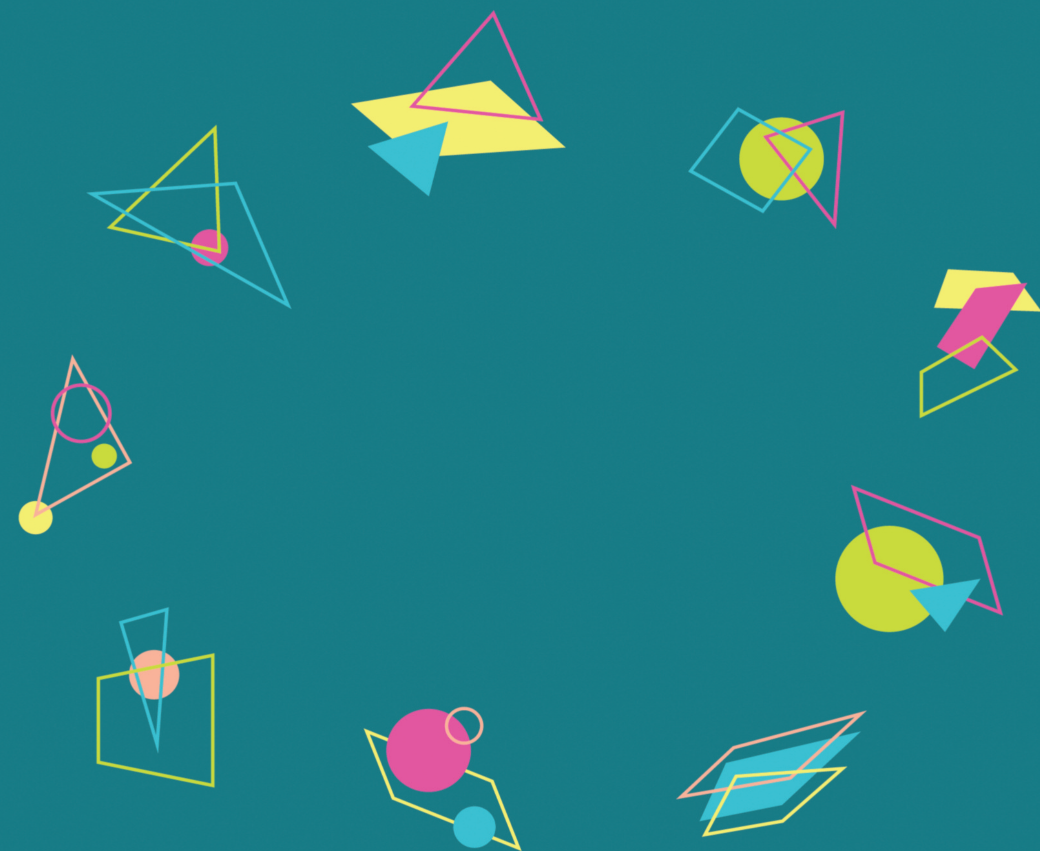
POLIMI DESIGN PHD_018

9 PhD theses on Design as we do in POLIMI

edited by Alessandro Biamonti, Luca Guerrini and Ilaria Mariani



D.I. FrancoAngeli
DESIGN INTERNATIONAL

The book is an overview on the wide field of research about Design, showing how Design is interpreted nowadays in POLIMI.

Being one of the younger member of this family, Design is often disruptive and unruly, working between intuition and method. Ranging from design culture and humanities, to innovation in its broad sense and contemporary applications, the book extends across interdisciplinary fields, exploring tangible and intangible aspects of our everyday life. This to show how design is today an on-going young discipline, which is reaching its own spaces and methods within the academic research community.

Nine PhD theses. Nine young researchers. Nine 3-4 years researches carried on by people mainly under 35 years old, coming from all over the world. An international, young, dynamic community, which is approaching complexity of Design from several sides, but with the same passion for building a better world.

