DRS2016
Design + Research + Society
Future-Focused Thinking

2016 Design Research Society
50th Anniversary Conference
27-30 June 2016, Brighton, UK

Supporting SMEs in designing sustainable business models for energy access for the BoP: a strategic design tool

Silvia Emili*, Fabrizio Ceschin and David Harrison

Brunel University London
*silvia.emili@brunel.ac.uk
DOI: 10.21606/drs.2016.349

Abstract: About 1.4 billion people from the Bottom of the Pyramid (BoP) currently lack sustainable energy services. In these contexts, SMEs and practitioners need to combine feasible technical solutions and appropriate business models. Distributed Renewable Energy (DRE) systems emerge as possible solution to provide small-scale and locally based electricity. DRE can be implemented with sustainable business models (Product-Service Systems – PSS) that shift the business focus from selling products to providing a combination of products and services that are able to fulfil customers' satisfaction. In this paper we explore the combination of DRE and PSS by presenting a strategic design tool that aims at supporting SMEs and practitioners in designing sustainable business models for energy in the BoP. The tool finds several applications which have been tested with companies and practitioners in South Africa and Botswana. The new version of the tool is then presented to support idea-generation for designing business models for energy access for the BoP.
Keywords: Product-Service Systems (PSS), Distributed Renewable Energy (DRE), Bottom of the Pyramid (BoP), strategic design tool

1. Introduction

One of the greatest challenges nowadays is to provide clean energy services to the so-called Bottom of the Pyramid (BoP), the around 4 billion people living with less than $1500 per year (Prahalad & Hart 2002). Among them, 1.4 billion people lack access to modern electricity (OECD-IEA 2010) and they live mostly in urban slums or rural areas in low-income and developing contexts. The lack of energy access represents a fundamental barrier to development and it is in fact addresses in the 2030 Sustainable Development Goals (Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all) (UN 2014). In low-income and developing contexts the grid connection is not suitable to satisfy energy needs in the short term due to infrastructure constraints, financial barriers and required policy measures (Zerriffi 2011; Myers 2013). Furthermore BoP customers usually have low energy demand and a large part of their income, about 30%, is spent usually to buy small expensive units from a diverse range of dangerous and polluting sources (e.g. kerosene, LPG, dry-cell and car batteries) for cooking, heating and lightning (IFC & WRI 2007). Hence the little financial availability of BoP customers is not adequate to ensure economic sustainability of grid extension. For these reasons **Distributed Generation (DG)** appears as a viable option to provide energy services (Zeriffi 2011).

Distributed Generation is defined as *"electric power generation within distribution network or on the customer's side of the network"* (Ackerman et al. 2001). When Distributed Generation uses renewable energy sources, such as hydropower, sun, biomass, wind or geothermal power, we refer to **Distributed Renewable Energy (DRE)**. Many authors agree on the benefits of DG in providing energy access to off-grid customers, such as lower transmission costs for remote regions; greater flexibility and economic resilience; reduced environmental impact, democratisation of energy access and communities self-sufficiency (Friebe et al. 2013; Terrado et al. 2008; Zerriffi 2011).

However, even if promising, the implementation of DRE models is not always straightforward. There are in fact some technological barriers (e.g. limited capacity, low voltage and transmission). However, in most cases the issue is not of a technical matter. DRE systems require adequate policies (Beck & Martinot 2004; Terrado et al. 2008) but the biggest barrier is an economic one: companies venturing in these contexts need access to capital. Most importantly, solutions must be affordable for low-income customers, who have a very limited purchasing power and cannot pay a high initial investment. Enabling local maintenance is another key issue (Schäfer et al. 2011; Terrado et al. 2008). There are several examples of DRE systems that stopped working short time after installation because of the lack of a planned maintenance and repair service. Thus, it is a matter of designing appropriate business models (Jun et al. 2013).

In this context the model of **Product-Service System (PSS)** emerge to be relevant. 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). In terms of environmental sustainability, PSSs presents several advantages: when properly designed, PSSs can decouple economic value from consumption of materials and energy (White et al., 1999; Stahel 2000; Heiskanen & Jalas 2000; Wong, 2001; Zaring et al. 2001; UNEP 2002).This means that providers are economically motivated to reduce energy and material resources to provide the agreed satisfaction to customers because they are paid per unit of performance and not per unit of product sold. In this way the stakeholders providing the PSS are interested in improving productivity, for example by producing long lasting products and avoiding disposal and manufacturing of new products (Halme et al. 2004).

In BoP markets PSSs can tackle challenges where traditional business models fail in reaching customers (Shäfer et al. 2011) by offering integrated solutions instead of traditional product-focused approaches (Jagtap & Larsson 2013).

PSSs have been studied as promising models for reaching BoP customers by several authors (Castillo et al. 2012; Jagtap & Larsson 2013; Shafer et al. 2011; Moe & Boks 2010). The reasons why this type of value proposition is suitable for BoP markets are several: PSSs favour a low-resource intensive economy that can facilitate socio and economic development by jumping the stages of individual consumption/ownership (Tukker & Tischner 2004); these value propositions can address some critical BoP issue such as resource use and waste due to their sustainability potential (Schafer & Parks 2011); they enable communities to access services and products through new business models that favour locally-based solutions (Castillo et al. 2012); PSSs represents a more accessible alternative for lower-income customers who cannot afford to pay for the whole value of products (Tukker et al. 2006).

Within the applications of Product-Service Systems in BoP markets, energy access appears as a sector where PSSs and DRE models can be successfully combined. In fact, the combination of these models present several benefits: environmental ones (reduced environmental impact, increased reliability and efficiency); economic advantages (lower costs of transmission, reduced investment costs, flexibility) and socio-ethical benefits (increased energy independence, strengthening of local economies and increase of employment, customisation to users' needs) (Vezzoli et al. 2015).

An example of PSS applied to DRE: Gram Power, India

Gram Power connects households and small businesses in off-grid villages through mini grid running on solar, wind or biomass power. Customers get connected and receive a 240 VAC connection to plug the appliances they need. Once the micro grid is installed, Gram Power recruits a local entrepreneur and trains him/her for operation, management and fee collection. Customers have smart meters installed and pre-pay for the energy they consume while the entrepreneur earns a commission fee on the energy credits. Gram Power keeps ownership of the energy systems and distribution systems and remains responsible for maintenance and repairs.

Although PSS, DRE and BoP concepts have been widely explored by scholars, there is a lack of studies that look at these models combined and that provide design-supporting methods and tools for practitioners and companies operating in these contexts.

A variety of methodologies and tools exist for PSS design (Beuren et al. 2013) but none of them has a specific focus on energy. Morelli (2006) in fact states that the PSS discipline has not yet defined a standard set of tools that support the design process but that these apply differently according to the context of use.

On the other side, DRE tools and methodologies provide guidelines, successful examples and best practices by focusing solely on one or few aspects at time. Schillebeeckx et al. (2012) affirm that DRE literature focuses either 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

The literature on design for the BoP and design of PSS in BoP contexts focuses mainly on design approaches and strategies without providing specific tools for specific issues. Some authors consider the application of PSS tools (Moe & Boks 2010; Jagtap & Kandachar 2011; Jagtap & Larsson 2013) and in particular Moe & Boks (2011) combine some of the PSS tools (stakeholder mapping or network analysis, value creation and focus on customers) with BoP strategies (stakeholders involvement and co-design, avoiding business as usual). In terms of energy access, specific tools that link PSS design applied to BoP contexts are missing.

The aim of this investigation is to look into the applications of PSS to DRE for the Bottom of the Pyramid customers and to provide supporting tools for SMEs (Small Medium Enterprises) and practitioners for designing energy services for the BoP.

The first part of this research aimed at exploring PSS and DRE models and classifying them (Emili et al. 2015; Emili et al. 2016) and in this paper we summarise its findings and conclusions. In this paper we present the latest outcome: the PSS+DRE Innovation Map, a tool to classify PSSs applied to DRE models and to support SMEs and practitioners in designing sustainable energy systems for BoP contexts.

The paper is structured as follows. First we illustrate the methodology adopted in this research. Then we describe the first version of the PSS+DRE innovation map and how it has been tested and evaluated. In the last section we present the improved version and its applications as strategic design tool for SMEs for generating sustainable PSS ideas for energy access in BoP contexts. We conclude discussing future research activities.

2. Methodology

The methodological approach adopted in this research has been structured in three stages: a theory building approach[1] and case studies analysis has been applied to develop the first version of the Innovation Map. The tool has then been tested in Botswana and South Africa with local companies, energy experts and practitioners. The feedback collected has been used to refine the Innovation Map and develop new features and applications.

The three steps, illustrated in Figure 1, are detailed as following:

1. Development of the 1st version of the PSS+DRE Innovation Map. Drawing conclusions from the literature review and having identified the main characterising dimensions of PSS and DRE, the Innovation Map is built with a polarity diagram (Section 3.1). The map has been then empirically populated with 56 case studies, bundled in groups of similar cases. This process has led to the identification of 15 archetypal models of PSS applied to DRE that present key similar characteristics (Figure 4).

[1] This refers to the *"analytical conceptual research"* approach (Meredith 1998; Wacker 1998) and involves the integration of literatures from different backgrounds, in this case PSS and DRE, and proposing relationships between their variables. The aim is to build new insights starting from the defined concepts of PSS and DRE and logically develop the relationships between them.

2. Testing activities. The first version of the Innovation Map and its archetypal models has been used as strategic design tool by companies and practitioners operating in Botswana and South Africa. The aim was to test its completeness, its ease of use and its usefulness. In total 21 participants (from eight companies, one research centre on innovation and technology, one design consultancy and five DRE experts) have been engaged in the activities. Testing activities were structured as follows:

- <u>Introduction</u>: participants were introduced to the concept of PSS applied to DRE.
- <u>Testing the completeness</u>: in order to validate the completeness of the tool, we asked companies and experts to verify that the tool can include all possible models of PSS applied to DRE and that archetypal models comprehend all existing cases of PSS+DRE.
- <u>Testing the ease of use</u>: with the purpose of verifying the ease of use and clarity of the tool, we asked participants to position a set of five case studies on the PSS+DRE Innovation Map.
- <u>Testing the usefulness</u>: in a third phase, participants were asked to use the tool for mapping their offers, analyse the energy context, explore new business opportunities and to rate the applications of the PSS+DRE Innovation Map.

