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Towards sustainable energy for All

Designing Sustainable Product-Service System applied to Distributed Renewable Energy.

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Summary

From the first days of mankind, from human-power to mechanical-power, energy has been enabling human progress: increasing life quality, supporting income generating activities, thus fostering socio-economic development. So forth, access to sustainable energy is recognized as one of the main drivers towards sustainable development.

Nowadays, the centralized and non-renewable energy approach is the most diffused, but it is far from leading the way towards sustainable energy access to All[1]. From the environmental point of view, the use of non-renewable (or exhaustible) resources is: fastening the depletion of the resources themselves; damaging the environment through the processes of extraction and transformation of resources (as these processes have high damaging emissions on the eco-system). On the socio-ethical perspective, the extraction of exhaustible resources, is (often) depriving local communities of natural resources e.g. water and land used for the extraction plants, without giving them benefits. Furthermore, as centralized systems are not cost-effective to connect a reduced number of utilities or low-purchasing power utilities, this leaves them outside the covered utilities. Finally, from the economic point of view, due to the dimension of the plants, the losses in transmission and distribution, and the progressive depletion of available resources, a complex planning and monitoring is required, which increases life-cycle costs and risks to setup and manage such big plants. Due to the unsustainability of the current situation, several authors dealing with sustainable development agreed that a paradigm shift in the energy sector is needed: to move from the current centralized generation, based on non-renewable (exhaustible) resources, to a distributed generation based on renewable energies, i.e. Distributed Renewable Energies (DRE), as they could be a key opportunity for a more equal distribution of resources and the democratization of access to sustainable energy for All. **(Chapter 1 – Towards sustainable energy for All)**

Distributed Renewable Energy (DRE), is a concept based on the use of local renewable resources (and technologies), and is configured as small-productive plants, that produce energy at or near the point of use, where the users can be the producers. A DRE approach, can benefit the environment because it uses local renewable resources which are "almost ready" resources e.g. solar radiation is directly

[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.

providing energy to solar cells generators, so the (socio-ethical and environmental) impact of extraction and transformation is negligible compared to the one of exhaustible resources. Moreover, DRE uses the energy at/near the point of production, thus distribution & transmission costs are reduced or avoided. On the socio-ethical stand point, DRE allows individuals and local communities to access renewable and reliable energy. Indeed, due to the small dimension of DRE plants, they can be setup for a small number of utilities or one, thus increasing equity in the redistribution of resources and democratizing access to energy. Finally, DRE as distributed production system, needs to build up local competences (e.g. for management and technical assistance, thus creating employment opportunities. Despite DRE potential has been assessed, limits still affect its diffusion. First, the initial investment costs to buy the DRE micro-generator and related components e.g. solar panel, wires, inverter, is (often) not affordable, especially in low and middle-income contexts. This limit could affect also the initial investment cost to buy Energy Using Products (EUE) and Equipment (EUE) e.g. lights or phone are Energy Using Products, a sewing machine is an Equipment. Second, life-cycle costs e.g. maintenance and repair of the (DRE) micro-generator and related components, or Energy Using Products and Energy Using Equipment, are often cause of drop-off, as they are too high or unexpected, thus becoming unaffordable for the customer. Third, there may be a lack in technical and commercial competences about DRE. **(Chapter 2 – Distributed Renewable Energy (DRE): key leverage towards sustainable development)**

To overcome the limits of the DRE concept, this research proposes the adoption of the Sustainable Product-Service System (S.PSS) model. It has been studied in industrialized contexts for more than 25 years, and more recently as an opportunity even for low and middle-income contexts, as it is defined 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 providers continuously seeks environmentally beneficial new solutions.*" (Vezzoli et al., 2014). In fact, S.PSS is not the sale of only products, but is the offer of products and services combined, to achieve a demand of satisfaction from the user. On this perspective, it can be the interest of the provider (owner of the products that delivers the satisfaction) to promote longer utilization of the involved products, through different strategies such as life extension, re-use, etc., this decreasing the need of producing new products as well as the related costs, and the consequent environmental impact of the solution. For example, to have access to energy, when a S.PSS is adopted, it is not necessary that a customer owns an energy production system (e.g. solar home system), as more configurations can be designed. **(Chapter 3 - Sustainable Product-Service System (S.PSS): a promising model to support Distributed Renewable Energy)**

To address the above proposal from the research, the following Research Questions were proposed:

RQ1. Is Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) a promising and relevant model for sustainable development?

a. what are the dynamics and the characteristics that facilitate development of S.PSS applied to DRE within low and middle-income (all) contexts?

RQ2. Can Sustainable Product-Service System Design have a role in the development of such model?

a. And if so, what kind of knowledge-base and know-how are needed by a designer?

b. From an operational point of view, what are the design approaches, the methods and the tools that can be used?

To summarize, the proposal of this research is to explore and characterize the win-win value of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE). Moreover, this research aims to equip the designers (and the actors dealing with S.PSS applied to DRE), with a proper knowledge-base and know-how to deal with such S.PSS applied to DRE model.

To answer the Research Questions, a design-based research approach, with three research-stages was applied **(Chapter 4 – Research Methodology)**. The *preliminary research stage*, was aimed to explore and characterize the adoption of S.PSS applied to DRE solutions in low and middle-income (all) contexts. **(Chapter 5 - Understanding Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE)**

The first stage of the research started with a literature review. The obtained results, contributed to build a stronger definition of the energy challenge (above), as well as to understand potential dynamics that makes the two models of S.PSS and DRE potentially win-win models in favor of sustainable energy for All.

In parallel with the literature review, a case study research was conducted. Fifteen case studies were selected for the research and investigated to verify “how” S.PSS applied to DRE solutions takes place, and if the adoption of S.PSS helped to overcome the *initial investment cost* and *life-cycle costs* of (DRE) micro-generator and related Energy Using Product (EUP) and Equipment (EUE) of DRE solutions i.e. Solar panel is a DRE micro-generator; a light is a EUP, a sewing machine is a EUE.

The case studies research, provided evidence that the adoption of the S.PSS applied to DRE model, if properly conceived and contextualized, can locate the *initial investment* cost, and (unexpected) *life-cycle costs* on the provider or product manufacturer (or their partnership), thus increasing affordability for the customer, and opening market opportunities for the provider/s. Moreover, as the S.PSS applied to DRE model, aims to deliver a customer (energy) satisfaction through a mix of products and services (and not by selling a DRE product), the setup of a *network of actors* e.g. energy supplier, product manufacturer, service provider, was required, thus to produce, manage and deliver such satisfaction, such as (potentially) involving local rather than global stakeholder and favoring local empowerment. These characteristics were explored both when the customers of a S.PSS applied to DRE is a Business to Customer and Business to Business solution; as well as when the offer is only the Distributed Renewable Energy (DRE) system e.g. solar panel with appliances, or DRE system plus Energy Using Products or Equipment.

To highlight and narrate the characteristics emerged from the case study research, a Sustainability Design Orienting Scenario (SDOS), was designed. The Scenario, based on four visions, depicted promising configurations of S.PSS applied to DRE, aimed to fulfil a demand of (energy) satisfaction, with low environmental impact, high socio-ethical quality and high economic and competitive value.

Based on the insights from literature review, case studies research, and the Sustainability Design Orienting Scenario, the conceptual framework of the research was developed.

The entry point of the conceptual framework was defined by the *(I) paradigm shift from non-renewable/centralized to distributed/renewable energy generation systems*, which brought to the assessment of the Distributed Renewable Energy (DRE) concept as win-win towards sustainable energy for All. Despite the assessed potentialities of the DRE concept, the second point of the conceptual framework, are *(II) three limits* of the concept: the initial investment cost to buy the DRE system, which is often not affordable for the customers (B2C – B2B), especially in low and middle-income contexts; the (unexpected) life-cycle costs for the DRE system e.g. operation & maintenance, or repair, often not accessible, increasing the risk of drop-off; the (potential) lack of local expertise - (manufacturing, management and technical assistance) for DRE systems. The last point of the conceptual framework of this research is the *(III) Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model* itself. Indeed, in the variety of its configurations, S.PSS applied to DRE allows to cut the *initial investment* costs and (unexpected) *life-cycle costs* of DRE micro-generator and (if any) Energy Using Product and Equipment for the customer, locating them on the provider, making access to energy more affordable even in low and middle-income contexts. Moreover, as S.PSS applied to DRE is based on a mix of products and services, it involves a *network of actors* e.g. energy supplier, product manufacturer, service provider, who produce, manage and deliver such (energy) satisfaction, thus favoring (local) empowerment, and going towards sustainable development.

The *prototyping and assessment stage*, was aimed at refining the role and attitudes for the designers to deal with S.PSS applied to DRE in low middle-income (all) contexts, and with design knowledge-base and know-how to support design practice. A design approach and related tools, were designed within this research (and the LeNSes[2] project), aimed to visualize, design (at concept level) and evaluate S.PSS applied to DRE solutions. The developed design approach and tools, followed an iterative path of prototyping, evaluation, redesign/refinement. **(Chapter 6 - Towards new knowledge and know-how)** So forth, they were adopted and evaluated during *five design-research activities* conducted by the researcher in Africa (Botswana and Uganda) and Europe (Italy). The first design-research activity was a design exercise for design students in Italy, followed by two vocational courses for practitioners in Africa (Botswana and Uganda), and two workshops for practitioners (Italy). The shared goal of such design-research activities, was the use the tools to design S.PSS applied to DRE concepts, varying in customers and contexts for each experience. For the researcher, the aim was to present the model and design approach, and to test and evaluate the tools with students, energy practitioners, academics, and designers, to receive feedback and observations. The researcher was directly involved in all design-research activities, both to design, implement and observe all stages. This gave the researcher the opportunity to collaborate and interact with students and practitioners as well as with other academics and designers. **(Chapter 7 - Design-research activities)**

Addittionally, to support the practice, and to promote the adoption of the S.PSS applied to DRE model among professionals, researchers, academics and students, an

[2] *LeNSes – the Learning Network on Sustainable energy systems, represents the scientific context of this research, together with the LeNSin project, and the LeNS network.*

open course on System Design for sustainable energy for All, was developed. **(Chapter 8 – Supporting System Design for sustainable energy for All)**

The *reflection and assessment stage*, was aimed at retrospective analysis of the study, specifying main research findings and innovative aspects, as well as limits, generalizations and recommendations for future researches. **(Chapter 9 - Conclusions and further research directions)**

The research presented three *innovative aspects*. First, the two models of S.PSS and DRE are well known in the scientific community dealing with sustainable development. Anyhow, they have never been coupled or studied as a combined win-win strategy towards sustainable development. Thus, this research (within the LeNSes project) can be considered pioneer in this direction. Second, the research outlined the role the designers could have to deal with S.PSS applied to DRE solutions, which integrates to the current role of *(energy) products design* the *Product-Service System design*. So forth, the contribution from the design field can become more relevant and, if properly supported with knowledge-base and know-how, could increase both product and system sustainability of DRE solutions. Finally, a third innovative aspect of this research, is its open-knowledge ethos adopted by this research (shared with the LeNSes project), which enables that all contributions developed are available in open source and copy-left, so that everyone can easily access, download, reuse and remix them for her/his purposes. Speeding up the diffusion of the knowledge and know-how developed, favoring external contributions and updates on it, as well as fostering the design contribution in the path towards sustainable energy for All.

Two main *Research limits* were highlighted. The (energy) context, especially in emerging countries (where the research was mainly conducted) is in continuous evolution. Consequently, the findings and outcomes developed in this research are subject to the risk of obsolescence. To reduce the effects of the obsolescence process, the produced resources, tools, case studies and the open course, are available in open-source and copy-left, entailing to be continuously upgraded according to the local needs. A second limit was the need of customization of the same resources while working in different countries, and especially in the emerging ones. On one side, this brought to a higher customization of the knowledge-base and know-how for the specific case. On the other side, this was a limit for the sharing of the outcomes for mutual-learning worldwide.

Regarding the *generalization of the research results*, as most of the activities were conducted in Africa, the results could be tested and adapted in other countries, to verify similarities and differences. This is currently happening in China, within the LeNSin project (the researcher is involved). In a wider perspective, previous researches and EU funded projects on S.PSS, as well as the outcomes of this research and the LeNSes project, gave room to expect a potential role in the adoption of S.PSS, to other type of Distributed Economies (DE) e.g. Distributed Production (DP), Distributed Information (DI), Distributed manufacturing (DM), Distributed Software (DS), beyond Distributed Renewable Energy (DRE).

Next research directions can be oriented to three main directions. First, *refine the achieved results and define characteristics for other countries*. In fact, it could be valuable to make new design-research activities on sustainable energy for All, also to test, evaluate and refine the design approach and tools, as well as the *open course on System Design for sustainable energy for All*. Furthermore, as for now the design process is aimed to design S.PSS applied to DRE concepts, a valuable improvement could be to extend the intervention to support the design of the implementation paths for S.PSS applied to DRE solutions. Second, *Explore the results of the research in new fields;* one hypothesis could be to explore S.PSS to support different Distributed Economies (DE). The LeNSin project is already working in this direction (the researcher is involved). A second option, could be to open the field of intervention, as a strategy to satisfy (or prevent) the (energy related) needs in emergency situations such as, earthquakes, floods or migrations. The Solarkiosk AG company is already working in this direction (the researcher is involved), in partnership with the United Nations. Finally, verify the *Implications of this research in the fields of S.PSS and DRE education*. Within the academic field, the potential contribution of S.PSS and DRE in teaching activities has been assessed. Anyhow, as open-process of collaborative knowledge, video recorded lectures, slides, tools and case studies developed are expected to evolve on time both as contents and modalities. Further research, tests and verification will be needed in this perspective.

To conclude, the contribution of this research is the definition of a new framework of intervention for Product-Service System Design for Sustainability, within the path towards sustainable energy for All. The first step was the exploration and characterization of the S.PSS applied to DRE model, as promising solution towards sustainable energy for All, and enabler for sustainable development. To work on it, the knowledge-base for the designer was defined and elaborated. To support designers in practice a design approach, design process and related tools were developed. Finally, an open course on System Design for sustainable energy for All, was designed. Coherently with the ethos of this research, all contents are available in open source and copy-left.

List of frequently used abbreviations

DRE - Distributed Renewable Energy
PSS - Product-Service System
S.PSS - Sustainable Product-Service System
S.PSS applied to DRE - Sustainable Product-Service System applied to Distributed Renewable Energy
S.PSS & DRE - Sustainable Product-Service System applied to Distributed Renewable Energy
SE4A - Sustainable Energy for All
SD4SEA – System Design for Sustainable Energy for All
SDGs - Sustainable Development Goals
T&D - transmission and distribution
SMEs – Small and Medium Enterprises
MSDS – Method for System Design for Sustainability
LeNSes - the Learning Network on Sustainable energy systems
LeNSin - the international Learning Network on Sustainability
LeNS - the Learning Network on Sustainability

Part I - Towards sustainable energy for All

Chapter 1 – Introduction

The chapter describes the challenge towards sustainable energy for All addressed by this research. It introduces the need of a systemic-approach, and claims that Sustainable Product-Service System applied to Distributed Renewable Energies (S.PSS applied to DRE) represent a possible model to support the energy for All transition. Then, the chapter illustrates the goal of the research of validating and characterizing the model, as well as defining how System Design can deal with it. After, the LeNSes project (the Learning Network on Sustainable energy system – EU funded, 2013-16) as scientific context in which the research is developed is presented. Finally, the chapter describes the audience which could be interested in this research and the thesis outline.

1.1 Towards sustainable energy for All

To introduce the concept of sustainable energy for All, and the needed path towards it, an overview on sustainable development is firstly given, as wider environment where energy is rooted.

During past decades, the concept of sustainable development, has been discussed within scientific communities, and has evolved through different definitions. The term refers to an environmental, socio-ethical and economic development which takes place (Vezzoli et al., 2014):

- *within the limits of environmental resilience, i.e. within environment capacity to absorb the effects of human impact without causing any irreversible damage;*
- *based on equal redistribution of resources where everyone has the same rights to environmental space and the same access to global natural resources;*
- *without compromising the ability of future generations to meet their own needs, i.e. maintain the natural capital which will be passed on to future generations.*

Looking at these premises, it results evident that our current growth, with consumption and production patterns, is not in line with sustainable development. For example, every year by 2012, 1.6 Earths biocapacity[3] is needed to provide humanity with the natural resources and services that are consumed in the year (Global Footprint Network, 2016). This consumption brings us to: cut more trees than how many are mature, harvest more fish than the oceans reproduction capacity, or emit more carbon than forests and oceans can absorb (WWF International, 2016). The consequences are clear, and will bring the planet to the loss of habitat and species, and accumulation of carbon in the atmosphere, thus making it inhospitable to life.

Among other resources (e.g. water, food), energy is needed to achieve sustainable development, as qualifying factor for livelihood as well as for activities that can generate income both low and middle-income (all) contexts (Hunt et al., 2010 – Pachauri et al., 2012). So forth, its access is recognized as one of the main drivers towards sustainable development (UN, 2011-2012 – Ochs & Makhijani, 2012). Anyhow, current centralized and non-renewable energy approach is far from being able to take sustainable energy to All. In fact, most of the electricity is delivered through large centralized power plants, based mainly on exhaustible resources such as, coal, oil and gas. Thus, this has negative implications (UN, 2011), both at environmental level i.e. greenhouse gases emissions produced from the use of

[3] *Biocapacity refers to the biologically productive land and water surfaces required to supply the goods and services we use and then compares that with the area that exists (Living Planet Report 2016, WWF).*

exhaustible resources, are contributing to climate changes on the Earth running out of the resilience of the planet, and affecting survival perspectives; at socio-ethical level i.e. most untapped communities live in isolated areas, where the grid is not an option to achieve access to energy; at economic level i.e. exhaustible energies have high cost of extraction, transformation, use and transportation, resulting unsustainable solutions (more details in the next paragraph).

1.1.1 The two dimensions of the challenge towards sustainable energy for All

So forth, if we look at our energy production and consumption, both from the perspective of access to sustainable energy for All, as well as from the centralized use of resources, we need to recognize that we are not doing well. Let's see why.

Poor families worldwide, especially in developing countries, devote a significant part of their income to energy services (7-12 % Bacon et al., 2010 and up to 19 % Winkler et al., 2011), e.g. to buy candles and kerosene or to collect wood, but still cannot afford modern energy services (Hunt, 2012). Nowadays, 1.06 billion people, mainly from Sub-Saharan Africa, lack access to electricity (UN, 2017). This prevents the provision of health services, reliable household services such as lighting and cooking, as well as limiting access to mechanical power, transport and telecommunication services necessary to overcome subsistence. Nearly 80% of those without access to electricity, are in rural areas, and this defines a need for a further effort with appropriate energy access strategies and technical solutions (WEO, 2014). Aside the electricity issue, around 2.7 billion people, mostly in Asia and sub-Saharan Africa, use traditional biomass sources for cooking, without clean technologies (e.g. efficient cook-stoves), and this causes 4000 premature deaths everyday due to biomass fumes (Pachauri et al., 2012 - UN, 2014). Access to more efficient technologies for cooking could reduce health damages especially for women and children usually charged of household duties as drudgery for collecting fuel daily (Colombo et al., 2013). Furthermore, as the biomass burnt is often not sustainably harvested e.g. no replenishment actions are in place, this has the disadvantage of not being even CO_2 neutral, contributing to the causes of climate change (Pachauri et al., 2012). These conditions of no access to electricity and clean technologies, especially in low and middle-income contexts, are (among other reasons) due and reinforced by: lack of energy options, e.g. as the lack of grid connection, often not available due to infrastructure barriers and unsuitable policies (Yonavjak, 2013); limited purchasing-power of customers e.g. to buy stand-alone energy systems where the grid is not available, or while waiting for the grid to come; limited purchasing-power to pay unexpected damages to the energy system.

Regarding the second perspective, is notable that current electricity access worldwide is still predominantly large centralized power plants, that link end users via transmission and distribution (T&D) systems, and mainly rely on fossil fuel sources such as coal, oil and gas (Komor & Molnar, 2015). From the environmental point of view, the use of exhaustible resources, is fastening the depletion of the resources themselves, so forth being in contrast with the resilience principle of sustainable-development. Furthermore, the use of exhaustible resources, is damaging the environment through its processes of extraction, transformation, refinement and finally use. In fact, these processes deprive local resources, thus entailing irreversible damages to the local eco-system; as well as they have high emissions e.g. greenhouse gases, fastening climate changes. The centralized configuration, based on transmission and distribution (T&D) systems for the energy delivery, is estimated to have high transmission losses, due to obsolete connection plants. As an average, transmission losses are assumed to be the lowest for heavy industry (7% in 2010, expected 5% in 2020), medium for urban (17-30% in 2010, expected 13% in 2020), and the highest for rural areas (20-35% in 2010, expected 25% in 2020) (IRENA, 2015). On the socio-ethical perspective, as most untapped customers are from rural areas, a centralized system cannot be an appropriate approach, as it is currently inefficient due to high costs and transmission losses. Furthermore, the large dimension of the plants, together with the resources extraction, is depriving local communities of useful natural sources e.g. water and land, often without providing local benefits. From the economic point of view, due to the dimension of the plant an uncertainty of resources availability, is required a complex planning and monitoring, that could increase life-cycle costs and risks. Due to the unsustainability potential of a centralized and non-renewable system, it comes more evident the role hold by the energy sector. In fact, incumbent electricity providers, who base their economy on fossil fuel processes, are directly influencing government's decision in the matter of energy policies; as well, they still receive subsidies, that let exhaustible resources floating on the market, slowing down the competitiveness of renewable energies (Komor & Molnar, 2015 – Klein, 2014 – Szabó et al., 201 – Rifkin, 2011).

Despite the interconnection of the two challenges, this research will focus predominantly on favoring access to sustainable energy for All, through the distributed generation of renewable energy concept, towards sustainable development.

1.1.2 Evolution of approaches towards sustainable energy for All

After understanding the dimension of the access to energy challenge, an overview is given on current approaches to deal with it. However, as the energy challenge, has been excerpt from sustainable development only from 2011 (more below), the approaches presented below are more general for sustainable development, and references to their adoption for sustainable energy for All are given.

Due to the openness of the sustainable development concept, talking at the same time of priorities to meet the needs of the poor, protecting the environment and promote a more rapid economic growth, the approaches in use are various and act at different levels. From the donation of products/equipment alone, to international cooperation with government's involvement and strategies definition, to the development of participatory approaches for local empowerment. To simplify readability, three approaches are presented below, as separated views. However, sustainable development is a complex entity, where such approaches are sometimes overlapping. For example, participatory experiences on field, are (often) promoted through actions from the international cooperation for development.

In the last decades, the **donation of technological products** and equipment from industrialized countries in favor of emerging ones, raised as ready solutions to cover gaps in services (Howie et al., 2008). In fact, donations can be considered desirable, even necessary, and potentially well working solutions. However, in the real picture, several times they create an overflow of products and equipment, that locals are not able neither to use, repair and/or integrate in their economy, so forth remaining a continuous cycle of ineffective solutions to pressing needs. For example, estimations report that up to 50% of medical equipment in the developing world is unusable (WHO, 2000-2002), and this is predominantly due to lack of local technical expertise, unaffordability of life-cycle costs e.g. maintenance, or in some cases, the donated equipment are incompatible with the electric supply (if it's available and consistent) in the target country e.g. difference in voltage. Furthermore, has been observed that donations could be used to avoid disposal of old equipment; this increase the obsolescence of products and equipment, that are often landfilled in illegal dumps, increasing healthy problems caused from burning of the products/equipment, while decreasing safety conditions of the landfill area and surroundings. Only few projects have been developed to transform landfilled products and equipment in business opportunities as recycling of spare parts. Thus, it became clear that, donation to be successful cannot comprise only the product or equipment, but needs to include technology transfer in the meaning of know-how for expert personnel, information and training services and so on, this combined to a management and financial plan. Furthermore, donations should remain limited, to avoid the "dependency syndrome" that slows down any possibility of development (Maathai, 2009).

Donations happen similarly to promote sustainable energy for All, and for long time energy equipment and appliances were delivered to locals without plans for their use, repair, upgrade and landfill as well as without building local expertise. This resulted in the local introduction of new technologies but with services restrictions compared to the countries of origin. As an example, mobile phones are currently owned and used from almost everyone in Africa; at the same time, only 1/3 of the population has reliable and sustainable access to electricity to charge them (IEA, 2014).

The **international cooperation for development** started in the early 1960s when decolonization began and suddenly first partnerships, aimed at working together to eradicate poverty and to get integration into the world economy (EU, 2014) were settled with Africa, Asia, Latina America and European surroundings. On this purpose, international cooperation for development provides guidelines and targets for all countries, to adopt in accordance with their own priorities and the environmental challenges of the world at large. Anyhow, insights are not legally binding, so forth the efforts still depend on each government, that could correctly address priorities, being then reflected in market directions and competitiveness e.g. definition of renewable energy policies can influence the energy market (Szabó et al., 2013).

To set collaborations and partnerships, three approaches by the international cooperation for development were proposed (EU, 2014). The first, *budget support* which involves financial transfers to the national treasury of the partner country, combined with intense policy dialogue to create partnerships and set country development strategies. For example, the year 2000 saw the signature of the partnership between African, Caribbean and Pacific (ACP) countries and the European Union (EU). The second, *projects, grants and contracts* includes a series of actions within a given period, supported from a grant and under a specific agreement between project proposers and the EU. This research for example, fits within an EU funded project through the Edulink II ACP programme (more in the following section). The last, is *sector support* which refers to funding made available by the EU to target specific sectors such as energy, agriculture or education.

A key action of the international cooperation for development, during the United Nations Conference of Sustainable Development held in Rio de Janeiro in 2012, was the overcoming of the Millennium Development Goals (MDGs), with the launch of the Sustainable Development Goals (SDGs)[4], which are 17 objectives towards

[4] *The presentation on the SDGs can be found at* www.un.org/sustainabledevelopment.

sustainable development to be reached between 2015 and 2030. Among the others, SDG 7 focuses on universal energy access to "ensure access to affordable, reliable, sustainable and modern energy for all"[5]. This objective reinforced the debate and international commitment towards sustainable energy access for All, initiated the same year (2012) as the Year of Sustainable energy for All, and continued through the establishment of the Decade of Sustainable energy for All, from 2014 to 2024, which is achieving first results. How to ensure adequate support to actions on field, across the many partner countries over the course of the years (2015-2030), remains a key challenge for the Sustainable Development Goals (SDGs) and Sustainable energy for All (SE4A) initiatives. In fact, without proper follow-up and engagement, commitment makers would be left with little direction on how to contribute in tangible ways. To conclude, must be underlined that, often a problematic disjunction between the economic growth agenda and the social policy agenda can limit the (positive) impacts of the social side and still favoring economic interests, especially for international actors (Mah & Freitas, 2012).

More recently, the **bottom-up approach**, has been introduced in the actions towards sustainable development and towards sustainable energy for All (Practical Action, 2016) and in last decades a higher number of experiences adopting the approach in a participatory way have been developed. This type of inclusive approach, involves local actors in decision-making and strategy development, as well as to select priorities of local intervention, aiming at more narrowed solutions in relation to context and inhabitants (Maathai, 2009). The involvement of target groups (actors) aim to support capacity building, as knowledge and know-how on a specific area through acquisition, technology, and training (Maathai, 2009 - Miller Center for Social Entrepreneurship, 2015). Limit who prevents the adoption of this approach is the long-term needed, which is determined by the need to train the actors as future responsible of the solutions, thus this mindset discourages actions in this direction (Maathai, 2009 – Hunt, 2012 – Stevens, 2016). Therefore, the involvement of actors is often reduced to the analysis stage, but further steps need to be made for a more impacting participation. The small-dimension of the interventions could be seen both as an advantage and limit of the approach. In fact, to work on a specific context could increase the level of success, but it requires a big effort with a limited impact (in terms of dimension of the outcomes). Additionally, small scale needs from the agenda of public policy or innovators are often ignored (Gupta, 2012). Thus, reducing funding opportunities and slowing down the process. Furthermore, the

[5] *Info about the Sustainable Development Goal SGD7, related to energy can be found at https://sustainabledevelopment.un.org/sdg7*

limited experience with such approach, is not based on a defined structure or strong background, and this could reduce (for now) the impact of the outcomes.

