the Learning Network on
Sustainable energy systems

SYSTEM DESIGN FOR SUSTAINABLE ENERGY FOR ALL
A new knowledge base and know-how developed within the LeNSes European and African project

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ABSTRACT

This paper presents the results of the Learning Network on Sustainable Energy Systems (LeNSes) an African-European multi-polar network for curriculum development on Design for Sustainability (DfS) focused on Distributed Renewable Energy (DRE) and Sustainable Product-Service Systems (S.PSS), i.e. System Design for Sustainable Energy for All (SD4SEA). The project has been funded by the European Union (EU) 2013-2016, Edulink Programme and involves four African and three European universities offering design-specific programmes of study. The results are articulated in knowledge-base and know-how outcomes. Regarding knowledge level the paper highlights the design role within the framework of the S.PSS applied to DRE and how they can be used to develop and implement sustainable energy solutions for all in the African, or more in general low and middle-income context. The discussion is supported by the presentation of projects shaped in the courses regarding sustainable energy product service systems involving for example cooking, mobility, lighting, and healthcare. The United Nations' Global Action Agenda [1] highlights indeed action areas for the achievement of long-term sustainable development as Modern Cooking Appliances & Fuels, Distributed Electricity Solutions, Grid Infrastructure & Supply Efficiency, Large Scale Renewable Power, Industrial & Agricultural Processes, Transportation, Buildings & Appliances.From the know-how (design methods and support tools) point of view they consist in a new modular and adaptable package of learning resources focused on System Design for Sustainable Energy for All (SD4SEA); in pilot courses at African Higher Educational Institutions (HEIs) targeted at undergraduate and graduate students, practitioners and companies; and in an open web platform for distributed production and transfer of learning resources (lectures, tools, case studies, student projects…) in this area.

Key Words: Sustainable product service system design, Distributed energy, Partipatory design, Copy left

1. INTRODUCTION

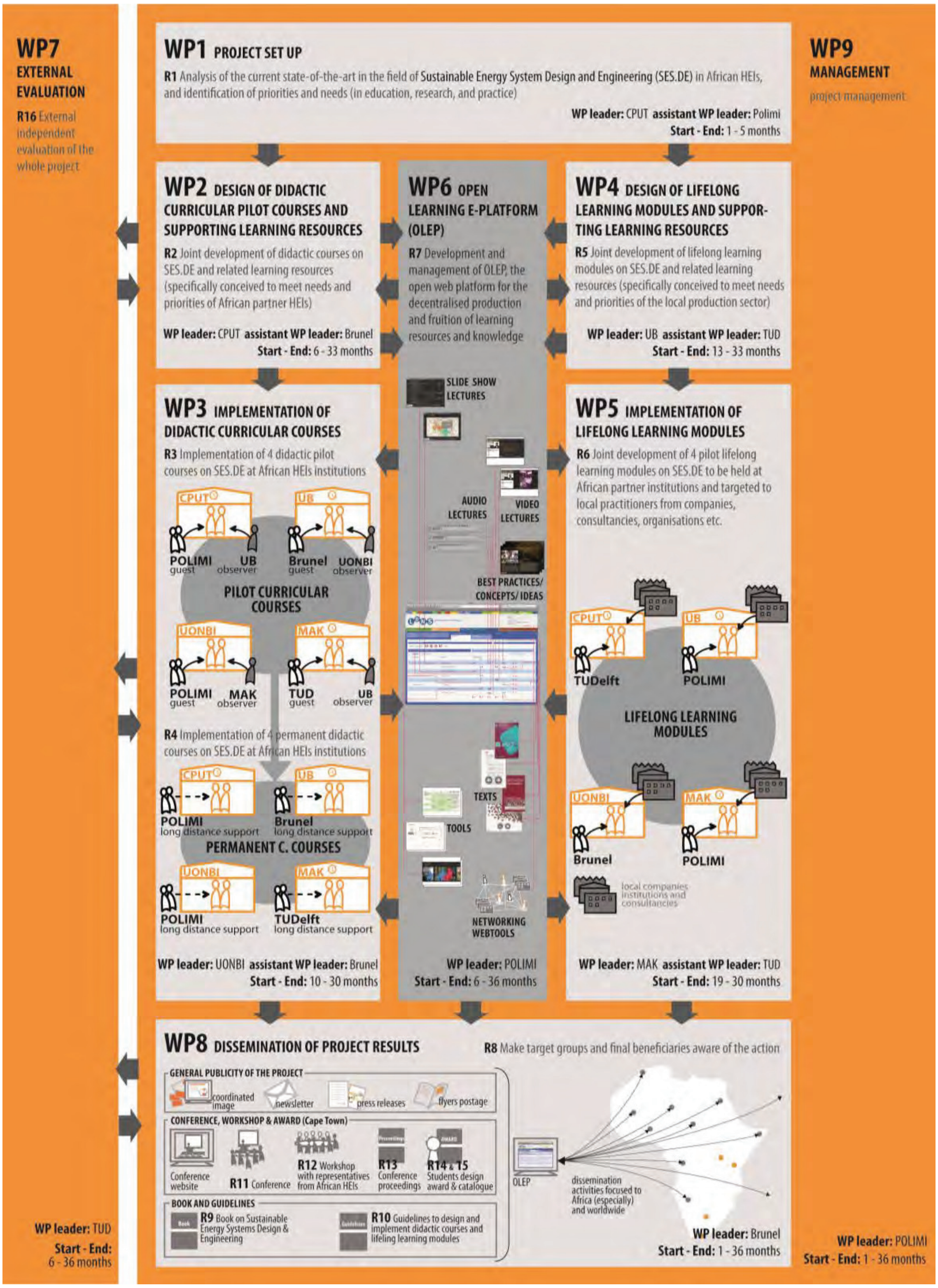
A study conducted by Rogelj, McCollum and Riahi (2013) on the compatibility of the 'Sustainable Energy for All' initiative with a warming limit of 2°C shows that achieving the three energy objectives (ensure universal access to modern energy services; double the share of renewable energy in the global energy mix; double the rate of improvement in energy efficiency) could provide an important entry point to climate protection, and that sustainability and poverty eradication can go hand in hand with mitigating climate risks. But the researchers warn that the likelihood of reaching climate targets within the scenarios depends also on a variety of other factors, including future energy demand growth, economic growth, and technological innovation.
Therefore securing energy for all within the existing environmental boundaries requires further political measures and financial resources. According to Nilsson (2012) "Investment costs for these pathways are large but often profitable for society and most of them have already been set in motion. Still, progress is slow and must be accelerated at national and regional levels. Carbon pricing is necessary but not sufficient: beyond this, governance responses need to be put in place to induce transitions through scaling up a diversity of supply and demand options. White and green certificates, feed-in tariffs, technology standards and removal of fossil subsidies are important first steps already under way. These contribute to nurturing and scaling up new technological regimes, as well as destabilizing old and unsustainable ones."
Results of innovations have to be evaluated considering the associated risk of a rebound effect. The rebound effect is the reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioral or other systemic responses. For example the availability of energy produced though PV panels can drive to the installation of air conditioning units which were not considered as needed before.
The evaluation of the PSS sustainability is thus very important and at the same time it is very difficult. A first effort concerns the definition of system boundaries because environment is an open system, furthermore it has to be taken into account that the modification of an element brings not predictable changes in the system.
Distributed Renewable Energy (DRE) has a key role ensuring sustainable energy for all since increased access to energy and improvement in energy efficiency could also result in more total energy consumption and pollution. DRE represent a promising opportunity to couple several benefits: economic ones (reduced cost of energy, increased reliability), ecological (efficiency gains, reduced emissions) and socio-ethical ones (democratisation of access to energy, participation and independence of local people). Specific environmental benefits of a DRE are based on the fact that they are non-exhaustible resources, have low greenhouse gases emission, lower environmental impact for extraction, transformation, distribution (low energy transmission losses).
Moreover Distributed Economies (DE), small scale locally-based demand/offer models, based on DRE are a good intervention scale because as Johansson et al. (2005) explain they "allow for the local community to possess higher ownership and consequently gain more power in directing these systems in ways that add quality to their lives." They also "have the great advantage of bringing many of the fundamental issues of sustainable development (even those of an ethical value) closer to the individual, both as a consumer and as a producer." An important element is thus the direct involvement of users that can be experimented in S.PSS co-design workshop to elicit also tacit needs (Martin and Schmidt, 2001). In this context as Bannon (2006) argues "Design teams and users must be prepared to acknowledge each others competencies and to realize that effort must be made by both parties to develop a mutually agreed upon vocabulary of concepts that can be shared across the different groups that comprise the project. It is no easy task for different disciplines and work activities to accomplish this, and it is in this area that additional research would be valuable." Education, concerning both the overall diffusion of scientific knowledge on sustainability and the training on specific know how, is also very important to support the development of sustainable energy solutions for all.