Feedback and suggestions have been collected through questionnaires and the results are presented in Section 3.2.

3. Refinement and new features. The testing activities led to draw some considerations for improving the tool. In Section 4 the new PSS+DRE Innovation Map is presented as a strategic design tool that supports the idea generation process of PSS applied to DRE.

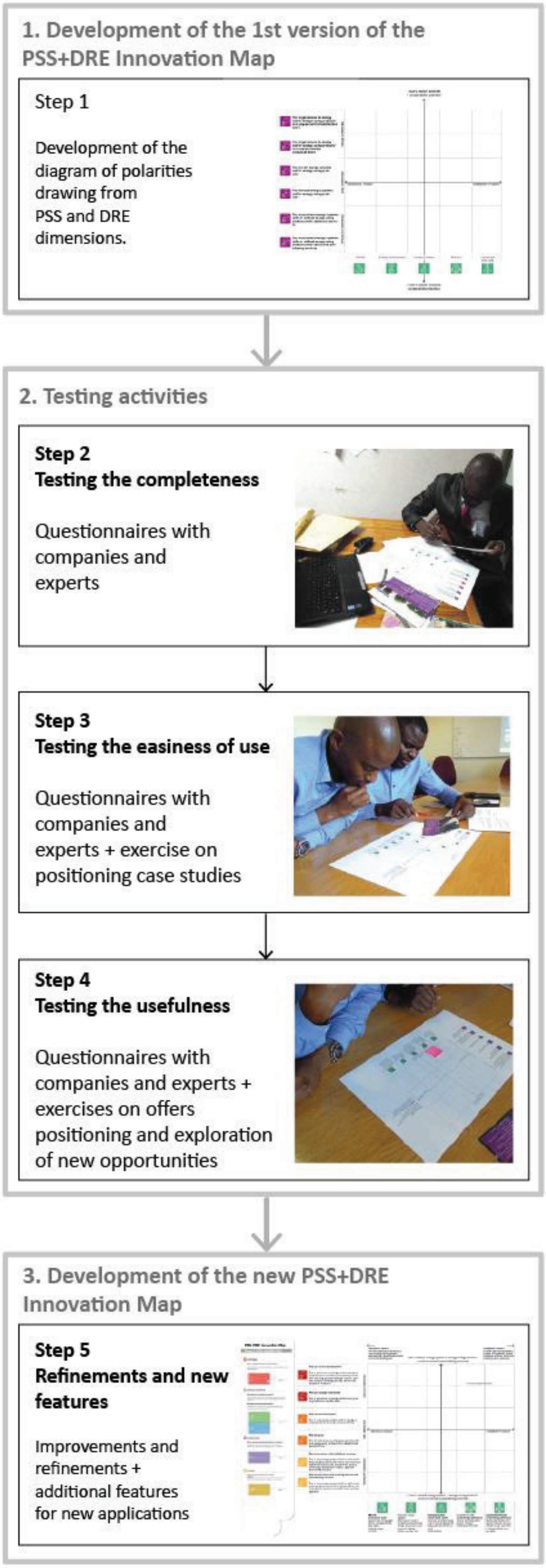


Figure 1 - Methodology adopted in this research

3. The PSS+DRE Innovation Map: first version

3.1 PSS and DRE: characterising dimensions and classifications

Both PSS and DRE models have been extensively explored by scholars, but there is a lack of research that studies the combination of these models and a classification that encompasses both. In PSSs literature, most authors use the classification proposed by Tukker (2004) which distinguishes three categories of Product-Service Systems and their eight archetypal models (Table 1):

- **Product-oriented PSS:** a value proposition where the provider(s) sells products with additional services concerning the life-cycle of the products involved (e.g. maintenance, repair, recycling)
- **Use-oriented PSS**: a value offer where the provider(s) offers the access to a product or tool or capability that enables him to get the desired satisfaction. The customer pays for the time the product is used without a shift in ownership.
- **Result-oriented PSS:** a value proposition where the provider(s) offers a "final result" as combination of products and services that fulfil customer's satisfaction. In this case users do not own and operate on the products, but they pay to receive the integrated solution.

Table 1 - PSS archetypal models considered by Tukker (2004)

PSS archetypal models	
Product-oriented	1- Advice and consultancy 2- Product-related services
Use-oriented	3- Leasing model 4- Renting/sharing model 5- Pooling model
Result-oriented	6- Activity management 7- Pay per service unit 8- Functional result

While the PSS classification is largely accepted by scholars, on the other hand DRE literature presents different approaches in classifying these models and a unified classification that considers all dimensions is still missing. A broad differentiation classifies DRE systems in:

- **Stand-alone energy systems**: off-grid generation serving a single user (Rolland 2011). They can be differentiated in:

  - *Mini kits:* composed by a small generator (1-25W) and appliances (e.g. lights, phone chargers).

  - *Individual energy systems:* fixed system installed at a household, business activity or at a larger community building (e.g. hospital).

- *Charging stations:* individual system composed of generator and storage system for the provision of charging services or other energy-related services (e.g. internet connection) (Rolland 2011).

- **Grid-based systems**: it is composed by a large generation system with a local distribution network and it can be connected or not to the main electricity grid.

- *Isolated mini grids*: independent grids that supply power locally.

- *Connected mini grids:* grids that supply electricity through the local distribution and are able to exchange power with the main electricity grid.

In order to fill the lack of a shared classification, the first part of this research aimed at identifying the major characterising dimensions used in literature to classify PSS and DRE models, i.e. the elements used to describe these models and their relative classifications (Emili et al. 2015; Emili et al. 2016). In particular, a detailed analysis of literature of PSS and DRE models has been carried out with the purpose of identifying the dimensions used to classify PSS and DRE models. Once these have been determined, we have established PSS+DRE characterising dimensions (Emili et al., 2016). These are summarised in Table 2.

Table 2 - Dimensions describe PSS applied to DRE

PSS Dimensions	DRE dimension	PSS+DRE dimensions and description
-	Energy system	Energy system: Defines the connection type (stand-alone, grid-based systems) and renewable source involved (solar, wind, biomass etc.)
Value proposition / payment structure	Value proposition / payment structure	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.
-	Capital financing	Capital financing: Describes how the capital costs are covered (e.g. loans, grants, subsidies etc.)
Products ownership[1]	Energy system ownership	Ownership (of energy system & 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.
-	Organisational form	Organisational form: Defines the type of organisation providing the energy solution (private company, NGO, cooperative, community etc.)
Product operation	Energy system operation	Energy system operation[1]: Defines who operates the energy system.

[1] In PSS classification the ownership refers to all products involved in the PSS solution, while DRE ownership refers only to the energy system.

-	Target customer	Target customer: Indicates the type of end-user (e.g. household, community, public building etc.)
Provider/customer relationship	-	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.
Environmental sustainability potential	-	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.

3.1 PSS+DRE Innovation Map

Having defined the dimensions characterising PSS and DRE models, the first version of the PSS+DRE innovation map has been built by clustering the majority of them (eight out of ten) in two groups. The innovation map is essentially a polarity diagram that aligns these dimensions (Figure 2):

- **'x' axis**: on the horizontal axis we combined the *energy system* and the *target customer* dimensions. These are in fact strictly related: stand-alone systems satisfy individual use of energy, from smaller (mini kits) to larger generation (individual energy systems). Charging stations target groups of users but they still allow the individual use of products (e.g. lanterns sharing systems). Lastly, PSSs using mini grids target communities of a variety of users.

***'y' axis**: on the vertical axis we combined several dimensions together. The value proposition/payment structure can be aligned with the ownership (of energy system and energy-using products) as they range from user-owned products (in Product-oriented PSSs) to provider-owned products (in Use and Result-oriented PSSs). Energy system operation can also be aligned with the value proposition because it refers to who operates on the energy system. In Product-oriented PSS the user operates on the energy system while moving towards Result-oriented this becomes responsibility of the PSS provider. The provider/customer relationship ranges from being transaction-based (selling products) in Product-oriented PSSs, to relationship-based in Result-oriented PSSs where a more intense relationship between provider and customer is established. For these reasons it is aligned with the value proposition. Lastly, the environmental sustainability potential is higher in*

[1] The PSS+DRE dimension, energy system operation, refers only to the operation of the energy system. Energy-using products in fact are always operated by the user, thus it is not considered as a PSS+DRE dimension.

result-based solutions[1] and it can also be aligned in this axis.