Aside to the generally defined bottom-up approach, two bottom-up approaches are briefly introduced. A long time existing approach, is the so-called *Innovation for the poor by the poor* approach (Gupta 2012). It assumes that economically-poor people are or can be knowledge-rich people, who deserve to be listened and to act in the front line of sustainable development (Maathai, 2009 - Gupta, 2012). A more recent tendency, could be defined as *crowd-Design* approach, and connects creative problem solvers worldwide especially through the web, to jointly design local solutions as product or systems (Santos et al., 2015) for big challenges. For example, the openIDEO platform (www.openideo.com) is an online platform who connect people worldwide, to join challenges related to worldwide issues, such as food scarcity, water purification or other, aiming to crowd-design promising solutions to be translated in local prototypes and/or projects. Similarly, the Innonatives platform (www.innonatives.com) is an online platform aimed to crowd-design activities to design sustainable solutions, both as products and systems, to solve challenges directly proposed by the participants.

The three approaches illustrated in the paragraph, highlighted different perspectives as well as values and limits for each of them in working towards sustainable development and sustainable energy for All. As introduced, they should not be considered mutually exclusive, but rather their combination is saw as a more realistic interpretation of the panorama towards sustainable development. In fact, if the international cooperation for sustainable development has the risk to a reduced engagement from partner countries, the bottom-up approach can increase local commitment and success to the implementation of initiatives in tangible ways. On the other hand, to avoid displacing problems from one area to another by actions, problems are not local but global, so that actions and impacts should be considered internationally (Hopwood et al., 2005 - Wackernagel and Rees, 1996). Finally, interventions need to be planned on their entire life-cycle and with long-term vision to effectively guarantee reliable solutions towards sustainable development (Szabó et al., 2013).

1.2 Goals and Research Questions

Due to the relevance of the energy challenge worldwide, which affects predominantly low and middle-income contexts but requires worldwide attention to move towards sustainable development, this research aims to bring the design contribution in promoting the offer model of Sustainable Product-Service System (S.PSS) and Distributed Renewable Energy (DRE) as promising to tackle sustainable energy for All. First goal is to explore and characterize the model of S.PSS applied to DRE as win-win towards sustainable energy for All. Second goal, is to understand and develop the design role within the transition in terms of approach and related tools to inspire future designers/professionals/academics to play an active role in designing and diffusing S.PSS applied to DRE solutions, and thus fostering sustainable energy for All. Thus, answering to the following Research Questions:

RQ1. Is S.PSS applied to DRE a promising and relevant model for sustainable development?
a. what are the dynamics and characteristics that facilitate development of S.PSS applied to DRE within low and middle-income (all) contexts?

RQ2. Can Sustainable Product-Service System Design have a role in the development of such model?
a. And if so, what kind of knowledge-base and know-how are needed by a designer?
b. From an operational point of view, what are the design approaches, the methods and the tools that can be used?

The research methodology adopted to answer the RQs is presented in a dedicated chapter (see chapter 4.).

1.3 Scientific context of the research: the LeNSes project

This research was developed within the scientific context of the Learning Network on Sustainable energy system - LeNSes project (2013-16 – www.lenses.polimi.it) funded by the Edulink II, ACP-EU Co-operation programme in Higher Education (www.acp-hestr.eu), coordinated by Politecnico di Milano and where the researcher had a role in the research development and project management.

The LeNSes project fitted the Edulink II call dedicated to energy access and efficiency, dealing with the worldwide challenge of sustainable energy for All in the bigger picture of sustainable development. The aim of the LeNSes project was to contribute to curriculum and lifelong learning capacity development on sustainable energy for All, fostering a new generation of practitioners capable of extending the access to energy, based on the promising models of S.PSS and DRE, and addressing equity and gender issues. The LeNSes project involved 4 universities in Africa – University of Nairobi (Kenya), Makerere University (Uganda), University of

Botswana (Botswana) and Cape Peninsula University of Technology (South Africa) - and 3 universities in Europe – Politecnico di Milano (Italy - coordinator), TUDelft University (The Netherland) and Brunel University (United Kingdom) – targeting especially academics, researchers and students from Design and Engineering fields.

This scientific context of academics and researchers, was relevant to the researcher giving room for discussion with experts from the area of S.PSS and with experts and practitioners dealing with DRE especially in the African context.

Even though the project ended with the final conference "Sustainable energy for All by Design" hold in Cape Town in October 2016 (www.lensesconference.polimi.it), the LeNSes network as scientific community is still dealing with the topic, aiming at being a support base of knowledge and know-how for anyone working towards sustainable energy for All. The LeNSes network in fact, proposes a learning-by-sharing logic in which all contents from the website (e.g. slideshows, videos, courses) are available in open source and copy-left and all members can upload and share their own as well as to download, reuse and remix those available.

This research, is now under further development within the scientific context of the international Learning Network of networks on Sustainability - LeNSin project (2015-18 – www.lens-international.org) funded by the Erasmus+ programme for capacity building (www.ec.europa.eu), dealing with the topics of S.PSS and Distributed Economies (DE) including Distributed Renewable Energy (DRE). The LeNSin project, involving 14 partners and 22 associates from Mexico, Brazil, India, South Africa, China and Europe, is coordinated by Politecnico di Milano; the researcher has a role in the project management and research development.

Finally, this research fits in the general Learning Network on Sustainability (LeNS), as self-financed network dealing with Design for Sustainability. The network involves, for now, around 100 universities worldwide organized in 13 regional networks. This opportunity, enlarges the room for discussion and the field of diffusion for the research outcomes and results.

Coherently with the aim of all LeNS projects, this research is open source and copy-left, thus ensuring a wider access to the outcomes and results.

1.4 Audience of the research

The research is dedicated to a wide public to spread new knowledge and know-how on sustainable energy for All and specifically on the S.PSS applied to DRE offer model. First, is dedicated to academics and researchers who are dealing with S.PSS (both from design and management and/or other fields) or more in general with system-perspectives. In fact, the research aims at providing new knowledge and know-how to apply the S.PSS model to the DRE one, opening new trajectories for such promising model. Second, the research opens to the energy sector practitioners (consultants, SMEs, NGOs, etc.) to introduce them to the S.PSS applied to DRE offer model while giving them first support for its understanding, design, diffusion and implementation. Finally, is available for students (both from design, management and/or other fields) to introduce them to the S.PSS perspective and to its application towards sustainable energy for All.

1.5 Outline of the research

The thesis is structured in four parts as follows.

The first part introduces the challenge and he Research Questions addressed by this research. Then, promising models of S.PSS and DRE as background are introduced. Finally, the methodology used to address the Research Questions, together with the research strategy are illustrated.
Chapters 1 - 4.

The second part presents the S.PSS applied to DRE offer model proposed by the research and presents benefits and potential limits that influence its successful development. Consequently, the conceptual framework is defined based on the results of literature review, case studies research and a sustainability design orienting scenario. In fact, this part seeks to provide an answer to the first set of Research Questions.
Chapters 5.

The third part is aimed at presenting the necessary knowledge-base and know-how to enable designers to design and implement S.PSS applied to DRE, particularly in low and middle-income (all) contexts; as well the design approach (and associated tools) to support the design practice. Consequently, five design-research activities (one within curricular course, two within vocational courses and two as workshops on field), are presented. Furthermore, this part presents one of the main

contributions of the research: the open course on sustainable energy for All, with a set of open multimedia tools to support design and development of S.PSS applied to DRE and related design role. In fact, this part focuses on answering to the second set of Research Questions.
Chapters 6 - 8.

The fourth part is aimed at a retrospective analysis of the research, presenting and discussing the main findings. It summarizes the main lessons learnt from the research, highlighting and generalizing the main contributions, while indicating potential paths for further researches.
Chapter 9.

Chapter 2 - Distributed Renewable Energy: a key leverage towards sustainable development

The chapter gives an overview of the energy field. A focus is provided to describe the required shift towards sustainable energy for All and to the role of Distributed Renewable Energy (DRE) in this transition. The potential benefits (economic, environmental and socio-ethical) of the DRE model are also presented. Finally, limits for the diffusion of the DRE model are illustrated focusing the main gaps to be overcome.

2.1 Energy overview

From the first days of mankind, from human-power to animal-power and from animal-power to mechanical-power, energy leads human progress: increasing life quality, and creating new jobs opportunities, thus fostering socio-economic development (UN, 2011 – Colombo et al., 2013).

The energy role became increasingly relevant during the first and second industrial revolutions, going from low-power to power-intensive systems based on fossil fuels, which at that time brought comfort, prosperity and progress (UN, 2011 – Colombo et al., 2013). Lately, due to scientific advancements and discovers, nuclear fission entered the energy scenario, fascinating the industrial growth (Colombo et al., 2013). In the 1950s, the technological growth of the world wars led the exploration of energy storages and renewable energy sources such as sunlight and wind as mean for emergency in case supplies were interrupted. From the 1970s, renewable energy generation in the global energy market is progressively growing. By the end of 2015, renewable power generating capacity accounted for more than 28% of global capacity (IRENA, 2016; IEA, 2015); and for 23.5% of all electricity generation (IRENA, 2016).

Despite the progresses on renewable energy generation in the global energy scenario, the dominant approach for electricity access worldwide still based on large centralized power plants that mainly rely on fossil fuel sources such as coal, oil and gas, and link end users via transmission and distribution (T&D) systems (Komor & Molnar, 2015) (more is illustrated in chapter 1).

Among other factors, this inertia in the renewable energy integration in the worldwide panorama, is commonly attributed to: high capital costs needed to setup renewable energy plants; the lack of competences for installation and maintenance of such technologies, or to the intermittence of some renewable technologies e.g. wind is not at the same intensity during the day; as well as to a potential non-confidence from the customers (Komor & Molnar, 2015). Anyhow, is undoubtable the role holds by the incumbent electricity providers, who are directly influencing government's decision in the matter of energy policy; as well as the influence of the subsidies that they receive, who let exhaustible resources floating on the market, slowing down the competitiveness of renewable energies (Komor & Molnar, 2015 – Klein, 2014 – Szabó et al., 2013 - Rifkin, 2011).

The following paragraphs gives and understanding of the potential of renewable energies, especially when distributed in their generation and consumption.

2.2 Distributed Renewable Energies (DRE)

Distributed Generation (DG) and Renewable Energy are relevant concepts in the evolution of energy distribution which is increasingly present to achieve sustainable development. The current literature, however, does not present for them universal definitions.

Distributed Generation (DG), is accepted as "electric power generation within distribution networks or on the customer's side of the network" (Ackermann et al., 2001). Anyhow, DG does not entail a definition of the type of energy source in use, as well as accepts both that the energy is internally or externally used. Renewable Energy commonly refers to "energy that is derived from natural processes (e.g. sunlight and wind) that are replenished at a higher rate than they are consumed" (IEA 2002, OECD, IEA and Eurostat, 2005). A distinction could be made between those that are called inexhaustible resources, so their availability is not dependent on their use rate i.e. solar and wind power provide energy from sunlight and air movement which are not dependent from other conditions; and renewable resources who are replenished, but only if are used at a rate that is equal to or less than the rate of regeneration i.e. wood and other biomasses are renewable (and sustainable), depending on how they are harvested. Furthermore, the renewable resources dependent on replenishment, they could be renewable in one place but not in other, depending on the local availability of the resource. Wood for example, if properly cultivated and monitored, could be used as resource, while preventing deforestation.

2.2.1 Distributed Renewable Energies (DRE) a definition

Understanding the nature of the two concepts of Distributed Generation (DG) and Renewable Energies, has been functional to this research (and for the LeNSes project) to achieve a definition which comprises both, as well as characterize the Distributed Renewable Energy (DRE) definition selected to represent the merger of the two above concepts.

Distributed Renewable Energy (DRE), has been defined as *"Small-scale generation plants harnessing renewable energy resources (such as sun, wind, water, biomass and geothermal energy), at or near the point of use, where the users are the producers – whether individuals, small businesses and/or a local community. If the small-scale generation plants are also connected with each other (for example, to share the energy surplus), they become a Renewable Local Energy Network, which may in turn connected with nearby similar networks." (LeNSes project – Vezzoli et al. 2015)*

2.2.2 Distributed Renewable Energies (DRE) structure and sources

Key element of DRE can be defined as:

- the structure of the system: it refers to the configuration of the DRE system, depending on the interaction among the stakeholders of the system as well as from contextual conditions.
- type of renewable energy source: it refers to the renewable energy resource, or the mix of resources, used to deliver the energy services;

Concerning the structure of the system, two main configurations can be distinguished:

Distributed which refers to small-scale energy production units (e.g. a solar panel on a roof-top) in which customer is the prosumer[6] (producer + consumer) of its own energy. The production unit could be stand-alone or connected to other energy units (e.g. mini-grid connection to share the energy surplus), this creating a Renewable Distributed Energy Network. The production unit could be also connected to the main-grid, being integrated in the main energy distribution.

Decentralized which refers to small-scale energy production units (e.g. a solar panel on a roof-top) that deliver energy to the customers. The production unit could be stand-alone or connected to other energy units (e.g. mini-grid connection to share the energy surplus), this creating a Renewable Decentralized Energy Network. The production unit could be also connected to the main-grid, being integrated in the main energy distribution.

Centralized system, as large-scale production units (structure) that deliver their goods via transmission & distribution (T&D) networks, (often) far from the point of use, are as well configurations (structure) option for DRE. Anyhow, to centralize DRE, entails the loss of the advantages of being distributed or decentralized, particularly on the democratization of access to resources.

Further details, of the above configurations for DRE are presented below, and can be visualized in Figure 1.

<u>Distributed stand-alone:</u>

It refers to small-scale energy production units (e.g. a solar panel on a roof-top) in which the customer is the prosumer (producer + consumer) of its own energy. They can vary from mini-kits (e.g. solar lantern) to small energy systems (e.g. Solar Home

[6] *A prosumer is a person who consumes and produces media. The term was coined by Alvin Toffler.*

System) depending on their dimension and energy need to be satisfied. These systems are suggested from household use to small businesses. Strength of such configurations include easy installation (Plug & Play[7]), low investment cost, little maintenance, high degree of flexibility and scalability (Rolland, 2011).

Decentralized stand-alone:

It refers to small-scale energy production units that deliver energy at or near the point of production, with a higher load than single customer e.g. hospitals, schools. Decentralized stand-alone systems are commonly used as energy recharging centers, e.g. to charge lanterns and phones, or to provide energy services e.g. energy access in schools and hospitals, energy access for ICT facilities. In this case the complexity of the system, and the higher load, could require including an energy storage e.g. battery, or to use hybrid energy technologies e.g. solar panels + diesel generator. Maintenance and operations are still relatively easy to manage (Rolland, 2011).

Mini-grid:

Mini-grid (also called micro-grid or isolated-grid) provides energy at local level, without being connected to the main grid (Rolland, 2011). In this case, energy comes from energy production units, that could be both distributed and decentralized. Usually one (or more) operators are included to manage the system, and maintenance operations requires more competences e.g. distribution and storage systems need to be checked periodically. The strengths of the mini-grid are the reduction of operations costs, that are shared among customers; and the possibility of sharing the energy surplus. Unfortunately, especially in industrialized countries, energy regulations are reducing the power of sharing i.e. the energy surplus cannot go directly to other customers but needs to be sold back to the national-grid.

Especially in urban areas, the single energy production units, or a mini-grid, could be connected to the main-grid (or national-grid), being integrated in the main energy distribution. This creates advantages to the main grid, as it increases energy reliability for all customers e.g. blackouts damages can be limited (Ellabban et al., 2014 - Rolland, 2011).

[7] *Plug & Play comes from ICT dictionary and refers to an automatic installation. It is enough to plug the device (in this case the power system) to make it work. No technical competences are needed.*

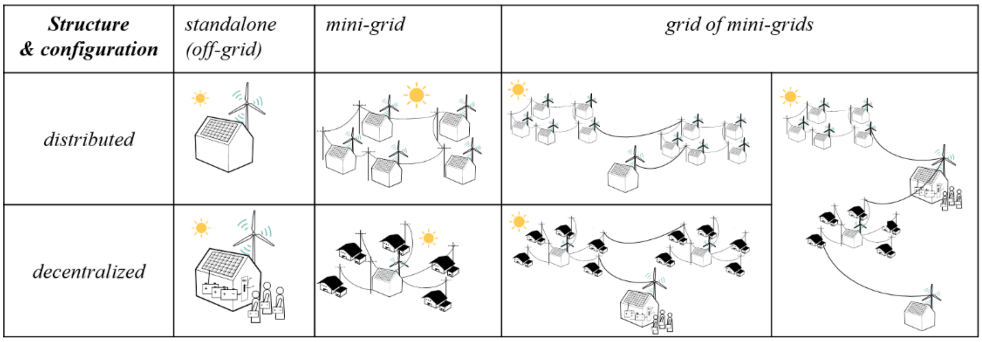

Figure 1. DRE configurations (structure)

Regarding the DRE system configuration, there is not a universal configuration, but among other variables, its choice strictly depends on the (expected) energy demand e.g. according to the expected energy need it could vary the configuration and the dimension of the plant; the density of utilities e.g. amount of households/businesses and their distance could lead to different options; as well as to cultural habits e.g. same amount of energy could be offered through a decentralized charging station and a number of distributed stand-alone systems.

Below, the types of renewable energy sources are introduced with the (for now) available technologies (Rolland, 2011 - Ochs & Makhijani, 2012 – Colombo, 2013).

<u>Solar energy:</u>

Most abundant and available renewable resource comes from the sun. In fact, the so-called solar radiation which is the energy from the sun, is available at any location and latitude, with higher radiation close the Equator, and depending on seasonal variations. There are two main solar energy technologies *solar photovoltaic (SPV) systems*, which use solar radiation to produce electricity, and *solar thermal systems* that make use of the heat from solar radiation e.g. for water heating for cooking or washing.

Solar photovoltaic technology:

SPV system is composed by a solar panel, inverter, wires and cables and (if needed) batteries and charge controller to storage the energy. The solar panel is based on modules of solar cells made from semiconductor-based materials e.g. silicon, and that absorb solar radiation to be converted in electricity through the SPV system. Due to absence of movable part, reliability of the system is guaranteed during the whole life time.

Solar thermal technology:
Solar thermal systems are composed of solar thermal collectors, a storage tank and a circulation loop. Solar thermal technology, converts solar radiation into renewable energy for heating and cooling using a solar thermal collector. Heat from the sun's rays is collected and used to heat a fluid who will drive the production of energy for heating/cooling. Produced heat can be used to heat water for hygiene and health, or for space heating/cooling. An alternative solar thermal technology is the Trombe Wall. In this case, heat from the sun's rays is passively absorbed through a Trombe Wall, installed in a house, then slowly released over night.

Wind energy:
Wind is one of the most spread renewable energies, its kinetic energy is converted through a generator into electric power. Wind is strictly site specific and its speed can vary during the day and differs significantly during seasons, so forth correct positioning is crucial for a successful implementation.

Wind technology:
There are two main configurations for wind systems: *horizontal axis wind turbines* and *vertical axis wind turbines*. Horizontal one is the most common. Wind system, both as horizontal and vertical, is composed by three blades, a rotor, a charge regulator and batteries, a pole (dimension it depends if is horizontal or vertical configuration).

Hydro energy:
Water use for energy provision is strictly site specific, while it can be continuous until the water is moving. Kinetic energy from water can be produced through different sources: water flow, waves or from the tide. In all cases, energy is transformed into mechanical power or could be converted directly into electricity. There are three different technologies using water: hydropower, energy from waves, energy from the tide. Currently, hydropower is a mature technology; last two are at level of experimentations.

Hydropower technology:
Hydropower plant needs a river or stream (with a minimum guaranteed availability of water flow) and is based on a hydraulic turbine and a generator. Storage is usually optional due to the continuous water flow. Hydropower plants transform kinetic energy of a river or stream into mechanical energy (convertible in electricity) using a hydraulic turbine. The energy available depends on the height (head) of the fall, and the rate at which the water is flowing.

Biomass energy:

Biomass is a generic term that refers to residual from organic matter e.g. crops, residues, and other biological materials that could be used to produce chemical energy i.e. gas that could be converted into electricity. Transportation fuels can be produced from biomass, helping to alleviate demand for petroleum products from the sector. Main transportation fuels are ethanol from corn and sugarcane, and biodiesel from soy, rapeseed, and palm oil.

Biomass technology:

Biomass technology is based on a reactor, a gas cooler with cleaning system, an engine and a blower. The gasification process to produce chemical energy, entails a partial combustion of biomass due to the limited presence of air in the reactor. The resulting thermal value depends on the biomass used. Biomass gasification is not suitable for home-based solutions due to the low efficiency and high quantity of biomass needed compared to the chemical energy produced.

Geothermal energy:

Geothermal energy is stored in rocks and in fluids circulating in the underground. Main use of geothermal energy is the direct use of the heat e.g. for space heating in cold areas and seasons, or its conversion into electricity for different purposes.

Geothermal technology:

Geothermal energy is exploited by using heat pumps which are made of a closed circuit where a refrigerant fluid is circulated. Heat pumps convert the low-temperature geothermal energy to thermal energy at a higher temperature, exploiting the physical property of fluids to absorb and release heat when they vaporize or condense, respectively.

Due to the variety of sources (and technologies) available, among other variables, the energy source must be carefully planned in relation to local resource availability i.e. energy sources are (usually) dependent on the location; and number of (expected) utilities e.g. biomass technology requires a medium number of utilities to run profitably. So forth, there is not a universal option of energy source, but it is context specific. Furthermore, the intermittency of some sources e.g. sun, wind, needs to be considered and a storage system should be included or another source will need to be added creating an integrated energy system providing reliable access to energy.

2.2.3 Distributed Renewable Energies (DRE): benefits and limits

Distributed Renewable Energies (DRE), presents a series of benefits and limits while compared to the traditional centralized distribution (Eleftheriadis & Anagnostopoulou, 2015). For example, DRE could be an option for rural communities, where to connect to the grid is not possible or cost-effective. Similarly, DRE could be used where energy access is available, to increase reliability of the system. On the other hand, DRE are facing limits as local gaps in technology and operation & maintenance in rural areas or the loss of the economy of scale in urban environments. On the customer side, limited purchasing power represents the main barrier for accessing energy (Rolland, 2011 - Bacchetti et al., 2016).

Major benefits and limits of DRE adoption are illustrated below. To facilitate readability, benefits are presented as environmental benefits, socio-ethical benefits and economic benefits, as per the three dimensions of sustainability. Limits are presented as cost limits, technology limits, regulatory limits and market entry limits (IRENA, 2017).

DRE Benefits:

Environmental benefits:

DRE systems are based on local renewable resources, thus, the greenhouse gases emission in use can be considered marginal. Furthermore, as renewable resources are "almost ready" resources e.g. solar radiation is directly providing energy to solar cells generators to be converted in energy, their impact in extraction and transformation is also negligible (Komor & Molnar, 2015). Furthermore, DRE systems use the energy at or nearly the point of production. So forth, distribution & transmission are reduced, hence transmission losses are limited (Alanne & Saari, 2006). Finally, DRE systems, if properly conceived, they do not deteriorate local landscape, e.g. small hydropower plants do not require to create dams. This is ensured from their use of local available of resources, as well as by their small energy load, that does not need large power plants and lines (Alanne & Saari, 2006).

Socio-ethical benefits:

DRE systems are small scale plants based on the use of local renewable resources. This allows individuals and local communities to access renewable and reliable energy, increasing equity in the redistribution of resources and democratizing access to energy[8] (Alanne & Saari, 2006). Due to the small scale of the DRE plant, the impact

[8] *Access to energy is intended not as an end itself, but as enabler towards sustainable development i.e. energy enables daily activities, increase in working conditions and job opportunities. (more on this in sections 1.1 and 2.1)*

of a potential damage e.g. temporary malfunction, this will affect a reduced number of utilities, compared to blackouts that affect centralized systems or, in the case of connection through Renewable Local Energy Network, the malfunction could be avoided thanks to the sharing of energy surplus (Rolland, 2011 - Alanne & Saari, 2006). Furthermore, DRE systems, as distributed production systems, need competences, such as for their management and technical assistance, at local level. Thus, this entails the need for local development of such competences, hence increasing potential employment opportunities and a consequent socio-cultural development.

Economic benefits:

DRE systems, due to their small scale, and to the progressive cost-effectiveness of renewable energy technologies, require a relatively small upfront investment compared to traditional centralized plants. This allows a path for direct private investments within strategies of market expansion (Komor & Molnar, 2015). Consequently, if properly conceived and thanks to technology advancement, DRE systems can be flexible, scalable and reliable structures e.g. SPV allows maintenance and substitution of single modules, as well single modules can be added to the existing system. Thus, these elements increase DRE appeal for stakeholders, who are encouraged from low life-cycle costs and to the possibility to obtain higher margins. Finally, DRE technologies are still under research & development to increase their efficiency, interconnection and storage technologies. This entails new job opportunities and returns both for companies e.g. higher margins, and final customer e.g. energy reliability and saving of money thanks to efficient technologies.

DRE Limits:

Cost limits:

First limit, is the low purchasing power of final customer, mainly in low and middle-income contexts, especially if compared with capital (investment) cost for purchasing DRE system. Furthermore, the lack of access to credit could additionally reduce the opportunities. Aside, as DRE systems require operation & maintenance (depending on technology and structure), this entails life-cycle costs to be paid from the customer. As often they are too costly for the customer, this can increase the risk of drop-off in case of malfunctioning in the system. Lastly, the (potential) local lack of (technical and commercial) experience and information could increase uncertainty and risk perception, thus reducing the willingness to purchase the DRE system from the final customer.

Technical limits:

DRE systems are usually based on product and equipment produced in one place and exported worldwide. This condition could increase the costs of local assistance to the final user due to the lack of mentorship and skills transfer, lack of support and communication networks, poor infrastructure, and difficulty in accessing financial capital, especially in low and middle-income contexts (Ciliberti et al., 2008), increasing the risk of drop-off if a part of the system gets broken.

Regulatory limits:

DRE systems allow final customers to become prosumer (producer + consumer) of their own energy. Often, the legal framework to allow independent production is non-existent or insufficient. Furthermore, restrictions in construction and transmission and interconnection of utilities are inadequate and slow down the process.

Market entry limits:

Current fossil fuel industry, access subsidies not available for renewable energy technologies. Thus, this reduce competitiveness of DRE, while prolonging life of (obsolete) fossil fuel technologies (Klein, 2014 - Rifkin, 2011).

2.3 Paradigm shift towards sustainable energy for All

Considering the dimensions of the energy challenge, the ineffectiveness of the current centralized and non-renewable energy sector in overcoming them, and the potential of Distributed Renewable Energy (DRE), it comes clear the need of a radical change in the energy sector.

Several authors (IRENA, 2016 - Vezzoli et al. 2015 - Klein, 2014 - Barbero & Pereno, 2013 - Colombo et al., 2013 – Hunt, 2012 - Worldwatch Institute, 2012 - UN, 2011 - Rifkin, 2011 - Johansson et al. 2002) have observed that a paradigm shift: moving from centralized generation, based on fossil fuel resources, to a distributed generation and consumption of renewable energies, i.e. Distributed Renewable Energies (DRE), could be a key opportunity for the global economy.

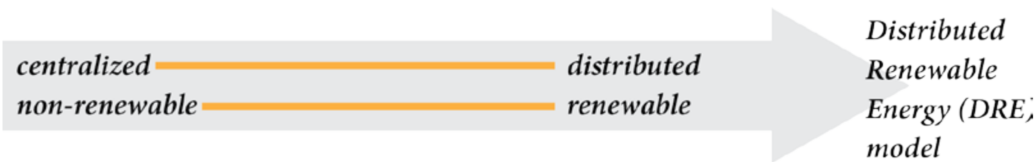

Figure 2 – Paradigm shift from non-renewable/centralized to distributed/renewable energy generation systems

This is mainly due to, DRE distributed structure, which allow local generation and consumption, fostering democratization and an equal redistribution of (energy) resources; as well as the use of (locally available) renewable resources, that can support socio-economic growth, facilitating energy access for daily life activities as well as to promote income generation activities, within the resilience of the planet (Vezzoli et al., 2015 - Klein, 2014 - Ellabban et al., 2014 - Colombo et al., 2013 - Rifkin, 2011).

Despite its potential, to overcome the initial investment to buy the DRE system and to manage its life-cycle costs; as well as to solve the gap of local technical and commercial competences, the DRE model shows the need of a supportive model. Coherently, renewable energy policies and regulations can facilitate DRE introduction and competitiveness in the market.

Therefore, a shift in the consumption pattern, moving the focus from the ownership of a product e.g. DRE system, to the satisfaction of a need e.g. charging a phone, through a mix of products and services, has been discussed as win-win transition to overcome the above limits affecting sustainable energy for All (Vezzoli et al., 2015).

So forth, a double paradigm shift required:
- from centralized generation based on fossil fuel, to Distributed Renewable Energy (DRE) generation;
- from product ownership, to satisfaction of a need through a system based on products and services.

