Design Framework & Cards by P1

P2	
Network of providers	• **Contractors:** to service plant O&M • Electricity technical services: generators, biofertilizer packaging, biogas packaging • **Community**: capacity building, technical training to be provided • **Coffee station** for technology • **Women groups**: MFI provide training • **ERC**: regulation +laws • **Kiambau community** • **KPL** added value • **Local entrepreneurs**: fertilizer packaging + biogas packaging • **NGO**: churches + others
Products	• Coffee processing waste water • **Connected mini grid** (KPLC): output plant and bio fertilizer • **Energy using products**: packaging biogas, possible flexi bag technology
Services	• **End-user training** • **Training station technicians** • Local entrepreneurs: women groups, coffee station to sell products • **Microfinance** institution: offer linkage to them • **Maintenance** and repair of whole system • As technology improve offer **product upgrade** • **Installation** of biogas plant
Offer	• **Result oriented**: pay per unit of satisfaction: pay to refill of flexibag gas • **KPL**: pay per energy consumed • **Product oriented**: biogas plant for coffee station – provide training to financial institution to facilitate credit to end-users (pay to purchase model)

Customers	• **Create awareness** to build trust with coffee stations, community, government, biogas stove manufacturers • Produce electricity to meet their needs and sell to KPLC • Bio fertilizer for **income generation** • Use registered women investment groups in the distribution of biofertilize and flexibiogas (**gender**). • **Work with end users** to define size of the technology needs. • **Training** in payment methods between women groups and coffee plants • **Ability to pay**: micro borrowing from MPesa method of saving daily payments for a group payment of flexibag • **Provide reassurance of sources**. Offer technology example of sources. • **Customer education** on energy and health benefits.
Payment channels	• **Credit and cash** to biogas system contractors • **Mobile payment** from customers to coffee station for flexigas

Table 2 - Idea generated with the Design Framework & Cards by P2

P3	
Network of providers	CONCEPT 1 • Private enterprise: distributors, installers, maintenance, management and training • Technology manufacturer: PV and pumps provision, training CONCEPT 2 • Private enterprise: in partnership with TEAM • Technology manufacturer: solar company and TEAM • Local entrepreneur: charging station management CONCEPT 3 • Private enterprise • Technology manufacturer: company selling solar panels
Products	CONCEPT 1 • Individual energy systems – solar pumps CONCEPT 2 • Charging station: solar CONCEPT 3 • Solar mini kit • Energy using products: radio, lights

Services	CONCEPT 1 • Installation • Training • Maintenance and repair • End-of-life disposal of batteries and panels CONCEPT 2 • Installation • Training • Maintenance and repair • End-of-life CONCEPT 3 • Training • End-of-life
Offer	CONCEPT 1 • Use-oriented: pay to lease + pay to purchase CONCEPT 2 • Use-oriented: pay to lease CONCEPT 3 • Product-oriented: Pay to purchase with training and advice
Customers	CONCEPT 1 • Mix of customers • Individual farmer • Community farm • Wildlife department • Commercial farm CONCEPT 2 • Mix of customers • Mobile company • Community CONCEPT 3 • Mix of customers • Households • Small businesses • Corporate gifts
Payment channels	CONCEPT 1 • cash payments CONCEPT 2 • cash payments CONCEPT 3

	• cash payments

Table 3 - Ideas generated with the Design Framework & Cards by P3

P4	
Network of providers	• private enterprise EFS: provides fodder and technical know-how • local entrepreneur EFS: for fodder supply for the biogas plant • Bostrich: provide technical know-how, installation, maintenance and training • Technology manufacturers Zorg: provide technology, training and installation • Community: maintenance • Farmers: provide feedstock for biogas plant • Public and government entity: post office for payment collection • Ministry of green technology, energy security for regulations
Products	• Isolated mini grid • Renewable sources: biomass, solar • Energy using products: bulbs and lights, cooling/heating, gas powered Kiln, cooking
Services	• Training: offer training for solar panels • Offer training to local technicians • Maintenance and repair: maintenance of solar panels, repair of gas bottles • Product upgrade: add more PV panels • End-of-life: Zorg will take back the components of the digestor • Installation of solar panels
Offer	• Result-oriented: electricity and gas: pay per energy consumed • Product-oriented: KILN: pay to purchase briquettes
Customers	• Individual households buying gas • Education and warranties • Affordable gas • Local entrepreneur: buying gas and electricity, pay monthly fees • Community: buying electricity, education and warranties • Public entities: school, clinics: buying gas and electricity