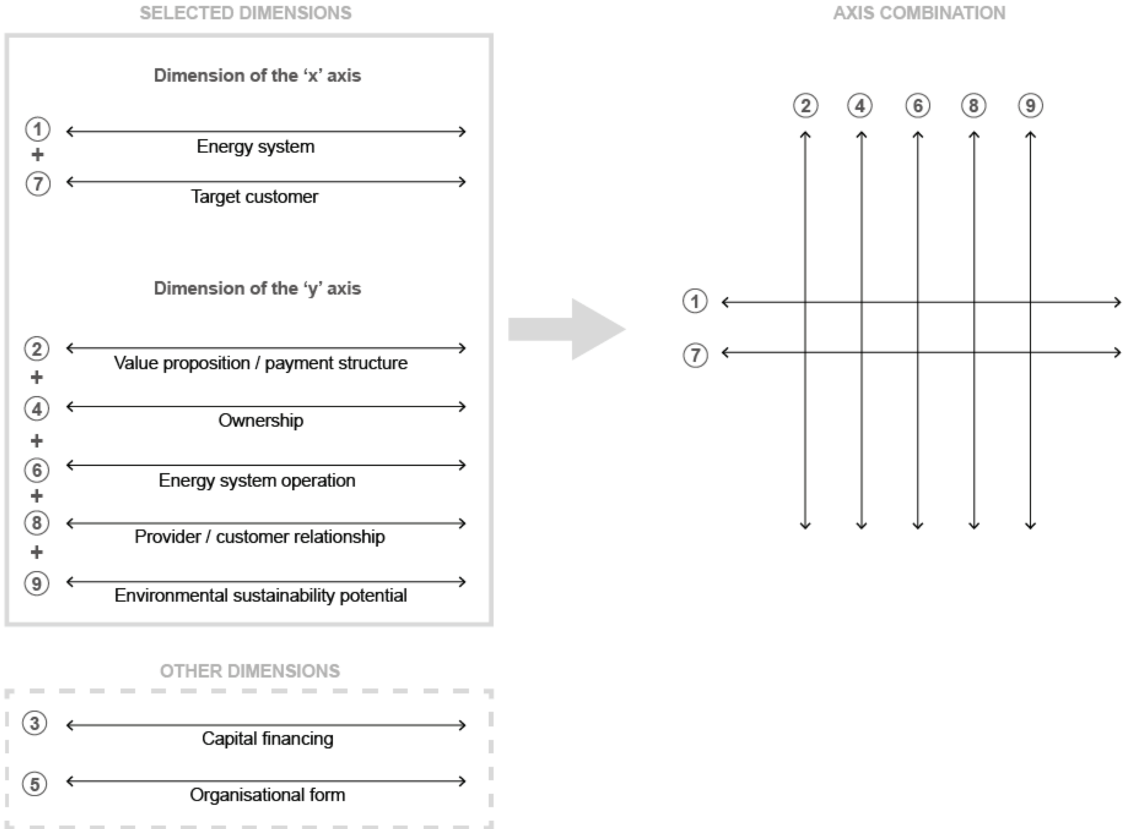


Figure 2 - Dimensions selection and combination to form the polarity diagram

Figure 3 represents the PSS+DRE Innovation Map as polarity diagram while the Innovation Map populated with case studies and clustered in 15 archetypal models is showed in Figure 4 (Emili et al. 2016). The archetypes represent different types of existing PSS models applied to DRE, meaning that each archetype encompasses similar cases in terms of offering type, target customer and energy system involved but that other elements, such as financing models or organisational form, can differ from case to case. The Innovation Map finds several applications not only as a classification system for PSS applied to DRE, but also a strategic design tool for SMEs and practitioners. In fact, it can be applied to explore all possible models of PSS+DRE, to position companies' offers and map competitors in a selected geographic area, to explore new business opportunities by repositioning and combining offers. More in details, the applications of the PSS+DRE Innovation Map are discussed in the following section.

[1] Environmental sustainability potential:

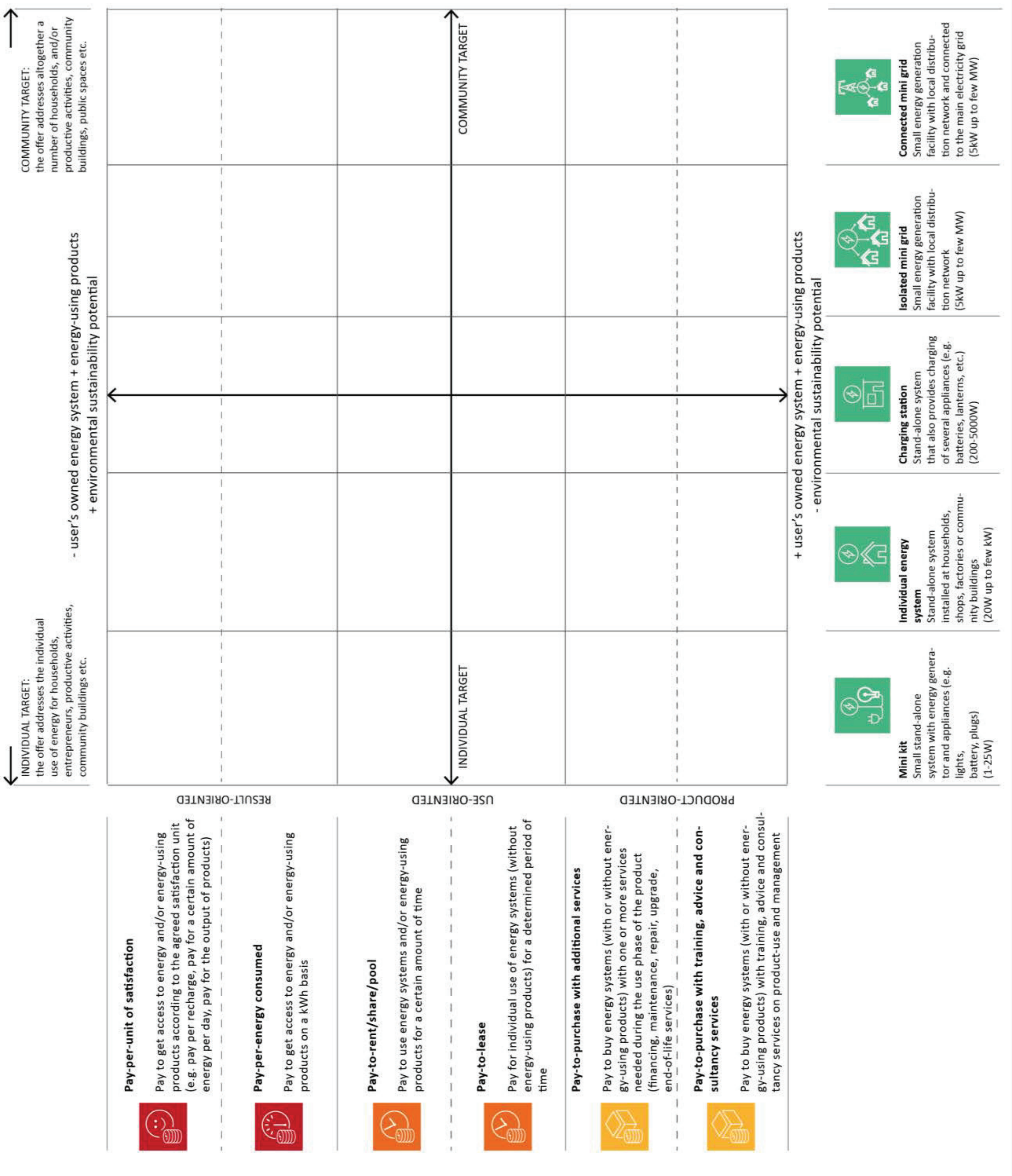


Figure 3 - The PSS+DRE Innovation Map

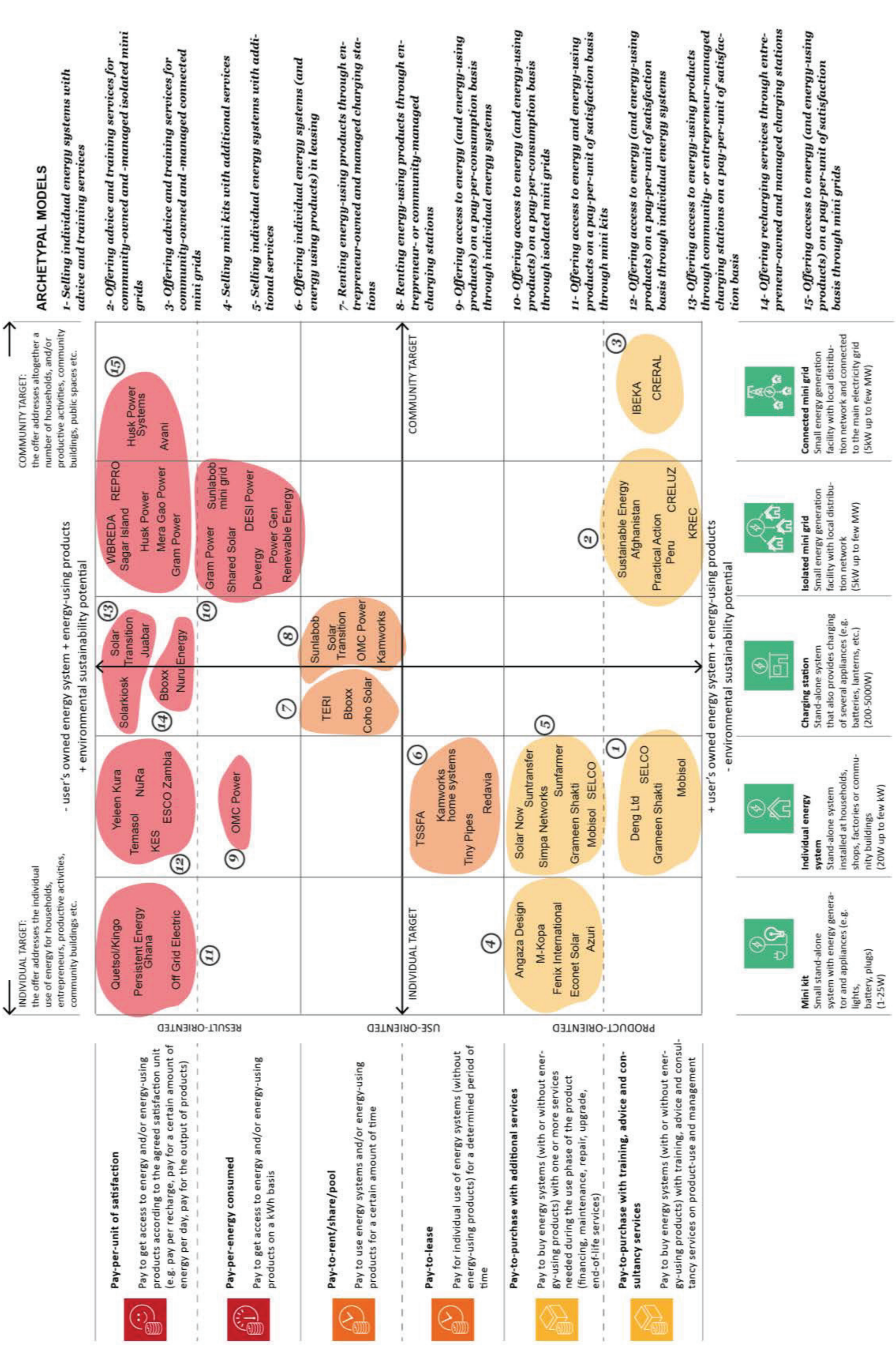


Figure 4 - The PSS+DRE Innovation Map populated with case studies which have been grouped in 15 archetypal models

3.2 Empirical applications and testing

The first version of the PSS+DRE Innovation Map and its archetypal models has been empirically tested in order to verify its completeness, ease to use and its usefulness as strategic design tool. In the following paragraphs we summarise the main outcomes of the testing activities with companies, experts and practitioners.