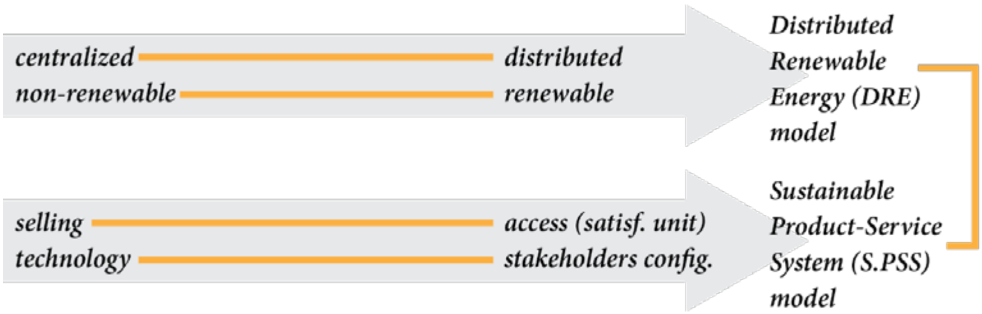

Figure 3 – A double paradigm shift.

On this purpose, chapter 3 presents the Sustainable Product-Service System (S.PSS) model, as support model to move from ownership of product to the satisfaction of a need.

Chapter 3 - Sustainable Product-Service System (S.PSS): a promising model to support Distributed Renewable Energy

The chapter gives an overview of functional economy, and then focuses on the Sustainable Product-Service System (S.PSS) model. The benefits (economic, environmental and socio-ethical) of the S.PSS model are also presented. Finally, limits for the development of the S.PSS model are illustrated.

3.1 Introduction

Previous chapters provided an overview of the challenges towards sustainable energy for All, and Distributed Renewable Energy (DRE) was presented as promising model to overcome them (more in chapter 2). Anyhow, DRE limits as initial investment to purchase DRE systems, unaffordability of (unexpected) life-cycle costs e.g. operation & maintenance, and (often) lack of local technical and commercial competences, are still there, thus reducing the potential for DRE diffusion.

To provide an alternative to the *traditional product sale* e.g. selling of solar panel and appliances, as well as to overcome *product donation* attitude and reducing the "dependency syndrome" (see more in section 1.1), this chapter introduces the concept of functional economy, aimed to deliver functions, instead of products or technologies (Mont, 2002 - Stahel, 1997). Then, the Sustainable Product-Service System (S.PSS), as model of functional economy, is presented.

3.2 Functional Economy

Industrial economy, considers the product as the center of the offer, and its economic growth is based on the increase of resources (energy and material) consumption from the customer (Stahel, 1997). On the contrary, functional economy is oriented to deliver functions, considering products and technologies as means to deliver the function (Stahel, 1997 - Mont, 2002 - Baines et al., 2007). For example, functional offers are intended as mobility systems instead of cars, or cleaning services instead of washing machines (Mont, 2002). Thus, the economic growth of functional economy, depends on the amount of functions delivered and can be reinforced by their efficiency, changing the reward system of the transaction (Ceschin, 2012). As promising in the field of functional economy, the Sustainable Product-Service System (S.PSS) model is presented below.

3.3 Sustainable Product-Service System (S.PSS)

The concept of Sustainable Product-Service System (S.PSS) has been studied in industrialized contexts from more than 25 years as promising model for innovation. Among other definitions, S.PSS refers to "*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 providers continuously seeks environmentally and socio-*

ethically beneficial new solutions" (Vezzoli et al., 2014).

In fact, a S.PSS is not the sale of only products e.g. traditional sale of solar panel and appliances, but is a system-innovation offer of products and services combined, to achieve a demand of satisfaction from the user e.g. having access to energy. For example, the satisfaction of "having access to energy" does not include only the solar panel and appliances, but also the products e.g. lights, oven, to benefit from the energy access, as well as their related services such as maintenance, repair and disposal services. This means to provide a system-innovation and requires involving all socio-economic actors of the satisfaction (Vezzoli, 2010 – Vezzoli et al., 2014), such as: solar panel and appliances producers, products maintenance, repair and disposal suppliers. Furthermore, as based on a satisfaction, S.PSSs often involve changes in the ownership structure and property rights, compared to a traditional product selling (Mont, 2002). This can entail an interest of the provider (owner) into the life-cycle stages of the product involved e.g. use, end-of-life, remanufacturing of the solar panel and appliances to be efficiently managed at a lower cost both for the provider and (potentially) the environment.

When PSS re-orient unsustainable production and consumption patterns, and reduces the environmental impact of the satisfaction, it is referred as Eco-Efficient Product-Service System (Manzini & Vezzoli, 2003); in the case sustainable benefits are also related to the socio-ethical dimension, it is referred to Sustainable Product-Service System (Tukker & Tischner, 2006).

To clarify, the S.PSS:

- shifts the business focus from selling only products to offering a combination of products and services jointly capable of achieving customer satisfaction, thus moving the interest from ownership to access;
- shifts the (primary) innovation from new/improved technology to an innovation at stakeholders' level, favoring development of new stakeholders' relations and partnerships, such as between providers or even with customers;
- shifts the economic value from the economic growth, which derives from a constant increase of production and consumption patterns i.e. selling more and more washing machines, to the economic development, which derives from the reward of the given satisfaction i.e. satisfying the need of having clean clothes, thus reducing the impact (environmental, socio-ethical) of the solution (Tukker & Tischner, 2006).

Box 1. Example of Sustainable Product-Service System ***RICOH PAY-PER-PAGE***[9]

RICOH offers a full package (Pay per Page Green) for printing. The package includes installation, maintenance and collection at the end-of-life the printers and photocopiers, given in use to the customer but owned by RICOH. The customer pays for the number of delivered pages and copies. The innovative relation between the company and the client, make the company' economic interest to provide (and design) long lasting, reusable and recyclable printers and photocopiers. In fact, as far as the company is payed per number of pages printed, it has an economic advantage in the duration of the products, as well as the possibility to recycle the materials.

According to the above, S.PSS can be considered a promising solution towards sustainable consumption and development[10] due to its innovations, but the adoption of a Product-Service System approach, based on a mix of products and services, do not lead necessary to (environmental, socio-ethical, economic) sustainable solutions (Vezzoli et al., 2014), but needs to be supported by suitable approaches and tools to go towards sustainability (Tukker & Tischner, 2006 – Vezzoli et al., 2014).

Furthermore, it has been observed that, even if properly designed, the so-called rebound effect, can affect the sustainability of PSS solutions (UNEP, 2002). In fact, some unintended effects may happen, and turn potential environmentally-friendly solutions into an increased consumption of resources (energy and materials) in the practical solution (Binswanger, 2001). Rebound effects could affect also the socio-ethical perspective of sustainable PSS.

Furthermore, the topic of the ownership of PSS (that may vary from traditional selling of products), as other socio-ethical and environmental variables, should be investigated in the context (Mont, 2002). For example, in Botswana, one of the African regions where the research was conducted, the ownership of products corresponds to a demonstration of power, reflecting an industrial-oriented economy (Rapitsenyane, et al., 2014). So forth, dealing with PSS, the ownership is not a variable that could be ignored. To reduce its influence, a central role of the customer at all level of the design process must be guaranteed. The culture of access needs to grow,

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[9] *More info on the RICOH PAY-PER-PAGE can be found directly at* www.allsupport.it/ricoh/payperpage.aspx

[10] *More on sustainable development definition in paragraph 1.1.*

together with capacity building on the alternative PSS models, while improving acceptance of the solution, as owned by the customer.

Especially in emerging countries, where commodities are the main business instead of productive activities, it may be considered the fact that products and equipment to be included in the S.PSS offers come from outside, thus potentially challenging the sustainability value of the system, and limiting potential benefits of local capacity building and local employment. For example, to obtain a satisfaction without being part of the solution, such as to have access to energy but without being aware of its manufacturing knowledge, can reduce personal skills of both provider and customer, thus increasing dependency from external providers (Tukker & Tischner, 2006).

Due to the openness in the definition of Sustainable Product-Service System, this research, adopt the above presented one (Vezzoli et al., 2014), thus considering Sustainable PSS those solutions which move unsustainable consumption system towards sustainable ones (more in paragraph 1.1) in relation to the specific unit of satisfaction; while providing environmental, socio-ethical and economic benefits; being win-win solutions both for the stakeholders and the environment.

3.3.1 Sustainable Product-Service System (S.PSS) categories

Sustainable Product-Service System (S.PSS) can assume a variety of configurations to deliver a specific demand of satisfaction. The scientific community dealing with them, agree on three main categories of configurations, which differ in terms of creating, delivering and capturing value (Reim et al., 2015). These are Product-oriented PSS, Use-oriented PSS, Result-oriented PSS (Tukker, 2015 - Tukker & Tischner, 2006).

- Product-oriented PSS: or added value to product life-cycle. It defines a type of offer where a product/s is still sold, but additional services e.g. its installation, maintenance, repair, and so on, are included in the offer. The customer becomes owner of the product, but the provider, or an alliance/partnership of providers remain responsible for some life-cycle services. In term of sustainability, this innovative interaction reduces the responsibilities of customers on (some) life-cycle services, while increasing the interest of the provider in seeking environmentally sustainable solutions (Vezzoli, 2007).

Box 2. Example of Product-oriented PSS: ***Grameen Shakti, Bangladesh***[11]

The company offers Solar Home Systems (SHS) with a service package inclusive of: micro-credit, installation, maintenance and repair services. Customers, low-income households and small businesses from rural isolated communities own the SHS, purchased with micro-credit services and paid-back with a loan in 2-3 years. To ensure an effective after-sale service, Grameen Shakti trains women as local technicians for repair and maintenance of SHS, and for assemble solar accessories such as LED lights and charge controllers.

Is economic interest of the company, to reduce life-cycle costs of the SHS, providing customers with an efficient product, thus increasing the margin, provided by the pay-back from the customers.

- Use-oriented PSS: or enabling platform for customers. It defines a more radical type of offer, where the product still plays a central role, but is owned from the provider. The customer has the product available in some forms e.g. car sharing, and receives tools, training or opportunities to obtain the expected satisfaction. The customer pays only for the time of use, as the product could be shared with other customers. In sustainability terms, this innovative interaction reduces the responsibilities of customers (product is owned by the provider), increasing provider interest in seeking environmentally sustainable solutions (Vezzoli, 2007).

Box 3. Example of Use-oriented PSS: ***Solar-Powered Café, South Africa***[12]

The Solar-Powered Café pilot-project offers a solar-powered connection centre and charging point, bringing low-cost access (free for students, subsidized for adults) to IT services. Ownership of the connection centre and charging point (and of all the included Energy Using Products) is retained by Solar Charge. The customer pays per use with three different offers at same price: one internet access; one IT-service; one phone

[11] *The example of Grameen Shakti, is included in the case studies research of the thesis. The card of the case study is available in Annex Ib at the end of this thesis book. More info can be found in the case study profile at* www.lenses.polimi.it, *section case studies, or at the direct website www.gshakti.org.*

[12] *More info on the Solar-Powered Café can be found in the case study profile at* www.lenses.polimi.it, *section case studies.*

charging. The connection centre has a highly-trained administrator to manage any problems that may arise. As additional service internet access its free for students, favouring education within the township.

Is economic interest of the company, to equip customers to efficiently obtain the agreed result, thus increasing the number of users and the corresponding margins for the company, provided by the pay-per use from the customers.

- Result-oriented PSS: or providing results for customers. It defines a radical offer, as a mix of products and services, where the customer pays to reach an agreed result. The role of the product is not central anymore, is owned by the provider or alliance/partnership of providers and not direct responsibilities are allocated to the customer. In term of sustainability, this innovative interaction changes the roles of customer and provider, where the customer reduces his/her responsibilities, and pays to obtain the results. The provider has more freedom in define how to obtain the agreed result, thus increasing his/her interest in seeking environmentally sustainable solutions (Vezzoli, 2007).

Box 4. Example of Result-oriented PSS: ***Shared Solar, Uganda***[13]

Shared Solar connects houses and small businesses of Ruhira village through a decentralized mini-grid based on solar energy. The solar station (micro generator + its accessories) are owned by Shared Solar, as donation from the Millennium Village project (sponsoring the project). Users pre-pay per time, to receive a predefined amount of energy in each time. Customers can pay through scratch cards or mobile phones (without fee). Added services as installation and life-cycle services (i.e. maintenance, repairing) are all in charge to Shared Solar.

Is economic interest of the company, to provide the most efficient way to obtain the agreed result, thus increasing the margin, provided by the customers through the payment of result.

[13] *The example of Shared Solar, is included in the case studies research of the thesis. The card of the case study is available in Annex Ib at the end of this thesis book. More info can be found in the case study profile at* www.lenses.polimi.it, *section case studies, or at the direct website* www.sharedsolar.org.

Furthermore, the categories of Product-oriented, Use-oriented and Result-oriented PSS, each includes PSS offers with different economic and sustainability characteristics. Among the category of PSS, these have been clustered in the following eight types (Tukker, 2004)[14].

Product-oriented PSS:
Product-related service, where the provider (or alliance/partnership of providers) sells the product, and includes offers services for its use stage, such as, a maintenance contract, a financing plan, an end-of-life treatment, or other. A*dvice and consultancy,* in this case, the provider (or alliance/partnership of providers) sells the product, together with advices to increase the efficiency in use, such advices to organize the team dealing with the product.

Use-oriented PSS:
Product lease, as per its category, the product is own by the provider (or alliance/partnership of providers), who is usually in charged for maintenance, repair and control. The customer pays a fixed fee to use the product, that is normally given with unlimited and individual access. *Product renting or sharing,* as above, the product is generally owned by the provider (or alliance/partnership of providers). The user pays for the use (time) of the product. In this case, as the use is limited in time, the product is available for the use of different customers. *Product pooling,* even with similarity to the renting or sharing type, in this case the use of a product is simultaneous, while is sequential for renting/sharing.

Result-oriented PSS:
Activity management/outsourcing, to obtain the agreed result, a company can outsource some activities, increasing their efficiency and quality. *Pay per service unit*, here the customer again focuses on the result to be obtained, often as one-shot solution, e.g. pay-per-print. *Functional result, as* provider (or alliance/partnership of providers), agree with his/her customer on a result to be delivered. This entails high level of involvement and freedom of the provider, which with his/her knowledge-base and know-how deliver the agreed result.

3.3.2 Sustainable Product-Service System (S.PSS) benefits and limits

S.PSS, if properly designed, can provide environmental, socio-ethical and economic benefits. Meanwhile, limit to its implementation need to be overcome.

[14] *The PSS categories, were introduced in previous resources, such as (Zaring et al., 2001) and (Tukker & van Halen, 2003).*

S.PSS benefits:

Environmental benefits:

As S.PSS often involves changes in the ownership structure and property rights, compared to a traditional product selling (Mont, 2002), it can be interest of the provider (product owner) to promote longer utilization of products, through different strategies such as life extension, remanufacturing, re-use, etc., this decreasing environmental impact of the solution (Stahel, 2000, Vezzoli, 2010). Furthermore, as S.PSS, promotes a mix of products and services to obtain a result, instead of favoring products production and ownership, this could lead to a more dematerialized economy (Stahel, 2000). In fact, if properly conceived, S.PSS gives the opportunity to reduce products and services offered, through their efficiency, without compromising customer satisfaction (Stahel 2000).

Socio-ethical benefits:

As S.PSS) focuses on needs, they are highly flexible, and adaptable, thus this could increase the value for the customers with a higher satisfaction. Still from the customer, the opportunity to access S.PSS through small payments (especially for Use-oriented and Result-oriented PSS), this can increase the answer to unsatisfied demands, especially in low and middle-income contexts (UNEP, 2002). Finally, since S.PSS is labor and relationship-intensive solution, this entails the need for local development of skills, hence increasing potential employment opportunities and a consequent socio-cultural development (UNEP, 2002), as well as potentially empowering the local net of customers, promoting local involvement.

Economic benefits:

The adoption of S.PSS, where the provider retains the ownership, or at least some responsibilities on the product, creates longer term relationship with the clients, while ensuring a stable income for the provider during the whole life-cycle of the product e.g. fixed fee from the customer to obtain the result. Furthermore, if based on an existing product, it requires a smaller investment, thus being promising especially for low and middle-income contexts (Tukker & Tischner, 2006). The development of strategic partnerships (e.g. national governments, investors, etc.), could easy the reiteration of projects in other contexts, as well as strengthening market position of the investor. On the customer side, the offer of products and additional services (e.g. design, maintenance, training), or the offer of a result, guarantee the economic affordability of the solution, and consequently, the satisfaction of the demand.

S.PSS limits:

Environmental limits:

As introduced above, not all Product-Service System (PSS) are sustainable per se, thus they need to be conceived on a sustainability perspective. In fact, both the product used in the solution and the system of stakeholders itself, need to be designed to reduce the (environmental) impact of the solution. At system level, the solutions must consider unwanted side effect e.g. limitless responsibility from users who do not own the products, commonly known as rebound effects (UNEP, 2002 – Mont, 2002).

<u>Socio-ethical limits:</u>

From the customer point of view, especially when the product ownership stays with the provider/s, there is the need of a cultural shift guidance, to support S.PSS development, while reducing potential rebound effect e.g. cultural barriers (Vezzoli, 2010 - Ceschin & Gaziulusoy, 2016). In fact, the ownership concept of the Use-oriented and Result-oriented PSS, could be an obstacle towards local acceptance of the innovation (Ceschin, 2013 - Mont 2002; UNEP 2002 – Manzini et al., 2001 - Goedkoop et al. 1999). From the provider/s perspective, can be perceived barriers such as current company's organization (Ceschin & Gaziulusoy, 2016 - Vezzoli, 2010), production and marketing strategies (Mont, 2002). Finally, complexity of S.PSS and weakness in local competences e.g. technical and commercial, need to be properly addressed to become drivers of the innovation to produce socially, environmentally and economically viable PSS (Van Halen et al., 2005).

<u>Economic limits:</u>

Due to complexity of S.PSS, could be difficult, to perceive long-term costs e.g. life-cycle costs and benefits, thus reducing the appealing of the solution (Vezzoli, 2010 - White et al., 1999). Furthermore, the lack of local infrastructure and technology e.g. management of product collection, remanufacturing, could further reduce internal and external interest in S.PSS solutions (Ciliberti et al., 2008 - Vezzoli, 2010 - Hernandez-Pardo et al., 2012).

To summarize, the potential benefits and limits of S.PSS need to be verified case-by-case. Rebound effects must be considered in the design of Sustainable Product-Service System (S.PSS), and should be addressed for the specific case.

3.3.3 Sustainable Product-Service System (S.PSS) for low and middle-income contexts

After deepening the potential benefits of S.PSS, it becomes even more evident why the model could be viable solutions in low and middle-income contexts (UNEP, 2002).

First, as S.PSSs are based on a mix of products and services, this allows to access (life-cycle) services of products usually not affordable in traditional product sales (especially via product-oriented PSS), thus increasing value of the offer. Second, as S.PSS (especially if Use-oriented and Result-oriented PSS), allows small payments to obtain a specific result, this can furtherly increase the answer to unsatisfied demands (UNEP, 2002). Third, as S.PSS offers are focused on the context of use, this can open (long-term) relation with local stakeholders, thus ensuring assistance for customers while opening new markets for the companies. In fact, this entails the need for local development of skills, hence increasing potential employment opportunities for local stakeholders (UNEP, 2002 - Vezzoli, 2010 – Sarkis et al., 2010). Finally, S.PSS adoption can favor the growth of bottom-up distributed economies, thus enhancing a democratic process of socio-economic development.

To exemplify the above arguments, here an example of Sustainable Product-Service System (S.PSS), coupling environmental, socio-ethical, and economic benefits.

Box 5. Sustainable Product-Service System in low income context: ***Solarkiosk, Africa***[15]

The Solarkiosk AG (German company), targets local intermediaries to manage and guarantee the provision of energy services in rural areas of Kenya, Rwanda and Tanzania. Solarkiosk designs, installs and owns the E-Hubb, a charging station provided with solar panels and Energy Using Products. A local intermediary is responsible (with a maximum of 5 collaborators) of the local E-Hubb, where (s)he provides a wide range of energy services such as, internet connectivity, copying, printing and scanning, etc. Customers pay per use e.g. pay to print, or they can buy some offered Energy Using Products such as solar lanterns, or other consumables. Local intermediary receives training for management, selling and accountability of the E-Hubb, as well as to solve basic maintenance and repair. Currently, as new market segment for the E-Hubb, Solarkiosk is offering energy connection to local shops, thus entailing more favorable conditions for the local economy e.g. in food-shop, the access to reliable energy can power refrigerators to keep goods.

For the customer, the opportunity to obtain her/his result, is given from the small payment (s)he can give for each use. In the case of products which are

[15] *The example of Solarkiosk, is included in the case studies research of the thesis. The card of the case study is available in Annex Ib at the end of this thesis book. More info can be found in the case study profile at* www.lenses.polimi.it, *section case studies, or at the direct website* www.solarkiosk.eu.

sold to the customer e.g. solar lantern, the local intermediary is in charge to solve eventual problems as additional service, without extra costs for the customer. The products, both used in the E-Hubb and sold, are certified, so that quality and efficiency are ensured, both for the local intermediary to work on them, and for the clients. For the local intermediary, the training courses can increase their competences and future opportunities for job career. On the side of the Solarkiosk AG company, they had the opportunity to enter the untapped market of rural areas. In fact, even though all customers have limited power-purchase, the possibility to cover high numbers still give them margins of return. Finally, on the environment, the use of Renewable Energy solutions, both the E-Hubb as well as the products such as lanterns and efficient cook-stoves, can increase the quality of the given results, while reducing their impact.

3.4 Designing Sustainable Product-Service System (S.PSS)

The above paragraphs introduced the S.PSS model, with its categories, potential benefits and limits. This paragraph focuses on its design attitudes and practical skills.

As S.PSS, is a mix of products and services towards a specific demand of satisfaction, a designer to work on them, need the abilities to (Vezzoli, 2010 - Vezzoli et al., 2014):

- design environmentally sustainable products and services together;
- design and facilitate new configurations (interactions/partnership) between different stakeholder to achieve a convergence of economic and environmental interests;
- operate/facilitate a participatory process among entrepreneurs, users, NGOs, etc.

However, given that not all Product-Service Systems (PSSs) are sustainable, the design process of such innovations must be oriented towards a sustainable perspective. Accordingly, the designer should need further abilities to (Vezzoli, 2010 - Vezzoli et al., 2014) to orientate the design process towards sustainable solutions: both at product and system level, as well as both at environmental and socio-ethical perspectives.

Therefore, the main approaches for Sustainability Product-Service System Design are:

- A satisfaction-system approach, entailing the design of a specific demand of satisfaction (satisfaction unit) and all its related products and services;

- A stakeholder configuration approach, entailing designing stakeholder interaction in relation to the satisfaction-system;
- A system sustainability approach, entailing to design the sustainability of stakeholder' interactions, based on mutual economic, socio-ethical and environmental benefits, as a way of achieving sustainable solutions.

To design S.PSS solutions, based on the above presented approaches, a series of methods and tools have been developed[16] within researches funded by the European Union. The most recent from EU funded researches are SusHouse[17], ProSecCo[18], HiCS[19], MEPSS[20], and SusProNet[21].

The Method for System Design for Sustainability (MSDS), is the most recent one and has been developed and updated during (some) of the above research projects[22]. The Method for System Design for Sustainability (MSDS), aims to support and orient the development of system innovations towards sustainability and is based on stages, processes and tools, which have been tested during a set of pilot courses as part of the LeNS project (Asialink EU funded 2007-2010), as well as in several consultancies with companies. The MSDS is organized in five modular stages[23]:

- The *Strategic Analysis stage*, can support the collection of background information useful to setup the stage for the innovation.
- The *Exploring Opportunities stage*, can support the generation of promising strategies opportunities and ideas at S.PSS level.
- The *Design System Concept stage,* can support the design of S.PSS concept/s.
- The *Design (and engineering) the System stage*, can support the detailing of the most promising concept/s generated, into a version ready for discussion with external (potential) actors, and for concept/s implementation.
- The *Communication stage,* is dedicated to draw up reports to communicate the system designed, and particularly its sustainable characteristics.

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16 *An extenstive review of main methods and tools to support PSS is available in (Verkuijl et al., 2006).*

17 *SusHouse: Strategies towards the Sustainable Household Project (EU funded, 1998–2000).*

18 *ProSecCo: Product-Service Co-design project (EU funded, 2002–2004).*

19 *HiCS: Highly Customerised Solutions Project (EU funded, 2001–2004).*

20 *MEPSS: MEthodology for Product Service System development Project (EU funded, 2002–2005).*

21 *SusProNet: Sustainable Product-Service co-design Network Project (EU funded, 2002–2005).*

22 *The Method for System Design for Sustainability MSDS has been elaborated within the MEPSS project (EU 5th FP Growth), the HiCS project (EU 5th FP Growth) and refined within the LeNS project (EU Asia-Link), particularly by DIS unit, Design Dept., Politecnico di Milano (coordinator).*

23 *A detailed description of the stages, with aims and processes is available in Table 3. (chapter 7), where the Method for System Design for Sustainability (MSDS) is adapted to be used for the design process of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions.*

Several tools[24] are available to be used within the Method for System Design for Sustainability (MSDS). They can be divided as: tools to support the identification of design priorities; tools to lead the generation of ideas towards sustainable solutions; tools to define the potential improvements (environmental, socio-ethical and economic) delivered by the solutions designed; tools to visualize the sustainability characteristics of the system innovations designed.

Despite the potentialities of the model, and its several applications to support the design of S.PSS solutions, the model is still far from being commonly adopted. On one side, since the method and tools have been developed recently, it will take a while both for academia and companies, to create internal competences to work on them, as well as to introduce both them and the S.PSS model within normal practices. Furthermore, the intrinsic complexity of S.PSS, can be managed differently by working groups, so forth reducing the possibility to have a unique methodological approach (maybe not even required). Thus, new case studies and further applications of the method, can contribute to improve the methodological approach towards S.PSS design.

After deepening the S.PSS model, chapter 5 introduces the coupling the two models of Distributed Renewable Energy and Sustainable Product-Service System (S.PSS applied to DRE) as win-win towards sustainable energy for All. Before, chapter 4 presents the research methodology adopted by this research.

[24] *Descriptions of the tools currently included in the MSDS, are published in (Vezzoli et al., 2014).*

Chapter 4 - Research methodology

This chapter describes the research approach adopted by the research, and then the research strategy with the related stages.

4.1 Scientific research paradigm

Scientific research paradigm can be defined as a set of common beliefs and agreements shared between scientists on how problems should be understood and addressed (Kuhn, 1962 - Guba, 1990). Indeed, it is relevant to question the scientific paradigm of a research, because it substantially influences how to undertake a study framing the understanding of social phenomena (Wahyuni, 2012). The choice of the research paradigm determines the researcher position, thus defining the development process of the research as well as the extent to which its findings will be evaluated.

The two main philosophical dimensions to distinguish scientific research paradigms are *ontology* and *epistemology* (Guba, 1990 - Shrestha, 2009). So forth, the answers to the following questions determine the scientific research paradigm to be adopted for a specific research.

Ontology - *what is out there to know?* Or *what is the nature of the "knowable"?*

Epistemology - *what and how can we know about it?* Or *what is the nature of the relationship between the knower (the inquirer) and the known (or knowable)?*

This research is positioned within the scientific research paradigm of *constructivism*. On the *ontological* position, this implies that the perception of reality is constructed by social actors and people's perceptions (Wahyuni, 2012). In fact, knowledge is built by the researcher interacting and having dialogues with the other practitioners, researchers, participants involved in the process. Therefore, constructionists reject the *positivism* ontology, where truth is one, external and objective, and considers reality as constructed, that may change and based on multiple perspectives (Guba, 1990 - Hennink, Hutter and Bailey 2011). These aspects of subjectivity and incomplete and imperfect knowledge, are reinforced by the complexity of the research topic and context, thus giving to the researcher a partial view. The Models and mental constructions created by the researcher in the process (subjective), can be of help to simplify this complexity.

On the *epistemological* perspective, the adoption of the scientific research paradigm of *constructivism*, implies that a subjectivist position. In fact, the role of the researcher is directly linked to the object to be researched, thus inevitably affecting (and being able to understand) the perception of it. Indeed, epistemology concerns with the theory of knowledge, and the possible ways of gaining and validating it (Shrestha, 2009). So forth, the researcher is not only aimed to observe and discover "its" reality, but to act on it, thus building new knowledge. To deal with such complexity, the research uses different methods, both qualitative and quantitative, recognizing them as complementary.