Payment channels	• Fee collection: through the post office • scratch cards: to buy electricity • smart meters: to monitor electricity usage • mobile payments: electricity purchased through mobile payments

Table 4 - Idea generated with the Design Framework & Cards by P4

Appendix V – Ethical approvals and participant information sheets to carry out research activities

1. Participant Information Sheet for undertaking research in Botswana (March-May 2015)

Participant Information Sheet

School of Engineering and Design

http://www.brunel.ac.uk/sed

When our undergraduate students/research students conduct their major projects/dissertation project, they often need to carry out some initial research with the target market and later with stakeholder groups to evaluate the proposed design solutions or engineering innovation ideas.

- This is an invitation to you to join the study, and to let you know what this would involve.
- This project is being supervised by the project supervisor (Fabrizio Ceschin).
- When the project is completed, results will be added to appropriate document (Word documents, photos). No personal information will be identified but images of participants may be used within the final presentation if you have explicitly given your permission.
- If you want to find out more about the project, or if you need more information to help you make a decision about joining in, please contact Silvia Emili (silvia.emili@brunel.ac.uk) or Fabrizio Ceschin (fabrizio.ceschin@brunel.ac.uk).

Your Participation in the Research/Project

Why you have been asked?

You have been asked because we think you are a target user or a relevant stakeholder of the proposed project. The targets of the project are design students, practitioners, companies involved in the renewable energy sector. The participation in the study is entirely voluntary; there is absolutely no obligation of any kind to join the study.

What happens if you want to change your mind?

If you decide to join the study you can change your mind and withdraw at any time.

What would happen if you join the study?

If you agree to join the study, then we will ask you to develop a design brief by using the tools we are presenting (innovation map, design framework and guidelines). You will be asked to generate ideas on PSS applied to DRE and develop a concept design.

Are there any risks?

We shall try to minimise any possible risks. If you did feel that there was any stress involved you can stop at any time. Just tell the researcher that you want to stop.

What happens to the research results?

The student conducting the research is responsible for putting all the information from the study (except names and addresses, and personal identification information) into a computer programme such as Excel, Word or PowerPoint. The student then analyses the information via graphs and images presented in a research report (often these reports are not public documents). The objective is to prove and evaluate the design of the tools (innovation map and SDSE4A framework and guidelines). For presentation purposes, digital imagery and video may be used at public presentations. If this is the case then prior permission will be sought from participants.

What will I gain from taking part?

You may find the project interesting and use the tools in your future projects, and you may develop new design skills. Your opinions may inspire the researcher to innovate, but you will not receive any particular direct benefit otherwise.

How we protect your privacy

All information that is collected about you during the course of the research will be kept strictly confidential. Any information recorded about you will have your name and address removed so that you cannot be recognised from it.

If I have more questions, who can I ask?
Please feel free to ask us any question you would like about the study.

Thank you very much for taking the time to read this sheet.

Researcher’s name and contact detail

Silvia Emili - silvia.emili@brunel.ac.uk

Supervisor’s name and contact detail

Fabrizio Ceschin – fabrizio.ceschin@brunel.ac.uk

Title of Project: Product-Service Systems applied to Distributed Renewable Energy: tools to support designers

Name of Researcher: Silvia Emili

This project has been approved by the ethics committee of the School of Engineering and Design, Brunel University, on 25 March 2015.

Consent Form

The participant should complete the whole of this sheet him/herself

Please tick appropriate box

	YES	NO
I have read and understood the Participant Information Sheet	☐	☐
I have had an opportunity to ask questions and discuss this study	☐	☐
I understand that I am free to withdraw from the study:		
- **at any time**	☐	☐
- **without having to give a reason for withdrawing**	☐	☐
I give permission to the researchers for recording the interview	☐	☐
I give permission to the researchers for taking photos and videos during the study	☐	☐
I agree to take part in this study	☐	☐

Signature of Participant…………………………………….. Date……………………...