3.2.1 Tool's completeness

This step aimed at demonstrating that the PSS+DRE innovation map can encompass all possible models of PSS+DRE and that archetypal models cover all existing models of PSS+DRE. We asked participants to indicate whether they know other cases that could be included in the archetypal models and all of them (21 out of 21 responses) were not able to identify cases that fall out of 15 archetypes (Table 3). This means that the Innovation Map represents a complete picture of PSS applied to DRE models.

3.2.2 Tool's ease of use

A second step aimed at validating the ease of use, i.e. we intended to demonstrate that the meaning of the axis could be easily understood by users and that the classification system is clear. In order to prove that, we asked participants to position case studies on the Innovation Map and to rate the tool's usability through the questionnaire. Most interviewees mapped the cases correctly (87% has been placed properly). Participants commend the clarity of the tool (“ *the visual nature of the mapping tool makes it extremely user-friendly*”; *“[the map] clearly separates cases [offers] making it easy to use”*) and considered the positioning of cases simple to perform, however some suggested few improvements to help distinguishing PSS types with short text descriptions and colour-coding (see Section 3.3).

3.2.3 Tool's usefulness

Application 1: analysis of energy solutions provided in a specific context. The first application of the PSS+DRE Innovation Map lies in mapping energy solutions in a selected geographical area. For example companies can map their competitors by exploring the most diffuse type of energy system in a specific market and the type of offering provided (Figure 5). Another opportunity lies in mapping offerings for a selected technology (e.g. solar home systems) and in visualising which empty areas on the map can be potentially explored (Figure 6). Interviewees support this application of the PSS+DRE Innovation Map and expressed appreciation in using the tool for picturing *“gaps in the market”* and get a *”better understanding of competition”.*

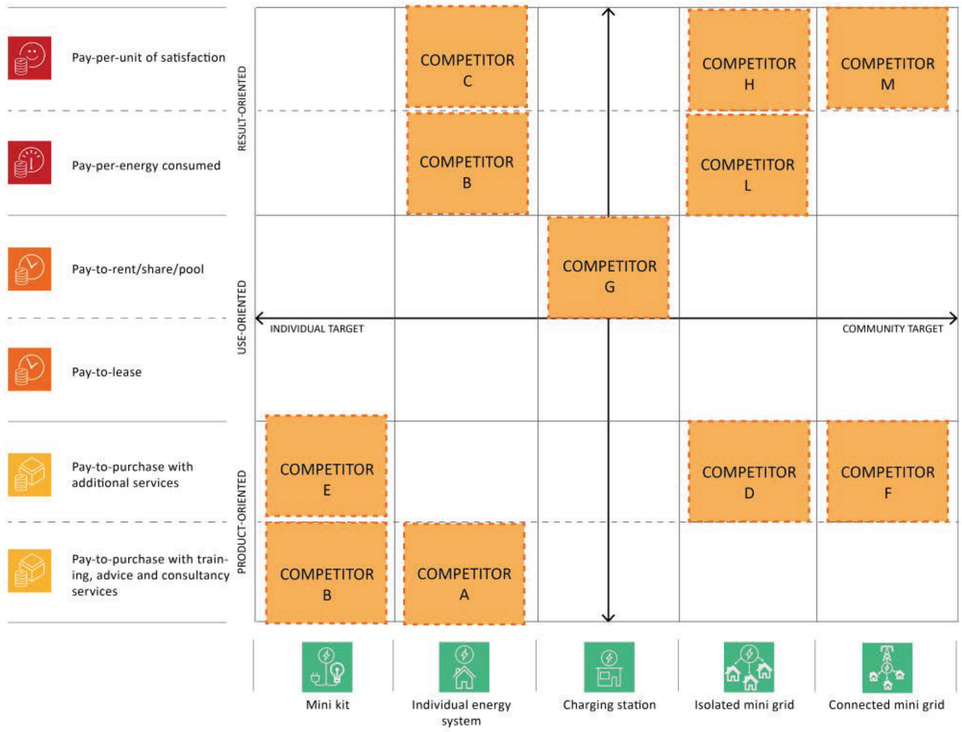


Figure 5 - The Innovation Maps used for mapping existing energy offers in a determined context (adapted for optimised view)

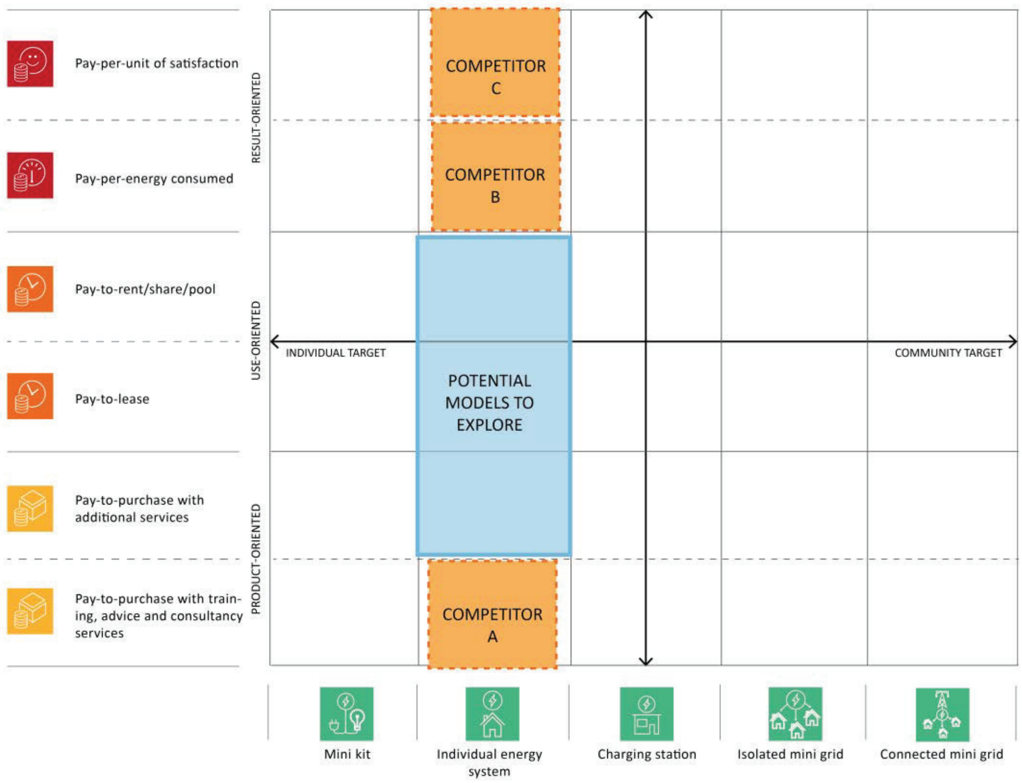


Figure 6 - The Innovation Map used for mapping offerings relative to a selected technology (individual energy systems)

Application 2: mapping of companies' offer(s). Companies can use the PSS+DRE Innovation Map to position their offerings on the map. A company can simultaneously position more than one offering, for instance selling individual energy systems with additional services - offer a- and renting energy-using products through charging stations –offer b- (Figure 7). Similarly to the exercise of positioning case studies, participants have been asked to position their offerings. Most of them found this application of the tool very useful: they appreciated the fact they could understand better the existing offerings in relation to potential alternatives and that they stated they would use the tool for this purpose in the future ("*A company can easily locate where it fits in*"; "*companies can see where they are and plan where they want to be*").