4.2 Research approach and strategy

Main aim of this research, is to clearly understand the promising model of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) (RQ.1), as well as to equip the actors dealing with it, with a proper knowledge-base and know-how (RQ.2). Therefore, this entails a multi-focal perspective of the research, devoted both to *exploring* and *describing* current practices (RQ.1) e.g. case study research, as well as to *designing* and *developing* new methods and tools (RQ.2) e.g. research by design, towards sustainable energy for All.

The selection of the research approach, is coherent with the research questions to be answered, and to the context of intervention. Indeed, the double focus of the research, both on exploring/describing and designing/developing, as well as the development of the research within a real context of application, can be integrated within a Design-based research.

4.2.1 Design-based research

Design-based research (Reeves, 2000, 2006 - Herrington et al., 2007 – Plomp, 2009, 2013 - Kelly, 2013), is a systematic but flexible research approach aimed at: addressing complex problems in real contexts in collaboration with practitioners; integrating known and hypothetical design principles with technological affordances to provide plausible solutions to these complex problems; conducting rigorous and reflective inquiry to test and refine innovative learning environments as well as to define new design principles. So forth, Design-based research is intrinsically linked to, and developed with, multiple design and research methodologies (Wang and Hannafin, 2005). Indeed, according to the research different methodologies can be integrated, and the researcher assumes the functions of both designer and researcher. This requires intensive and long-term collaboration involving other researchers and practitioners, developing solutions to practical problems in learning environments with the identification of reusable design principles (Herrington et al., 2007).

Below, Figure 4. represents graphically the Design-based research approach.

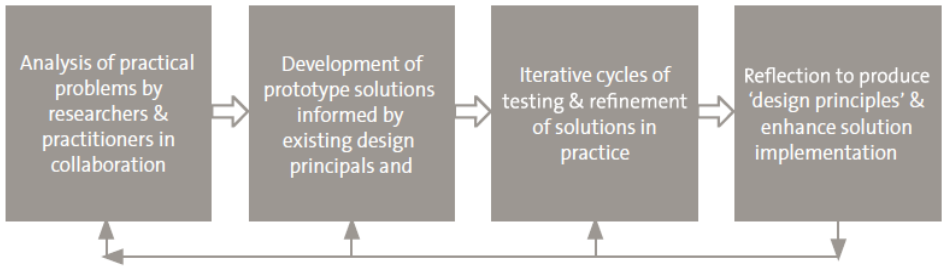

Figure 4. Design-based research approach. (Reeves, 2006).

The above characteristics of the Design-based research, made it coherent with this research, aiming to both integrate and develop design principles, as well as to test and refine innovative learning environments. Finally, as Design-based research promotes that everyone involved in the project, both researchers and practitioners, have much to learn from one another (Herrington et al., 2007), this is coherent with the research (and LeNS network) ethos, aimed at mutual learning.

4.2.2 Research strategy

As per the above, a Design-based research, have been identified as preferable approach for this research. The research strategy followed three main stages (Diehl, 2010), based on the following (Nieveen et al.2006, Plomp, 2009, 2013):

- *preliminary research:* needs and context analysis, review of literature, development of the conceptual framework of the study;
- *prototyping stage:* design stage consisting of iterative research activities, each with evaluation as the most important research activity, thus aiming to improve and refine the intervention;
- *assessment stage:* evaluation to conclude if the solution/intervention meets the pre-determined specifications. This stage, often includes recommendations for improvement of the intervention. This stage often includes a retrospective analysis, followed by specification of design principles and articulation into the conceptual framework.

Below the stages adopted and adapted in this research are presented.

The *preliminary research stage*, was aimed at identifying characteristics which contributes to the design of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions in low and middle-income (all) contexts. Thus, answering Research Question 1 (RQ.1). This stage was based on a literature review, and a case studies research on Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions was carried out to identify characteristics, similarities and patterns. A Sustainability Design Orienting Scenario was developed, aimed to highlight the characteristics emerged from the case study research. Consequently, a conceptual framework was defined based on the results above, and accordingly with new understanding.

The *prototyping and assessment stage*, was aimed at refining the (potential) role to design S.PSS applied to DRE in low middle-income (all) contexts; building up a tentative design know-how to support design practice. Thus, answering Research Question 2 (RQ.2). Firstly, a tentative design role and related knowledge-base and know-how (methods and tools) was developed. Consequently, the developed design approach, design process and tools were tested during design-research activities. Most of the design-research activities, which were a design exercise for international design students in Italy, vocational courses with Small and Medium Enterprises dealing with energy in Africa, and workshops with cooperatives in Italy, were developed within the LeNSes – the Learning Network on Sustainable energy system project (EU funded, Edulink II, 2013-16, www.lenses.polimi.it) as scientific context of the research, and coordinated by Politecnico di Milano as network of African-European universities (more in section 1.3). From the LeNSes community, experts on sustainability and Distributed Renewable Energies were involved to evaluate the design approach, design process and the tools.

The *reflection stage*, was aimed at retrospective analysis of the study and specified the main research findings, as well as limits, generalizations and recommendation for further researches.

The figure below (Figure 5.) illustrates the research strategy adopted by this research.

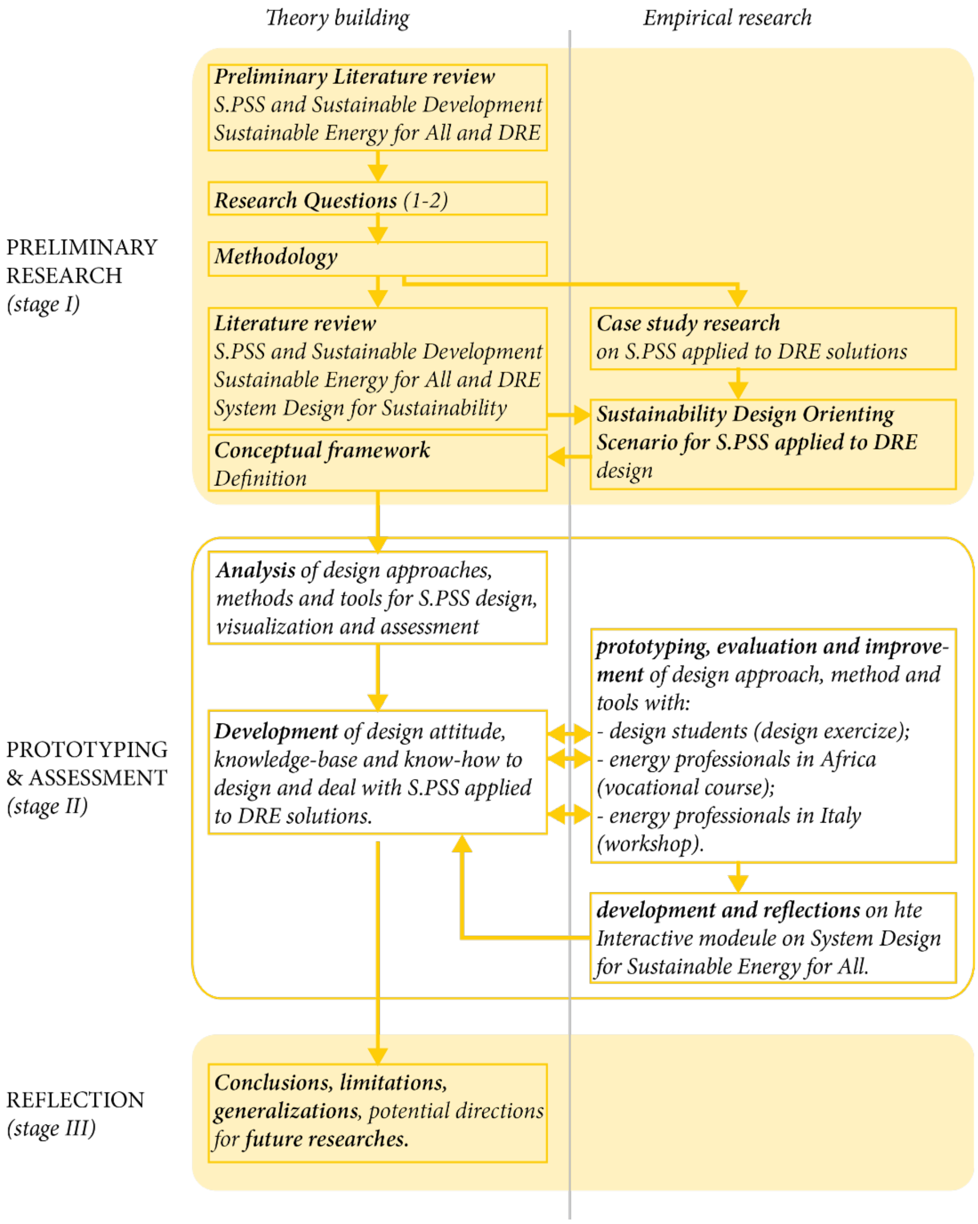

Figure 5. Research Strategy.

4.2.3 Research validity[25] and reliability[26]

Any research needs to ensure its validity and reliability. On this purpose, different researchers (McKenney et al., 2006) discussed and proposed a series of guidelines for conducting Design-based research, and to support the researcher in monitoring the scientific character of her/his research. To ensure validity of the research, four of the guidelines have been followed:

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[25] *Research validity can be defined as the consistency of research conclusions, inferences or propositions.*

[26] *Reliability refers to the repeatability of findings, and is often defined as reproducibility.*

- have an explicit conceptual framework: the conceptual framework of this research, was developed in the first stage of the research, based on insights from literature review, case study research and the development of a Sustainability Design Orienting Scenario;
- use triangulation (of data source, data type, method, evaluator and theory): triangulation has been applied in the case study resource, thus using different sources; furthermore, design approach and tools were evaluated from different actors (increasing validity and reliability);
- apply a variety of methods and strategies, and reasonings for data analysis.: the first stage of the research included literature review, case study research and the development of a Sustainability Design Orienting Scenario; the second stage developed a design approach and tools that were evaluated with different modalities; both deductive, inductive and abductive reasonings were adopted in the research process;
- empirical testing of both usability and effectiveness of the intervention: the design approach and tools developed were tested in terms of usability and impact in the process.

4.3 Research stage I

The *preliminary research stage*, was aimed at identifying characteristics which contributes to the design of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions in low and middle-income (all) contexts. Thus, answering Research Question 1 (RQ.1).

4.3.1 Literature review

The literature review process in Design-based research, is not only aimed to explore the identified problem, but can facilitate the development of draft design guidelines to support the design process to address such problem (Herrington et al., 2007), thus making the literature review even more critical for the process. As first step of this research, a literature review was conducted (chapters 1, 2, 3) the following fields:
- *Sustainable Energy for All and Distributed Renewable Energy (DRE):* aiming to understand the model and its benefits and limits, particularly in low and middle-income contexts;
- *Sustainable Development and the role of Sustainable Product-Service System (S.PSS):* aiming to understand the potential role of the S.PSS and related dynamics and processes.
A wider overview on (System) Design for Sustainability was also deeply investigated.

An initial broad selection of sources was provided, to cover publication formats including journal articles, conference proceedings, international reports, theses and books. Keywords for the fields of investigation were identified, combined and used to search, and the results were edited to remove duplicate records, thus ensuring correctness and relevance to the review. Finally, the abstracts of all remaining articles and papers were reviewed before final review. The aim was to explore Sustainable Product-Service System (S.PSS) as support for the diffusion of Distributed Renewable Energy (DRE) solutions, while leading the way towards sustainable development. Therefore, investigating the *DRE model to* understanding the energy state of the art and main dynamics; and the *S.PSS* researching on the model itself and the available knowledge and know-how as support.

The obtained results contributed to understand potential dynamics for the adoption and design of S.PSS applied to DRE solutions.

4.3.2 Case studies research

The Design-based research approach, as multiple methodologies approach, suggests complimenting the literature (theory), with research on ongoing interventions (practice), as rich source of data (Plomp, 2009). Indeed, the case studies research strategy was selected by this research, as coherent for studying new areas and issues where little theory is available (Eisenhardt, 1989 - Yin, 1994). In fact, even though both the models of S.PSS and DRE, present a wide literature, is not the same for their coupling, where on field experiences (practice) are the most advanced available knowledge. Furthermore, as the questions of this research were mainly related to "how" and "why", so forth to an explanatory approach, case studies research was recognized as (one of) the preferred research strategies (Yin, 1994). Below are presented the steps that describe the process followed by this case studies research.

Definition of aim and objectives of the case studies research:
First step of the case studies research, was to state the theory (from the literature review), and the definition of the research problems to be answered (Yin 1994). The results from the literature review, gave the room to set the objectives of the case studies research. Therefore, the main aim of the case studies research, was to explore and characterize the adoption of Sustainable Product-Service System to diffuse Distributed Renewable Energy (S.PSS applied to DRE), as promising one towards sustainable energy for All.

Definition of selection criteria and research boundaries:

Once the problem to be answered is defined is relevant to identify the case or cases to research about (Yin, 1994). In fact, it is possible to use a single case study, or multiple-case studies. The evidence from multiple-case studies is often considered more robust (Herriott & Firestone, 1983). Moreover, greater heterogeneity among the cases may enhance generalizability, while homogeneity enhances internal validity (Yin, 1994). Fifteen case studies, who adopt S.PSS applied to DRE model were selected for the research. Selection criteria were: 1. Case studies developed for low and middle-income contexts[27] 2. Case studies at the stage of project. Product-oriented[28], Use-oriented[29], Result-oriented[30] case studies have been accepted, to increase the comparison. To improve validity of the overall objective, it has been verified within the defined system boundaries as: when S.PSS is applied to DRE as both Business to Business (B2B) and Business to Customer (B2C) offers, as well as when the offer is the DRE system alone or when it is coupled with related Energy Using Products (EUP) or Equipment (EUE). A case study format has been designed to collect the needed information, and is structured on the following sections: 1. general information 2. system characteristics 3. competitive factors 4. limits and constraints encountered 5. business model 6. sustainable benefits. Table 1. illustrates the 15 case studies with PSS configuration, their customer and type of offer.

Table 1. Case studies of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE).

Case studies	PSS configuration			Customer		Offer	
	Product oriented PSS	Use oriented PSS	Result oriented PSS	Business to Customer	Business to Business	DRE micro Generator	DRE + EUP/EUE
Husk power			X	X			X
OMC power			X	X		X	
Off-Grid electric		X		X			X
Solar transition	X				X		X
Shared solar		X			X	X	
Grameen shakti	X			X			X
M-kopa solar	X			X			X
Bboxx energy	X			X			X

[27] *Context it is not referred to a geographical area, but reflects a condition. The context where basic energy related services are not guaranteed every day can be considered low and middle-income context.*

[28] *Product-oriented: configuration of Product-Service System (PSS), where the product/s is still sold to the customer, but additional services are provided e.g. maintenance, repair, upgrade, and end-of-life treatment.*

[29] *Use-oriented: configuration of Product-Service System (PSS), where the product/s is owned by the provider, but access is given to the customer with different modalities.*

[30] *Result-oriented: configuration of Product-Service System (PSS), where provider and customer agree on a specific result to be obtained with a mix of products and services. The provider owns the product/s.*

Case studies	PSS configuration	Customer	Offer				
	Product oriented PSS	Use oriented PSS	Result oriented PSS	Business to Customer	Business to Business	DRE micro Generator	DRE + EUP/EUE
Solarkiosk	X	(X)		X	(X)		X
Domestic biogas	X			X		X	
Indigo	X			X			X
Gram power			X	X		X	
Onergy solar	X			X			X
Teri	X				X	X	
Sunlabob		X			X		X

Collection and analysis of case studies:

Is notable that, among different sources of information, such as documentation, direct observations, and more others, there is not one with complete advantages compared to the others (Yin, 1994). Rather they are often complementary, thus reducing risk of bias of the source. Therefore, is a good practice to use as much sources as possible (Yin, 1994). The case studies research was based on two main sources: documentations and (semi-structured) interviews. In fact, each case study has been analyzed through desk-research, including companies' websites and internal documents, scientific papers, and case studies made by other researchers. On a second stage, semi-structured interviews have been done with relevant companies' personnel (e.g. CEOs, directors, project managers, etc.). A record has been developed for each case study using the case study format[31]. The analysis helped to collect characteristics among the selected S.PSS applied to DRE case studies (deductive reasoning).

Cross-case analysis of case studies:

After analyzing each case study, a cross case studies analysis was conducted. The aim was to verify similarities and differences on "how" S.PSS applied to DRE solutions overcome the *initial investment cost* and *life-cycle costs* of (DRE) micro-generator and related Energy Using Product (EUP) and Equipment (EUE). In fact, such limits were affecting DRE diffusion and the adoption of the S.PSS was expected to solve them.

Coherently with the objective of the cross-case analysis, the following variables were investigated: *initial investment to buy the DRE system, life-cycle services of the DRE micro-generator, life-cycle services of the Energy Using Products or Equipment*. Given

[31] *Collected case studies are available free of charge and copy-left at* www.lenses.polimi.it *section case studies.*

the adoption of a S.PSS approach, which can affect the ownership of the products included in the DRE system, the variables of *ownership of the DRE micro-generator,* and *ownership of the Energy Using Products or Equipment,* were also investigated (deductive reasoning).

Theory validation:

To strengthen the findings of case studies research, a comparison between *Traditional product sale of DRE* and *DRE offered through an S.PSS* (S.PSS applied to DRE) was made. A *Traditional product sale of DRE* consists in the sale of a DRE system with related components (e.g. solar panels with wires, inverter, storage), installation and maintenance services. On the contrary, a *DRE offered through an S.PSS,* consists in a sustainable offer model applied to a DRE system, based on different configurations (Product-oriented, Use-oriented, Result-oriented), guarantying (DRE) access with a reduced/avoided investment and life-cycle services costs.

Table 2. Traditional product sale of DRE and DRE offered through an S.PSS.

Variables	a) **Traditional product sale of DRE**	b) **DRE offered through an S.PSS**		
		Product-oriented PSS *services providing added value to the product life cycle*	**Use-oriented PSS** *services providing 'enabling platforms' for customers*	**Result-oriented PSS** *services providing 'final results' for customers*
(1) **initial investment**	customer	provider	provider	provider
(2) **ownership of the DRE micro-generator**	customer	customer	provider	provider
(3) **life-cycle services for the DRE micro-generator**	customer	customer	provider	provider
(4) **ownership of the Energy Using Products / Equipment**	customer	customer	provider	provider
(5) **life-cycle services for the Energy Using Products / Equipment**	customer	customer	provider	provider

The results emerged from the case studies research, together with insights from literature review set the bases for the development of the conceptual framework of this research (inductive reasoning). Furthermore, a Sustainability Design Orienting Scenario was outlined to contribute to conceptual framework definition (see below).

4.3.3 Sustainability Design Orienting Scenario development

The Design-Orienting Scenario (DOS) thinking approach has been developed, from future thinking methodologies, during the EU funded SusHouse Project[32]. A DOS represents possible futures of a given situation, and aims to orient the related socio-economical and/or technological decisions (Manzini & Jégou, 2000 – Manzini, 2003). The Design-Orienting Scenario (DOS) came from the more traditional Policy-Orienting Scenarios (POS), but focuses on a given situation instead of general trends, thus generating possible futures for a specific product/service, in collaboration with a given panorama of stakeholders (Manzini & Jégou, 2000). Within a design process, a DOS can be used for different purposes as to explore product or service opportunities within a specific context, or to propose sets of possible and potentially sustainable (i.e. economically, environmentally and socio-ethically) strategies for companies' re-orientation.

A DOS, is composed by three different components (Manzini & Jégou, 2000):
- *a series of visions, developed and narrated as concrete products and/or services;*
- *a global scenario, which narrates the effect of the implementation of the visions and their possible impact on the reference context;*
- *the main characteristics, which narrate the main effects and benefits of the scenario and its visions.*

The Sustainability Design Orienting Scenario (SDOS), developed within this research and adapted from the Design-Orienting Scenario (DOS) approach, has been used to design and represent promising visions towards sustainable energy for All solutions, based on stakeholders' configurations, with low environmental impact, high socio-ethical quality and high economic and competitive value (Vezzoli and Bacchetti, 2017). Indeed, the SDOS, has been developed on the bases of the characteristics emerged from the case study research, and combined with new emerging factors to support discussions among potential (energy) stakeholders (inductive and abductive reasoning). Below are presented the steps followed to develop the Sustainability Design Orienting Scenario (SDOS) of this research.

Case studies research:
Case studies of S.PSS applied to DRE collected for the case studies research were used as base for the Scenario development. Additional case studies were collected with

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[32] *The SusHouse project was funded by the European Union's Environment and Climate Research programme Theme 4: On Human Dimensions of Environmental Change (ENV4-CT97-0446) and coordinated by the Delft University of Technology. http://www.sushouse.tudelft.nl.*

same requirements of the case studies research.

Guideline definition:
By abstraction and generalization of the characterization from case studies research, six criteria and an articulated set of guidelines were developed aimed at supporting the design of S.PSS applied to DRE solutions.

Workshop sessions:
Guidelines were used in brainstorming sessions, to generate ideas of S.PSS applied to DRE[33]. Resulting ideas were clustered within a polarity diagram, using the two axes defined for the case studies research[34].

SDOS (global scenario, vision and characteristics) development:
From the clusters of ideas of S.PSS applied to DRE solutions, emerged the four visions that together represent the overall Scenario. Each vision represented a Sustainable win-win opportunity towards sustainable energy for All, based on a S.PSS applied to DRE offer and customer configuration. Main (sustainability) effects and benefits of each vision, were represented in the SDOS. The results of the Scenario, contributed to a further definition of the conceptual framework of this research.

4.3.4 Conceptual framework development

Based on the insights from literature review, case studies research, and the outcomes of the Sustainability Design Orienting Scenario, the conceptual framework of the research was developed. To summarize, the conducted case studies research[35], explored 15 S.PSS applied to DRE solutions, to understand and verify key characteristics of such innovation and its financial structure (e.g. initial investment, payment modality). On these bases, a Sustainability Design Orienting Scenario (SDOS) was developed, as meta-project tool to highlight key characteristics of S.PSS applied to DRE model and possible configurations. So forth, the conceptual framework was defined combining the factors that emerged and were elaborated from the study, and removing the factors that were not confirmed among the

[33] *The SDO Toolikt has been adapted to the new criteria and guidelines for sustainable energy for All. The related idea boards of the tool have been used. The SDO toolkit was developed by Carlo Vezzoli and Ursula Tischner within the MEPSS EU 5th FP, Growth project.*
[34] *i.e. the horizontal axis shows the customer type: Business to Customer (B2C) or Business to Business (B2B)); the vertical axis presents the offer: Distributed Renewable Energy micro-generator (e.g. solar panel system plus its components such as storage, inverter, wires, etc.) is offered alone, or together with related Energy Using Products or Energy Using Equipment (e.g. phone and television are Energy Using Products; woodworking machine, sewing machine are Energy Using Equipment).*
[35] *The results of the case studies research are also published in Bacchetti et al., 2016.*

different methodologies adopted. Within the conceptual framework, a first (potential) role of design was introduced, based on the elaboration of confirmed factors from the study.

After the definition of the conceptual framework, the research strategy moved to the second stage, to answer the second set or Research Questions (RQ.2).

4.4 Research stage II

The *prototyping and assessment stage*, was aimed at refining the (potential) role and needed attitudes to design S.PSS applied to DRE in low middle-income (all) contexts; building up a tentative design know-how to support design practice. Thus, answering Research Question 2 (RQ.2).

4.4.1 Development of the (draft) design approach and tools

Based on what emerged from the previous stages of the research, a draft design approach and tools were developed. Insights were taken from the available know-how on System Design for Sustainability, and particularly from what used to design and deal with S.PSS (Tukker and Tischner, 2006 – Vezzoli et al., 2014). As tools related to S.PSS applied to DRE were not available, within this research (and the LeNSes project) a set of dedicated tools were designed, through a process of analysis and selection, design and/or adaptation, followed by an iterative one of prototyping, evaluation, improvement and redesign/refinement. Existing tools analysis regarded their potential contribution in the design process towards S.PSS applied to DRE solutions, and their need of being adapted; then the selection and design/adaptation process followed, to be adopted within the new approach. The design/adaptation process included brainstorming and workshop sessions with experts on System Design for Sustainability. Then the iterative process of prototyping, evaluation, improvement and redesign/refinement was developed through the adoption of the proposed design approach and tools within design-research activities, such as design exercises, vocational courses and workshops both with students, academics and professionals.

4.4.2 Assessment of design approach and tools

The (draft) design approach and tools, were tested during *five design-research activities* (see more in chapter 8) which included a design exercise, two vocational training courses and two workshops conducted by the researcher. The aim of such design-research activities was to get insights for the (draft) design approach and tools prototyping, evaluation, improvement and redesign/refinement.

The researcher was directly involved in all design-research activities, both to design, implement and observe all stages, where she covered both the role of designer and researcher (Wang and Hannafin, 2005). This favored long-term collaborations with other researchers, academics, students and practitioners, developing solutions to (practical) problems in learning environments and defining design principles (Herrington et al., 2007).

The participants of the design-research activities, they were asked to evaluate the tools through a questionnaire aimed to verify each tool in terms of: *tool comprehension and usability; tool impact in the design process*. Additionally, the participants of vocational courses and workshops were asked to evaluate the presented *contents* in terms of: *clarity of contents, grade of exploration of contents, relevance and usefulness of the design exercise in the course/workshop, potential re-use of contents in other contexts.* After participant's assessment, the contents and structure of the course and workshop were discussed among the researcher and the board. These evaluations adopted a systematic approach, in fact, all tools were presented, tested, and evaluated by participants with similar modalities, thus favoring comparison of results. Emerged inputs have been elaborated and combined with observations from the researcher. The scientific context of this research, based on the international scientific community of the Learning Network for Sustainable energy systems (LeNSes – www.lenses.polimi.it), gave the researcher room for discussion with experts from the area of S.PSS and with experts and practitioners dealing with DRE, both from the African and Italian context.

4.4.3 Refinement of the design approach and tools, and development of the needed knowledge-base

The developed design approach and tools, followed a path of analysis, selection, design, followed by an iterative one of prototyping, evaluation, improvement and redesign/refinement. This is a consolidated approach for Design-based research, as gives room for sharing among researcher and other actors involved, which is considered an added value of the Design-based research approach. In fact, the iterative path gave to the researcher the possibility of integrating insights from participants as well as from expert assessments, which could be lost in a linear process. After each design experience, based on the feedback received (from participants and experts), as well as on the results obtained in the design exercise, course and workshop, the design approach and tools were revised accordingly by the researcher. Furthermore, observations were collected by the researcher on the design approach and tools, in relation to the specific design experience, to facilitate retrospective analysis and to elaborate (contextual) design principles (Shavelson et al., 2003). These processes led the researcher to reflect on the knowledge-base (and know-how) needed for the designer towards sustainable energy for All, when adopting the S.PSS applied to DRE model.

4.4.4 Development of an open course

As contribution from this research, an open course on System Design for sustainable energy for All, was developed. The aim of this output, was to facilitate the diffusion of the above knowledge-base and know-how on System Design for sustainable energy for All, and the adoption of the model among professionals, researchers, academics and students. Therefore, the structure of the open course is a downloadable file with links to deep contents related to sustainable energy for All (the current version of the open course is presented in chapter 8).

4.5 Research stage III

The *reflection stage*, was aimed at retrospective analysis of the study and specified the main research findings, as well as limits, generalizations and recommendation for further researches. This last activity focused on reflection on the methodology adopted and the achieved results. Furthermore, it gave room for discussion about research findings, research contribution, innovative aspects and limits, possible generalization. Finally, a reflection was made on next research directions.

Part II - S.PSS applied to DRE a promising approach

Chapter 5 - Understanding S.PSS applied to DRE

The chapter presents the research process that brought to the current understanding on the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model. First, the characterization of S.PSS applied to DRE emerged from case studies of is illustrated. Second, the four visions developed within a Sustainability Design Orienting Scenario (SDOS), aimed to further refine the S.PSS applied to DRE model are introduced. Then, the conceptual framework of this research, built on the above is introduced. Finally, the chapter focuses on the S.PSS applied to DRE model, its definition, as well as its benefits and limits, and its adoption in low and middle-income (all) contexts.

5.1 Introduction

This chapter presents the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model, with its characteristics, as well as its (potential) benefits and limits. This new level of understanding on the model was achieved in a process of case studies research, development of a Sustainability Design Orienting Scenario, and definition of the conceptual framework of the research.

5.2 Case studies research

As method to investigate new areas where little theory is available (Eisenhardt, 1989 - Yin, 1994), a case studies research was performed.

The following results show similarities and differences of the five variables on *traditional product sale of DRE* and on the three ways in which a *DRE can be offered through an S.PSS* (Product-oriented, Use-oriented, Result-oriented).