Name in capitals……………………………………………………………………………..

When completed, 1 copy for participant and 1 copy for researcher site

UNIVERSITY of BOTSWANA

Faculty of Engineering and Technology

Department of Industrial Design & Technology

Corner of Notwane
and Mobuto Road,
Gaborone, Botswana

Pvt Bag 0061
Gaborone

Tel: [267] 355 4223
Fax: [267] 395 2309
moalosi@mopipi.ub.bw

March 27, 2015

Brunel University London
Kingston Lane
Uxbridge
Middlesex UB8 3PH
United Kingdom

Dear Sir/Madam

APPROVAL TO CONDUCT WORKSHOPS AND DESIGN EXCERCISES

With this letter I certify on behalf of the University of Botswana that Silvia Emili who is a PhD student at your University has received the approval to undertake her research activities through conducting workshops and design exercises in Botswana.

She will receive support for the organisation of workshops with students under the University supervision as well as being provided with the appropriate space and materials to run the design activities.

We will support Silvia Emili in getting in touch and recruiting local companies and provide the required assistance to organise meetings and design activities.

If you have any question, please do not hesitate to contact me.

Yours sincerely

Prof Richie Moalosi
Head of Department

www.ub.bw

2. Ethical approval for undertaking research in South Africa (February 2016)

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

1 February 2016

LETTER OF APPROVAL

Applicant: Miss Silvia Emili

Project Title: Testing of design tools in South Africa

Reference: 2107-LR-Feb/2016-1562

Dear Miss Silvia Emili

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment
- The Research Ethics Committee highly recommends that you complete the Ethics Training via Blackboard Learn prior to commencing your research project.
- https://blackboard.brunel.ac.uk/webapps/blackboard/execute/displayLearningUnit?content_id=_480363_1&course_id=_20958_1&mode=view&framesetWrapped=true

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

College of Engineering, Design and Physical Sciences
Department of Design

Participant Information Sheet

RESEARCH AT BRUNEL UNIVERSITY LONDON

When our research students conduct their dissertation project, they often need to carry out some initial research with the target market and later with stakeholder groups to evaluate the proposed design solutions or engineering innovation ideas.

• This is an invitation to you to join the study, and to let you know what this would involve.

• This project is being supervised by the project supervisor (Fabrizio Ceschin).

• When the project is completed, results will be added to appropriate document (Word documents, photos). No personal information will be identified.

• If you want to find out more about the project, or if you need more information to help you make a decision about joining in, please contact Silvia Emili (silvia.emili@brunel.ac.uk) or Fabrizio Ceschin (fabrizio.ceschin@brunel.ac.uk).

This research has been approved by the College of Engineering, Design and Physical Sciences Research Ethics Committee on 1 February 2016.

Your Participation in the Research Project

Why you have been asked?

You have been asked because we think you are a target user or a relevant stakeholder of the proposed project. The targets of the project are practitioners and companies involved in the renewable energy sector, focusing in low-income and developing countries. The participation in the study is entirely voluntary; there is absolutely no obligation of any kind to join the study.

What would happen if you join the study?

If you agree to join the study, then we will ask you to participate in the course, to its design exercises (workshops) and to complete the questionnaires.

What happens to the research results?

The student conducting the research is responsible for putting all the information from the study (except names and addresses, and personal identification information) into a computer programme such as Excel, Word or PowerPoint. The student then analyses the information via graphs and images presented in a research report (often these reports are not public documents). The objective is to gather information to understand companies and practitioners' knowledge on designing sustainable business models for energy access. Photos taken during the course will be used by the student for her research publications, names and companies will not be made public.

What will I gain from taking part?

You may find the project interesting and be willing to participate in further studies or get updates on future research results. Your opinions may inspire the researcher to innovate, but you will not receive any particular direct benefit otherwise.

How do we protect your privacy?