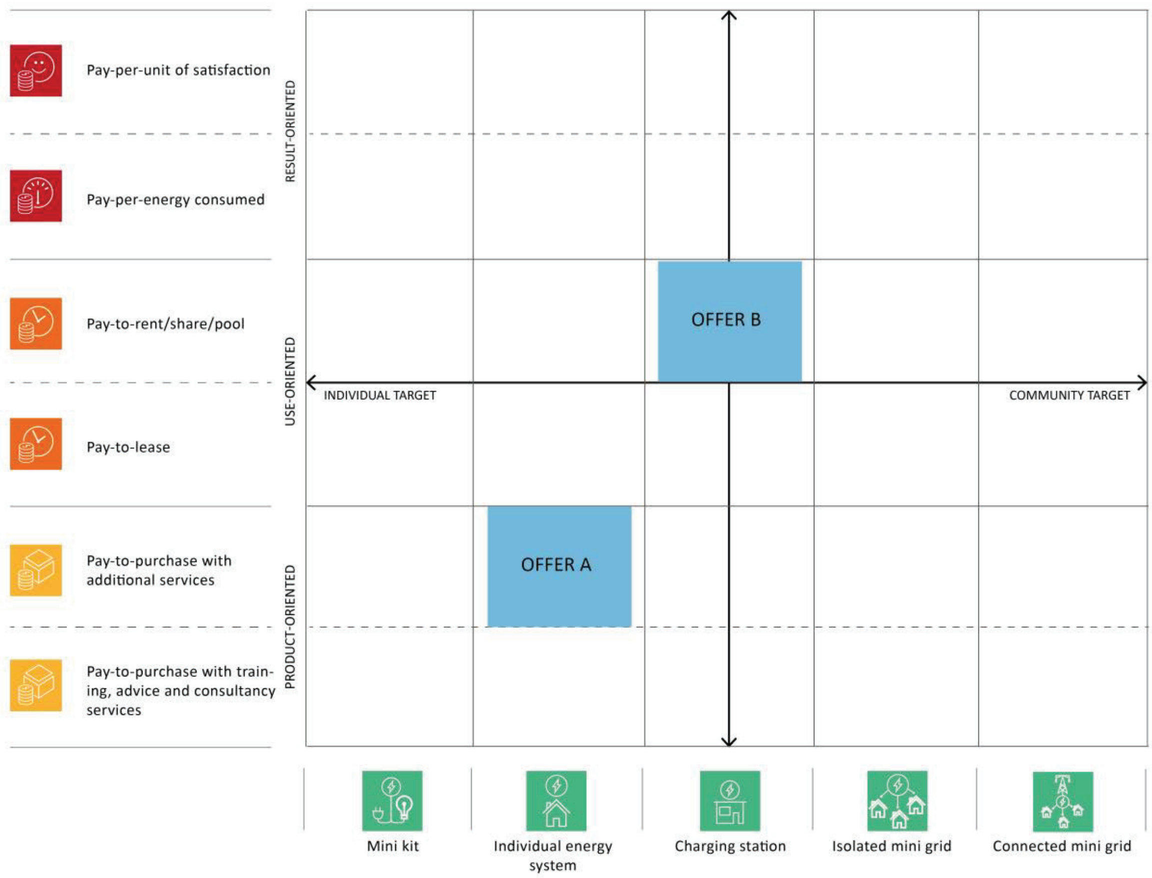


Figure 7 - The Innovation Map used for mapping a company's offers

Application 3: exploration of new business opportunities. Companies can use the PSS+DRE Innovation Map to explore new scenarios by repositioning their offers or by combining different offers together. For instance a company selling individual energy systems with additional services -offer a- can shift towards a leasing model –offer A1- (Figure 8). Another application is for companies that can combine more offers together, for example by offering energy services through individual systems on a pay-per-consumption basis and, at the same time, providing renting of energy-using products charged through the same energy system –offers B+B1 - . Interviewees appreciated the possibility of picturing new business opportunities and exploring innovative models of providing energy solutions (*"it paints a picture of opportunities that lie outside of what [the company] does"* and *"[explore] other ways by providing solutions instead of the traditional way of selling products"*).

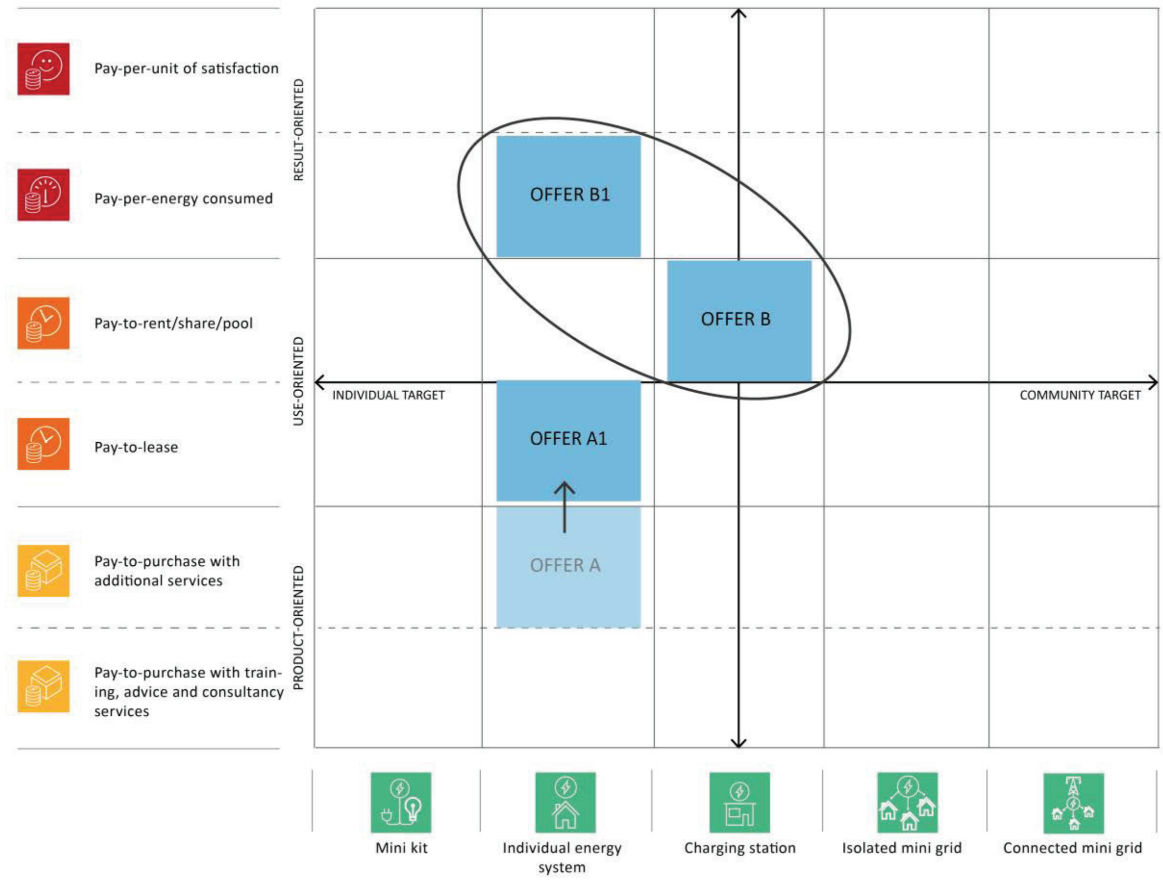


Figure 8 - The Innovation Map is used to explore new opportunities: offering repositioning and combination of two offers.

Table 3 - Feedback collected from the questionnaires with companies, practitioners and experts

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: very poor	2: poor	3: sufficient	4: good	5: very good	Average
2. To what extent is the classification system easy to understand (i.e. the meaning of each axis is clear)	0 (0%)	0 (0%)	2 (10%)	7 (33%)	12(57%)	4.5
3. To what extent is the positioning of case studies in the classification system easy for you?	0 (0%)	0 (0%)	2 (10%)	6 (28%)	13 (62%)	4.5
Testing the usefulness						
Questions	1: very poor	2: poor	3: sufficient	4: good	5: very good	Average
4. The classification system is intended to be used for positioning a company's offer(s). To what extent is the classification system contributing to the achievement of this objective?	0 (0%)	0 (0%)	2 (10%)	8 (38%)	11 (52%)	4.4
4.1 Would you use the classification system for this purpose in the future?	Yes: 21 (100%) No 0 (0%)					
5. The classification system 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 classification system contributing to the achievement of this objective?	0 (0%)	0 (0%)	1 (5%)	9 (43%)	11 (52%)	4.5
5.1 Would you use the classification system for this purpose in the future?	Yes: 20 (94%) No 1 (6%)					
6. The classification system is intended to be used for exploring new business	0 (0%)	0 (0%)	0 (0%)	12 (57%)	9 (43%)	4.4

opportunities (repositioning of offer, combination of different offers). To what extent is the classification system contributing to the achievement of this objective?						
6.1 Would you use the classification system for this purpose in the future?	Yes: 21 (100%) No 0 (0%)					
7. The classification system and archetypal models can be used for generating ideas. To what extent is the classification system contributing to the achievement of this objective?	0 (0%)	0 (0%)	1 (5%)	7 (33%)	13 (62%)	4.6
7.1 Would you use the classification system for this purpose in the future?	Yes: 21 (100%) No 0 (0%)					

3.3 Considerations and new design opportunities

Some issues and limitations emerged from the testing activities. Regarding the completeness of the tool, participants confirmed that the archetypes cover all existing models and that all possible models of PSS+DRE can be mapped on the tool. This however can be linked to the fact that participants were from a similar socio-economic context (Botswana and South Africa) and that they might have a limited overview of the energy sector. Future testing activities will aim at involving a broader number of companies and practitioners from different geographical contexts.

Other issues led to improve the tool. In particular, in relation to the ease of use, some participants reported initial doubts in distinguishing between renting and leasing models and between mini kits and individual energy systems. Although they affirmed it was mainly related to more time needed to fully understand the Innovation Map, we added a short text description of both PSS types and energy systems to avoid confusion distinguishing different PSS+DRE model. We also differentiated PSSs types with colour-coding (red, orange and yellow) and thus simplified their classification.

The testing activities also led to identify new design opportunities to add features to the PSS+DRE Innovation Map.

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 application resulted from positioning companies' offers and during the discussion about the identification of new solutions. These feedback and the fact that participants endorsed the potential application of the tool for generating ideas (Table 3) led to explore the application of the PSS+DRE Innovation Map as tool to generate new sustainable business models that could support SMEs in generating PSS+DRE design concepts. In the following section we present the second version of the Innovation Map and its applications as supporting tool for sustainable business model generation.

4. The new PSS+DRE Innovation Map: a tool to generate sustainable business models for energy

4.1 New features

Drawing conclusions from the testing activities, the PSS+DRE Innovation Map has been improved with new features that allow the tool to be applied in idea generation sessions for designing sustainable energy solutions.

We added a step-by-step guide on the left-hand side of the map, which explains the main steps to be undertaken (Figure 9). The idea generation is thought to be structured in layers: first by drawing a picture of the current situation which consists in positioning the company's offers, its competitors in the selected context and choosing the areas that are promising to be explored. Then, the idea generation layer includes all design elements of new PSSs applied to DRE: target customers, products and services included, the network of stakeholders and payment modality.