<u>1) Initial investment:</u> it refers to the cost for the setup of a Distributed Renewable Energy (DRE) solution, i.e. the purchase of the (DRE) micro-generator and its components (e.g. solar panel with wires, inverter, storage). In a traditional product sale, this cost goes to the customer, who becomes the owner of the DRE solution. When Sustainable Product-Service System is applied to Distributed Renewable Energy (S.PSS applied to DRE) the initial investment cost stays with the provider and customers pay only the access to the DRE system or the related need to be satisfied. Let's see the how this happens in relation to the three types of PSS:

- In the case of a Use-oriented PSS, customer doesn't own the (DRE) micro-generator but can access her/his satisfaction through different modalities. The customer can: pay a fixed fee - daily/weekly/monthly - to access the DRE solution during the paid time; pre-pay a predefined period e.g. 20 hours, to access the DRE solution that could be shared by others (e.g. sharing, pooling); pay the output of the DRE solution e.g. amount of light, but (s)he operates on it. For example, Off-grid Electric case study from Tanzania, offers to its customers (B2C) a distributed stand-alone Solar Home System with 2 lights, 1 radio, 1 phone charger. The initial investment and ownership of the system stays with the provider. The customer, to access the DRE solution, pays a fixed fee weekly or monthly as per how (s)he prefers.
- In the case of Result-oriented PSS, provider retains the ownership of the (DRE) micro-generator and through it satisfies the specific need of the customer e.g. access to energy, or energy service. In this case the customer can pay-per-use, so

(s)he pays to obtain a result; or can pay a fixed fee - daily/weekly/monthly – to receive the desired result anytime. For example, the OMC power company makes investment to deliver power plants at the point of use of single telecommunication companies. Each telecommunication company receives energy for its needs and pays in relation to the energy used. OMC power retains the ownership of the plants and provides installation, operation and maintenance.

- In Product-oriented PSS, the customer becomes the owner of the (DRE) micro-generator, but the initial investment cost is covered by the provider, and is paid back by the customer e.g. fixed fee, pay per period, or a mix of the two. In Product-oriented cases, financial support e.g. crowdfunding, micro-credit, public funding, could favor the access to the solution. For example, Grameen Shakti sells Solar Home Systems with 2 lights. In the package are included installation, maintenance and repair until the Solar Home Systems and the 2 lights are paid-back. The customers of Grameen Shakti, often use micro-credit to afford the acquisition of the system, and micro-credit allows them to have a financing source even if they are unbankable customers, and to take 2-3 year for the complete pay-back.

Looking to the provider (or partnership of providers), the initial investment for the DRE solution (to buy or build the components) can be coherent with a growth strategy. In fact, with the adoption of the S.PSS applied to DRE model, and independently from the PSS configuration, the provider: expands his market reaching customers who would not be able to sustain the cost of a DRE micro-generator or would not be able to pay it in one instalment; (s)he creates longer term relationship with the clients, while ensures himself a stable income during the whole life-cycle of the DRE solution; (s)he can increase the number of potential customers thanks to; (s)he can strength her/his market position developing strategic partnerships (e.g. national governments, investors, etc.).

The cross-case analysis showed that when S.PSS is applied to DRE, it makes possible to move the initial investment from the customer to the provider, thus retaining (or increasing) the satisfaction for the customer. For example, was found that "the customers of Off-grid Electric case study, who were used to buy kerosene for lanterns, now can access DRE at an affordable price. In fact, without the initial investment cost (retained by Off-grid Electric), the energy cost remains same as they already spent, while improving their quality of life (i.e. reduction of health diseases caused using kerosene lamps)".

A further observation was made regarding the initial investment cost. Although the access of a S.PSS applied to DRE, could be more affordable then to buy a (DRE) micro-generator (as the initial investment cost and life-cycle costs stay with the provider) there are customers with lower budget than the needed, or with no budget at all e.g. communities where the currency is based on exchanges. In these cases, could be required to plan a different strategy of payment e.g. in-kind payments. For example, Domestic Biogas case study (configured as Product-oriented PSS), it allows future customers to pay-back part of the initial investment cost with in-kind contribution i.e. customers provide labor force and/or materials to build up their biogas plants.

<u>2 and 3) Ownership of the DRE micro-generator and life-cycle services:</u> it investigates on who owns the (DRE) micro-generator (e.g. solar panel with wires, inverter, storage) and who is the responsible for its life-cycle services and costs e.g. installation, operation & maintenance, repair, upgrade, end-of-life treatment. In traditional product sale of DRE, both (ownership and life-cycle costs) are responsibility of the customer who owns the (DRE) micro-generator and pays the life-cycle services when needed or through a warranty plan. On the contrary, when a Use-oriented or Result-oriented PSS is applied to a (DRE) micro-generator, its life-cycle services and costs are on the provider who owns it. In the case a Product-oriented PSS is applied to (DRE) micro-generator an intermediate solution emerges. In Product-oriented solutions, since the product is sold to the customer, the life-cycle costs are responsibility of the customer but they are managed as small periodic payments usually affordable for the customer, and this avoids the risk of unexpected (and unaffordable) costs.

Looking to the provider, since (s)he (maybe in a partnership) retains the ownership, or at least some responsibilities over the life-cycle of the (DRE) micro-generator, (s)he has an economic incentive to extend (DRE) micro-generator lifetime, postponing both the disposal and re-manufacturing costs; as well as to provide high quality DRE products lowering life-cycle costs and increasing her/his margins. These economic benefits, bring benefits on the environment e.g. postponing disposal of products, reducing the need of spare parts.

The cross-case studies analysis showed that, when a Use-oriented or Result-oriented PSS is applied to (DRE) micro-generator, its life-cycle costs are covered by the provider. When a Product oriented PSS is applied, the life-cycle costs are replaced by small periodic payments from the customers, while the provider is still retaining some responsibilities. For example, the CEO of Bboxx told that "in Bboxx case study (Product-oriented PSS) the life-cycle costs are covered by the customer who owns the (DRE) micro-generator and related appliances after pay-back. To avoid unexpected costs (s)he can go for a warranty contract, thus receiving full assistance from Bboxx staff. More than 50% of the customers have opted for this solution". Moreover, the cross-case studies analysis highlighted that the change of ownership from customer to provider could be an obstacle towards local acceptance depending on cultural habits. So forth, especially where cultural habits support ownership, the S.PSS applied to DRE model has to be introduced together with the culture of access.

<u>4 and 5) Ownership of the Energy Using Products or Equipment (EUP-EUE) and life-cycle services:</u> this variable investigates on ownership and life-cycle costs responsibilities of the Energy Using Products (e.g. phone and lights) and/or Energy Using Equipment (e.g. refrigerator and printer) in a system. In traditional product sale of DRE, EUP and EUE are both responsibility of the customer who owns the DRE micro-generator and pays the life-cycle services when needed or through a warranty plan. In some case studies when EUP and EUE were offered with PSS configurations, both Use-oriented and Result-oriented, the EUP and EUE life-cycle costs were located to the provider. In the case of Product-oriented solutions, since the EUP or EUE is sold to the customer, its life-cycle costs are responsibility of the customer who can managed them as small periodic payments.

As for variables 2 and 3, the provider retains the ownership, or at least some responsibilities over the life-cycle of the EUP and EUE. So forth, (s)he has an economic incentive to extend their lifetime, postponing both the disposal and re-manufacturing costs; as well as to provide high quality DRE products lowering life-cycle costs and increasing her/his margins.

The cross-case analysis showed that, highlighted different approaches to Energy Using Products and/or Energy Using Equipment ownership. For example, "in Solar Transition the rechargeable lanterns provided, they are owned by the Cooperative Based Organization settled locally. This allows local people to rent lanterns without owning them, and encourages them to continue the relation with the service, favoring the creation of relationships and cohesion in the village". In a similar situation, the representative from Solarkiosk told that "in Solarkiosk, we sell the solar lanterns and other products to the final customers, this to avoid the complex management of the renting that could reduce efficiency in the availability of products." These different configurations, underline the need of managerial abilities for the local dealer, thus suggesting capacity building activities as support.

5.2.3 Final observations

To summarize, the analyzed case studies provided evidence of the fact that, the adoption of the Sustainable Product-Service System (S.PSS) model to Distributed Renewable Energy (DRE), if properly conceived and contextualized, can:

- cut the *initial investment* cost for the customer locating it on the provider. This increases affordability for the customer, while opens market opportunities for the provider/s i.e. unbankable customers or those who are not able to pay in one instalment. This was verified both when Use-oriented and Result-oriented PSS are adopted, as the DRE solution is owned by the provider. For Product-oriented PSS, the initial investment stays with the provider, but is paid-back by the customers who becomes owner of the (DRE) micro-generator and (eventually) Energy Using Products or Equipment.
- avoid (unexpected) *life-cycle costs* for the customer. This was validated for the three configurations of PSS (Product-oriented, Use-oriented, Result-oriented PSS). If Use-oriented or Result-oriented PSS are adopted, the provider owns the DRE solution, and is responsible for its life-cycle management. If a Product-oriented PSS is adopted, the ownership goes to the customer, but the provider retains some responsibilities of life-cycle services of the DRE system, paid with small periodic payments from the customer.

Moreover, as the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model, aims to deliver a customer (energy) satisfaction through a mix of products and services (and not by selling a DRE product), it is based on a *network of actors* e.g. energy supplier, product manufacturer, service provider, who produce, manage and deliver such (energy) satisfaction. This entails long-term relations among actors and between the actors and the customer, thus increases affordability for the customer i.e. initial investment and life-cycle costs are substituted by small customizable payments; as well as it opens market opportunities for the provider/s i.e. unbankable customers or those who are not able to pay in one instalment. Moreover, as the provider (or a partnership of providers), retains ownership, or at least some responsibilities on the DRE products offer, it is her/his economic interest to reduce DRE products life-cycle costs i.e. postponing disposal and re-manufacturing costs, thus beneficiating the environment.

To conclude, as per the above observations from the case studies research, the adoption of Sustainable Product-Service System (S.PSS) to Distributed Renewable Energy (DRE), if properly conceived, can reduce/cut both the initial (investment) cost of access to energy and the life-cycle costs while improving local skills and rising local employment, as well as beneficiating the environment.

5.3 Sustainability Design Orienting Scenario for S.PSS applied to DRE

To highlight and narrate the characteristics emerged from the case study research, a Sustainability Design Orienting Scenario (SDOS), was developed. Thus, the (from now on) Scenario contributed to detail the conceptual framework of this research. The Scenario was also conceived as a tool, to inspire designers, (energy) professionals and academics, through new visions on towards sustainable energy for All, and facilitating strategic conversations (more about the Scenario as a tool in section 7.2).

The term Sustainability Design Orienting Scenario (SDOS) refers to vision/s that depict promising configurations of stakeholders, aimed to fulfil a demand of satisfaction, with low environmental impact, high socio-ethical quality and high economic and competitive value.

5.3.1 The four visions towards sustainable energy for All

The four visions that composes the overall Scenario, are positioned in four quadrants, as intersection of the two axes validated by the case studies research. The horizontal axis defines the customer of the offer that can be a final customer (B2C) or a small business/local entrepreneur (B2B); the vertical axis defines the type of offer, as Distributed Renewable Energy (DRE) micro-generator only, or together with Energy Using Products or Equipment (EUP – EUE). The visions include both Use-oriented and Result-oriented PSS applied to DRE. Product-oriented PSS were not proposed, as less radical innovations for future Scenarios. The aim of these visions is to highlight possible configurations where Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) is adopted, in low and middle-income (all) contexts. Distinctive characteristics of Sustainable Product-Service System (S.PSS), such as ownership changes and consequent initial investment costs and life-cycle costs modifications are underlined. Below the four visions are presented through a short explanation and a case study. In the Scenario as a tool, case study is substituted by a narration.

<u>Vision 1 - Energy for All in daily life</u>: the vision presents a business to customer (B2C) offer of a (DRE) micro-generator. The provider owns the (DRE) micro-generator and its components (e.g. solar panel, wires, storage), while the customer makes periodic payments e.g. pay-per-time, to access it. For the customer, this avoids both initial investment cost of the DRE system (e.g. the purchase of solar panel, wires, storage and their installation) and its life-cycle costs (e.g. operation & maintenance), which are substituted by pay-per-time payments, thus making access to energy

economically viable in low-middle income (all) contexts. The *Box 6. Case study for: Energy for All in daily life* shows a case study, representative of vision 1.

Box 6. Case study for: Energy for All in daily life – vision 1.

The ***Husk Power***[36] *company provides energy solutions by designing and installing decentralized biomass power plants (from 25 kW to 100 kW) and wiring villages of up to 4000 inhabitants to deliver electricity. Households pre-pay a fixed monthly fee, ranging from 2 to 3 euro, to light up their Energy Using Products e.g. fluorescent lamps or a mobile charging station. The company retains ownership of the plants and employs local agents for operation, maintenance and fee collection. A partnership with local farmers is established to provide rice husk to power the local plant.*

In this way, customers do not have to buy the solar system and components; they just access electricity produced by the decentralized biomass plants, by paying an agreed fee every month. The energy supplier retains the ownership and responsibility over the plants and related energy services. In this case the interest of the energy supplier is to use high-quality plants, thus reducing maintenance needs (included in the offer), and increasing his business margins. This can result in a reduced environmental impact, due to the reduced number of spare parts needed as high-quality plants are in use. At socio-ethical level, the energy solution could benefit customers with energy access, as well as increasing job opportunities locally, e.g. rice husk providers or local agents.

Vision 2 - "Pay x use" your daily life products and energy: this vision represents a business to customer (B2C) offer, but in this case the (DRE) micro-generator (and the related components) is provided together with Energy Using Products and/or Equipment (EUP - EUE). This configuration locates the initial investment costs, ownership and life-cycle costs of both (DRE) micro-generator and Energy Using Products or Equipment (EUP-EUE) to the provider. The customer pays to access the energy services as a pay x use e.g. one shot, as per his/her need, thus avoiding fixed costs maybe not affordable. This configuration of "one-shot use" allows the provider to rent the DRE micro-generator and/or EUP to more customers, thus increasing

[36] *The example of Husk Power, is included in the case studies research of the thesis. The card of the case study is available in Annex Ib at the end of this thesis book. More info can be found in the case study profile at* www.lenses.polimi.it, *section case studies.*

her/his margins. The *Box 7. Case study for: "Pay x use" your daily life products and energy* shows a case study, representative of vision 2.

Box 7. Case study for: "Pay x use" your daily life products and energy – vision 2.

Solar Transition[37] *is a charging and energy-service station based in Kenya, that provides renewable energy for a range of daily services: lantern and battery charging and renting, charging of phones, IT-services (typing, printing and photo-copying), and TV shows. The funder of the project designed and installed Solar transition in the village. A local Cooperative Based Organization has been established and the staff trained, and is now operating the system. The local Cooperative Based Organization owns the charging and energy-services station, and related Energy Using Products and Equipment, and is paying them back until the next years. Final customers pay an initial membership fee, then they pay for each service they use (pay per use)***.**

The customers don't have to buy the Solar Home System and neither the Energy Using Products. They just pay to access their need e.g. renting a lantern, charging the phone. The energy supplier retains ownership of the SHS and EUPs, and cover also related services. If the system and products are of high quality, this reduces maintenance and repair needs, thus favoring the business of the energy supplier. Furthermore, as the customers use the EUPs for a limited time, this gave to the energy supplier the possibility to rent them to many customers in different times, thus increasing her/his returns. Additionally, the availability of local skilled technicians in the center, can reduce costs, and environmental impact in case a maintenance work is needed. At socio-ethical level, the energy solution could benefit several customers with "one shot" energy services.

Vision 3 - Energize your business without initial investment cost: this vision shows the offer of a (DRE) micro-generator to business to business (B2B) customers. The (DRE) micro-generator and related components are owned by the provider. The customer (if needed) has only to purchase the necessary Energy Using Products or Equipment (e.g. solar lamps to be rented, sewing machine for the tailor shop). This

[37] *The example of Solar Transition, is included in the case studies research of the thesis. The card of the case study is available in Annex Ib at the end of this thesis book. More info can be found in the case study profile at* www.lenses.polimi.it, *section case studies.*

configuration gives stable access to energy to small businesses/local entrepreneurs, thus allowing them to start-up or upgrade their income generating activities and to receive stable access to energy. In fact, with reliable energy access they can guarantee the production/delivery of a predefined quantity of products (or services) within a given period, thus satisfying their clients and opening new market opportunities. The *Box 8. Case study for: Energize your business without initial investment cost* shows a case study, representative of vision 3.

Box 8. Energize your business without initial investment cost – vision 3.

The ***OMC Power***[38] *company offers energy solutions to telecommunication companies in India, through stand-alone power plants running on solar, wind and biogas. Telecommunication companies get the power plant installed on site and pay per the energy they use (kWh). OMC Power retains the ownership of the energy system and provides installation, operation & maintenance, repair. As complementary service OMC Power offers charged lanterns to local communities (pre-payment or pay-per-use).*

In this way, Telecommunication companies (customer of the B2B offer) do not need to buy the solar system and components, but they can pay per consumption or a fixed rate per period to access them. The energy supplier retains the ownership of the power plants and responsibility over related services, such as maintenance and repair. Thus, is the interest of the energy supplier to reduce service needs, improving his business return. This could be achieved by installing high quality plants, thus resulting in a reduced environmental impact, due to the avoided spare parts and services. At socio-ethical level, the energy solution could benefit customers (B2B) with reliable access to energy, which allow them to provide stable working conditions.

Vision 4 - Start-up your business paying per period for equipment and energy: this vision is identified as an offer of a (DRE) micro-generator (and the related components) plus Energy Using Products or Equipment for business to business (B2B) customers. In this case, a small entrepreneur/business receives a (DRE) system package (e.g. carpenter's workshop) composed of a (DRE) micro-generator and

[38] *The example of OMC Power, is included in the case studies research of the thesis. The card of the case study is available in Annex Ib at the end of this thesis book. More info can be found in the case study profile at* www.lenses.polimi.it, *section case studies, or at the direct website www.omcpower.com.*

related components and, the related Energy Using Equipment (e.g. circular saw, drill) without necessarily own them. This configuration cuts the initial investment costs for both the (DRE) micro-generator and the Energy Using Equipment (EUE), and their life-cycle costs. The *Box 9. Case study for: Start-up your business paying per period for equipment and energy* shows a case study, representative of vision 4.

Box 9. Start-up your business paying per period for equipment and energy – vision 4.

Sunlabob[39] *company provides energy-services for locals in Laos. Sunlabob leases a charging station with Energy Using Products (EUP - e.g. solar lanterns) to an established village committee who rents the products to the individual households. The committee is responsible setting prices, collecting rents and perform basic maintenance. Sunlabob retains ownership and maintenance responsibilities, and offers training services. Final customers can rent the recharged lantern for 0.50 euro and it will last for 15 hours of light. To use the charging station, the committee pays around 1.70 euro per month.*

The village committee doesn't need to buy the charging station and neither the Energy Using Products to be rented from final customers. The village committee just pay a fixed fee per period, as the company (i.e. Sunlabob) retains ownership and related maintenance responsibility. If the system is of high quality, this reduces maintenance and repair needs, thus favoring the business of the energy supplier. This can result in a reduced environmental impact, coherently with the quality of the products in use. Furthermore, the availability of local skilled technicians, can reduce costs, and environmental impact in case a maintenance work is needed. At socio-ethical level, the energy solution could benefit customers with energy access, aimed to enable different daily activities, as well as opening new working and training opportunities. Furthermore, due to the presence of the village committee this increases reliability of the offer from the customer's perspective.

[39] *The example of Sunlabob, is included in the case studies research of the thesis. The card of the case study is available in Annex Ib at the end of this thesis book. More info can be found in the case study profile at* www.lenses.polimi.it, *section case studies, or at the direct website www.sunlabob.com.*

5.3.2 Final reflections

The Scenario, showed four promising configurations of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE), both for: Business to Customer (B2C) or Business to Business (B2B); as well as when the offer of only DRE micro-generator e.g. solar panel with appliances, or DRE micro-generator plus Energy Using Products (EUP) or Energy Using Equipment (EUE) e.g. a lantern is a Product, a sewing machine is an Equipment.

The four visions, were used to translate what observed in the case studies research. The visions emphasized typical characteristics of S.PSSs, such as: ownership changes and consequent initial investment costs and life-cycle costs modifications.as well as DRE peculiarities, such as DRE configuration. So forth, the Scenario and its visions gave a deep understanding for the definition of the concept of S.PSS applied to DRE.

5.4 Conceptual framework: towards the model of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE)

The entry point of the conceptual framework was defined by the ***(I) paradigm shift from non-renewable/centralized to distributed/renewable energy generation systems***. In fact, the current energy approach evidenced by the literature, mainly based on centralized and non-renewable energy generation, is assessed as not viable to achieve the goal of sustainable energy access for All. From the environmental point of view, the use of non-renewable (or exhaustible) resources: is fastening the depletion of the resources themselves, as they are not able to be replaced in due time; is damaging the environment through the processes of extraction and transformation of resources, as these processes have high emissions, thus entailing irreversible damages to the (local) eco-system. On the socio-ethical perspective, the extraction of exhaustible resources, is (often) depriving local communities of natural resources e.g. water and land used for the extraction plants, without giving them benefits. Furthermore, as centralized systems are not cost-effective to connect a reduced number of utilities or low-purchasing power utilities, this leaves them outside the covered utilities. So forth, several authors in the literature, agreed on the need for such paradigm shift from centralized and non-renewable energy systems, to a distributed generation based on renewable energies, i.e. Distributed Renewable Energies (DRE). Distributed Renewable Energy, has been defined as *"Small-scale generation plants harnessing renewable energy resources (such as sun, wind, water, biomass and geothermal energy), at or near the point of use, where the users are the producers – whether individuals, small businesses and/or a local community. If the* *small-scale generation plants are also connected with each other (for example, to share the energy surplus), they become a Renewable Local Energy Network, which may in turn connected with nearby similar networks"* (LeNSes project, 2017).

DRE, can benefit the environment because it uses local renewable resources which are "almost ready" resources e.g. solar radiation is directly providing energy to solar cells generators, so the (socio-ethical and environmental) impact of extraction and transformation is negligible compared to the one of exhaustible resources. Moreover, DRE uses the energy at/near the point of production, thus distribution & transmission costs are reduced or avoided. On the socio-ethical stand point, DRE allows individuals and local communities to access renewable and reliable energy. Indeed, due to the small dimension of DRE plants, they can be setup for a small number of utilities or one, thus increasing equity in the redistribution of resources and democratizing access to energy. Finally, DRE as distributed production system, needs to build up local competences (e.g. for management and technical assistance, thus creating employment opportunities.

Despite the assessed potentialities of the DRE concept, the second point of the conceptual framework are the ***(II) three limits*** of the concept: the initial investment cost to buy the (DRE) system, which is often not affordable for the customers (B2C – B2B), especially in low and middle-income contexts; the (unexpected) life-cycle costs for the (DRE) system e.g. operation & maintenance, or repair, often not accessible, thus increasing the risk of drop-off; a (potential) lack of local expertise (manufacturing, management and technical assistance) about Distributed Renewable Energy (DRE) systems. The above mentioned limits, gave room to the definition of the last point of the conceptual framework, explored and characterized within this research (and the LeNSes project) is the ***(IV) Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model***. The case studies research conducted, and the configurations developed within the Sustainability Design Orienting Scenario, proved that the S.PSS applied to DRE model can provide access to (energy) needs, even in low and middle-income contexts. This statement, founds reasons in the fact that S.PSS applied to DRE avoids the *initial investment* costs, of the (DRE) micro-generator (and if included) of the Energy Using Products or Equipment for the customer, locating them to the provider, and making access to energy more affordable even in low and middle-income contexts. Moreover, it avoids (unexpected) *life-cycle costs* for the customer as, both if the provider owns the DRE solution (Use-oriented, Result-oriented PSS), or if the ownership goes to the customer (Product-oriented PSS), the provider retains responsibilities of life-cycle services of the DRE system. Moreover, as the S.PSS applied to DRE model is based on a mix of products and services, it involves a *network of actors* e.g. energy supplier, product manufacturer, service provider, who produce, manage and deliver such (energy) satisfaction. Indeed, the Sustainable Product-Service System (S.PSS) configuration, it entails long-term relations among actors, thus beneficiating both the customer, who pays only for her/his satisfaction, and the provider opening new market opportunities and ensuring a stable income for himself during the whole life-cycle of the (DRE) system. Moreover, the involvement of (local) actors, can favor (local) employment and empowerment, thus providing socio-ethical benefits.

In the proposed conceptual framework of research, a contribution from the design field and a consequent design role is perceived, especially from Product-Service System Design and Design for Sustainability (DfS). Indeed, to deal with S.PSS applied to DRE, a need for a knowledge-base and know-how, with design process and tools was recognized. Chapter 6 is dedicated to this topic.

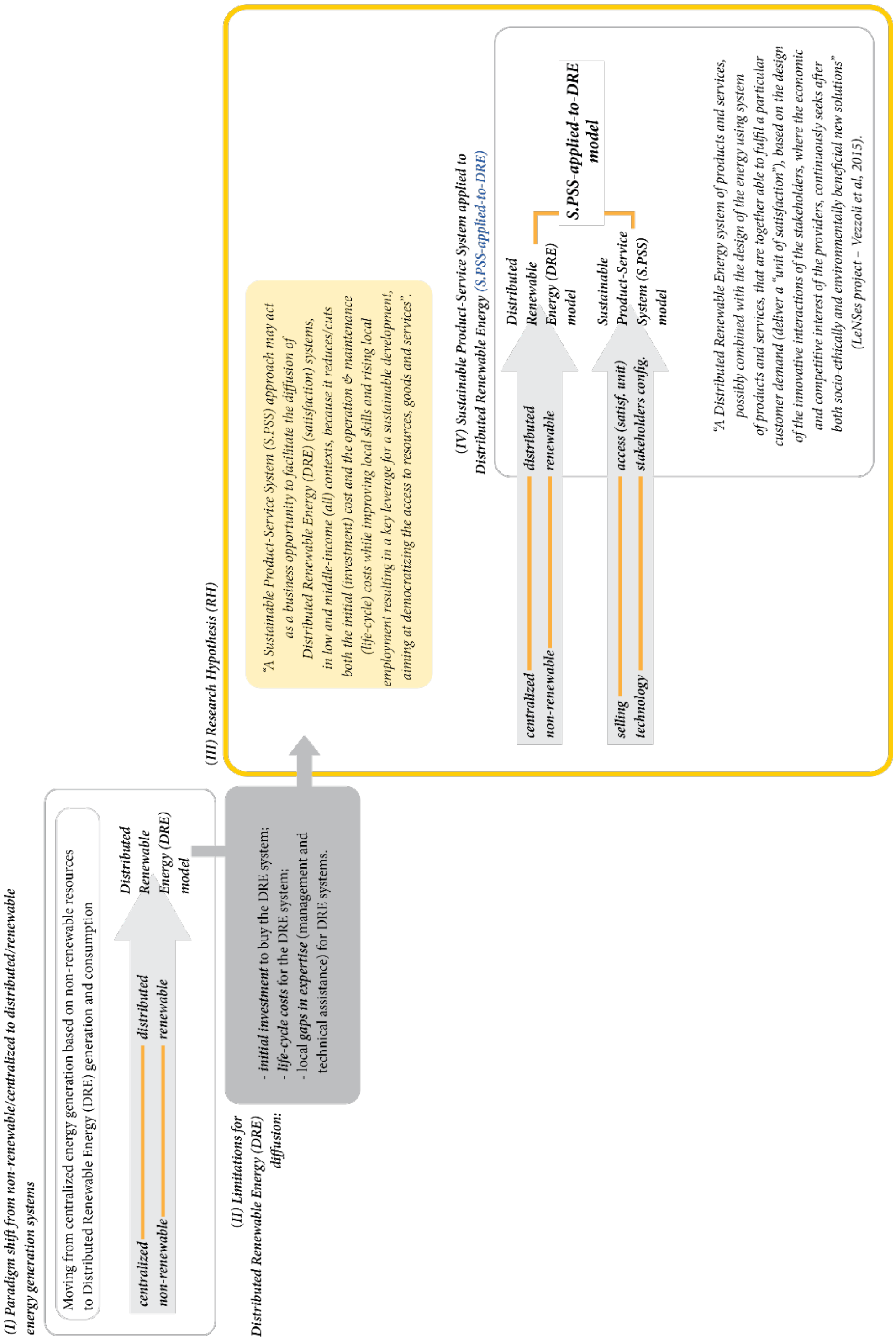


Figure 6. Conceptual framework.