2. METHOD/APPROACH

The study identifies the convergence between the S.PSS and DRE models as promising approaches to provide sustainable energy solutions for all by increasing its access. The project partners have collaboratively developed new curricula and lifelong learning activities focused on these combined approaches.
More in detail in a first phase, each partner gathered and shared knowledge from previous didactic and research experiences in the field of locally-based System Design for Sustainable Energy for All, and African partners shared specific needs and priorities involving local companies, associations and NGOs.
The results of these activities is the base for the following phase consisting in the design and implementation of the didactic pilot modules. At this stage, all the necessary inputs for the implementation of the didactic pilot courses and teaching subsidies have been developed in collaboration between African partners, European partners and with the support of the local associates (companies, consultancies and organisations operating in the energy sector). In a

first round, the pilot modules implementation are carried out through an exchange modality: each African partner hosts a course, and acts as observer in another course implemented in another African partner HEI. Each European partner collaborates in the implementation playing the role of a guest school. In the second round, courses are integrated in the African partners' curricula (with a long distance support by European partners).
The following phase has been the design and implementation of lifelong learning pilot modules. At this stage deals all the necessary inputs for the implementation of professional training modules for companies, consultancies and organisations has been produced. As a pilot case, each African partner (in collaboration with European partners) developed and delivered professional training to the respective local companies, consultancies and organisations.
The method adopted in the courses development and implementation is founded on the participation of local stakeholders, the involvement of an interdisciplinary design teams and the deployment of Distributed Renewable Energy (DRE). The courses' specific contents are defined through the collaboration of different stakeholders from research and practice community, such as experts in ethnography, ergonomics, engineers, architects and designers as well as staff and managers from local companies, associations and NGOs sharing their knowledge and experience and S.PSS are developed observing users' needs and priorities. This Multi-competence approach integrates different toos into a design method increasing the quality of final results (Brannen, 2005).

In parallel with the didactic curricular and lifelong learning activities, all the acquired knowledge - such as lectures (slide shows, texts, audio, video, etc.), case studies classified per set of criteria and guidelines, students' projects and System Design for Sustainable Energy for All tools - is collected in an Open Learning E-Platform (OLEP) to be freely and easily accessible in a copy left and open source modality, so forth enabling others in the design community worldwide to acquire them free of charge, with the possibility to replicate, modify, remix and reuse. Since this is an open package, it will continue to be updated even after the end of the project.
The whole process of curricular and lifelong learning activities design and implementation is constantly assessed by an independent external evaluation and the results of the implementation of both the didactic curricular courses and lifelong learning modules are collected and used in a number of dissemination activities. Finally, a book on System Design for Sustainable Energy for All will be published, and a set of guidelines to support HEIs in implementing didactic courses and lifelong learning activities. Most importantly, the OLEP represents itself the main dissemination tool: the OLEP is in fact aimed at facilitating the adoption, adaptation of the project results by other HEIs to activate similar courses on this emerging and challenging new discipline for design.



[Figure 1] LeNSes Process: main activities and expected results (legend: WP = Work Package; R = Result)