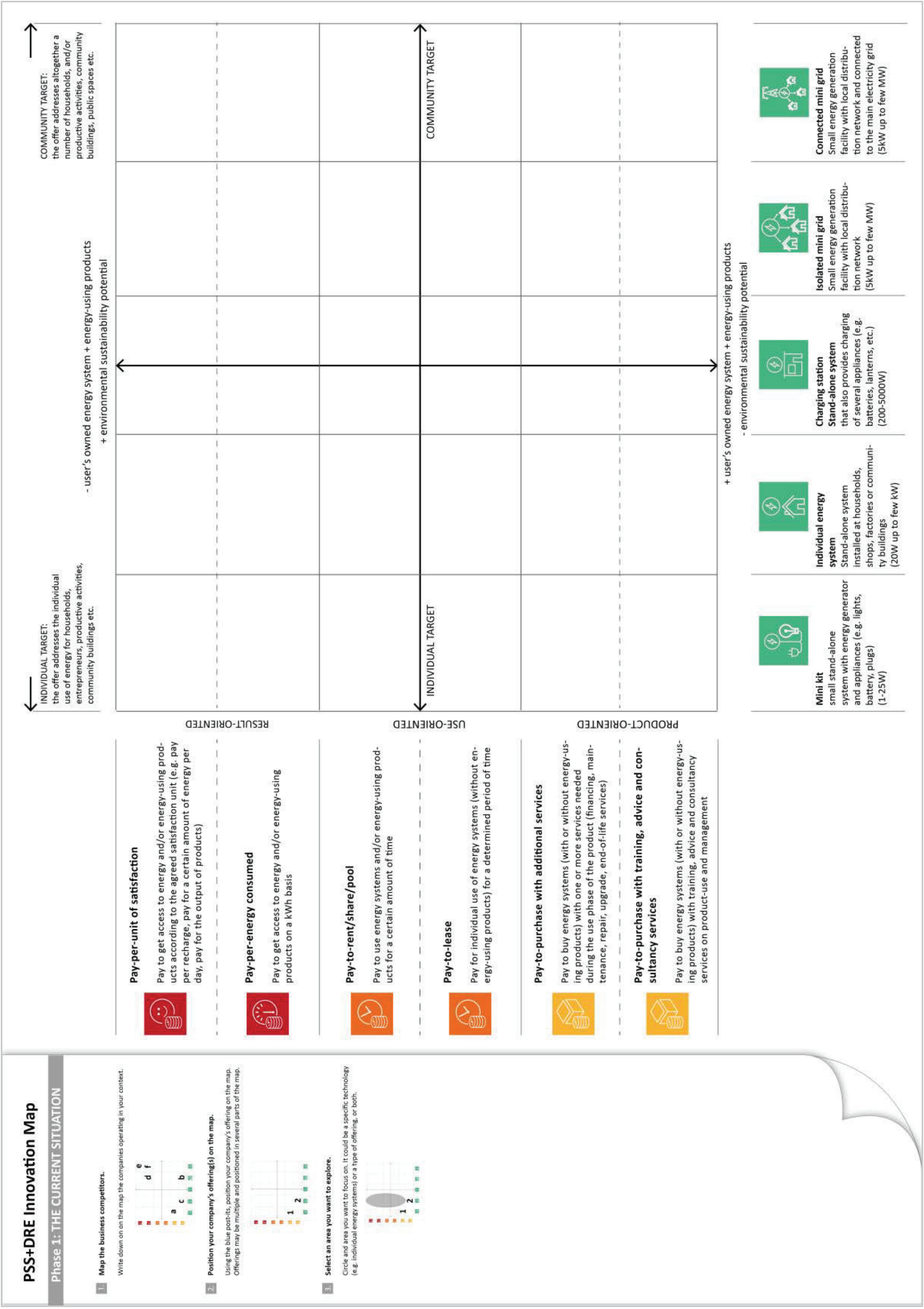
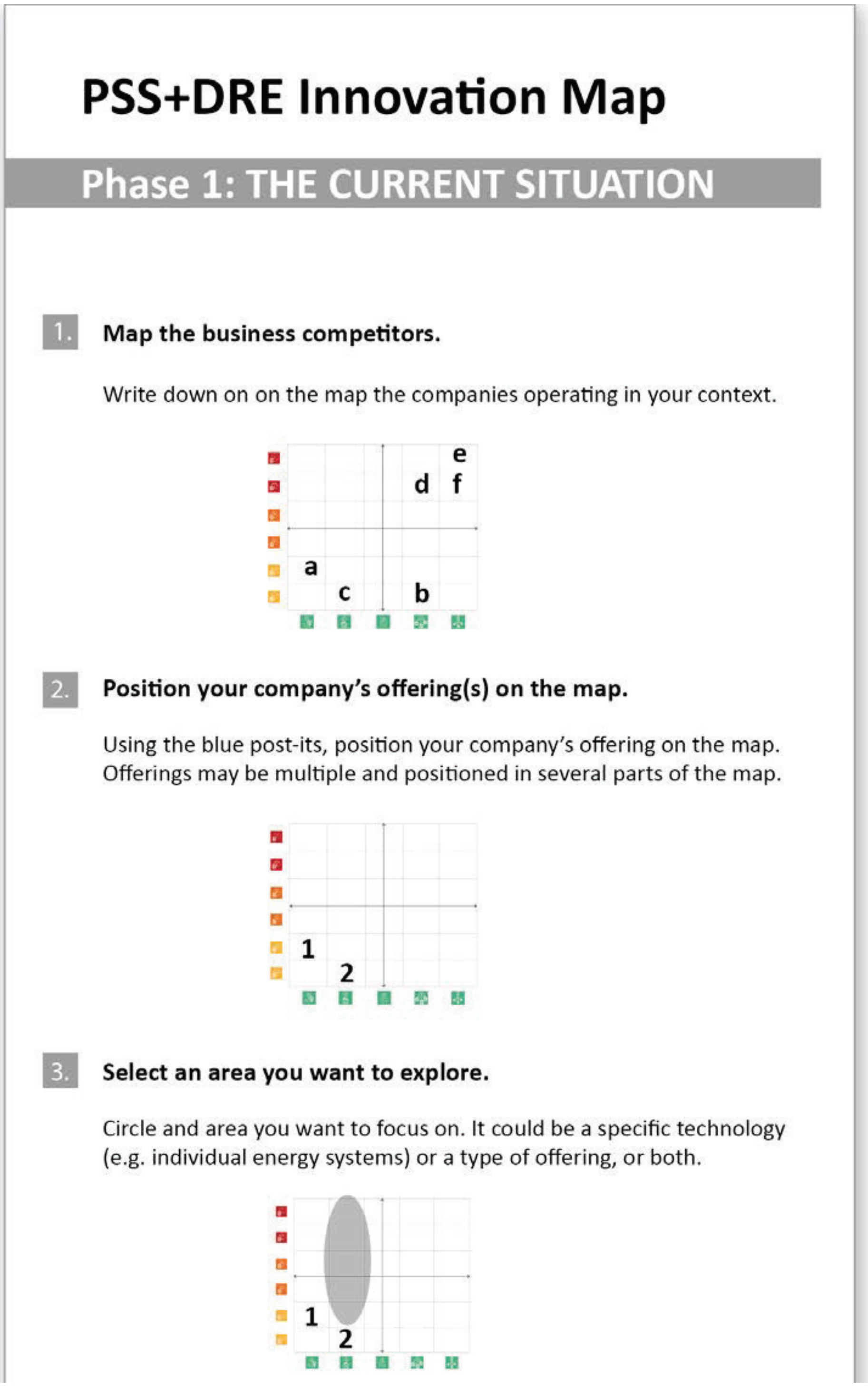


Figure 9 - The new PSS+DRE Innovation Map with a step-by-step guide for Phase 1: the current situation



PSS+DRE Innovation Map

Phase 1: THE CURRENT SITUATION

1. **Map the business competitors.**

Write down on on the map the companies operating in your context.

2. **Position your company's offering(s) on the map.**

Using the blue post-its, position your company's offering on the map. Offerings may be multiple and positioned in several parts of the map.

3. **Select an area you want to explore.**

Circle and area you want to focus on. It could be a specific technology (e.g. individual energy systems) or a type of offering, or both.