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FrancoAngeli
La passione per le conoscenze

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Towards Sustainable Energy for All. Designing Sustainable Product-Service System Applied to Distributed Renewable Energy

Elisa Bacchetti

Nowadays, there is a consolidated understanding that "Sustainable development is not possible without Sustainable Energy for All" (UN, 2011). Within this framework, the Distributed Renewable Energy (DRE) concept is recognized as a promising one to achieve this aim, bringing Sustainable Energy to All. This research fits into this framework, as it aims to validate and characterize the promising model of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) as a win-win solution to spread sustainable energy access to All, within low- and middle-income (all) contexts. Moreover, this research aims to equip designers with a knowledge base and know-how to deal with such model and towards Sustainable Energy for All. This chapter presents the results achieved by this research, especially the contribution made in terms of practical know-how for designers. A design activity conducted by the researcher in Africa with energy professionals, using the developed design approach and tools, is introduced. Finally, future opportunities based on the research are presented.

The challenge of energy

From the first days of mankind energy has been contributing to human progress: empowering daily life and income generating-activities, thus fostering socio-economic development (UN, 2011; Colombo *et al.*, 2013).

Nowadays, the non-renewable and centralized energy approach is the most widespread (Rifkin, 2011; Komor and Molnar, 2015), but it is far from bringing the needed sustainable energy access to All[1].

[1] All refers to: everyone, both a single entity, company, community or people, for whom economic difficulties limit access to sustainable energy, and which can be found both in emerging and industrialized countries.

This unsustainability comes, from an environmental point of view, as the use of non-renewable (or exhaustible) resources such as oil, coal and gas, is speeding up the depletion of resources and is damaging the environment, introducing high emissions into the eco-system. From a socio-ethical perspective, the use of non-renewable (or exhaustible) resources (often) deprives natural resources from local communities, e.g. local water and land are used by the energy plants. Furthermore, as centralized plants are not cost-effective in connecting a limited number of low-purchasing power utilities, this leaves small communities outside energy access. Finally, from an economic point of view, as a complex planning and monitoring of such plants is required, this implies high costs for their setup and management.

Given the unsustainability of the current situation, several authors dealing with sustainable development (Johansson *et al.*, 2002; Rifkin, 2011; UN, 2011; Hunt, 2012; Barbero and Pereno, 2013; Colombo *et al.*, 2013; Klein, 2014; Vezzoli *et al.*, 2015; IRENA, 2016) agreed on a necessary paradigm shift in the energy sector: to move from the current centralized generation based on non-renewable (exhaustible) resources, to a distributed one based on renewable energy.

Distributed Renewable Energy (DRE)

Distributed Renewable Energy (DRE) is a concept based on local renewable energy resources (and technologies) such as sun, wind, water, geothermal and biomass energy, and is configured as small-productive plant that produces energy at or near the point of use, where the consumer can be the producer (LeNSes project, 2017). DRE can thus benefit the environment as it uses local renewable resources for which the (socio-ethical and environmental) impact is negligible compared to the one of exhaustible resources (Komor and Molnar, 2015). From a socio-ethical viewpoint, DRE allows individuals, local communities and even small businesses to access renewable and reliable energy. Indeed, DRE plants are cost-effective even with a limited number of utilities or just one, thus fostering equity in the redistribution of access to energy (Alanne and Saari, 2006). Finally, DRE as locally based production/consumption system favors the development of local skills, e.g. local management and technical assistance are required, thus favoring local employment opportunities.

DRE limitations

Despite the assessed DRE potential, limitations are still affecting its diffusion. First, DRE systems are usually sold, e.g. the customer purchases solar panels with wires, inverter, storage. This implies that the initial investment costs to buy the DRE system, is covered by the customer for whom, especially within low and middle-income contexts[2], is (often) not affordable. This limitation can also affect the purchase of Energy Using Products e.g. lights or phone and Energy Using Equipment, e.g. sewing machine or drill that are needed to access energy. Second, life-cycle costs, e.g. operation and maintenance or repair of DRE system and/or Energy Using Products/Equipment are often a cause of drop-off, as they are too high or unexpected for the customer. Third, there may be a local lack of technical and commercial skill about DRE systems and/or Energy Using Products/Equipment, thus limiting long-term use of the products (ARE, 2011).