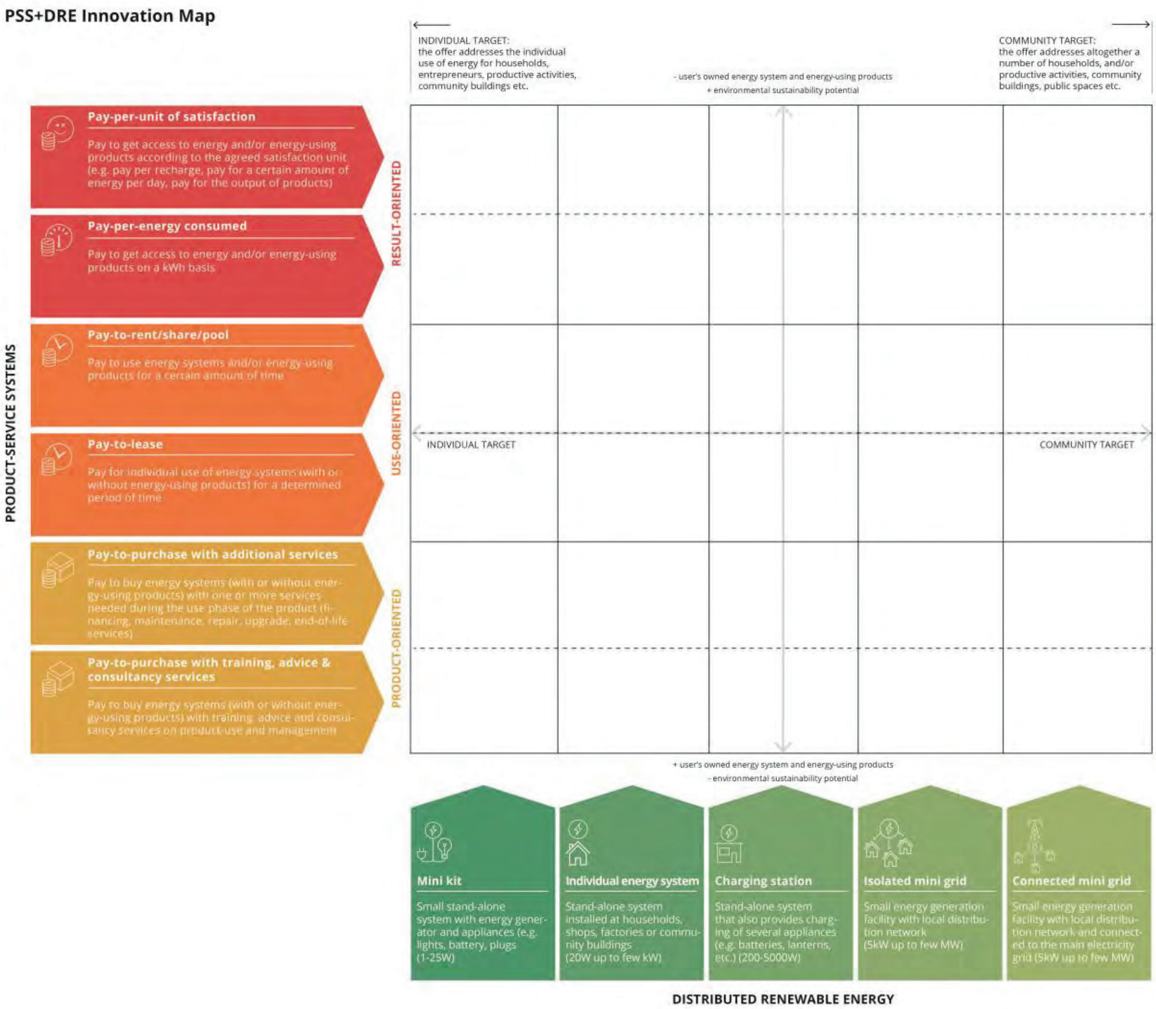
3. TOOLS

The courses gave also the opportunity to apply and test newly developed tools to design S.PSS applied to DRE. The main are below shortly introduced:

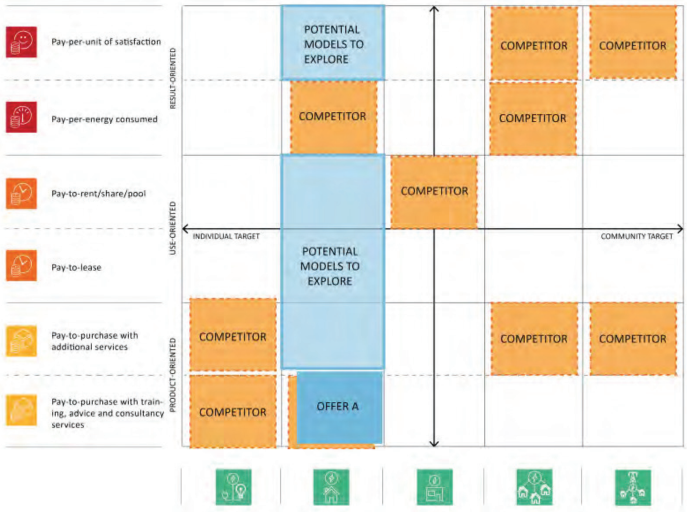
- PSS+DRE Innovation Map;
- PSS+DRE Design Framework and Cards;
- Energy Stakeholder System Map;
- Design Orienting Scenario (SDOS) for S.PSS&DRE;
- Sustainable Energy for All Idea Tables and Cards;
- Innovation Diagram for S.PSS&DRE;
- S.PSS&DRE Concept Description form;
- Estimator of Distributed Renewable Energy load/need and production potential (E.DRE)

3.1. PSS+DRE Innovation Map

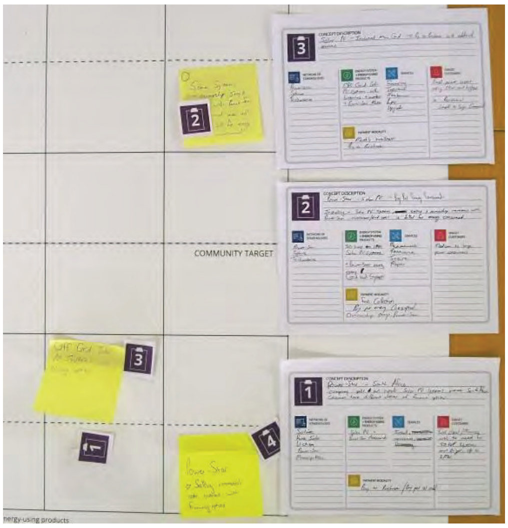
It's a tool for classifying PSS models applied to DRE, positioning company's offers, analysing competitors in the market and exploring new opportunities. The tool can be also used for generating new concepts of PSS+DRE (Emili, Ceschin & Harrison, 2016a; 2016b).



[Figure 2] PSS + DRE Innovation map: format



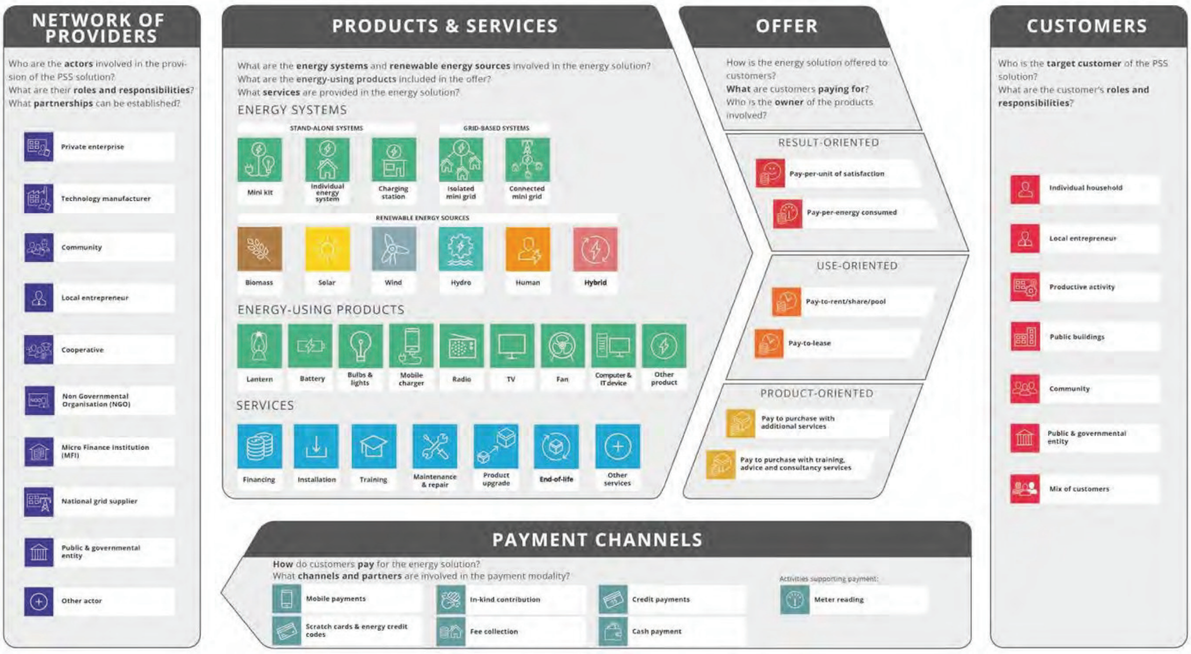
[Figure 3] *PSS + DRE Innovation map: sample application*