Figure 10 - Detail of the step-by-step guide for Phase 1

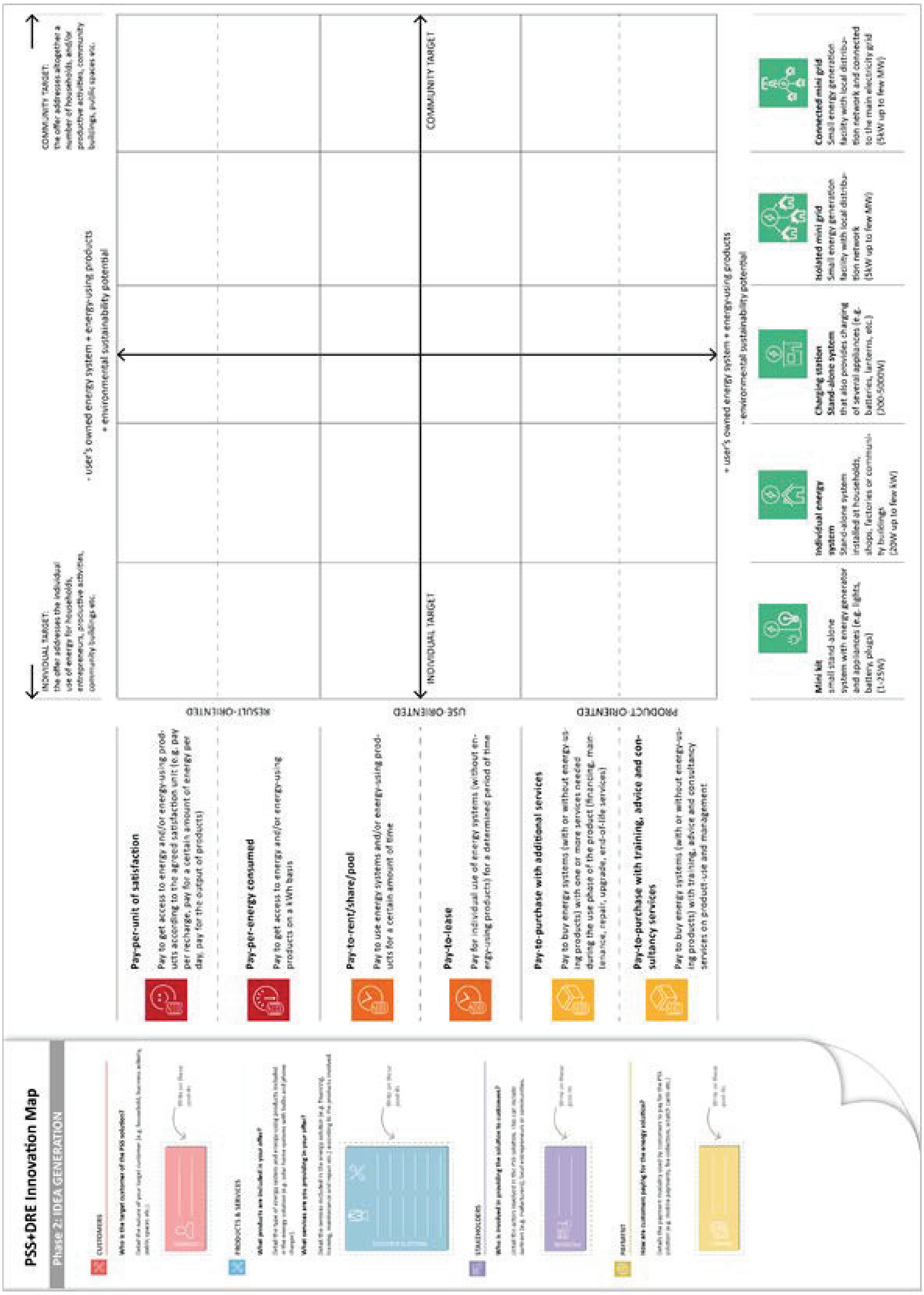

PSS+DRE Innovation Map
Phase 2: IDEA GENERATION
CUSTOMERS
PRODUCTS & SERVICES
STAKEHOLDERS
PAYMENT
Pay-per-unit of satisfaction
Pay to get access to energy and/or energy-using products according to the agreed satisfaction unit (e.g. pay per recharge, pay for a certain amount of energy per day, pay for the output of products)
Pay-per-energy consumed
Pay to get access to energy and/or energy-using products on a kWh basis
Pay-to-rent/share/pool
Pay to use energy systems and/or energy-using products for a certain amount of time
Pay-to-lease
Pay for individual use of energy systems (without energy-using products) for a determined period of time
Pay-to-purchase with additional services
Pay to buy energy systems (with or without energy-using products) with one or more services needed during the use phase of the product (financing, maintenance, repair, upgrade, end-of-life services)
Pay-to-purchase with training, advice and consultancy services
Pay to buy energy systems (with or without energy-using products) with training, advice and consultancy services on product-use and management
RESULT-ORIENTED
USE-ORIENTED
PRODUCT-ORIENTED
INDIVIDUAL TARGET:
the offer addresses the individual use of energy for households, entrepreneurs, productive activities, community buildings etc.
COMMUNITY TARGET:
the offer addresses altogether a number of households, and/or productive activities, community buildings, public spaces etc.
- user's owned energy system + energy-using products
+ environmental sustainability potential
+ user's owned energy system + energy-using products
- environmental sustainability potential
INDIVIDUAL TARGET
COMMUNITY TARGET
Mini kit
Small stand-alone system with energy generator and appliances (e.g. lights, battery, plugs)
(1-25W)
Individual energy system
Stand-alone system installed at households, shops, factories or community buildings
(20W up to few kW)
Charging station
Stand-alone system that also provides charging of several appliances (e.g. batteries, lanterns, etc.)
(300-5000W)
Isolated mini grid
Small energy generation facility with local distribution network
(5kW up to few MW)
Connected mini grid
Small energy generation facility with local distribution network and connected to the main electricity grid
(5kW up to few MW)

Figure 12 - Detail of the step-by-step guide of Phase 2: Idea generation

4.2 Applications of the new PSS+DRE Innovation Map

7. Phase 1: the current situation. The first step aims at picturing the current scenario of competitors, existing energy solutions and the company's offerings. Following the same dynamics of the previously tested applications, the new PSS+DRE Innovation Map presents a step-by-step guide to position the competitors' offerings, map the company's existing offers and select an area that users want to explore (Fig 13). At the end of this stage, users will be able to draw a picture of gaps in the market and envisage possible solutions to explore.

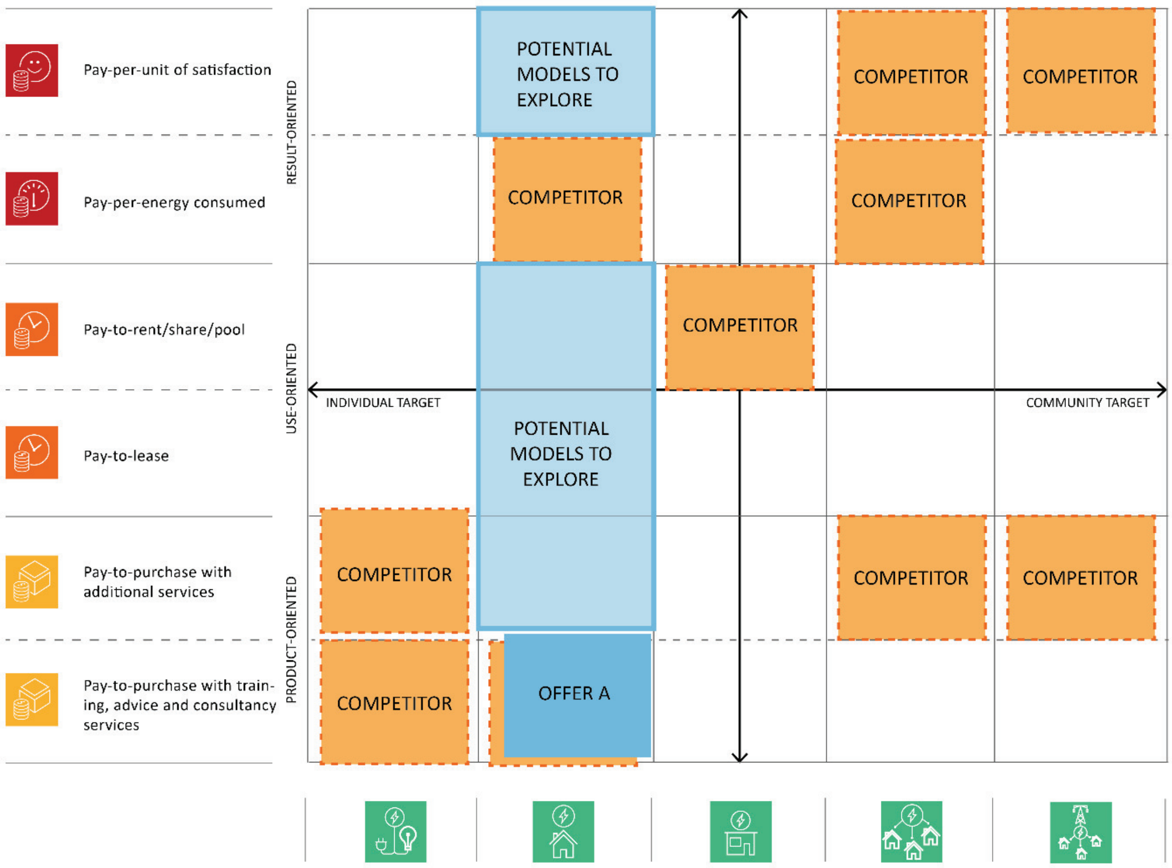


Figure 13 - The PSS+DRE Innovation Map describes the current situation of company's offer, competitors and promising models to explore

8. Phase 2: idea generation. The second step focuses on using the tool for generating innovative solutions of PSS applied to DRE. In this phase, users follow the guide on the left-hand side of the tool that suggests what elements need to be considered when designing PSS applied to DRE. In order to facilitate the idea-generation process, the step-by-step guide is composed of specific questions and accompanied with colour-coded post-it notes to write down ideas and place them on the map.

In particular, the first step is to detail the type of *target customer*, specifying for example if the PSS addresses the needs of households, small businesses, or communities of a variety of users. Users write down their ideas and place the post-it on the area they are planning to explore. Then the idea generation focuses on detailing the *products and services* provided in the offer, specifying what type of energy-using products are included (e.g. lights or phone chargers) and what services are provided (e.g. maintenance, upgrade). In a third moment, the *stakeholders* involved in the provision of the energy solution are listed with their roles in providing the PSS solution (e.g. manufacturing company, local NGOs). Detailing the *payment modality* completes the process, i.e. specifying how users are paying for the energy solution (e.g. mobile payments, monthly fee collection). Moreover, during the idea generation, the archetypal models descriptions with case studies are used to support the process as inspiration for SMEs and practitioners.

For each area of the map it is possible to brainstorm different ideas, therefore, placing several post-its and grouping them as concepts with several ideas (see Figure 14).

The final result is a set of concepts that encompass all the design elements of PSSs applied to DRE. For example, as showed in Figure 14, two concepts emerge from the "Offering individual energy systems in leasing": the first one involves solar home systems and appliances to be leased to households; the second one refers to leasing wind systems and appliances to productive activities. These ideas can then be further selected and developed when refining the concepts.