Sustainable Product-Service System (S.PSS): a promising model towards Sustainable Energy for All

To overcome the limitations of the DRE concept, several authors agreed that the adoption of the Sustainable Product-Service System (S.PSS) model is a win-win solution. The S.PSS model has been studied in industrialized countries from the 90's, and more recently as an opportunity for low and middle-income contexts, as «an offer model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a "unit of satisfaction"), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the provider continuously seeks environmentally beneficial new solutions» (Vezzoli *et al.*, 2014).

Indeed, the S.PSS model moves from the "business as usual", as it is not the traditional sale of products, to the offer for products and services combined, to achieve a demand for satisfaction ("satisfaction unit") from the customer, i.e. access to energy. For example, when a S.PSS is adopted, to satisfy access to energy, it is not necessary that a customer buys a DRE system (e.g. solar home system), as the access can in fact be achieved through different configurations of products and services combined.

[2] Low and middle-income context, it refers to an economic condition that can be found both in emerging and industrialized countries, so it is not related to a geographical perspective.

A case study where the Sustainable Product-Service System (S.PSS) model is applied to a Distributed Renewable Energy (DRE) solution is presented below.

Sunlabob[3] *company leases a charging station with a solar system and with Energy Using Products (EUP - e.g. solar lanterns) to an established village committee who rents the lanterns to the individual households. Sunlabob retains ownership and maintenance responsibilities over the charging station and EUP, and offers training services. The committee is responsible for setting prices, collecting rents and performing basic maintenance. To use the charging station, the committee pays a rental of around 1.70 euro per month. Customers rent the recharged lanterns for 0.50 euro that cover around 15 hours of light.*

From the customer's perspective, the energy solution can bring affordable access to sustainable energy, to benefit daily life activities and, if need be, to increase the reliability of working activities. This configuration can be beneficial both for the local committee, who can activate a local business at reduced risk and no initial investment cost, as well as for Sunlabob, that can expand its market - to those who are not able to buy a DRE system or to pay it in one instalment. As Sunlabob provides maintenance and repair, it has an interest to provide a DRE system and lanterns of high quality, thus reducing their life-cycle costs. At environmental level, this can result in a reduced impact, i.e. limited need of spare parts with related pre-production, production, transportation.

To clarify the matter further, the following characteristics point out why the adoption of S.PSS to provide DRE solutions (S.PSS applied to DRE) is an opportunity, especially for low and middle-income contexts:

- focuses on (energy) access rather than DRE system ownership: it avoids the initial investment cost for the end customer/local business to buy the DRE system and eventually the Energy Using Products/Equipment (EUP – EUE);
- sells the "unit of satisfaction" (e.g. energy access) rather than the DRE system: it avoids (unexpected) life-cycle costs for operation & maintenance or repair on the DRE system (and/or Energy Using Product/Equipment), thus reducing the risk of drop off;
- focuses on the context of use: it leads to (competent) local stakeholder involvement (and thus empowerment), rising (local) employment and

[3] More info can be found in the case study profile at www.lenses.polimi.it, in the "case studies" section, or directly at the website www.sunlabob.com.

empowerment, and the diffusion of skills, reducing the dependency syndrome (Maathai, 2009) especially in low and middle-income contexts.

Therefore, S.PSS applied to DRE appears as a promising strategy to speed up diffusion and guarantee the long-term use of DRE solutions within low and middle-income (all) contexts.

A new framework towards Sustainable Energy for All

As introduced above, the adoption of a S.PSS applied to DRE model, changes the rules of "business as usual", aiming to deliver a customer (energy) satisfaction through a mix of products and services combined (and not by selling a DRE product).

This focus on (energy) satisfaction, and "satisfaction unit", increases flexibility of the offer configuration. In fact, when S.PSS is applied to DRE a new framework towards Sustainable Energy for All can be outlined. Below, an introduction to the framework is given.

Among different options, a S.PSS applied to DRE solution can be configured as a business to customer (B2C) offer, to empower daily life activities through access to a DRE solution. In this case, the adoption of a S.PSS model allows the offer provider to own the DRE system (e.g. solar panel, wires, storage), while the end customer makes periodic payments, e.g. pay-per-time, to access her/his (energy) satisfaction. For the customer, this means neither an initial investment cost of the DRE system (e.g. the purchase of solar panel, wires, storage and their installation) nor unexpected life-cycle costs (e.g. operation & maintenance), thus making access to energy economically viable even in low-middle income (all) contexts. For the provider, this increases the opportunities to expand her/his market to those who are not able to buy a DRE system or to pay it in one instalment.