[Fig 4] *PSS + DRE Innovation map: working draft*

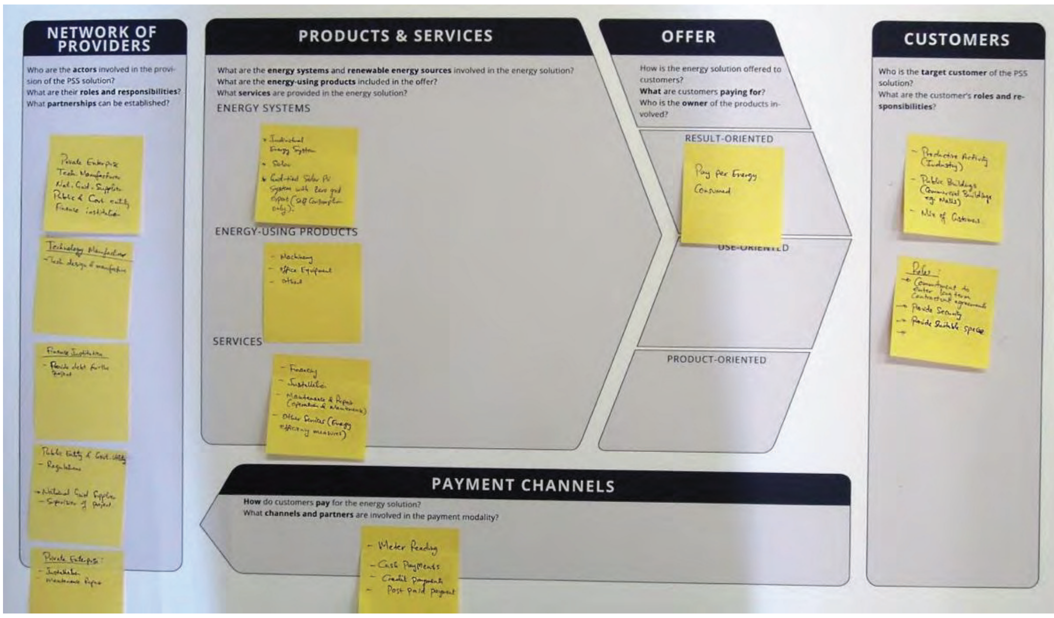
3.2. PSS+DRE Design Framework and Cards

It'a a tool for visualising all elements of PSS applied to DRE and support the idea generation of new concepts. The Framework is combined with a set of cards that collects guidelines, key factors and case studies that aim at supporting the design process of PSS applied to DRE. The cards are divided according to the elements of the framework: network of providers, products, services, offer, target customers and payment channels (Emili, Ceschin & Harrison, 2016c).