Figure 14 - Detail of a complete session of idea generation and how the generated ideas form PSS+DRE concepts, by including all design elements

4.3 Discussion

The PSS+DRE Innovation Map can be used to design sustainable energy solutions by SMEs, practitioners and other actors involved in the energy sector.

By embedding most of the characterising dimensions of DRE systems and adopting a systemic approach, the Innovation Map aims at simultaneously consider several aspects of the energy solution, not only in terms of technology options but also considering the target customer, network of providers, services offered, type of offer and payment methods . For this reason, this study aims at filling the lack of a comprehensive approach that currently characterises DRE literature and tools.

In comparison to other tools used in the PSS literature or for generating solutions applied to BoP contexts, the Innovation Map adds a specific focus on energy and combines some of the approaches used in PSS literature: the strategic analysis, the exploration of opportunities and PSS idea generation.

In sum, the new PSS+DRE Innovation Map supports the creation of sustainable energy business models by combining three elements: a PSS design approach with a narrow focus on energy, a multi-dimensional approach to the design of DRE models that include most elements of energy solutions, a systemic approach required to target BoP markets.

5. Conclusions and future research activities

This research aims at exploring the application of Product-Service Systems to Distributed Renewable Energy in BoP markets and at designing supporting tools for SMEs and practitioners venturing in these contexts. The first results led to identifying the characterising dimensions of PSS+DRE models and providing a classification system. By populating the system with case studies we identified a set of 15 archetypal models that illustrate the applications of PSS and DRE. The classification system can be applied not only to understand the applications of PSSs to DRE but also as a strategic design tool: the PSS+DRE Innovation Map. Validation of the tool has been achieved by using it with companies, experts and practitioners and we have identified its several applications: the tool is used for mapping competitors in a specific context, to position companies' offerings and to explore new business opportunities. Drawing feedback from the testing activities, we identified new features and applications of the PSS+DRE Innovation Map: it can be used as a tool to support the idea generation of sustainable energy solutions for the BoP. The new version of the PSS+DRE Innovation Map is presented in this paper with its applications for supporting the design process of PSS applied to DRE.

Further research activities will focus on testing its envisioned applications in idea-generation sessions with companies and practitioners in Kenya and South Africa.

Acknowledgements:

This research is framed within the LeNSes project (Learning Network for Sustainable energy systems), a three yearlong project funded by the EU (Edulink II) that involves seven African and European Universities.

6. References

Ackermann T., Andersson G., Söder L. (2001) Distributed generation: a definition. Electric Power System Research 57 194-204

Beck F. & Martinot E. (2004) Renewable Energy Policies and Barriers. Encyclopedia of Energy, Volume 5. Elsevier Inc.

Beuren F., Gomes Ferreira M., Cauchick Miguel P. (2013) Product-Service Systems: a literature review on integrated products and services. Journal of Cleaner Production 47, 221-231

Castillo L.G., Diehl J.C., Brezet J.C. (2012) Design Considerations for Base of the Pyramid (BoP) Projects. Proceedings of the Cumulus Helsinki 2012 Conference

Friebe C. a., Flotow P. Von, & Täube F. a. (2013) Exploring the link between products and services in low-income markets—Evidence from solar home systems. Energy Policy, 52, 760–769.

Halme M., Jasch C., Scharp M. (2004) Sustainable homeservices? Toward household services that enhance ecological, social and economic sustainability. Ecological Economics 51 (1-2), 125-138

Heiskanen E., Jalas M. (2000) Dematerialisation through Services: A Review and Evaluation of the Debate. Helsinki: Ministry of the Environment, Environmental Protection Department.

IFC & WRI (2007) The Next 4 Billion — Market Size and Business Strategy at the Base of the Pyramid. Washington, USA: International Finance Corporation and World Resources Institute

Emili S., Ceschin F., Harrison D. (2015) Product-Service Systems applied to Distributed Renewable Energy systems: a classification system and a strategic design tool. Conference proocedings KIDEC – Indigenuous Design - Kampala 2015

Emili S., Ceschin F., Harrison D. (2016) Product-Service Systems applied to Distributed Renewable Energy: a classification system and 15 archetypal models. Energy for Sustainable Development (in press)

Jagtap S., Larsson A.(2013) Design of Product Service Systems at the Base of the Pyramid. International Conference on Research into Design, Chennai, India. A. Chakrabarti and R. V. Prakash (eds.), ICoRD'13, Springer India.

Jun S., Dongmyung L., Park J. (2013) Determining business models in bottom-of-the-pyramid markets. Industrial Management & Data Systems, 113 1064-1082

Meredith J. (1993) Theory building through conceptual methods. International Journal of Operations and Production Management, Vol. 13 No. 5, 3-11.

Myers S. (2013) The Economic Challenge of Rural Electrification : Community Solutions Initiative in Africa. Global Humanitarian Technology Conference (GHTC), IEEE.

Moe H.P., Boks C. (2010) Product Service Systems and the Base of the Pyramid: A Telecommunications Perspective. CIRP IPS2 Conference 2010

Morelli N. (2006) Developing new product service systems (PSS): methodologies and operational tools. Journal of Cleaner Production 14, pp. 1495-1501

OECD/IEA (2010) Energy poverty. How to make modern energy access universal? World Energy Outlook, Paris

Prahalad C.K. & Hart, S. (2002) The Fortune at the Bottom of the Pyramid. Strategy+Business Magazine Issue 26.

Rolland S. (2011) Rural Electrification with Renewable Energy. Technologies , quality standards and business models. Alliance for Rural Electrification (ARE) Brussel, Belgium

Schäfer M., Kebir N., Neumann K. (2011) Research needs for meeting the challenge of decentralized energy supply in developing countries. Energy for Sustainable Development, 15(3), 324–329.

Schafer C., Parks R., Rai R. (2011) Design for emerging Bottom of the Pyramid markets: a Product-Service System (PSS) based approach. Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference. Washington DC 2011.

Schillebeeckx S.J.D., Parikh P., Bansal R., George G. (2012) An integrated framework for rural electrification: Adopting a user-centric approach to business model development. Energy Policy 48, 687–697

Stahel W.R, et. al. (2000) From Manufacturing Industry to a Service Economy, from Selling Products to Selling the Performance of Products. Geneva: Product-Life Institute.

Terrado E., Cabraal R. A., Mukherjee I. (2008) Designing Sustainable Off-Grid Rural Electrification Projects: Principles and Practices. Operational Guidance for World Bank Group staff, Washington

Tukker A. (2004) Eight types of Product-Service: eight ways to Sustainability? Experiences from Suspronet. Wiley InterScience, 260, 246–260.

Tukker A. & U. Tischner (2004) New business for old Europe: Product Service Systems as means to enhance competitiveness and ecoefficiency. Final report of Suspronet

Tukker A., Tischner U., and Verkuijl M. (2006) Product-services and Sustainability. In: Tukker, A., and Tischner, U. (eds.) New business for Old Europe. Product Services, Sustainability and Competitiveness. Sheffield: Greenleaf publishers.

Tukker A. & Tischner U. (2006) Product-services as a research field: past, present and future. Reflections from a decade of research. Journal of Cleaner Production, 14(17), 1552–1556.

United Nations Environmental Programme (UNEP) (2002) Product-Service Systems and Sustainability. Opportunities for Sustainable Solutions. UNEP, Division of Technology Industry and Economics, Production and Consumption Branch, Paris.

United Nations General Assembly (2014) Report of the Open Working Group of the General Assembly on Sustainable Development Goals.

Vezzoli C., Ceschin F., Diehl. J.C. (2015) Sustainable Product-Service System Design applied to Distributed Renewable Energy Fostering the goal of sustainable energy for all. Journal of Cleaner Production.

Wacker J.G. (1998) A definition of theory: research guidelines for different theory-building research methods in operations management, Journal of Operations Management, Vol. 16 No. 4, pp. 361-385.

White A.L., Stoughton M., Feng L. (1999) Servicizing: The Quiet Transition to Extended Product Responsibility. Boston: Tellus Institute

Wong M. (2001) Industrial Sustainability (IS) and Product Service Systems (PSS): A strategic Decision Support Tool for Consumer Goods Firms. Cambridge, UK: University of Cambridge, Department of Engineering

Zaring O., Bartolomeo M., Eder P., Hopkinson P., Groenewegen P., James P., de Jong P., Nijhuis L., Scholl G., Slob A., Örninge M. (2001) Creating Eco-Efficient Producer Services, report of an EU project. Gothenburg Research Institute, Gothenburg.

Zerriffi H. (2011) Rural Electrification. Strategies for Distributed Generation. Springer International Publishing.

About the Authors:

Silvia Emili is a PhD design student at Brunel University London. With a background on sustainable Product-Service System and strategic design, she is currently exploring the applications of PSS to DRE systems and the design of sustainable business models for energy. She is an active member of the EU-funded LeNSes project.

Fabrizio Ceschin is a Lecturer in Design for Sustainability at the Design Department of Brunel University London. He holds a BSc and MSc degrees in Industrial Design, and a Ph.D. degree (awarded by Politecnico di Milano in 2012) on the topic of sustainable Product-Service Systems. He was research fellow at Politecnico di Milano before joining Brunel University London in September 2012. He has 10 years of research experience in the areas of Design for Sustainability, co-design and open innovation. His most recent book is '*Sustainable Product-service Systems: Between Strategic Design and Transition Studies*', Springer (2014)

David Harrison is a Professor of Design Research and Theme Leader for Sustainable Manufacturing at Brunel University London. David Harrison holds a Chair in Design in the College of Engineering, Design and Physical Sciences. He is a Chartered Engineer and has been an investigator on nineteen EPSRC grants, eight of these as principal investigator. He has research interests in sustainable design and printed electronics, and is a Member of the IET, and a Fellow of the Higher Education Academy.