To add more value to this option, the same offer can also provide the Energy Using Products/Equipment (EUP - EUE) (e.g. lantern is a EUP, drill is a EUE) with a S.PSS logic, such as giving access to them, instead of their ownership. In this case, the customer pays to access her/his (energy) satisfaction given through the EUP/EUE as a pay x use, e.g. one shot, as per his/her need, thus avoiding fixed costs that might not affordable. This "one-shot use" option allows the provider to lease the DRE system and EUP/E to more customers, thus increasing her/his margins.

As alternative option, to favor even local entrepreneurs/small businesses, a S.PSS applied to DRE solution can be configured as a business to business

(B2B) solution. The DRE system is owned by the provider, while the local entrepreneur/small business (if needed) has only to purchase the necessary Energy Using Products/Equipment (e.g. solar lamps to be rented, sewing machine for a tailor shop). This option gives stable access to energy, thus allowing local entrepreneurs/small businesses to start-up or empower their income-generating activities. In fact, with a stable energy access, they can guarantee the production/delivery of a predefined quantity of products (or services) within a given period, or they can ensure the continuity of their activities, or others, thus satisfying their clients and opening new market opportunities.

Even in this case, it is possible to complete the S.PSS applied to DRE solution for businesses, with the related Energy Using Product/Equipment (e.g. circular saw, drill) without necessarily owning them, but adopting a S.PSS logic. This option avoids the initial investment costs for both the DRE system and the EUP/EUE and their life-cycle costs, thus benefiting local entrepreneurs/small businesses and consequently the offer provider, who has an economic interest in retaining a longer relationship with the local entrepreneur/small business who can guarantee a fixed return.

Fig. 1 - Representation of the framework towards Sustainable Energy for All.

Fig. 1 shows a graphic representation of the presented framework towards Sustainable Energy for All. The narrations in the four quadrants represents the presented options that can be achieved through S.PSS applied to DRE solutions and that can open the way to combined options according to the specific case.

In fact, it is possible to design countless combinations of products and services to satisfy a specific demand for (energy) satisfaction, depending on the type of customer (B2C or B2B), the type of offer (DRE system or DRE system + Energy Using Products/Equipment), as well as on the specific context and the related skills available. The presented framework was translated into a Scenario tool, to be used to give inspiration in designing local solutions of S.PSS applied to DRE (more in the next paragraphs).

Designing Sustainable Product-Service System applied to Distributed Renewable Energy

Given the complexity of S.PSS applied to DRE solutions, a design knowledge base and know-how have been perceived as a need to support the designers, in the design of new solutions where the S.PSS applied to DRE model is adopted.

At practical level, this resulted in the definition of the System Design for Sustainable Energy for All (SD4SEA) approach, which entails designers moving from an appropriate technological approach, often applied in interventions at the Bottom of the Pyramid (BoP)[4], to an approach aimed to design appropriate interactions among actors (system-perspective).

The proposed approach can be summarized as the combination of the following approaches:

- Satisfaction-system: this approach entails the design of the satisfaction ("satisfaction unit"), in this case, to achieve access to energy and related products and services, thus moving the focus from mere product selling to a complex system;
- Stakeholder configuration: this approach entails designing stakeholder interaction related to the particular "satisfaction unit". In this case, this means that all stakeholders in the life-cycle of a product-service need to be considered/involved in the design process;
- System sustainability: this approach entails designing the sustainability of stakeholder' interactions, considering mutual economic, socio-ethical and environmental benefits, as a way of achieving sustainable DRE solutions.

[4] Bottom of the Pyramid (BoP) is the four billion people who live on less than say $3,000 per year (Shah, Anup., 2016).

Additionally, since a product, e.g. DRE system, is always included in the S.PSS applied to DRE solution, the designer, even if working at system-level, needs to have specific skills to propose sustainable products for the system, thus increasing the sustainability of the whole system. To give an example, current all-inclusive offers for smartphones, where the smartphone is changed often with no possibilities for upgrade or repair, cannot be considered a sustainable solution, due to the high impact of the product itself.