[Figure 5] PSS + DRE Design framework and Cards

[Figure 6] PSS + DRE Cards

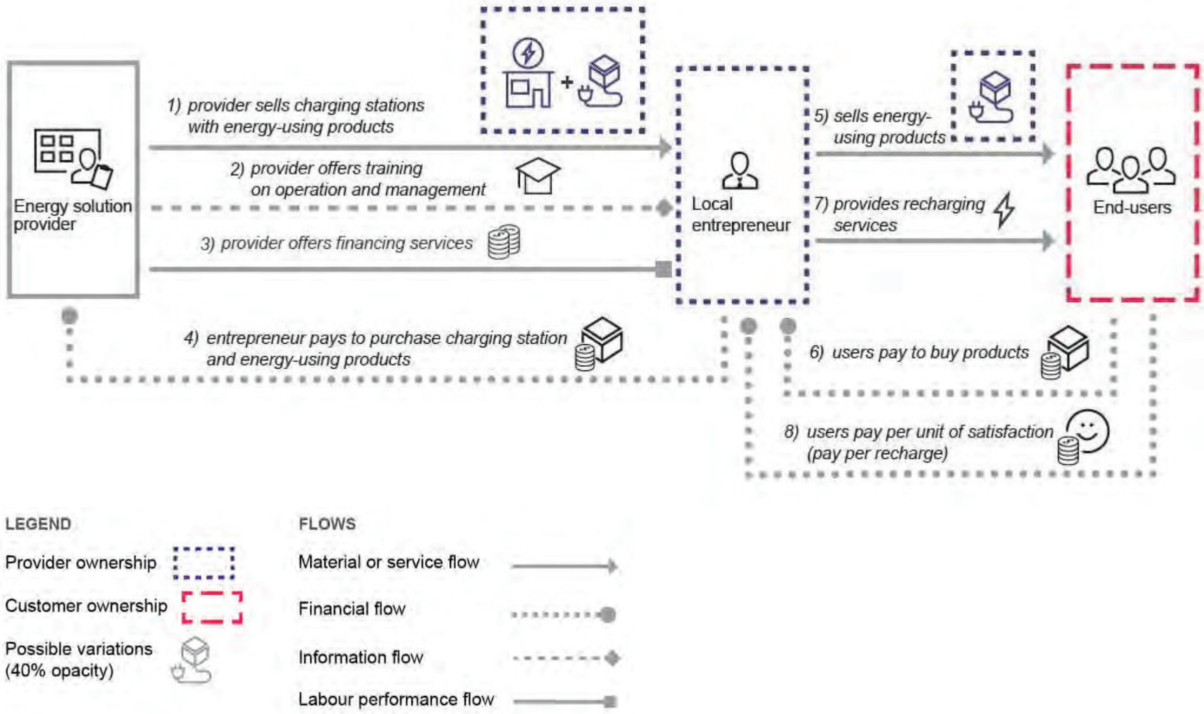


[Figure 7] PSS + DRE Design framework: working draft

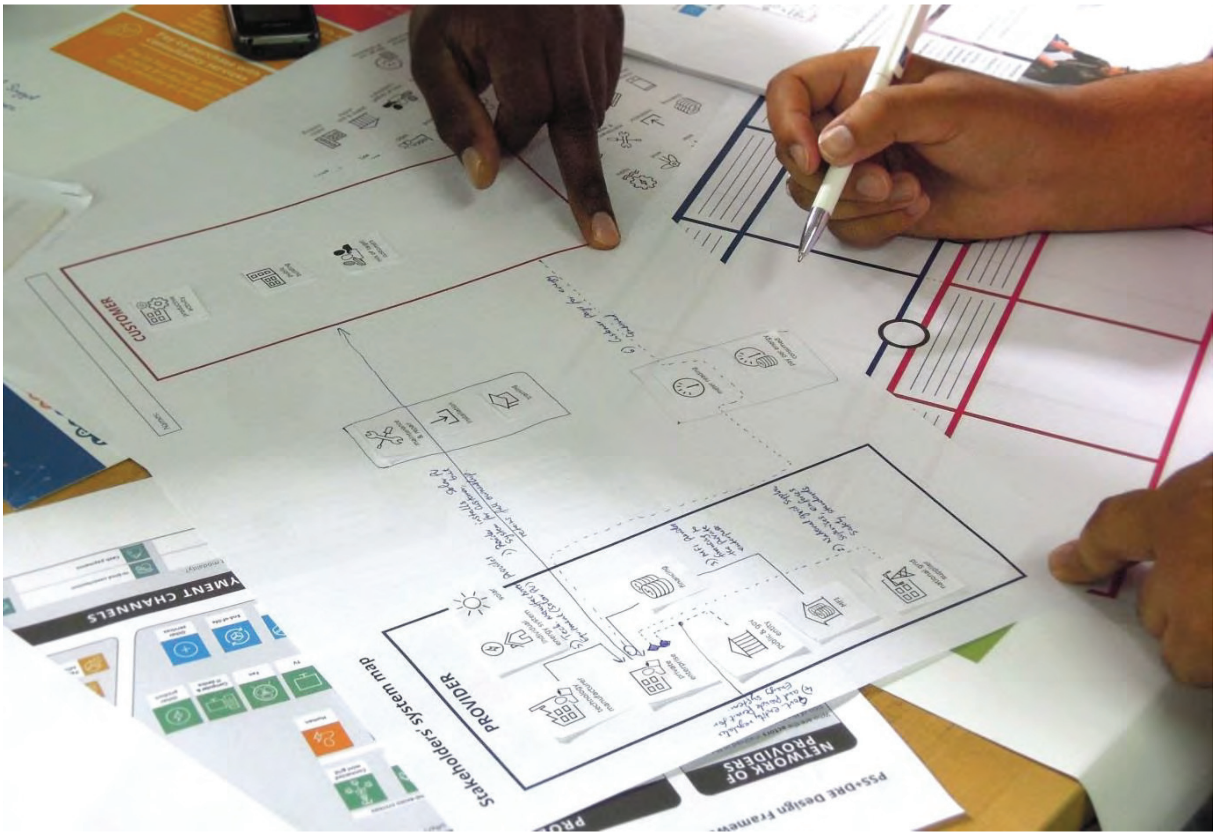
3.3. Energy Stakeholder System Map

It'a tool to visualise the network of stakeholders involved in energy systems (Emili, Ceschin & Harrison, 2016d). A set of energy-related icons and flows can be used to shows the stakeholders and their interactions (in terms of material, financial and information flows). The tool is an adaptation/development of the Stakeholder System Map tool (Jégou, Manzini, Meroni 2004).

[Figure 8] *Icons for S.PSS applied to DRE*



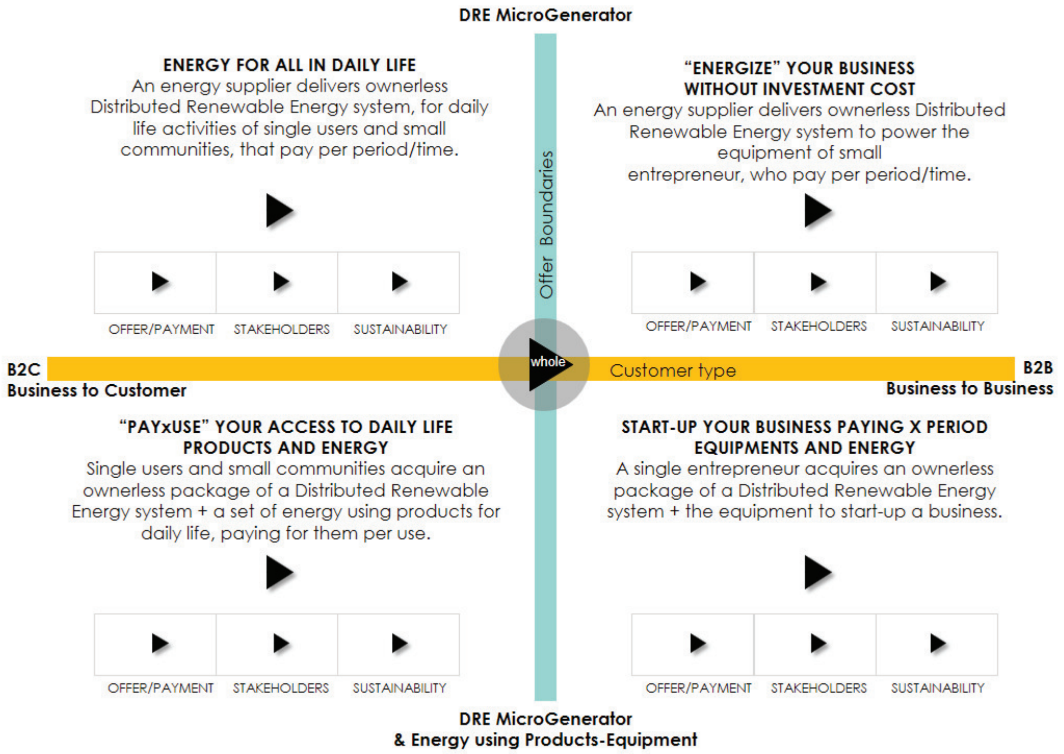
[Figure 9] Example of Energy System Map



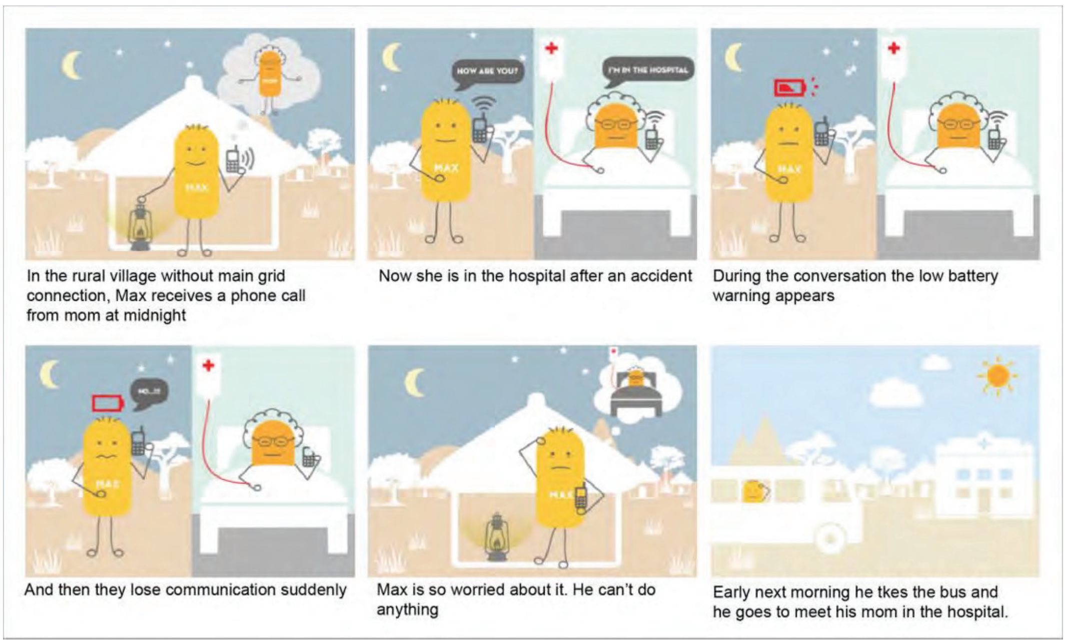
[Figure 10] Company using the tool for visualizing their S.PSS offer

3.4. Design Orienting Scenario (SDOS) for S.PSS&DRE

It's a tool to inspire and inform designers to design towards radically new social, economic and technical visions, based on the LeNSes project research hypothesis: Sustainable Product-Service Systems (S.PSS) are a promising model to diffuse Distributed Renewable Energies (DRE) in low and middle-income contexts. The System Design Orienting Scenario (SDOS) for S.PSS&DRE presents four visions narrated through a series of interactive videos accessible through a navigator file. (Vezzoli, Bacchetti, 2016). The tool is downloadable (free and copy-left) in digital version from www.lenses.polimi.it.