5.5 S.PSS applied to DRE: a promising model towards sustainable energy for All

5.5.1 S.PSS applied to DRE: a definition

As introduced above, the model of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE), is based on the coupling of the S.PSS model, and DRE model.
So forth, the S.PSS applied to DRE model, it is not the sale of DRE products, such as a traditional sale of solar panel and appliances, but is the offer of DRE products and services combined, to achieve a demand of (energy) satisfaction from the users. As highlighted from the case studies, S.PSS applied to DRE) can entail changes in the ownership architecture, as well as in the generation of economic value, that, should depend on the delivered satisfaction (e.g. have phone charged). This brings the interest of the provider (especially if (s)he owns the DRE products) to have high quality DRE products, thus beneficiating the environment. Below, an example of S.PSS applied to DRE is provided.

Box 10. Example of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE).

Example of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) is the ***OFF-GRID ELECTRIC***[40].

M-POWER company, owner of OFF-GRID ELECTRIC, offers Solar Home Systems (SHS) which include the hardware to generate energy (Solar panel + Storage + Wires) and related Energy Using Products (EUP - two lights + phone charger), to rural people in Tanzania. Customers pay a pay-per-period fee, usually on daily basis. OFF-GRID Electric retains the ownership of the SHSs and the EUPs, and provides installation, operation & maintenance, end of life services. The offer can be upgraded in relation to the energy needs. OFF-GRID Electric organizes training for installation for local dealers and customers. Recently has been opened the first OFF-GRID Academy for technical training.

To summarize, S.PSS applied to DRE is considered an opportunity towards

[40] *The example of OFF-GRID Electric, is included in the case studies research of the thesis. The card of the case study is available in Annex Ib at the end of this thesis book. More info can be found in the case study profile at* www.lenses.polimi.it, *section case studies.*

sustainable energy for All (Bacchetti et al., 2016) as:

- focuses on the satisfaction of a specific customer need (e.g. access to energy), through a mix of product and services, rather than through the selling of a product (e.g. DRE system of solar panel and related appliances), thus reducing/avoiding initial investment cost to buy the Distributed Renewable Energy (DRE) micro-generator and Energy Using Products or Equipment (EUP – EUE), often not affordable for the customer;
- focuses on satisfaction instead of product ownership, thus it avoids (unexpected) life-cycle costs, as operation & maintenance or repair on the product, for the customer, thus reducing the risk of drop-off;
- focuses on the specific context of use, this leads to the involvement of (competent) local stakeholders, rising (local) employment and empowerment, and the diffusion of skills.

Based on the above consideration, the LeNSes project, gave the following definition of Sustainable Product-Service System applied to Distributed Renewable Energy: *"A **Distributed Renewable Energy Product-Service System**, possibly combined with the design of the energy using system of products and services, that are together able to fulfil a particular customer demand (deliver a "unit of satisfaction"), 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, environmentally and economically beneficial new solutions"* (LeNSes project, 2017).

5.5.2 S.PSS applied to DRE benefits and limits

The potential benefits and limits of DRE and S.PSS have been illustrated respectively in chapters 2 and 3. Here, benefits and limits of their coupling (S.PSS & DRE) are discussed.

S.PSS applied to DRE benefits:

<u>Environmental benefits:</u>

The adoption of the S.PSS approach to diffuse DRE, focuses on access to a specific (energy) need, instead of (energy) products i.e. DRE micro-generator and eventually Energy Using Products/Equipment ownership. So forth, it is interest of the provider who owns the (energy) products or at least some responsibilities on them, to promote longer utilization of DRE system and related appliances, through different strategies such as life extension, re-use, etc. (Stahel, 2000). As well as to minimize the resources (energy and material) to produce and use the (energy) products, this decreasing environmental impact of the solution (Vezzoli, 2010), without compromising customer satisfaction (Stahel, 2000).

Socio-ethical benefits:

The adoption of the S.PSS approach to diffuse DRE, allows individuals and local communities to access energy, as well as to become prosumer (producer + consumer) of their own energy, this increasing equity in the redistribution and democratization of resources. In fact, final customers pay to access their (energy) satisfaction, while avoiding initial investment cost to buy (energy) products as well as their (unexpected) life-cycle costs e.g. operation & maintenance, repair, upgrade, and related disposal.

From customers perspective, the opportunity to access S.PSS applied to DRE through small payments (especially for Use-oriented and Result-oriented PSS), can increase the answer to unsatisfied and customized (energy) demands, especially in low and middle-income contexts (UNEP, 2002). Reliability of energy access could also benefit small businesses/local entrepreneurs, who receive a full-package of products and services, which increase stability of their business and open new market opportunities. Finally, since S.PSS applied to DRE is labor and relationship-intensive solution, this entails to involve local (competent) rather than global stakeholders, hence increasing potential employment opportunities and a consequent socio-cultural development (UNEP, 2002).

Economic benefits:

From a customer perspective, the opportunity to access (energy) satisfaction instead of products ownership avoids the initial investment and unexpected life-cycle costs, guarantying the economic feasibility of the offer.

From a provider perspective, a S.PSS approach can increase competitiveness of the offer as more customized on customer needs, and creates longer term relationship with the clients, thus ensuring a stable income for the provider. Furthermore, the offer of access instead of ownership could open new market opportunities for the provider, towards unexplored target i.e. those unable to pay a DRE in one instalment. Finally, as S.PSS applied to DRE solutions require to be managed at local level, this can offer opportunities to strengthen the local economy and increase local employment.

S.PSS applied to DRE limits:

Environmental limits:

The adoption of a PSS approach to DRE is not environmentally sustainable per se, thus needs to be conceived on a sustainability perspective. In fact, both the (energy) products i.e. DRE micro-generator and eventually Energy Using Products/Equipment and services i.e. design, financing, training, operation & maintenance, upgrade and disposal, combined to provide the (energy) satisfaction, need to be designed to reduce the (environmental) impact of the solution, thus fostering the economic interest of the provider/manufacture to seek environmentally sustainable solutions. S.PSS & DRE must consider unwanted side effect commonly known as rebound effects (UNEP, 2002 – Mont, 2002) (more in section 3.3). An example of rebound effect in DRE solutions, is the increase of energy consumption, especially where energy access was not available before (see below).

Socio-ethical limits:

From the customer perspective, especially when the (energy) products i.e. DRE micro-generator and eventually Energy Using Products/Equipment ownership stays with the provider/s, there is the need of a cultural shift guidance, to support Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions while reducing potential rebound effect e.g. cultural barriers (Vezzoli, 2010 - Ceschin & Gaziulusoy, 2016). In fact, the ownership concept of the Use-oriented and Result-oriented PSS, could be an obstacle towards local acceptance of the innovation (Ceschin, 2013 - Mont 2002; UNEP 2002 – Manzini et al., 2001 - Goedkoop et al. 1999). From the provider/s perspective, can be perceived barriers such as current company's organization (Ceschin & Gaziulusoy, 2016) and production and marketing strategies (Mont, 2002). In fact, especially in the case of DRE system owned by the provider, this means a risk for the provider who retains a higher capital of products, thus needing to design them properly to last longer, and at a reduced level of obsolescence. Regulatory and political barriers (Ceschin & Gaziulusoy, 2016) can also limits S.PSS & DRE success e.g. legal framework to allow energy production from prosumer (producer + consumer) is often non-existent or insufficient, as well as energy policies are not stable in most developing countries, discouraging investments. Finally, weakness in local competences e.g. manufacturing of DRE products, need to be properly addressed to become drivers of the innovation. In fact, the need of local competences could generate new working opportunities, as well as clear communication of benefits, through local channels could speed up the diffusion of the model (Van Halen et al., 2005).

Economic limits:

Currently, fossil fuel industries access subsidies not available for Distributed Renewable Energies (DRE), thus, this reduces competitiveness of DRE, while prolonging life of (obsolete) fossil fuel technologies (Komor & Molnar, 2015 – Klein, 2014 – Rifkin, 2011). Furthermore, due to the complexity of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE), it could be difficult, especially in low and middle-income context, to perceive long-term costs e.g. life-cycle costs and benefits, reducing the appealing of the solution (Rolland, 2011 - White et al., 1999). Furthermore, the lack of local infrastructure and technology e.g. management of product collection, remanufacturing, could further reduce internal and external interest in S.PSS applied to DRE solutions (Vezzoli, 2010 - Ciliberti et al., 2008).

Aside to the characterizing benefits and limits of S.PSS & DRE that can be oriented, such solutions are expected to bring an increase in the energy demand, especially in countries currently without access to sustainable energy (IRENA, 2016), thus negatively affecting the impact on the environment. However, this will be offset by the reduction of non-renewable energy sources currently in use to provide to unavailability or unaffordability of sustainable energy access. Furthermore, a S.PSS approach, based on access (unit of satisfaction) instead of product ownership, could contribute providing sharing, leasing, pooling options, where the provider/s is interested to provide high quality products (high energy efficiency and longer life-span of products), thus limiting the environmental impact of such expected energy increase.

The potential benefits and limits must be verified case-by-case. Limits related to the development of S.PSS applied to DRE solutions, need to be addressed both at research level to be further explored, and at local level to be correctly outdated according to the context. For this reason, S.PSS applied to DRE must be conceived on a sustainability perspective.

5.5.3 S.PSS applied to DRE in low and middle-income (all) contexts

As characterized within the conceptual framework, a S.PSS applied to DRE, can be an opportunity to deliver satisfaction of (energy) needs, even in low and middle-income contexts. This was observed both for Business to Customer solutions e.g. guarantying access to sustainable energy for daily life activities, as well as for and Business to Business ones e.g. to guarantee a reliable access to energy, thus ensuring a stable production. Moreover, S.PSS applied to DRE was observed as offer of only the DRE micro-generator e.g. solar panel with appliances, or DRE micro-generator plus Energy Using Products or Energy Using Equipment e.g. a lantern is a Product, a sewing machine is an Equipment. Furthermore, to work on S.PSS applied to DRE, and especially in low and middle-income contexts, some considerations need to be properly planned. These are proposed below.

Customer:

The customer of a S.PSS applied to DRE can be a final customer (B2C) as a household, a community, a school; or a small entrepreneur/small business (B2B) such as a company, a local shop and others. To increase the level of customization and acceptance of the S.PSS applied to DRE offer, is important to involve the customers directly from the start of the process. Furthermore, the involvement of customers will help to understand gender equity in the context. So forth, will be crucial to consult both women and men and to provide further plans concerning sustainable development (Hunt, 2012– World Bank, 2013).

Customer energy need: the first step is to understand the customer demand of (energy) satisfaction, and the consequent energy need (Colombo et al., 2013 – Mandelli et al., 2014), to support the correct design of the energy system configuration, dimension and energy resource. In time is predictable an increasing of the energy demand, so this should be included to dimension the plant/s.

Customer awareness level: to introduce S.PSS applied to DRE innovations, consciousness and trust from the customers, both in the technology and (potential) benefits and limits is crucial. So forth, it is important to work on communication channels in relation to targets and contexts (GIZ, 2013 – World Bank, 2012).

Customer purchasing-power and willingness to pay: S.PSS to deliver DRE solutions, allows different payment modalities, usually affordable for the customer and closest to her/his habits. Anyhow, to understand the purchasing-power of the customer, and willingness to pay, is crucial to propose an affordable solution (Urpelainen & Yoon, 2015). A possibility is to verify the current expenses on energy and to propose a similar request; anyhow, is not obvious that funds will be redirect to the new solution (Urpelainen & Yoon, 2015), so forth, to increase awareness is fundamental. For example, as S.PSS applied to DRE is more complex than traditional product sale, and especially life-cycle costs are more difficult to predict, awareness on the potential advantages need to be increased (Rolland, 2011 - White et al., 1999).

Network of actors:

As S.PSS applied to DRE, is based on satisfaction of a need, the panorama of actors involved is wider compared to a traditional sale of products. Early involvement is fundamental to ensure their role in the system, and as well to plan, if needed, capacity building activities to setup the competences required by the system. Moreover, the early involvement of actors, could encourage partnerships that could benefit the entire system e.g. in the River Simple case study that offers a car-leasing service (discussed in chapter 3), the car manufacturer is in partnership with the service provider; this entails that the car manufacturer, retaining the ownership of the cars used by River Simple, is interested in offering long-lasting cars, this increasing environmental and economic benefits of the system. In fact, the high quality of the cars will reduce the need to produce new one, while will guarantees high margins of returns for the partnership. The roles of the actors could vary from energy supplier, products manufacturer, services provider, and regulatory & political actors.

Energy supplier: each S.PSS applied to DRE, includes an energy supplier that could be a multinational energy provider, the local/national public energy supplier, a small or medium energy company, a local cooperative of prosumers (producers + consumers) or others. If the energy supplier is based in the local context, this could increase sustainable benefits of the system, such as favoring local employment and providing energy solutions tailored on local needs and with higher commitment on the local resources empowerment and conservation.

Products manufacturer: the role of the manufacturer includes both the manufacturing of the DRE micro-generator (e.g. solar panel and related components) as well as the manufacturing of the Energy Using Products or Equipment (e.g. a lantern is a Product; a sewing machine is an Equipment). The manufacturer role is crucial in the S.PSS structure, as (s)he could reduce the environmental impact of the system, designing and manufacturing low impact products (e.g. long-lasting product with high energy efficiency) and processes. Furthermore, the manufacturer could be the owner of the products (User-oriented and Result-oriented PSS), or at least could retain some responsibilities on them (Product-oriented PSS). Currently, DRE micro-generators, as well as Energy Using Products or Equipment are produced in one place and exported worldwide. If the manufacturer could work on the context, or at least could train local technicians, this could reduce the costs of local assistance, and the risk of drop-off if a part gets broken, while increasing the efficiency of the system. Furthermore, if local materials are used, this could increase both environmental and also socio-ethical benefits of the solutions, thus valorizing local resources in tangible and intangible terms.

Service Provider: the role of service provider covers a variety of services such as product design, installation, maintenance, repair and substitution, upgrading and end of-life treatments; as well as financing, and marketing and communication services for the system. So forth, this role could be covered by many actors within the same system. For example, while a Non-Governmental Organization (NGO) could be fundamental for communication services as holder for expertise from the local context; a Micro Finance Institution (MFI) could manage the financing of the system. However, a single actor could offer more than one service alone, or can create partnership with other actors.

Regulatory and Political actors: even though, regulatory and political actors are not directly involved in the system, their role is fundamental to enable stabilization and diffusion of sustainable energy solutions. For example, as the DRE concept allows final customers to become prosumer (producer + consumer) of their own energy, the legal framework needs to be in line with independent production needs. So forth, to involve or increase awareness of regulatory and political actors at local, national and international level is crucial to speed up the process of stabilization, diffusion and reiteration of sustainable energy solutions.

Type of PSS:

S.PSS applied to DRE reflects the configurations of PSS (Tukker, 2006), emphasized in chapter 3.

Product-oriented PSS-applied-to-DRE: it refers to energy solutions where the customer pays-to-own the DRE system (e.g. DRE micro-generator and related components + eventual Energy Using Products or Equipment – lights are products, a sewing machine is an equipment), plus to receive additional services as installation, maintenance, repair, and others. The customer becomes owner of the DRE system, while provider/s retain some responsibilities on it. Financial support services can be included e.g. to allow the pay back of the DRE system.

Use-oriented PSS-applied-to-DRE: it refers to energy solutions where the customer pays-to-pool/rent the DRE system, on which the customer operates. It can include training to install, maintain, manage and so on. The provider/s retain the ownership of the DRE system while the customer can access/operate on it.

Result-oriented PSS-applied-to-DRE: it refers to energy solutions where the customer pays-per-use to reach a specific final result/satisfaction. The provider/s retain the ownership of the DRE system and is responsible for all related services e.g. maintenance, repair and so on, allowing the customer to get the paid result.

Within one S.PSS applied to DRE, more PSS configurations can be in place. This can happen when two different offers are provided e.g. the OMC power case study, which offers power plants at the point of production of telecommunication companies in rural India, and at same time provides lantern charging service for nearby communities. Alternatively, it can happen if the interaction between provider and intermediary, and intermediary-final customer (B2C-B2B), are both based on a PSS logic e.g. Solar Transition is paying-to-own a charging station with Energy Using Products and Equipment (EUP - e.g. solar lanterns EUE – e.g. printers) (Product-oriented PSS). Then, Solar Transition offers final results to its customers (Result-oriented PSS). This is win-win especially in low and middle-income contexts, where local entrepreneurs may need financial and technical support to start or upgrade their businesses, and investors need local entrepreneurs with experience in the field.

Product/s:

Both the DRE micro-generator (e.g. solar panel + wires and storage) and the Energy Using Products or Equipment (e.g. a phone is a Product; a sewing machine is an Equipment) can be adopted within S.PSS applied to DRE. So forth, they should bring a low environmental impact into the system. This depends, on one side, on their design e.g. long-lasting product or with an efficient disassembly system; on the other side, it depends on the management of its value chain: from pre-production, to production, distribution and use, and landfill. Both strategies, to lower the environmental impact of the included products, they need to be addressed.

Service/s:
Within a S.PSS applied to DRE solution, services ensure the long-term relation between provider and customer.
Product (related) services: the services related to the products (e.g. DRE micro-generator and related components + Energy Using Products and/or Equipment), such as *design, installation, maintenance* and *repair, upgrade, use optimization* and *end-of-life-treatment*, aim to increase product lifespan, so are key elements to ensure environmental sustainability (Mont, 2002). Services during use, such as maintenance, repair and upgrade, are crucial especially when the provider/s retain the ownership of the products. In fact, it is provider/s interest to reduce the need of services, thus this positively affects the environmental impact of the product. A use optimization service can be included in the offer as a service e.g. training on product/s use; or as technological solution e.g. smart device to check DRE system conditions. Product use optimization services can reduce cost to reach the customer satisfaction due to low energy use, as well as the costs for the provider in terms of energy costs and product replacement. On the environment side, use optimization products and services can reduce the need/use of resources as energy and materials. End-of-life-treatment services also contribute to lowering the environmental impact of the product, and can be more effective if are planned during the design stage e.g. disassembly, substitution of spare part.

Financial services: financial services are key important, especially in low and middle-income context, to start or upgrading energy solutions. Local financing institutions could support these services such as, micro-credit, public funding and others. Case by case, is crucial to understand the purchasing-power and willingness to pay of the target customers, to establish the correct support.
Training services: training services include consultancies, awareness activities, technical and management training. Such services ensure a correct participation from the actors involved, as well as from the customers, which is crucial especially if they need to operate on the system (Colombo et al., 2013 - Rolland, 2011). Furthermore, training services could facilitate acceptance and inclusiveness of the proposed solution. However, as training services increase the costs of the system, that they need to be focused on the real need of the system.
Payment modality:

S.PSS applied to DRE allows different payment modalities, as they depend on the satisfaction provided and the type of PSS configuration, and not on the product. The Product-oriented PSS, is based on a pay-to-own modality. This payment is typically done as: pay-per-period (e.g. fixed fee until repayment is completed), pay-per-time (e.g. pre-payment for a specific use time of the product to be own) or as mix of both payments. In the case of a Use-oriented PSS, aimed at pay-to-lease/share the DRE system, the customers usually pay-per-period, pay-per-time or pay-per-use (e.g. payment for a single use/unit of satisfaction) or a mix of previous payments. Finally, in Result-oriented PSS, where customers aim to reach a specific result/satisfaction unit, typically they pay-per-use. According to the local needs, payment can be done with different currencies, such as money, or in-kind payment e.g. customers provide labor force and/or materials to pay the energy access.

DRE configuration:

There is not a universal configuration, but among other variables, its choice strictly depends on the (expected) energy demand e.g. according to the expected energy need it could vary the configuration and the dimension of the plant; the density of utilities e.g. amount of households/businesses and their distance could lead to different options; and as well to cultural habits e.g. same amount of energy could be offered through a decentralized charging station and a number of distributed stand-alone systems. Main configurations for Distributed Renewable Energy (DRE) are introduced below (complete description and figure - Figure 1. - in section 2.2).

Distributed stand-alone: it refers to small-scale energy production units (e.g. a solar panel on a roof-top) in which the customer is the prosumer (producer + consumer) of its own energy.

Decentralized stand-alone: it refers to small-scale energy production units that deliver energy at or near the point of production, with a higher load than single customer e.g. hospitals, schools.

Mini-grid (also called micro-grid or isolated-grid): it provides energy at local level, without being connected to the main grid (Rolland, 2011). In this case, energy comes from energy production units, that could be both distributed and decentralized.

Main-grid connected: especially in urban areas, the single energy production units, or a mini-grid, could be connected to the main-grid (or national-grid), being integrated in the main energy distribution.

DRE source/s:

The energy source must be carefully planned in relation to local resource availability i.e. energy sources are (usually) dependent on the location; and number of (expected) utilities e.g. biomass technology requires a medium number of utilities to run profitably. So forth, there is not a universal option of energy source, but need to defined time by time. Furthermore, the intermittency of some sources e.g. sun, wind, needs to be considered and a storage system should be included or another source will need to be added creating an integrated energy system providing reliable access to energy. (more on the DRE sources in section 2.2)

5.6 Conclusions

To answer the first set of Research Questions, related to the potential of S.PSS applied to DRE model, as win-win solution for sustainable energy for All, and towards sustainable development, a literature review, and case studies research were conducted. To highlight what emerged, as well as to visualize potential future scenarios for the model, a Sustainability Design Orienting Scenario was designed. Coherently, the conceptual framework of this research was developed, validating and detailing the above. Thus, providing significant insights on how the model *is* and *takes place*.

In the next chapter, the design contribution in relation to the S.PSS applied to DRE model is presented, aiming to answer the second set of Research Questions.

RQ2. Can Product-Service System Design have a role in the development of such model? *a. And if so, what kind of knowledge-base and know-how are needed by a designer? b. From an operational point of view, what are the design approaches, methods and tools that can be used in practice?*

Part III - The role for design

Chapter 6 - Towards new knowledge and know-how

The chapter illustrates the knowledge-base needed by the designer to design S.PSS applied to DRE offers, as well as to be facilitator of the design process. Then, the know-how with design approach, design process and support tools are also presented.

6.1 System Design towards sustainable energy for All

As extensively described in chapter 5, the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model, can be considered win-win towards sustainable energy for All. The following paragraphs and chapters illustrates the knowledge-base and know-how for the designers (following paragraphs of chapter 6), the design-research activities to test, evaluate and refine them (chapter 7), and the open course on System Design for sustainable energy for All (chapter 8).

6.1.1 New knowledge-base for the designers

Design for Sustainability has evolved during time, moving from a product innovation level, based on product improvement or design, to a Product-Service System innovation level, where products and services are combined to fulfil as specific satisfaction (Ceschin & Gaziulusoy, 2016) (more in section 3.2). Consequently, designers (and those who contribute in Product-Service System design) need the abilities to: design environmentally sustainable products and services together; design and facilitate new configurations (interactions/partnership) between different stakeholder to achieve a convergence of economic and environmental interests; operate/facilitate a participatory process among entrepreneurs, users, NGOs, etc. (Vezzoli, 2010).

So forth, to play and active role for S.PSS applied to DRE, the designer needs to be equipped with a wider view, and a set of broader competences.

Understand the challenge:
To start, the designer needs to understand the current energy challenge, and the energy key-role towards sustainable development. This consciousness is fundamental for the designer to broader her/his view on the topic and to setup the path through the design of S.PSS applied to DRE solutions. Indeed, the designers need to have a clear understanding on:

- sustainable energy access, as enabler for daily life activities, as well as stable support to start-up or upgrade income generating activities, thus fostering sustainable (socio-economic) development;
- Distributed Renewable Energy (DRE) model, as key leverage, towards energy access for All, and related benefits and limits, as well as current technologies and sources;
- the role of the context while dealing with DRE, so forth on the importance of

involving local actors in such understanding, as well as to work on bottom-up solutions through the generation of local competences;
- the potential rebound effects related to both the DRE and S.PSS models and their coupling, in relation to the specific context.

Even though it won't be at direct influence of the designer, an understanding on local energy policies is required for the designer, as could facilitate the involvement of local administrations etc. to support the innovation at local level.

Deep into the model:

The designer needs to clearly understand the S.PSS applied to DRE model, to be able to work on it and to facilitate its design process and diffusion. So forth, the designer should:
- acquire competences on Design for Sustainability (DfS), both at system and product level. In fact, since the Sustainable Product-Service System, focuses on a mix of products and services, both need to be designed on a sustainability perspective to guarantee the sustainability of the solution;
- understand both models of S.PSS and DRE, especially on their structures, potential benefits and limits; but as well in terms of the knowledge-base and know-how available for each model.
- understand the S.PSS applied to DRE model, especially on its structure, as well as on model potential benefits and limits.

As ownership, has been understood could affect acceptance of a S.PSS applied to DRE solution, the designer needs to carefully analyze and design it, according to local needs and culture. Furthermore, to reduce unwanted side-effects (e.g. rebound effect), a specific attention need to be given to long-term effects, as well as to side-activities indirect from the model.

Learn how to (co)design the model:

After understanding the model, the designer should be able to design it. Furthermore, as the S.PSS applied to DRE, is based on a mix of products and services to be produced, delivered and managed by different actors, the designer should act as facilitator in managing the co-design process with the actors to be involved e.g. customer, provider, side-actors. In fact, the designer should have the abilities and capabilities to:
- manage the design approach, design process and tools, to support the design S.PSS applied to DRE solutions;
- facilitate the co-design process, to collaborate with the actors related to the solution during the whole process;
- feel empathy with the actors of the co-design process e.g. customer, provider, side-

actors, listening and understanding them, thus enriching the whole process.
Due to the (potential) distance between the designer and the actor/s, or among actors, a confidence level needs to be established before and during the design process. For example, (when possible) get informed consent from the subjects specifying the goal of the design process, the benefits each actor can get, as well as potential risks could arise; as well as (if asked), to provide data and research results to the actors, even after the process ending. Furthermore, gaining insights from empathy with user's emotions, aspirations, and fears, could both to reduce pressure on the actors, while increasing their participation and involvement as well as increasing the quality and effectiveness of the results. Finally, as the designer is often from outside the working context, is fundamental for her/him to get information in advance, both to plan the content' level of the design process, and the timing of the co-design activity, to respect preparation, culture and attitudes of participants.

To summarize, the above discussed abilities needed by the designer, must be properly supported by a new knowledge-base. So forth, a designer must know the S.PSS applied to DRE model and how it is structured and can be facilitated. Awareness on S.PSS applied to DRE complexity and dependency on the context is also required. Furthermore, a designer, must have proper knowledge-base, to understand the role that S.PSS applied to DRE can have towards sustainable energy for All, and of its related role to play and facilitate it among other actors.

6.1.2 New know-how for the designers

To support the practice towards S.PSS applied to DRE solutions, the designers need to have a design approach, design process and tools. Below is illustrated the proposed design approach, while the following paragraph introduces the design process and related tools.

As the S.PSS applied to DRE model adopts a Sustainable Product-Service System (S.PSS), this entails the need to work with a multi-faceted approach. In fact, as introduced in chapter 6, the model is configured as a mix of products and services, which are produced, delivered and managed by many actors whose interactions are aimed to fulfil the demand of (energy) satisfaction, while fostering economic, socio-ethic and environmental sustainable solutions. This complexity, entailed the adaptation of the strategic design approach (more in section 3.4), towards the design of the S.PSS applied to DRE) model. The proposed design approach is composed by the following ones (Bacchetti, 2017):

- Satisfaction-system: this approach entails the design of demand satisfaction ("satisfaction unit"), meaning, 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. This moves the focus of the energy offer from mere DRE product ownership e.g. solar panel and related appliances to the satisfaction of a specific (energy) demand e.g. access to energy, through a system of products-services which can result more valuable both at provider, customer and environment levels (Mont, 2002). For example, if the satisfaction is to read in the night, the solution won't be to sell a DRE micro-generator, but could be a charged solar lantern, paid per time, or per use. In this perspective, the designer will need to clearly identify the correct satisfaction be met and this process could be planned as co-design activity with provider and/or customer. System Design tools could be used as support (more in section 7.2).
- Stakeholder configuration: this approach entails designing stakeholder's interactions in relation to the "satisfaction unit". In this case, this means that all stakeholders in the life-cycle of a product-service need to be considered and involved in the design process, increasing the level of stability of the solution, while opening the field to more innovative partnership and opportunities. Specific tools have been designed for this purpose (more in section 7.2).
- System sustainability: this approach entails designing the sustainability of stakeholder' interactions, based on mutual economic, socio-ethical and environmental benefits, as a way of achieving sustainable DRE solutions. Furthermore, since a product e.g. DRE system is every time included in the S.PSS applied to DRE offer, the designer needs to have specific competences to propose sustainable products for the system. For example, current all-inclusive offers for smartphones, where the smartphone is changed often with no possibilities of upgrade or repair, cannot be considered as sustainable solutions, due to the high impact of the product itself.