To support the designer in the adoption of this approach and to design towards Sustainable Energy for All, several learning resources including slides, video-lectures, case studies and design tools, were designed within this research and the LeNSes project, and are available for free and copy-left at www.lenses.polimi.it, so that everyone can easily access, download, reuse and remix them, aiming to speed up the diffusion of System Design for Sustainable Energy for All.

System Design for Sustainable Energy for All (SD4SEA) tools

The developed tools are aimed to design, visualize and evaluate S.PSS applied to DRE solutions. A peculiarity of all tools is their ability to be co-design tools, aimed at facilitating collaboration between the designer and the client or community. Below, the tools designed by the Author and the Design and system Innovation for Sustainability research group of Politecnico di Milano are briefly presented. To test and improve them, they were prototyped in collaboration with partner universities of the LeNSes project between Africa and Europe.

Innovation Diagram for S.PSS applied to DRE

It is a tool aimed to orient the design of new S.PSS applied to DRE concepts, and to analyze and re-orient existing energy solutions. The tool allows the positioning of existing energy solutions /new concepts within its polarity diagram to visualize and design the type of customer (B2C or B2B) and the type of offer (DRE system or DRE system + Energy Using Products/ Equipment) provided. Therefore, the tool also allows us to characterize both existing energy solutions /new concepts to understand the available/missing products and services that could be useful in the design of the new concept.

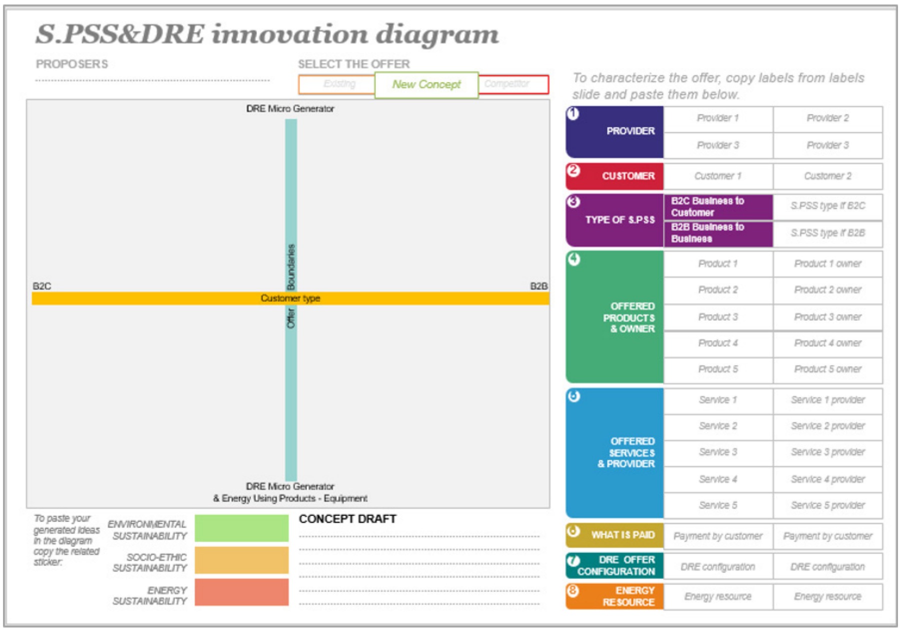

Fig. 2 - Innovation Diagram for S.PSS applied to DRE.

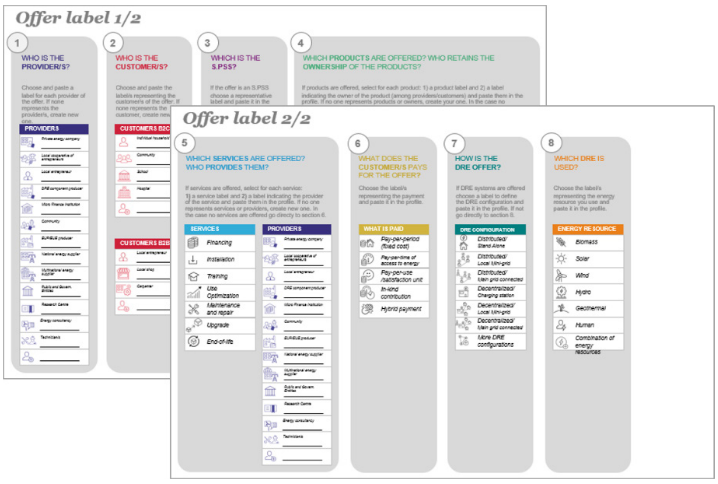

Fig. 3 - Label to support the Innovation Diagram for S.PSS applied to DRE.