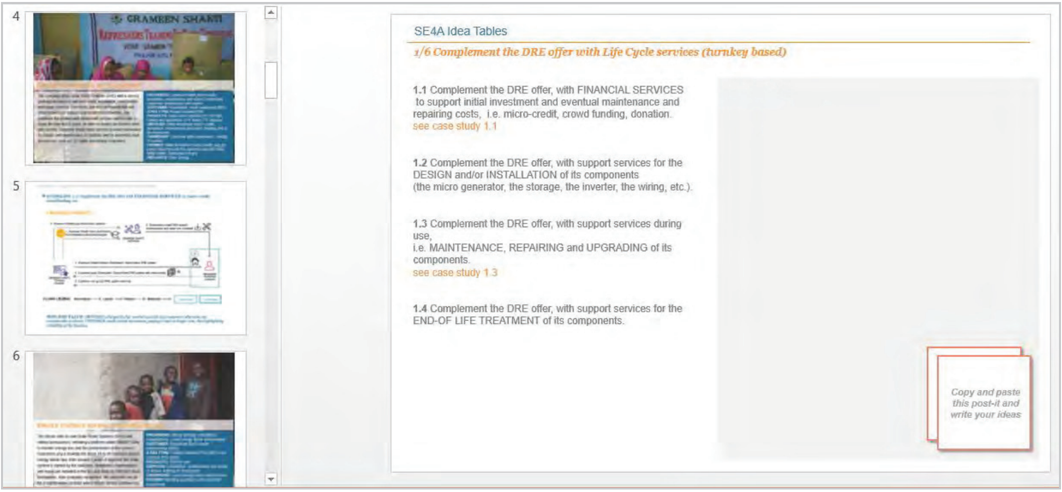
[Figure 11] Design Orienting Scenario for S.PSS&DRE, visions navigator-interactive file



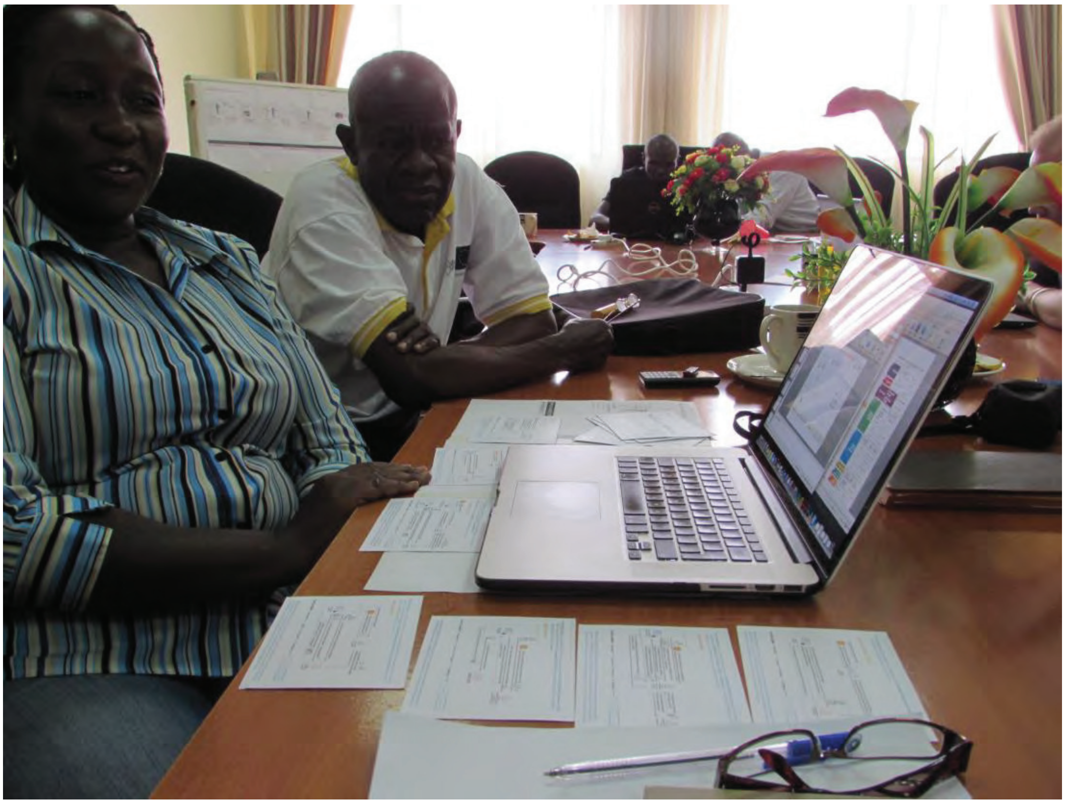
[Figure 12] Screenshot from the Design Orienting Scenario for S.PSS&DRE

3.5. Sustainable Energy for All Idea Tables and Cards

A tool to generate Sustainable Energy for All ideas. The tool is based on six tables with guidelines and sub-guidelines, to orientate the design of key elements of S.PSS applied to DRE. A set of case study cards can be used as supportive examples related to the guidelines. The tool is downloadable (free and copy-left) in digital and paper version from www.lenses.polimi.it.



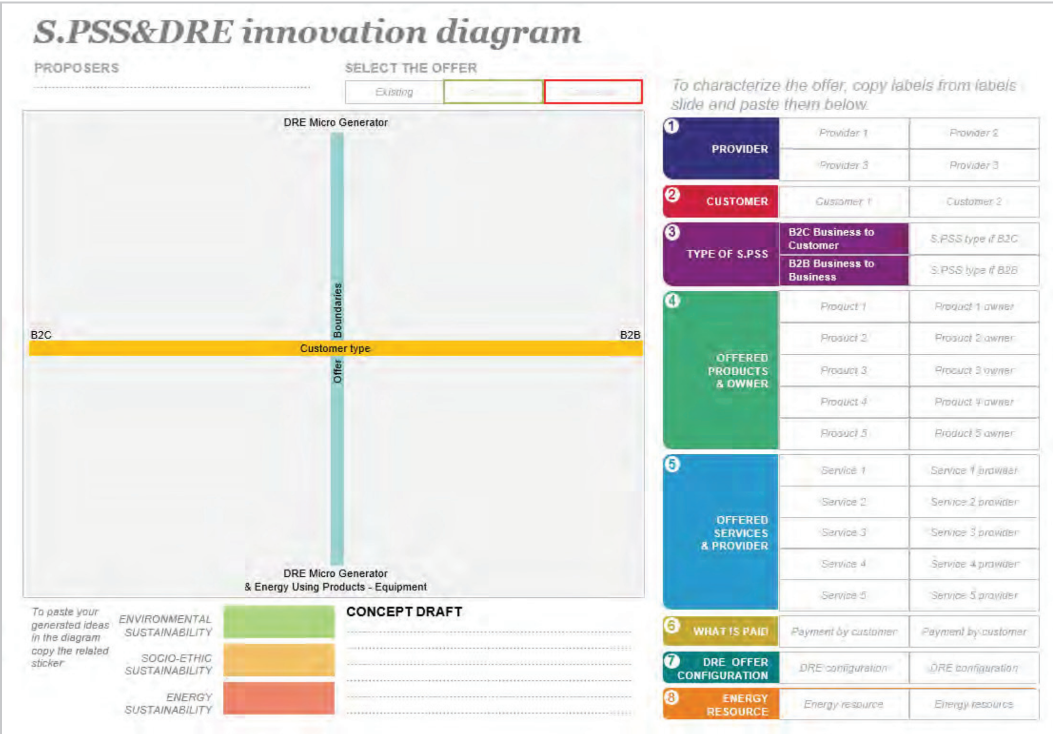
[Figure 13] Sustainable Energy for All Idea Tables and Cards, the tool (digital version)