On the one hand, the above approach showed the complexity of dealing with S.PSS applied to DRE model, given by the nature of the model itself, as systemic one with a high grade of actor's involvement. In fact, products and services as well as the related stakeholder's interactions need to be managed simultaneously. On the other hand, the proposed design approach reveals opportunities for stakeholder's involvement, thus increasing the (potential) value of the designed solution.

To summarize, the proposed design role, called System Design for Sustainable energy for All, can be defined as *"the design of a **Distributed Renewable Energy Sustainable Product-Service System**, 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 - based on the design of innovative interactions of the stakeholders, in which economic and competitive interest of the providers, continuously seek after both socio-ethically and environmentally beneficial new solutions".*

6.2 System Design process and support tools

6.2.1 The design process

To support the design S.PSS & DRE, a design process is proposed. It can be guided through the Method for System Design for Sustainability (MSDS), already used in the design of Sustainable Product-Service System (S.PSS) (more in section 3.4). Let's see how.

The *Strategic Analysis stage*, can support the collection of background information useful to setup the stage for the innovation. In fact, in case of an existing situation to be improved, through the strategic analysis is possible to analyze the proposers, (qualitatively) evaluate the sustainability of the existing system foremost, so forth defining the scope of the design intervention and the satisfaction to be achieved e.g. to have access to energy. Looking on the proposer's perspective, it is possible to identify: the 'mission', the main areas of expertise, the strength and weaknesses, opportunities and threats. In addition, intentions from the proposer/s are included in the analysis to address the design activities e.g. to consolidate or to expand her/his market.

Furthermore, is possible to understand the conditions of access to energy in the context: as customer energy need and the related demand of satisfaction to be enabled by energy access, customer awareness level, customer purchasing-power and willingness to pay; as well as, to identify the actors that are present in the context and are potentially relevant for the innovation. These could be collected from on-field data, and supported by the collection and analysis of best practices, and general and macro-trends. Finally, local availability of resources can be verified. These activities can define the (qualitative/quantitative) priorities of intervention towards sustainable energy for All.

The *Exploring Opportunities stage*, can support the generation of promising strategies for S.PSS applied to DRE solutions, generate ideas at Sustainable Product-Service System (S.PSS) level e.g. ideas as a mobility system, but not a car, to orientate the sustainability (environmental, socio-ethical) of the innovation, as well as to generate the bases for the energy innovation itself. Sometimes, a Sustainability Design-

Orienting Scenario is outlined, to visualize future sustainable scenarios for the innovation.

The *Design System Concept stage,* can support the design of S.PSS applied to DRE concept/s. So forth, designing a draft concept of the PSS configuration/s of the solution, as well as the products and services to be included, and proposing payment options and DRE system configuration/s. Then, is suggested to provide a (qualitative) environmental, socio-ethical, and economic assessment of designed concept/s.

The *Design (and engineering) the System stage*, can support the detailing of the most promising concept/s generated, into a version ready for discussion with external (potential) actors, and for concept/s implementation. Even in this case, a (qualitative) environmental, socio-ethical, and economic assessment of the improved concept/s is suggested.

The *Communication stage,* is dedicated to narrating (internally/externally) the general and (above all) sustainable characteristics of the S.PSS applied to DRE. In fact, it is fundamental to have a solid narration to facilitate the involvement process of new actors in process, as well as to build acceptance among future customers.

Although the design process can follow the Method for System Design for Sustainability (MSDS) stages, is important to underline that there is not a fixed path to design a S.PSS applied to DRE. Rather, an iterative approach is often used. To clarify (Vezzoli et al., 2014), as the Method for System Design for Sustainability (MSDS) is a modular method:

- MSDS stages and processes can be used in sequence or separately, for designer/actor's needs. For instance, a company with already an S.PSS applied to DRE concept, can work on the *Design (and engineering) the System* stage;
- The available tools (many of them elaborated within EU funded research projects) can be included/or not during the design process and used in more than one stage, with and increased level of detail. Furthermore, is notable that other tools can be freely used in the model, depending on attitudes and needs from the designer and/or actors involved;
- The three dimensions of sustainability (environmental, socio-ethical and economic) can be explored and evaluated within the design process, through the Method for System Design for Sustainability (MSDS). It is possible to operate on one or more of them.

Table 4. illustrates Method for System Design for Sustainability (MSDS), with *stages, aims, processes.* Energy-related processes have been included in the table, and are marked with an asterisk *.

Strategic Analysis (SA) Stage	
Aims	*Processes*
To obtain information to facilitate the generation of S.PSS applied to DRE ideas	Analyse project proposers and reference context
	Analyse sustainability of existing system and set priorities for the design intervention
	Analyse access to energy in the context of reference*
	Collect and Analyse best practices
	Analyse General macro-trends
Exploring Opportunities Stage	
Aims	*Processes*
To make a 'catalogue' of promising strategies towards S.PSS applied to DRE e.g. a sustainability design-orienting scenario and/or a set of sustainably promising ideas	Generate sustainability-oriented ideas at system/stakeholder level
	Generate DRE oriented ideas at system/stakeholder level*
	Outline a Sustainable Design-Orienting Scenario
Design System Concepts Stage	
Aims	*Processes*
To determine one or more system concepts oriented towards S.PSS applied to DRE solutions	Select clusters and single ideas (environmental, socio-ethical, DRE oriented)*
	Develop system concept/s
	Design DRE system*
	Make environmental, socio-ethical, and economic assessment of system concept/s
	Evaluate the system concept/s developed
Design (and Engineer) the System Stage	
Aims	*Processes*
To develop the most promising system concept into the detailed version ready for implementation	Detail the system concept
	Define development plan for the system
	Make environmental, socio-ethical, and economic assessment of DRE system*
	Detail and evaluate the DRE system*
	Present/discuss the system developed e.g. outline main activities characteristics, actors
Communication Stage	
Aims	*Processes*
To communicate (internally/externally) the general and (above all) sustainable characteristics of the system designed	Draw up the documentation for (internal) communication
	Draw up the documentation for (external) communication

Table 3. Method for System Design for Sustainability (MSDS), adapted for the sustainable energy for All design process.

6.2.2 The System Design tools

Even though System Design tools are available in the Method for System Design for Sustainability (MSDS), tools to support the design of S.PSS applied to DRE concepts, or their analysis, were not there. So forth, within this research (and the LeNSes project) a set of dedicated tools were designed, prototyped, assessed and redesigned/refined. According to the aims of this research, which are exploring a new field of intervention for System Design and System Design for Sustainability, the tools are intended to support the design of S.PSS applied to DRE solutions at concept level. Furthermore, the tools to be correctly used, they require information related to the context, the satisfaction to be met, etc., that can be provided by the client or community, or collected by the designer i.e. information can be reached through a Strategic Analysis.

The set of tools includes:

- new tools, developed during the research (and within the LeNSes project), and are *Innovation Diagram for S.PSS applied to DRE*, and *Concept Description form for S.PSS applied to DRE.*
- adapted tools, elaborated during the research on existing tools from the design field, and adapted to the Distributed Renewable Energy (DRE) topic, and are *Sustainability Design Orienting Scenario for S.PSS applied to DRE, Sustainable Energy for All Idea tables and Cards*, and *Stakeholders Sustainability and Motivation Table.*

Other existing or adapted tools designed during the LeNSes project (without the direct contribution of the research) can be used in the design process towards sustainable energy for All (see table 3.). At the end of the chapter, a short parenthesis is dedicated to the tools developed within the LeNSes project.

To facilitate readability of the tools, their order reflects their position/s within the design process stages (see table 3.). Furthermore, each tool is presented with the same structure presenting: *aims, what it consists of, how to use the tool, results, integrating the tool into the design process, tool availability and required resources, designer/s.*

1. Sustainability Design Orienting Scenario for S.PSS applied to DRE

Aims: Design Orienting Scenario (Manzini et al., 2009), a tool to inspire and inform designers towards possible futures on specific topics, has been adapted (Vezzoli & Bacchetti, 2017 - Bacchetti et al., 2016b) for Sustainable Product-Service System

(S.PSS) applied to Distributed Renewable Energy (DRE). The tool, (from now on) Scenario presents four visions narrated as interactive videos accessible through a navigator file. The Scenario is presented as a visualization tool to inspire designers and stakeholders to design towards radically new social, economic and technical solutions and as co-design facilitating creative processes and strategic conversations among different actors.

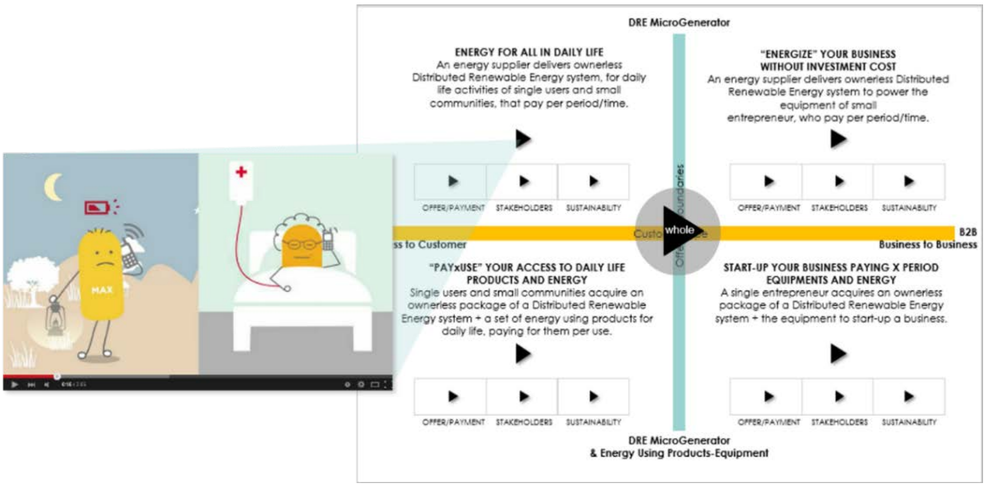


Figure 7. Sustainability Design Orienting Scenario for S.PSS applied to DRE.

<u>What it consists of:</u> the tool allows the visualization of four promising visions to inspire towards S.PSS applied to DRE solutions. The tool presents 4 visions within a polarity diagram of two axis a) the horizontal axis defines who is the customer of the narration final user (B2C), or as small entrepreneur/small business (B2B) b) the vertical one defines the offer: a DRE micro-generator (e.g. solar panel system plus its appliances such as storage, inverter, wires, etc.), or the sum of both the DRE micro-generator and the related Energy Using Products or Energy Using Equipment (e.g. phone and television are Energy Using Products; woodworking machine, sewing machine are Energy Using Equipment). Each vision is visually presented through one main video (around 90 seconds) that shows the narration, highlighting the key points of the vision (e.g. stakeholder relations, system ownership) and three sub-videos (around 30 seconds each): 1) shows the offer and the related payment modality; 2) shows the involved stakeholders and their interactions; 3) shows the sustainability dimensions (environmental, socio-ethical, economic) of the offer.

<u>How to use the tool:</u> the tool requires the use of a slideshow software (e.g. Microsoft PowerPoint, or the equivalent in Open Office). Each main video and sub-video can be watched separately or a central button is available to run the whole videos as one. The suggestion is to watch a main video first and after the related sub-videos; then the second main video and so on.

Results: the result is a set of new visions and ideas favoring creative processes and co-design activities towards S.PSS applied to DRE solutions.

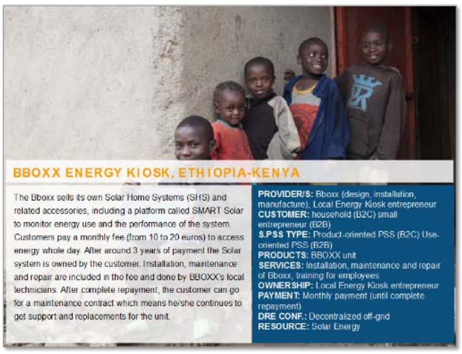
Integrating the tool into the design process: the Scenario can be used at various stages of the design process. In the Exploring opportunities, it can be used to inspire and inform designers and actors involved towards possible visions of S.PSS applied to DRE. In the System concept design, it can be used to verify the direction of the co-design activities and discussions and to get new inspirations during the process.

Tool availability and required resources: the tool is available for a free download at www.lenses.polimi.it. The tool has been designed to be used in workshops and co-design sessions, therefore a projector is preferable. The time required to visualize all videos is approximately 15 minutes.

Designer/s: Vanitkoopalangkul, K., Vezzoli, C., Bacchetti, E.

2. Sustainable Energy for All Idea tables and Cards

Aims: Sustainable energy for All Idea Tables (Vezzoli et al., 2016), structured on the SDO toolkit[41], it is a tool to generate ideas for S.PSS applied to DRE solutions, is based on six tables with guidelines. To the guidelines of each table are connected the fifteen case study cards to be used as examples. The Sustainable energy for All Idea Tables is presented as a co-design tool to generate (sustainable) ideas facilitating the creation process among different actors.



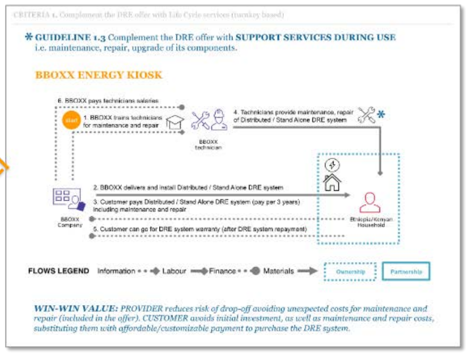


Figure 8. Cards (with case studies) to support the Sustainable Energy for All Idea tables

[41] *The SDO Toolikt has been 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.*

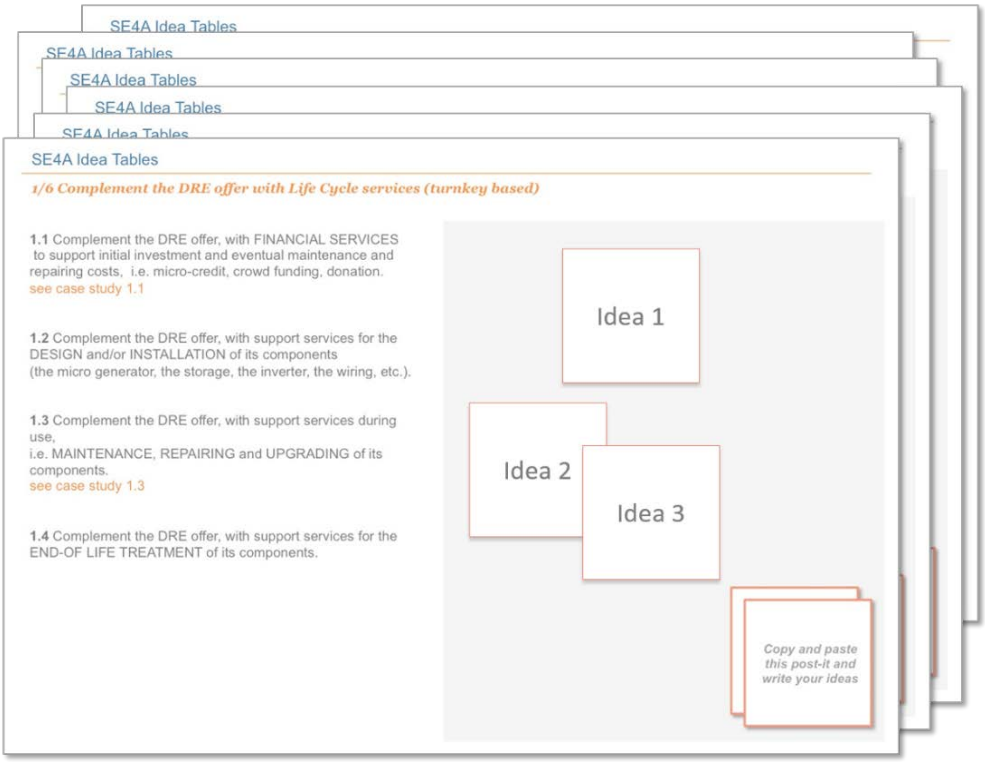


Figure 9. Sustainable Energy for All Idea tables

What it consists of: the tool allows the generation of (sustainable) ideas for S.PSS applied to DRE solutions. Six tables with criteria and guidelines are available to orientate the design process. Fifteen case study cards can be used as supportive examples associated to the guidelines.

Each table refers to a *criterion* (and includes specific guidelines) to design (sustainable) ideas for an S.PSS applied to DRE concept:
Complement the DRE offer with Life Cycle services (turnkey based): it refers to the need of adding life-cycle services in the case the S.PSS applied to DRE concept is offered as Product-oriented (e.g. pay-to-own + additional services as installation, maintenance, repair, and others). The guidelines invite to design additional services that could be valuable in relation to the defined customer/s and unit of satisfaction.
Offer ownerless DRE systems as enabling platform: it refers to the need to adding enabling services in the case the S.PSS applied to DRE concept is offered as Use-oriented (e.g. pay-to-lease/share + training to install, maintain, manage and so on). The guidelines invite to design enabling services that could be valuable in relation to the defined customer/s and unit of satisfaction.
Offer ownerless DRE systems with full services: it refers to the need to delivering a full package of services in the case the S.PSS applied to DRE concept is offered as Result-oriented (pay-per-use to reach a specific final result/satisfaction unit). The guidelines

invite to design full packages of services that could be valuable in relation to the defined customer/s and unit of satisfaction.

Add to DRE offer, the supply of ownerless Energy Using Products and/or Energy Using Equipment: it refers to the possibility to extend the S.PSS logic (Use-oriented or Result-oriented) adopted to the DRE offer (e.g. solar home system offered as a pay-to-lease for household use together with training for maintenance and monitoring services) to Energy Using Products and/or Energy Using Equipment (e.g. sewing machine, connected to the solar home system, is offered as a pay-per-use). The guidelines invite to offer Energy Using Products/Equipment through S.PSS logics that could be valuable in relation to the defined unit of satisfaction.

Delinked payment from pure watt consumption (affordable costs): it refers to the possibility to design different payment modalities (e.g. pay-per-use, pay-per-time, pay-per-period, in-kind payment, pay with financial support, or a mix) to increase the affordability of the S.PSS applied to DRE concept. The guidelines invite to choose a payment modality that could be valuable in relation to the defined customer/s and unit of satisfaction.

Optimize DRE systems configuration: it refers to how the S.PSS applied to DRE concept could be structured as distributed stand-alone system (e.g. solar home system, solar lantern), decentralized stand-alone system (e.g. energy recharging center), distributed-decentralized systems connected through mini-grid as well as distributed-decentralized systems connected to the main-grid. The guidelines invite to optimize the DRE systems configuration in relation to the defined customer/s, unit of satisfaction and context of use.

How to use the tool: the tool requires the use of a slideshow software (e.g. Microsoft PowerPoint, or the equivalent in Open Office) or, in the case is printed, it will require post-it and pens.

Use of the tables:
Each table needs to be used singularly, and presents a series of guidelines which are suggestions to orient the design of (sustainable) ideas in relation to a specific element of the offer. Aside to the guidelines, an empty space is left to post ideas. After reading the guidelines is possible to use the post-it (digital or in paper) to write ideas and stick them in the empty space. As general rules: no ideas are wrong; there is not a compulsory number of ideas to be written; the ideas need to be at system-stakeholder level and not at product level e.g. a mobility system to bring kids to school; but not a bike itself.

Use of the case study cards:

Each case study card represents an existing case of S.PSS applied to DRE in relation to a specific guideline. Each card is made of a short description + key information as: customer / provider / type of S.PSS / offered products (and related ownership) / offered services (and related provider) / what is paid / DRE source / DRE system configuration (front of the card); and a visualization of the stakeholder's interactions through a Stakeholder's System Map[42] (back of the card) where the interaction representing the guideline is highlighted.

Results: the results are new sustainable ideas (written in the post-it) to generate S.PSS applied to DRE solutions. The most promising ideas can be used within the tool *Innovation Diagram for S.PSS applied to DRE* to generate the concept (more about in the following presentation of the tool).

Integrating the tool into the design process: the Sustainable energy for All Idea Tables is used in the *Exploring opportunities* to support the generation of (sustainable) ideas towards S.PSS applied to DRE solutions.

Tool availability and required resources: the tool is available for a free download at www.lenses.polimi.it. The tool has been designed to be used in workshops and co-design sessions, therefore is good to work on it collectively. It is available both with digital version which could be used through a pc or a projector (suggested if the group is big) or as printable one (suggested to be printed as A3 – A2). The case study cards are available in digital and printable version, the suggestion is to print them to facilitate the exchanges between the group. The time required is approximately 60 minutes (10 for each Table).

Designer/s: Bacchetti, E., Vezzoli, C., Delfino, E.

3. Innovation Diagram for S.PSS applied to DRE

Aims: Innovation Diagram for S.PSS applied to DRE (Vezzoli et al., 2016), is a tool to re-orient existing energy solutions towards S.PSS applied to DRE ones, to analyze competitor's energy solutions; as well as to orient the design of new S.PSS applied to 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 applied to DRE concepts. Furthermore, it provides the characterization of

[42] *Stakeholder System Map tool, developed by (Jégou, Manzini and Meroni, 2002) to visualise the network of stakeholders in a PSS solution, and their interactions in terms of flows of goods, materials, services, money, labor and information.*

the designed S.PSS applied to DRE concepts through a set of labels and suggestions. The Innovation Diagram for S.PSS applied to DRE is presented as a co-design tool favoring a deep understanding of the solution/concept while facilitating collaborative processes and discussions among stakeholders.

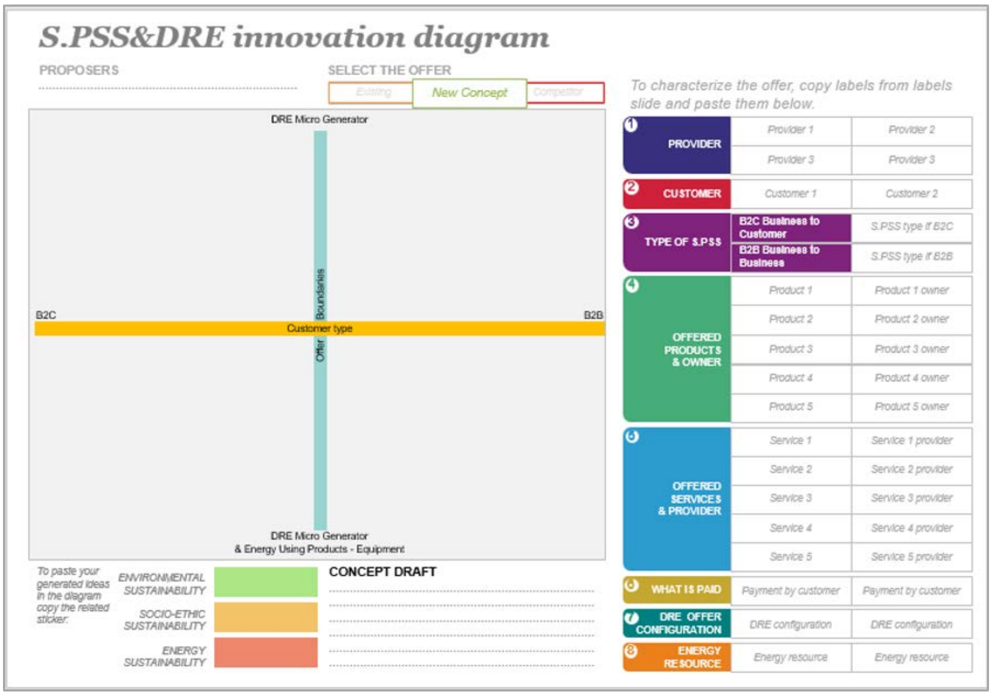


Figure 10. Innovation Diagram for S.PSS applied to DRE.

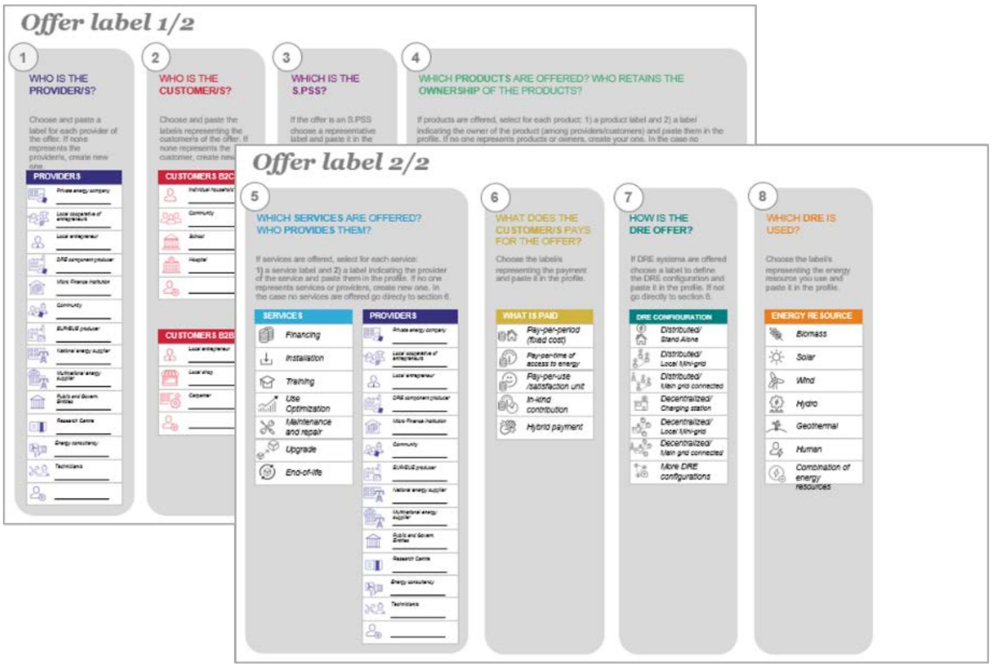


Figure 11. Label to support the Innovation Diagram for S.PSS applied to DRE.

What it consists of: the tool is the ID card of an energy solution or S.PSS applied to DRE concept. The tool is composed by three worksheets: for existing energy solutions, for competitors' energy solutions, for new concepts. Each worksheet is based on the following structure: title + proposer + unit of satisfaction + polarity diagram + profile (with labels) + short description. The worksheet for new concepts includes post-it to stick new ideas (or ideas from the Sustainable energy for All Idea Tables tool and from the SDO toolkit tool which are environmentally and socio-ethically sustainable ideas). Two additional worksheets with labels and instructions are available to fill the profile section of the tool.

Title: depending on the worksheet the title is the name of the solution/concept that will be explored.
Proposer: means the name/s of who is using the tool.
Unit of satisfaction: is the need satisfied/to be satisfied (e.g. access to energy, have clean clothes).
Polarity diagram: the polarity diagram (same of the Scenario one) is based on four quadrants built on two axes a) the horizontal axis defines to whom is addressed the solution/concept: final user (B2C), or small entrepreneur/small business (B2B) b) the vertical axis defines how much is extended (boundaries) the solution/offer: is related to the Distributed Renewable Energy micro-generator (e.g. solar panel system plus its appliances such as storage, inverter, wires, etc.), or to the sum of both the DRE micro-generator and the related Energy Using Products or Energy Using Equipment (e.g. phone and television are Energy Using Products; woodworking machine, sewing machine are Energy Using Equipment). Due to the variety of actors who can deal with energy solutions, is relevant to consider that actors can play in the polarity diagram even though they are not directly offering Distributed Renewable Energy micro-generator, and neither Energy Using Products or Equipment. For example, a consultancy on energy services could be positioned on one pole or the other on the typology of energy services.
Profile (with labels): the profile presents a table with empty spaces to be filled with *key information* regarding the energy solution[43]:
Provider/s: it refers to the providers involved in delivering the energy solution and could be one as alone actor or a partnership of providers and includes energy companies, NGOs, energy consultancies and others.
Customer/s: it refers to the customer of the energy solution and can be a final customer (B2C) as a household, a community, a school, and so on; or a small entrepreneur/small business (B2B) such as a company, a local shop and others;

[43] *To increase readabiity of this section, the researcher will use the term "energy solution" both to refer to existing energy solutions, competitor's energy solutions and new S.PSS applied to DRE concepts.*

Type of S.PSS: it refers to the type of S.PSS applied to the energy solution and could be Product-oriented (pay-to-own + additional services as installation, maintenance, repair, and others) or Use-oriented (pay-to-lease/share + training to install, maintain, manage and so on) or Result-oriented (pay-per-use to reach a specific final result/satisfaction unit).
Offered product/s (and related ownership): it refers to products which are included in the energy solution and integrates both the DRE generator (e.g. solar panel + wires and storage) and the Energy Using Products or Equipment (e.g. a phone is a Product; a sewing machine is an Equipment). It is required to define the ownership of the products included to lately verify the innovative and sustainability value of the energy solution.
Offered service/s (and related provider): it refers to services which are provided by the energy solution such as financial services, training services, maintenance services and so on. It is required to define who among the stakeholders is delivering the service to define and verify the role of each stakeholder in the energy solution.
What is paid: it refers to what the customer (B2C – B2B) pays to access the energy solution as pay-per-period, pay-per-use, pay-per-time, in-kind payment, payment with financial support, or a mix of different payments.
DRE system configuration: it refers to how the energy solution is structured. The options include: distributed stand-alone system (e.g. solar home system, solar lantern), decentralized stand-alone system (e.g. energy recharging center), distributed-decentralized systems connected through mini-grid as well as distributed-decentralized systems connected to the main-grid.
DRE source: it refers to the energy source used to power the energy solution as solar, wind, hydropower, biomass, and others and could be a single source or an integrated mix of them.