All information that is collected about you during the course of the research will be kept strictly confidential. Any information collected about you will have your name, details and company name removed so that you cannot be recognised from it.

Please feel free to ask us any question you would like about the study.

Thank you very much for taking the time to read this sheet.

Researcher's name and contact detail

Silvia Emili - silvia.emili@brunel.ac.uk

Supervisor's name and contact detail

Fabrizio Ceschin – fabrizio.ceschin@brunel.ac.uk

Title of Project: Product-Service Systems applied to Distributed Renewable Energy: tools to support designers

Name of Researcher: Silvia Emili

This project has been approved by the ethics committee of the School of Engineering and Design, Brunel University, on 1 February 2016.

Consent Form

The participant should complete the whole of this sheet him/herself.

Please tick appropriate box.

	YES	NO
- I have read and understood the Participant Information Sheet	☐	☐
- I have had an opportunity to ask questions and discuss this study	☐	☐
- I understand that I am free to withdraw from the study:	☐	☐
- **at any time**	☐	☐
- **without having to give a reason for withdrawing**	☐	☐
- I give permission to the researchers for taking photos and videos during the study	☐	☐
- I agree to take part in this study	☐	☐

Signature of Participant…………………………………….. Date……………………..

Name in capitals……………………………………………………………………….

When completed, 1 copy for participant and 1 copy for researcher

3. Ethical approval for undertaking research in Kenya (April 2016)

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

21 March 2016

LETTER OF APPROVAL

Applicant: Miss Silvia Emili

Project Title: Testing of design tools in Kenya

Reference: 2801-LR-Mar/2016- 2751-1

Dear Miss Silvia Emili

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.
- We note that approval was granted on 1st February 2016. It was recommended that you did the Ethics Training via Blackboard Learn prior to commencing your research project, which you have kindly completed.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

Page 1 of 1

College of Engineering, Design and Physical Sciences
Department of Design

Participant Information Sheet

RESEARCH AT BRUNEL UNIVERSITY LONDON

When our research students conduct their dissertation project, they often need to carry out some initial research with the target market and later with stakeholder groups to evaluate the proposed design solutions or engineering innovation ideas.

• This is an invitation to you to join the study, and to let you know what this would involve.

• This project is being supervised by the project supervisor (Fabrizio Ceschin).

• When the project is completed, results will be added to appropriate document (Word documents, photos). No personal information will be identified.

• If you want to find out more about the project, or if you need more information to help you make a decision about joining in, please contact Silvia Emili (silvia.emili@brunel.ac.uk) or Fabrizio Ceschin (fabrizio.ceschin@brunel.ac.uk).

This research has been approved by the College of Engineering, Design and Physical Sciences Research Ethics Committee on 21 March 2016.

Your Participation in the Research Project

Why you have been asked?

You have been asked because we think you are a target user or a relevant stakeholder of the proposed project. The targets of the project are practitioners and companies involved in the renewable energy sector, focusing in low-income and developing countries. The participation in the study is entirely voluntary; there is absolutely no obligation of any kind to join the study.

What would happen if you join the study?

If you agree to join the study, then we will ask you to participate in the course, to its design exercises (workshops) and to complete the questionnaires.

What happens to the research results?

The student conducting the research is responsible for putting all the information from the study (except names and addresses, and personal identification information) into a computer programme such as Excel, Word or PowerPoint. The student then analyses the information via graphs and images presented in a research report (often these reports are not public documents). The objective is to gather information to understand companies and practitioners' knowledge on designing sustainable business models for energy access. Photos taken during the course will be used by the student for her research publications, names and companies will not be made public.

What will I gain from taking part?

You may find the project interesting and be willing to participate in further studies or get updates on future research results. Your opinions may inspire the researcher to innovate, but you will not receive any particular direct benefit otherwise.

How do we protect your privacy?

All information that is collected about you during the course of the research will be kept strictly confidential. Any information collected about you will have your name, details and company name removed so that you cannot be recognised from it.

Please feel free to ask us any question you would like about the study.

Thank you very much for taking the time to read this sheet.