[Figure 14] Companies using the Sustainable Energy for All Idea Tables and Cards to generate new Energy for All ideas (digital version with paper cards)

3.6. Innovation Diagram for S.PSS&DRE

It's a a tool to design, re-orient and/or analyze, energy offer models, towards new S.PSS&DRE concepts. The tool allows selection and clustering of (environmentally, socio-ethically, energy) sustainable ideas within its polarity diagram, starting the design of new S.PSS&DRE concepts. Furthermore, it provides the characterization of the designed S.PSS&DRE concepts through a set of labels and suggestions. The tool is downloadable (free and copy-left) in digital and paper version from www.lenses.polimi.it.

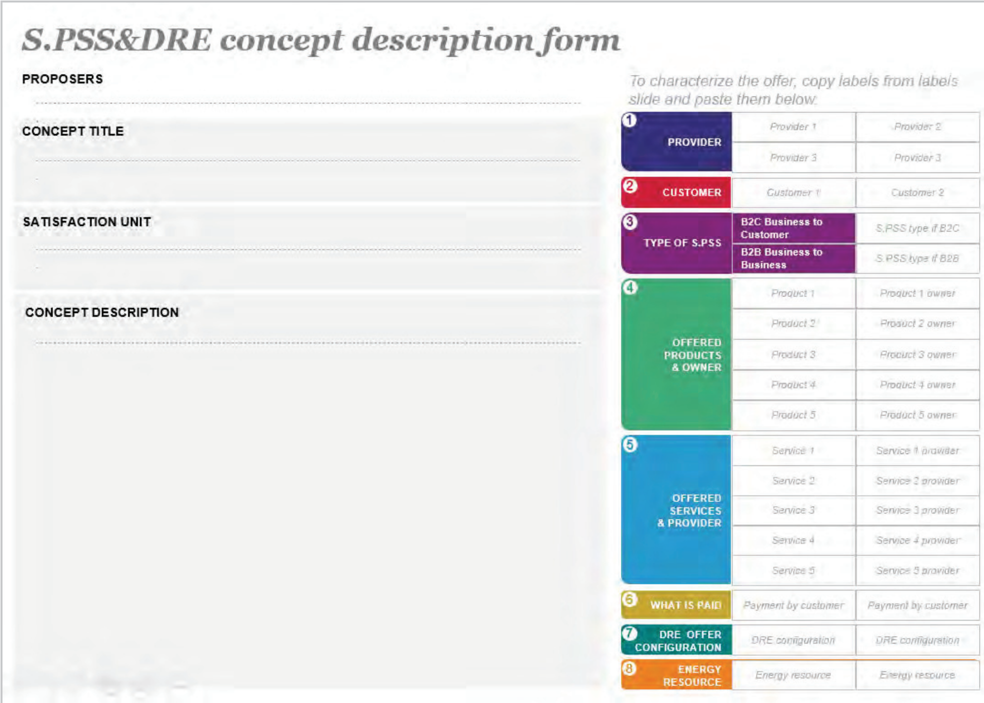


[Figure 15] Innovation diagram for S.PSS&DRE, the tool

[Figure 16] Companies using the Innovation diagram for S.PSS&DRE to re-orient their business offers

3.7. S.PSS&DRE Concept Description form:

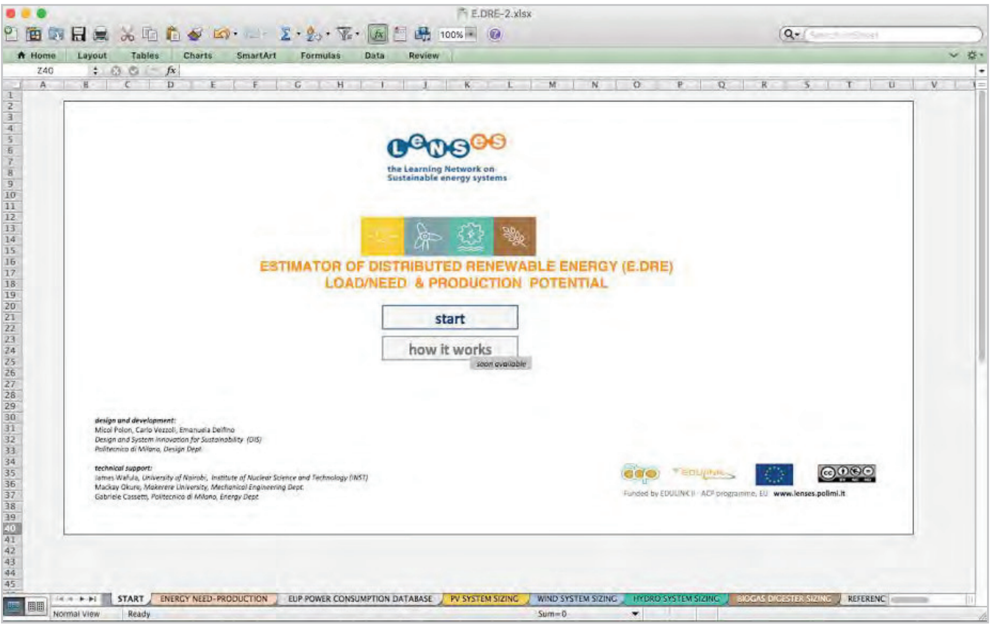
It's a tool to visualize and detail S.PSS&DRE concepts. The tool allow the definition of S.PSS&DRE concept title, unit of satisfaction and description, together with concept characterization through a set of labels and suggestions. The tool is downloadable (free and copy-left) in digital and paper version from www.lenses.polimi.it.