Sustainability Design Orienting Scenario for S.PSS applied to DRE

It aims to inspire designers and stakeholders to design towards S.PSS applied to DRE solutions, and to facilitate creative processes and strategic conversations among potential actors of the energy solution[5]. The tool presents four visions of S.PSS applied to DRE solutions narrated as interactive videos accessible through a navigator file.

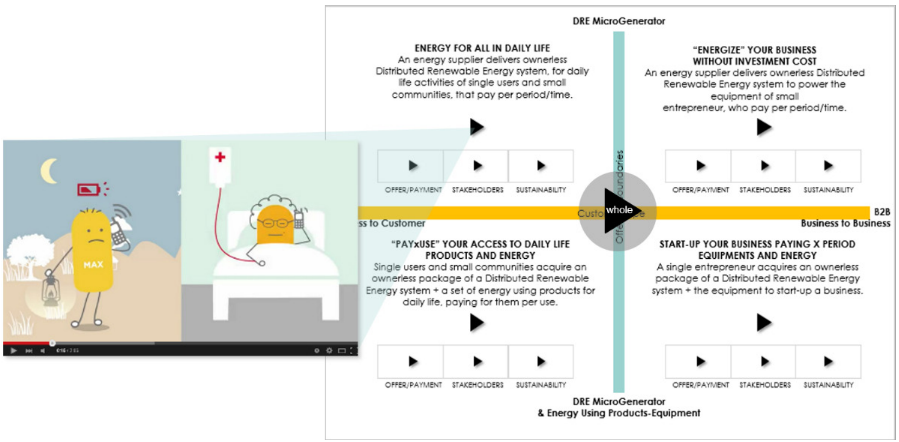

Fig. 4 - Sustainability Design Orienting Scenario for S.PSS applied to DRE.

Sustainable Energy for All Idea tables and Sheets, structured on the SDO toolkit[6], aims to support the idea generation phase towards S.PSS applied to DRE solutions. It is based on six tables with guidelines which are connected to the fifteen case study data sheets to be used as examples during the generation of system ideas.

[5] The tool is an adaptation of the original version of the Scenario, that was presented by Manzini, Jégou and Meroni, in 2009.

[6] The SDO Toolikt was adapted to the new criteria and guidelines for sustainable energy for All. The SDO toolkit was developed by Carlo Vezzoli and Ursula Tischner within the MEPSS EU 5th FP, Growth project.

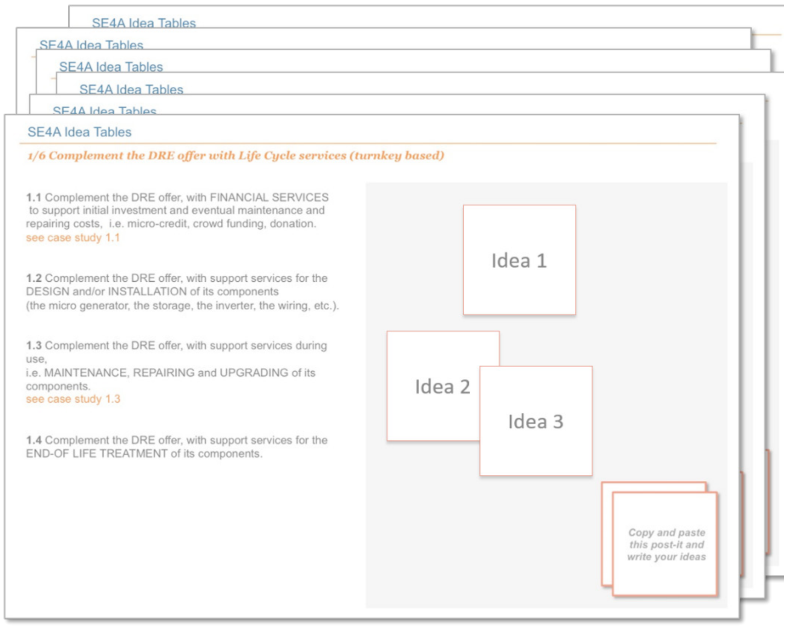

Fig. 5 - Sustainable Energy for All Idea tables.