Researcher's name and contact detail

Silvia Emili - silvia.emili@brunel.ac.uk

Supervisor's name and contact detail

Fabrizio Ceschin – fabrizio.ceschin@brunel.ac.uk

Title of Project: Product-Service Systems applied to Distributed Renewable Energy: tools to support designers

Name of Researcher: Silvia Emili

This project has been approved by the ethics committee of the School of Engineering and Design, Brunel University, on 21 March 2016.

Consent Form

The participant should complete the whole of this sheet him/herself.

Please tick appropriate box.

	YES	NO
- I have read and understood the Participant Information Sheet	☐	☐
- I have had an opportunity to ask questions and discuss this study	☐	☐
- I understand that I am free to withdraw from the study:	☐	☐
- **at any time**	☐	☐
- **without having to give a reason for withdrawing**	☐	☐
- I give permission to the researchers for taking photos and videos during the study	☐	☐
- I agree to take part in this study	☐	☐

Signature of Participant…………………………………….. Date……………………..

Name in capitals…………………………………………………………………………….

When completed, 1 copy for participant and 1 copy for researcher

4. Ethical approval for undertaking research at Brunel University London (May 2016)

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

9 May 2016

LETTER OF APPROVAL

Applicant: Miss Silvia Emili

Project Title: Testing at Brunel

Reference: 3028-LR-May/2016- 2984-3

Dear Miss Silvia Emili

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

College of Engineering, Design and Physical Sciences
Department of Design

Participant Information Sheet

RESEARCH AT BRUNEL UNIVERSITY LONDON

When our research students conduct their dissertation project, they often need to carry out some initial research with the target market and later with stakeholder groups to evaluate the proposed design solutions or engineering innovation ideas.

- This is an invitation to you to join the study, and to let you know what this would involve.
- This project is being supervised by the project supervisor (Fabrizio Ceschin).
- When the project is completed, results will be added to appropriate document (Word documents, photos). No personal information will be identified.
- If you want to find out more about the project, or if you need more information to help you make a decision about joining in, please contact Silvia Emili (silvia.emili@brunel.ac.uk) or Fabrizio Ceschin (fabrizio.ceschin@brunel.ac.uk).

Your Participation in the Research Project

Why you have been asked?

You have been asked because we think you can provide important insights for the development of this project. With this study we intend to test and refine some aspects of the design tools (usability, clearness, layout). The participation in the study is entirely voluntary; there is absolutely no obligation of any kind to join the study.

What would happen if you join the study?

If you agree to join the study, then we will ask you to participate to the session (2h), to complete the design exercises and to provide feedbacks through questionnaires.

You will be asked to evaluate the clearness and usability of strategic design tools that aim at designing sustainable business models for energy access in low-income contexts.

You don't need to have experience or knowledge about energy access, business models or sustainability, but you will be asked to provide suggestions on the clearness and efficacy of the information presented in the design tool.

What happens to the research results?

The student conducting the research is responsible for putting all the information from the study (except names and addresses, and personal identification information) into a computer programme such as Excel, Word or PowerPoint. The student then analyses the information via graphs and images presented in a research report (often these reports are not public documents). Photos taken during the course will be used by the student for her research publications, names will not be made public.

What will I gain from taking part?

You may find the project interesting and be willing to participate in further studies or get updates on future research results. Your opinions may inspire the researcher to innovate, but you will not receive any particular direct benefit otherwise.

How do we protect your privacy?

All information that is collected about you during the course of the research will be kept strictly confidential. Any information collected about you will have your name and details removed so that you cannot be recognised from it.

Please feel free to ask us any question you would like about the study.

Thank you very much for taking the time to read this sheet.

Researcher's name and contact detail

Silvia Emili - silvia.emili@brunel.ac.uk

Supervisor's name and contact detail

Fabrizio Ceschin – fabrizio.ceschin@brunel.ac.uk

Title of Project: Product-Service Systems applied to Distributed Renewable Energy: tools to support designers (Researcher: Silvia Emili)

This project has been approved by the ethics committee of the School of Engineering and Design, Brunel University, on 9 May 2016.

Consent Form

The participant should complete the whole of this sheet him/herself.

Please tick appropriate box.