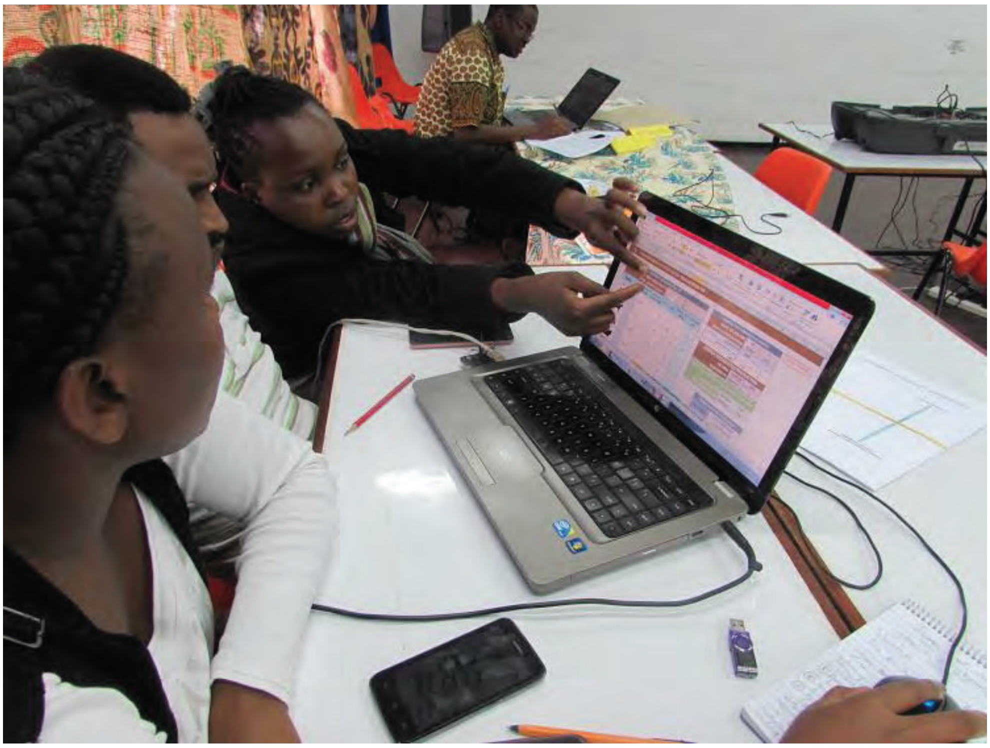
[Figure 17] S.PSS&DRE concept description form, the tool

3.8. S.PSS&DRE Estimator of Distributed Renewable Energy load/need and production potential

It's a a worksheet tool developed to support the design of DRE system, in order to guide the evaluation of the energy demand and need of the designed system concept, to assess the best system configuration and estimate the energy production potential. The tool integrates some existing and available databases and websites to allow getting data required for the evaluation and the dimensioning of the system concept (e.g. Geographical Assessment of Solar Resource irradiation). The tool is downloadable (free and copy-left) in digital and paper version from www.lenses.polimi.it.



[Figure 18] S.PSS&DRE Estimator of Distributed Renewable Energy load/need and production potential, the tool



[Figure 19] Students using the S.PSS&DRE Estimator of Distributed Renewable Energy load/need and production potential

4. FINDINGS

The projects activities have validated the research hypothesis that S.PSS applied to DRE is a promising approach to diffuse sustainable energy in low/middle income contests (for All). This has resulted throughout a literature review and case studies conducted by various partners, available in the (case study section). It has also been tested and validated by students and companies in curricular course and lifelong modules also collected in the same OPLEP. There are there main reasons for this: selling the access rather than DRE hardware ownership reduces or even avoids initial investment costs of DRE hardware; reduces or avoids running cost for maintenance, repair, upgrade, etc. also too high for low and middle-income people; leads to involvement of local rather than global stakeholders, increasing local employment and skills, i.e. local empowerment.

The research hypothesis has been characterized as follows: "A S.PSS applied to DRE is a promising approach to diffuse sustainable energy in low/middle-income contexts (for all), because it reduces/cuts both the initial (capital) cost of DRE hardware purchasing (that may be unaffordable) and the running cost for maintenance, repair, upgrade, etc. of such a DRE hardware (that may cause the interruption of use), while increasing local employment and related skills, resulting in a key leverage for a sustainable development process aiming at democratizing the access to resources, goods and services."

As a consequence arose a new knowledge-base and know-how on the role of the design in this framework, i.e. the emergence of a new discipline "system design for sustainable energy for all" highlighting a new role in (system) design for sustainable energy for all from "appropriate technologies" design to "appropriate stakeholder" design addressed to S.PSS allied to DRE. This discipline can be defined as "the design of a Distributed Renewable Energy system of products and services, able to fulfil the demand of sustainable energy of low and middle-income people (all) - possibly including the supply of the Energy Using Products/Equipment system - based on the design of the innovative interactions of the stakeholders, where the economic and competitive interest of the providers, continuously seeks after both socio-ethically and environmentally beneficial new solutions".

5. PRACTICAL IMPLICATIONS

The project has stimulated and increased the inter-institutional networking between HEIs in the African and with European HEIs not only related to educational contents but also to other academic issues such as collaborative research and administrative capacity building. Staff representatives of the different universities have worked together in the implementation of the pilot courses and have taken advantage of opportunities for 'virtual staff mobility' cooperating with other educational practitioners and/or experts online through the OLEP. Different in-depth classes has been prepared according to renewals energy local opportunities as for example wind exploitation in South Africa.
Local companies, consultancies, NGO's, public institutions were directly involved in the design and implementation of curricular courses, assuring that all the relevant and specific needs are addressed. Technologies applied in the different S.PSS depend from the peculiarities of the economic regions as for example PV Panels in Botswana and further innovation can be proposed taking advantage of the knowhow of the partners as for example emerging PV film printing under study at Poltecnico di Milano.
Through the OLEP geographic location is no longer a barrier to access to state-of-the-art research results and teaching materials. The matter of access to knowledge becomes even more crucial in a research field like Design for Sustainability and Sustainable Energy for All, characterized by being quite recent and therefore not extensively disseminated as well as rapidly developing (Vezzoli & Ceschin, 2011). Teaching materials prepared by partner institutions on fundamental disciplines (i.e. Physical principles, business tools…) and for similar educational and societal contexts enable teachers to speed up the process of developing new courses which enabled them to spend more time on implementation (teaching) than preparation (course development). Re-use of work of knowledge is encouraged and new ideas can evolve (Baranuik et al. 2004).
The OLEP platform provided students access to not only the educational materials of their own HEIs but also many others. This enabled them to acquire knowledge independently from outside, as well as being taught about the latest developments in Design for Sustainability (DfS) applied to S.PSS and DRE and get insights and inspiration of (real life) projects of other student teams which are localised and contextualised to the African setting. These new open knowledge supports a transformation of mind models in new generations from a product design approach to a product service system approach.

6. ORIGINALITY/VALUE

The innovation of the project described in the paper is twofold: firstly by developing unique curricula based on design for sustainability focused on S.PSS and DRE applied to the African contexts, and secondly by delivering it through an open platform free and in copy-left. This will equip design students in African universities with a broad knowledge base, as well as effective methods and tools with which to play an active role in the development and diffusion of sustainable energy systems.
The role of design in this context, as well as regarding other environmental problems, is to drive the application of technologies. In fact, according to Maldonado (1992) "innovative practice should take place not as a series of disconnected events, but as a process that incorporates continual controls of such events once they take place, such that the effects, predictable or otherwise, created by technological innovation on the physical, economic and social environment can be kept in check".

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