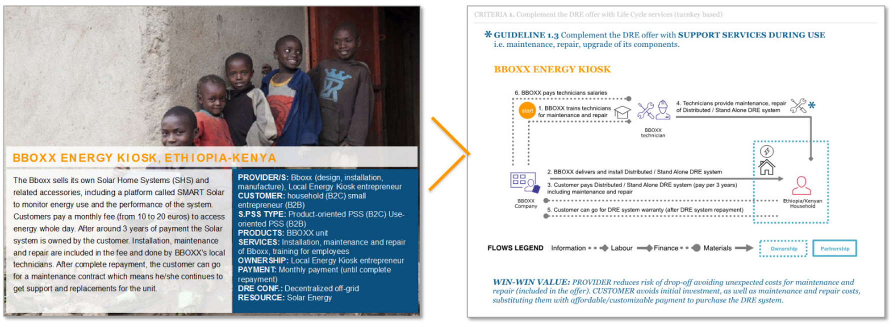

Fig. 6 - Sheets (with case studies) to support the Sustainable Energy for All Idea tables.

Concept Description form for S.PSS applied to DRE

It aims to support the visualization of S.PSS applied to DRE concepts. The Concept Description form is made of a worksheet with key information about the S.PSS applied to the DRE concept, facilitating a deep understanding of the concept itself, while presenting it to (existing - potential) stakeholders.

Fig. 7 - Concept Description form for S.PSS applied to DRE.

Stakeholders Sustainability and Motivation Table

It is a visualization tool aimed to identify and to show: motivations and contributions by each stakeholder of the energy system; sustainable (economic, environmental, socio-ethical) benefits from each stakeholder for being part of the same system[7]. The tool facilitates the involvement process and strategic conversations among (existing and potential) stakeholders.

The complete list of tools and related presentations to use them, are available for free and copy-left at www.lenses.polimi.it.

[7] The tool is an adaptation of the Motivation Matrix, presented by Jégou, Manzini and Meroni, in 2004.

Stakeholders' Motivation and Sustainability Table

Actors *Place below the icon of the actors and the name of the actor*	**Motivation** *Write the motivation of each stakeholder for being part of the system*	**Contribution to the partnership** *Write the contribution that each actor gives to the offer/system/ platform /partnership*	**Environmental Benefits** *Read the criteria in the next slides to describe the potential environmental benefits (given by each actor)*	**Socio-ethical Benefits** *Read the criteria in the next slides to describe the potential socio-ethical benefits (given by each actor)*	**Economic Benefits** *Write the economic benefit that each actor can get from being part of the system*
Insert actor name	···· ····	···· ····	···· ····	···· ····	···· ····
Insert actor icon Insert actor name	···· ····	···· ····	···· ····	···· ····	···· ····
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Fig. 8 - Stakeholders Sustainability and Motivation Table.

Protoyping System Design for Sustainable Energy for All (SD4SEA)

Several prototyping tests of the System Design for Sustainable Energy for All (SD4SEA) approach and tools were conducted during the LeNSes project. The one presented below was conducted by the Centre for Research in Energy and Energy Conservation (CREEC) of the Makerere University (Uganda) and the Politecnico di Milano (Italy) (the Author was part of the board), through a vocational course for nine Small and Medium Enterprises (SMEs) for energy, such as biogas, sun, hydropower and cook-stove technologies from Uganda.

The course duration was 3 days, plus a final half-day of plenary presentations. Attention was given to define new concepts of S.PSS applied to DRE, and to communicate them to external audiences, e.g. involving new stakeholders or requiring permission from local administrations. The SMEs representatives were asked to work in groups of 3-4 practitioners and to design innovative S.PSS applied to DRE concepts for their own businesses.