	YES	NO
- I have read and understood the Participant Information Sheet	☐	☐
- I have had an opportunity to ask questions and discuss this study	☐	☐
- I understand that I am free to withdraw from the study:	☐	☐
- **at any time**	☐	☐
- **without having to give a reason for withdrawing**	☐	☐
- I give permission to the researchers for taking photos and videos during the study	☐	☐
- I agree to take part in this study	☐	☐

Signature of Participant……………………………………. Date……………………..

Name in capitals………………………………………………………………….

When completed, 1 copy for participant and 1 copy for researcher

5. Ethical approval for undertaking research at in Kenya and Botswana (Nov-Dec 2016)

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

18 October 2016

LETTER OF APPROVAL

Applicant: Miss Silvia Emili

Project Title: Testing design tools in Kenya and Botswana

Reference: 3914-LR-Oct/2016- 4176-2

Dear Miss Silvia Emili

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

Page 1 of 1

College of Engineering, Design and Physical Sciences

Department of Design

Participant Information Sheet

RESEARCH AT BRUNEL UNIVERSITY LONDON

When our research students conduct their dissertation project, they often need to carry out some initial research with the target market and later with stakeholder groups to evaluate the proposed design solutions or engineering innovation ideas.

• This is an invitation to you to join the study, and to let you know what this would involve.

• This project is being supervised by the project supervisor (Fabrizio Ceschin).

• When the project is completed, results will be added to appropriate document (Word documents, photos). No personal information will be identified.

• If you want to find out more about the project, or if you need more information to help you make a decision about joining in, please contact Silvia Emili (silvia.emili@brunel.ac.uk) or Fabrizio Ceschin (fabrizio.ceschin@brunel.ac.uk).

Your Participation in the Research Project

Why you have been asked?

You have been asked because we think you are a target user or a relevant stakeholder of the proposed project. The targets of the project are practitioners and companies involved in the renewable energy sector, focusing in low-income and developing countries. The participation in the study is entirely voluntary; there is absolutely no obligation of any kind to join the study.

What would happen if you join the study?

If you agree to join the study, then we will ask you to participate in the course, to its design exercises (workshops) and to complete the questionnaires.

What happens to the research results?

The student conducting the research is responsible for putting all the information from the study (except names and addresses, and personal identification information) into a computer programme such as Excel, Word or PowerPoint. The student then analyses the information via graphs and images presented in a research report (often these reports are not public documents). The objective is to gather information to understand companies and practitioners' knowledge on designing sustainable business models for energy access. Photos taken during the course will be used by the student for her research publications, names and companies will not be made public.

What will I gain from taking part?

You may find the project interesting and be willing to participate in further studies or get updates on future research results. Your opinions may inspire the researcher to innovate, but you will not receive any particular direct benefit otherwise.

How do we protect your privacy?

All information that is collected about you during the course of the research will be kept strictly confidential. Any information collected about you will have your name, details and company name removed so that you cannot be recognised from it.

Please feel free to ask us any question you would like about the study.
Thank you very much for taking the time to read this sheet.

Researcher's name and contact detail
Silvia Emili - silvia.emili@brunel.ac.uk
Supervisor's name and contact detail
Fabrizio Ceschin – fabrizio.ceschin@brunel.ac.uk

Title of Project: Product-Service Systems applied to Distributed Renewable Energy: tools to support designers
Name of Researcher: Silvia Emili
This project has been approved by the ethics committee of the School of Engineering and Design, Brunel University, on 18 October 2016.

Consent Form

The participant should complete the whole of this sheet him/herself.
Please tick appropriate box.

	YES	NO
- I have read and understood the Participant Information Sheet	☐	☐
- I have had an opportunity to ask questions and discuss this study	☐	☐
- I understand that I am free to withdraw from the study:	☐	☐
- **at any time**	☐	☐
- **without having to give a reason for withdrawing**	☐	☐
- I give permission to the researchers for recording the session	☐	☐
	☐	☐

- I agree to take part in this study

Signature of Participant…………………………………….. Date……………………...

Name in capitals………………………………………………………………………..

When completed, 1 copy for participant and 1 copy for researcher