The first activity used the Innovation Diagram for S.PSS&DRE tool, aiming to understand the business of each SME. It was highlighted that most of the SMEs were selling products with a "business as usual" approach. Therefore, the Sustainability Design Orienting Scenario (SDOS) tool was used to give inspirations to participants to move out from that approach towards new DRE solutions. The participants were then asked to generate system ideas guided by the Sustainable Energy for All Idea Tables tool. This activity (as the others of the prototyping) was done in collaboration with the members of the course staff as facilitators.

Fig. 9 - Participants generating ideas using the SE4All Idea tables and sheets.

The most promising system ideas among those generated were pasted and combined in the Innovation Diagram for S.PSS&DRE tool, allowing each group to generate a more detailed concept. To define the interactions as well as motivations/contributions/benefits of (potential) system actors, the Energy System Map tool[8] and the Stakeholders' Motivation and Sustainability Table

[8] The Energy System Map is a tool to visualize the network of stakeholders involved in energy systems (Emili *et al.*, 2016), and to show their interactions (in terms of material, financial and information flows). The tool is an adaptation/development of the Stakeholder System Map tool (Jégou *et al.*, 2004).

tool were used by all groups. For the final plenary presentation, each group presented its concept, built on the results of each tool e.g. description of the concept with information from the Innovation Diagram for S.PSS&DRE, etc.

In tangible terms, three concepts of S.PSS applied to DRE were developed by the participants, as potential innovations for their current businesses including opportunities for collaboration.

One of the concept designed was ***Community Biogas!*** *A business to customer (B2C) solution owned by the local energy supplier Renewable Energies Ltd (REL). REL owns a community bio-digester, and is responsible for installation, training, repair and maintenance on the plant. REL offers to final customers charged batteries for lanterns, as well as biogas stored in bags to facilitate cooking activities. To access the energy services (charging/biogas refill), the customers pay-per-use, so for every time the batteries are recharged or the biogas bags are refilled. REL owns the batteries and biogas bags, while the customers own the lights and the stoves. To gain extra-money and to support the function of the bio-digester, customers can provide bio-waste that will be paid by REL.*

After the end of the vocational course, the participants had the opportunity to continue working on their concepts with the support of the Centre for Research in Energy and Energy Conservation (CREEC) of the Makerere University (Uganda), thus extending their opportunities for collaboration and implementation.

Conclusions

One of the main contributions of this research, is the definition of a promising framework of intervention for Sustainable Product-Service System Design, within the path towards Sustainable Energy for All (through the Distributed Renewable Energy concept). Indeed, the S.PSS applied to DRE model can support the development of win-win solutions, thus increasing the speed of energy access both at B2C and B2B level and contributing as enabler towards sustainable development.

A further contribution from this research, is related to the System Design for Sustainable Energy for All (SD4SEA) knowledge-base and know-how developed. In fact, they can support designers (and other actors dealing with energy) to design concepts of S.PSS applied to DRE, and to contribute towards Sustainable Energy for All. It is in this direction that the choice of making all learning resources, such as slides, video-lectures, case studies and tools available for free and copy-left (www.lenses.polimi.it) is moving, so that everyone can easily access, download, reuse and remix them, speeding up the diffusion of System Design for Sustainable Energy for All.

These outcomes are contributing in the current debate towards Sustainable Energy for All, within the higher education community dealing with sustainable development. In fact, a recently EU funded project, the international Learning Network on Sustainability – LeNSin project (www.lens-international.org) collaborating with 36 universities worldwide, is continuing this path on S.PSS applied to DRE, further extending S.PSS model adoption to other types of Distributed Economies (DE)[9]. Finally, the partners of the LeNSes project are still working on the energy challenge, thus contributing to the necessary paradigm shift to move towards a sustainable energy and sustainable development for All.

Aknowledgment

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[9] Distributed Economies (DE) are designed as small-scale, decentralized, flexible units that relate to each other, and make use of local resources, e.g. renewable energy, local food, and so on (IIIEE, 2009; Johansson *et al.*, 2005).

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