Labels and instructions:
The labels are divided as per the profile key information (see above) and offers for each of them a series of variable solutions e.g. for the customer there are several labels such as community / household / etc., the same is for all key information. To facilitate the use of the label a question and guideline for each key information is provided.

Short description:
The short description is no more than 200 characters, to be used to present the solution/concept highlighting the main innovation and sustainability value.

Post-it:
post-it are available in the worksheet for new concepts to stick new ideas (or ideas

from the Sustainable energy for All Idea Tables tool and from the SDO toolkit tool which are environmentally and socio-ethically sustainable ideas).

How to use the tool: the tool requires the use of a slideshow software (e.g. Microsoft PowerPoint, or the equivalent in Open Office) or can be used in the printed version. According to the aim of the co-design activity the corresponding worksheet/s need to be used.

How to analyze and re-orient and existing or competitor's energy solution:
First, write title of the solution that is going to be analyzed and re-oriented, together with proposer/s name/s of who is working on it and the unit of satisfaction (e.g. access to energy). Secondly, position the solution in the polarity diagram according to its customer and offer boundaries. As general rule is not compulsory that the solution correspond to a single position (e.g. B2C – B2B), if the case, is possible to locate the solution in the middle. Third, fill the profile following the instructions provided to copy/paste the labels. Considering that an existing or competitors' offer is not automatically an S.PSS or is not necessarily offering products and/or services, some spaces in the profile could remain empty. These empty spaces can be used starting point in case of a following design activity. Finally, write the short description of the solution emphasizing innovation and sustainability values. Follow up with discussion on the emerged ID and refine as needed.

How to design S.PSS applied to DRE concept:
First, write the (draft) title of the concept that is going to be designed, together with proposer/s name/s of who is working on it and the unit of satisfaction to be met (e.g. access to energy). Secondly, generate ideas or copy and paste the most promising ideas from the Sustainable energy for All Idea Tables tool and from the SDO toolkit, and position them in the polarity diagram. Creative discussions among the proposers will address the way to position the ideas according to customer and offer boundaries. As general rule is not compulsory that one idea corresponds to a single position (e.g. B2C – B2B), if the case, is possible to locate the solution in the middle and to decide after. Third, read all selected ideas and cluster them to create one/more concepts more defined, some ideas if not interesting anymore can be excluded. Then, select the most promising S.PSS applied to DRE concept emerged and fill the profile following the instructions provided to copy/paste the labels. Finally, check coherence of the whole information and write the short description of the designed S.PSS applied to DRE concept emphasizing innovation and sustainability values. Follow up with discussion on the emerged S.PSS applied to DRE concept and refine as needed.

Results: the result in the case of existing or competitor's energy solutions is their ID card where strengths and weaknesses can emerge, orienting in case of a following design activity. Otherwise, the result is the ID card of an S.PSS applied to DRE concept as a starting point to introduce and facilitate discussions among (in place – future) stakeholders.

Integrating the tool into the design process: the Innovation Diagram for S.PSS applied to DRE can be used at various stages of the design process. In the *Strategic Analysis,* it can be used to analyze and re-orient existing energy solutions, to analyze competitors' energy solutions and even to make a comparison and start to orient the design process. In the *System concept design,* it can be used to combine the generated ideas to design and characterize the new S.PSS applied to DRE concept.

Tool availability and required resources: the tool is available for a free download at www.lenses.polimi.it. The tool has been designed to be used in workshops and co-design sessions, therefore if the digital version is used a projector is preferable; in the case the paper version is preferred suggestion is to print the worksheet as A3 or A2. The time required to analyze and re-orient and existing or competitor's energy solution is approximately 20 minutes; in the case of the design of an S.PSS applied to DRE concept is approximately 30 minutes.

Designer/s: Bacchetti, E., Vezzoli, C., Delfino, E.

4. Concept Description form for S.PSS applied to DRE

Aims: Concept Description form for S.PSS applied to DRE (Vezzoli et al., 2016) is a tool to visualize and finalize the description and characterization of a new S.PSS applied to DRE concept. The Concept Description form presents a worksheet where to visualize key information about the S.PSS applied to DRE concept, facilitating a deep understanding of the concept while presenting it among (existing - potential) stakeholders.

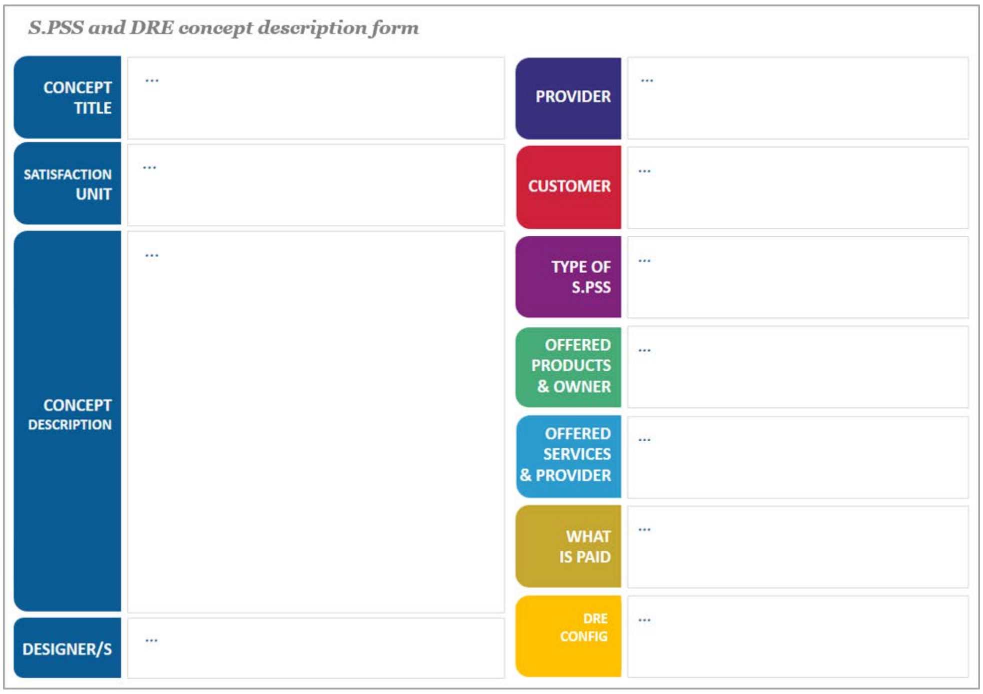


Figure 12. Concept Description form for S.PSS applied to DRE.

What it consists of: the tool presents a summary of a designed S.PSS applied to DRE concept. The tool is composed by one worksheet with the following structure: proposer + title + unit of satisfaction + short description + profile.

Proposer: means the name/s of who is using the tool.
Title: the title is the name of the concept that will be visualized with the tool.
Unit of satisfaction: Is the need satisfied/to be satisfied (e.g. access to energy, have clean clothes).
Short description: The short description is no more than 200 characters, to be used to present the solution/concept highlighting the main innovation and sustainability value.
Profile: The profile presents a table with empty spaces to be filled with text on key information as: customer / provider / type of S.PSS / offered products (and related ownership) / offered services (and related provider) / what is paid / DRE system configuration / DRE source; regarding the solution/concept.

How to use the tool: the tool requires the use of a slideshow software (e.g. Microsoft PowerPoint, or the equivalent in Open Office) or can be used in the printed version. First, is needed to write proposer/s name/s of who is working on the concept, together with title and the unit of satisfaction met (e.g. access to energy). Secondly, write the short description of the designed S.PSS applied to DRE concept emphasizing innovation and sustainability values. Third, fill the profile table with text for each key information. Follow up with discussion on the emerged S.PSS applied to DRE concept and refine as needed. Generally, if the Innovation Diagram for S.PSS applied to DRE have been used, most information can be taken there and updated according to the newest version of the concept. In fact, if the Innovation Diagram for S.PSS applied to DRE is a co-design tool, the Concept description form for S.PSS applied to DRE is more a visualization one.

Results: the result is the summary of an S.PSS applied to DRE concept, facilitating a deep understanding of the concept while presenting it among (existing - potential) stakeholders.

Integrating the tool into the design process: the Concept description form for S.PSS applied to DRE can be used at various stages of the design process. In the *System concept design* and in the *Design (and Engineer) System Details* it can be used to visualize and verify the new S.PSS applied to DRE concept. It is used also to present the visualization of the design concept.

Tool availability and required resources: the tool is available for a free download at www.lenses.polimi.it. The tool has been designed to be used in workshops and co-design sessions, therefore if the digital version is used a projector is preferable; in the case the paper version is preferred suggestion is to print the worksheet as A2 or A1. The time required to summarize an S.PSS applied to DRE concept is approximately 20 minutes.

Designer/s: Bacchetti, E., Vezzoli, C.

5. Stakeholders Sustainability and Motivation Table

Aims: Stakeholders Motivation Matrix (Jégou et al., 2004) , a tool to visualize motivations of the stakeholders, has been updated(Vezzoli et al., 2016) as a collaboration between DIS Research Group of Politecnico di Milano (Italy, Makerere University (Uganda) and TUDelft University (The Netherlands) becoming Stakeholders Sustainability and Motivation Table. The Stakeholders Sustainability and Motivation Table, is presented as visualization tool aimed to identify/show: motivations and contributions of each stakeholder; sustainable (economic, environmental, socio-ethical) benefits from each stakeholder; this facilitating involvement process and strategic conversations addressing (existing and potential) stakeholders.

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	···· ····	···· ····	···· ····	···· ····	···· ····
Insert actor icon Insert actor name	···· ····	···· ····	···· ····	···· ····	···· ····
Insert actor icon Insert actor name	···· ····	···· ····	···· ····	···· ····	···· ····

Figure 13. Stakeholders Sustainability and Motivation Table.

What it consists of: the tool allows the visualization of motivations and contributions of each stakeholder and the benefits that could be achieved at sustainable level. The tool is made of four worksheets: the table + two worksheets with guidelines to define environmental and socio-ethical benefits + a worksheet with icons.

Table: The table worksheet is made of a table with 6 columns: stakeholders / motivation / contribution to the partnership / environmental benefits / socio-ethical benefits / economic benefits; and a number of lines according to number of stakeholders.

Worksheets with guidelines: These worksheets present environmental and socio-ethical guidelines (developed within the SDO toolkit) to address the definition of sustainable benefits by each stakeholder.
Worksheet with icons: This worksheet presents icons representing several possible stakeholders divided as providers and customers that could be used in the first column of the table to describe each stakeholder.

How to use the tool: the tool requires the use of a slideshow software (e.g. Microsoft PowerPoint, or the equivalent in Open Office) or can be used in the printed version, in this case printed materials and a pen are sufficient. For each stakeholder is needed to fill all columns: stakeholders – representative icon + stakeholder' name / motivation - motivations for the specific stakeholder to be in the partnership of stakeholders / contribution to the partnership - contribution given by the stakeholder to the partnership of stakeholders / environmental – socio-ethical - economic benefits - benefits brought from the specific stakeholders in relation to sustainability. Follow up with a preliminary discussion addressing (existing and potential) stakeholders. To fill the environmental and socio-ethical benefits the two dedicated worksheets are available.

Results: the result is an informative table of motivations, contributions and potential benefits as way to orient strategic conversations addressing (existing and potential) stakeholders.

Integrating the tool into the design process: the tool can be used at various stages of the design process. In the *System concept design* and *Design (and Engineer) System Details* it can be used to verify and facilitate the involvement process and to orient strategic conversations addressing (existing and potential) stakeholders.

Tool availability and required resources: the tool is available for a free download at www.lenses.polimi.it. The tool has been designed to be used in workshops and co-design sessions, therefore if the digital version is used a projector is preferable; in the case the paper version is preferred suggestion is to print the worksheet as A3 or A2. The time required to fill the information is approximately 10 minutes for each actor.

Designer/s: Bacchetti, E., Delfino, E., Vezzoli, C., in collaboration with Makerere University (Uganda), TUDelft University (The Netherlands)

Design support tools from the LeNSes project

Below, the tools developed within the LeNSes project are shortly introduced aiming to give a complete overview of the available System Design tools to support the designers (or other contributors). The text is taken from (Vezzoli et al., 2016).

The tools are the following:
- PSS+DRE Innovation Map;
- PSS+DRE Design Framework and Cards;
- Energy Stakeholder System Map;
- Estimator of Distributed Renewable Energy load/need and production potential (E.DRE).

6. 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 et al., 2016a; 2016b).

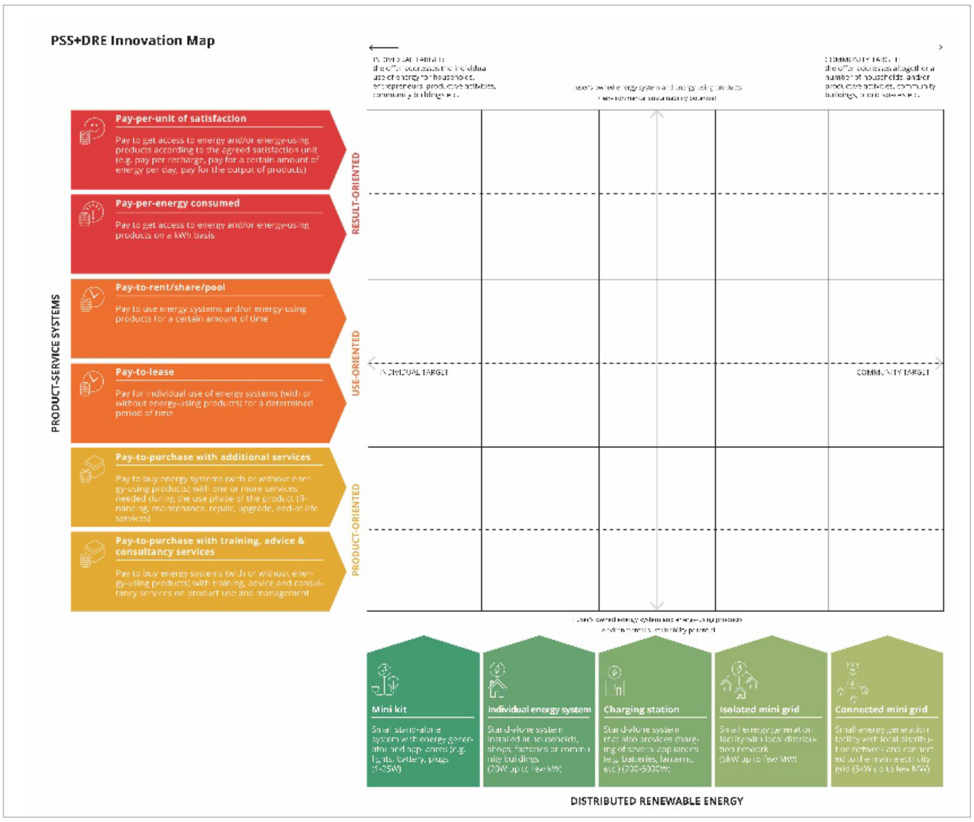


Figure 14. PSS + DRE Innovation map: format.

7. PSS+DRE Design Framework and Cards

It's 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).

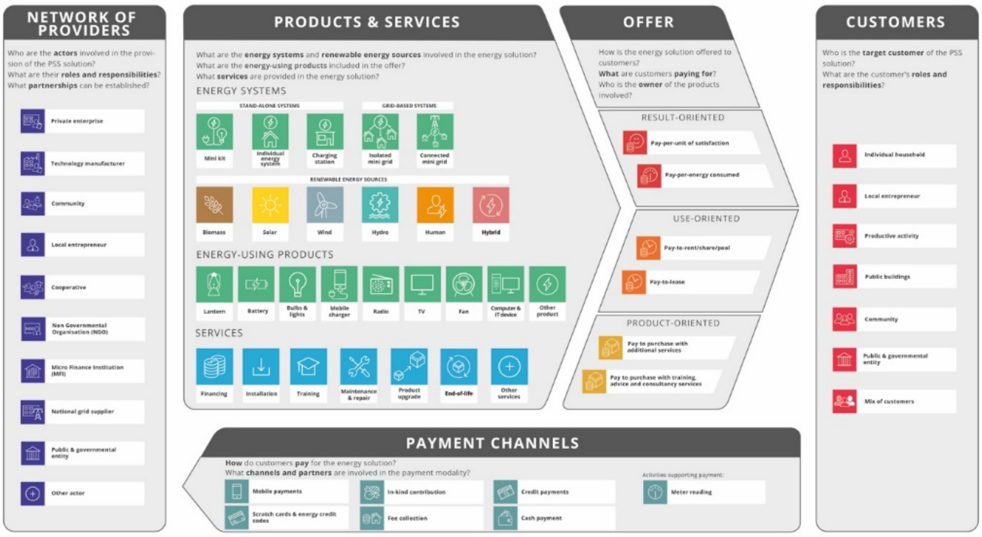


Figure 15. PSS + DRE Design framework and Cards.

Figure 16. PSS + DRE Cards.

8. Energy Stakeholder System Map

It's tool to visualise the network of stakeholders involved in energy systems (Emili, et al., 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, et al., 2004).

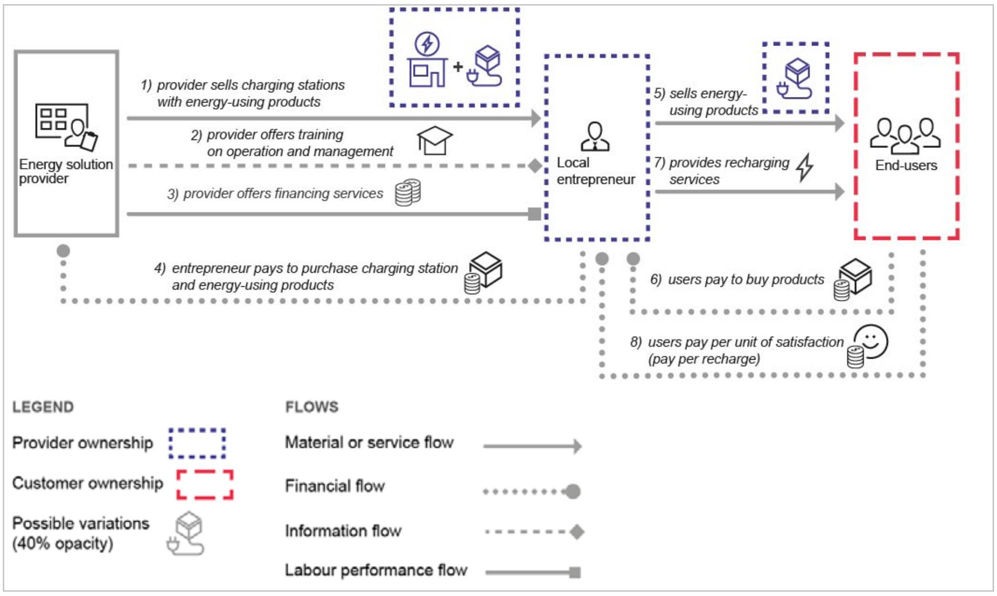


Figure 17. Example of Energy System Map

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

It's a worksheet tool developed to support the design of DRE system, 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.

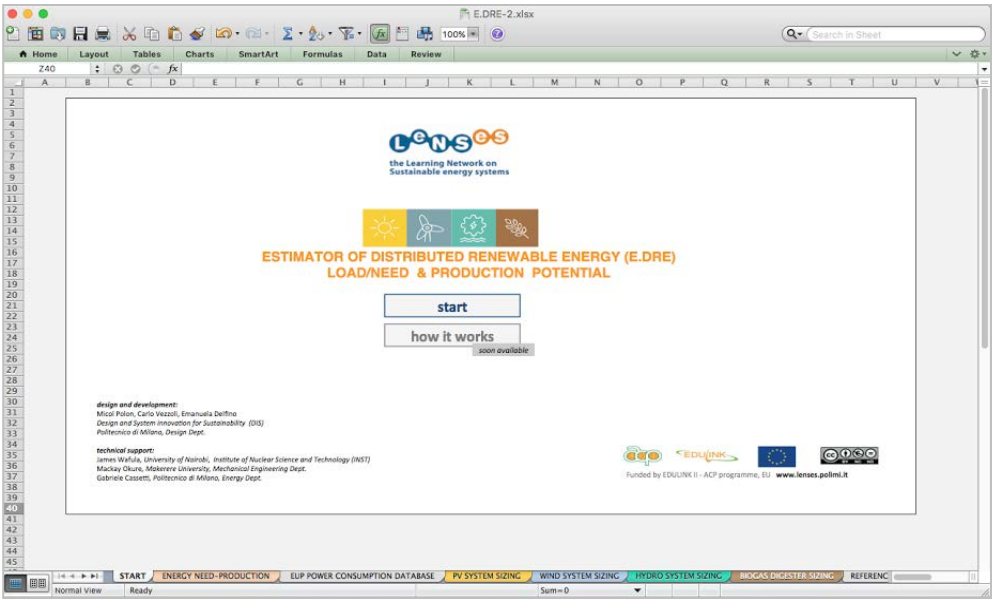


Figure 18. S.PSS&DRE Estimator of DRE load/need and production potential.

7.3 System Design for sustainable energy for All

As introduced in chapter 3, the design of Sustainable Product-Service System (S.PSS) solutions, can be supported from available knowledge-base and know-how developed on time, especially within the Design for Sustainability (DfS) (Tischner et al., 2009). However, to deal with Sustainable Product-Service System (S.PSS), when applied to Distributed Renewable Energy (DRE), new competence and capabilities are needed.

In fact, to design S.PSS applied to DRE solutions, the designer needs to *understand the challenge* of access to sustainable energy, and its key-role towards a sustainable development. Then, *deep into the model*, to clearly understand Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE), to be able to work on it and to facilitate its design process and diffusion. And finally *learn how to (co)design the model*, as the designer should act as facilitator in managing the co-design process with the actors to be involved e.g. customer, provider, side-actors. Finally, to support the diffusion of such model, the designer must transfer competences to the actors for a specific solution.

On this purpose, the new design role, refers to the term *System Design for sustainable energy for All*, which includes the needed knowledge-base towards sustainable energy for All, and related know-how, with design approach, design process and tools to deal with the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model.

Chapter 7 - Design-research activities

The chapter illustrates five design-research activities in Africa and Italy conducted by the researcher, where the aim was to test and get insights for the development, evaluation and refinement of the design approach and related tools. The design-research activities illustrated consist of one design exercise held in Italy for design students, two vocational courses held in Africa for Small and Medium Enterprises (SMEs) and stakeholder's dealing with energy, and two workshops held in Italy with a cooperative and one association working on Renewable Energy. The design-research activities were aimed at design S.PSS applied to DRE solutions; in the design exercise, the students were asked to design cooking and washing concepts based on the S.PSS applied to DRE model for four locations of the African LeNSes partners (communities in Kenya, Botswana, Uganda, South Africa), while in the vocational courses and the workshops, participants designed S.PSS applied to DRE concepts for their own energy businesses.

7.1 Introduction

The chapter describes *five design-research activities* conducted by the researcher, aimed at testing and get insights for the development, evaluation and refinement of the design approach, design process and related tools.

To facilitate readability, the five experiences are presented using a similar structure based on: *introduction, description of activities and outcomes, evaluation.* A final section is dedicated to discussing the lesson learned from the experiences.

The evaluation of each design-research activity was conducted by the participants through a questionnaire updated in time. Indeed, the questions are the same for all design-research activities, while the evaluation rate has been improved for the second vocational courses (see the questionnaire in *Annex II - Evaluation Questionnaire*, at the end of this book). To complement feedback from participants, evaluation reports were provided by professors invited to, in the role of observer of the design-research activities and aimed to verify impact and relevance of S.PSS and DRE, related resources, tools and case studies, within the open-learning process.

7.2 Design exercise for design students (Italy - 2015)

Introduction:
The design exercise was part of the System Design for Sustainability curricular course, held by Politecnico di Milano (Prof. Carlo Vezzoli, 2014-15), and involving 30 internationals post-graduate students from the design field. The aim of the design exercise was to develop concepts of cooking systems, based on the model of Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE), for in communities in South Africa, Botswana and Uganda; and washing systems for communities in Kenya. Four professors, one for each African partner institution of the LeNSes project: University of Nairobi (Kenya), Makerere University (Uganda), University of Botswana (Botswana) and Cape Peninsula University of Technology (South Africa), contributed with feedback on the design exercise for their context. The researcher role, was to introduce the design exercise with related design process and tools, as well as to support the students during the whole experience. At the end of the exercise observations from the researcher and outcomes from the evaluation questionnaires have been combined to make the required improvement on the design approach, process and tools.

Description of activities:
The design exercise duration was 24 hours divided in 6 afternoons (4 hours each), plus a final plenary presentation. The groups of students were made of 5-6 students, and divided in relation to topic (cooking and washing), and location (Kenya, Uganda, Botswana and South Africa).

Before starting the design exercise, the students were equipped with knowledge on both models of Sustainable Product-Service System (S.PSS) and Distributed Renewable Energy (DRE) as well as on System Design for Sustainability (SDS) through dedicated lectures. Design approach and an overview of the tools, were presented to the students during a dedicated lecture before the design exercise. Each tool was deeply presented before its use during the specific lecture. A strategic Analysis for each context was conducted by local professors, and given to the students to setup the design exercise. Below, the schedule of the design exercise, and a short description of the design exercise are provided.

Design exercise schedule:
Day I:
- Get inspiration, watching of the *Sustainable Design Orienting Scenario (SDOS) for S.PSS and DRE* (4 main videos + 12 sub-videos), and using the *Strategic Analysis* of each context;
- Session of sustainable ideas generation, adopting the *SDO toolkit* (environmental and socio-ethical ideas) and the *Energy for All Idea Tables with case study cards* (ideas towards sustainable energy for All).
- Selection, positioning and clustering of generated ideas on the *Innovation Diagram for S.PSS and DRE.*

Day II:
- Draft the concept from the clustered ideas, using the *Innovation Diagram for S.PSS and DRE* to fill the (draft) profile of the new concept, and to write a (draft) short description;
- Draft the stakeholders to be involved and their relations, using the *System Map*;
- Draft the actions to be performed by each involved stakeholder, through the *Interaction Table*[44].
- Review of the concept through feedback from the African professors.

[44] *The tool was developed by Daniela Sangiorgi during the MEPSS European research project (Methodology for Product Service Systems) Growth Programme / European 5th Framework).*

Day III:

- Visualization of the concept activities and narration trough *Offering diagram*[45] and *Interaction Storyboard*[46];
- Increase of the concept details, updating the *System Map*.

Day IV:

- Rendering of *Touch-Points/Evidences* of the concept;
- Increase concept details, updating the needed tools with new info;
- Review of the concept through feedback from the African professors.

Day V:

- Sustainability check (environmental and socio-ethical), using the *SDO toolkit*;
- Review of the concept through feedback from the African professors.

Day VI:

- Increase concept details, updating the needed tools with new info;
- Design of the *Animatic* for the plenary presentation.

Day VII:

- Plenary presentation of students works, using the *Animatic*. Each group had 5 mins to present the developed concept, emphasizing: concept description, offer characteristics, stakeholders relations and sustainability value.
- Evaluation questionnaire.

To start the design exercise, the students were equipped with a detailed Strategic Analysis made by the local collaborators, with information on cooking/washing, and the local energy conditions. Furthermore, the students used the Sustainability Design Orienting Scenario (SDOS) tool to get inspirations for their concepts. They used the Sustainability Design Orienting (SDO) Toolkit and the Sustainable Energy for All Idea Tables to generate system ideas; SDO to address environmentally and socio-ethically sustainable priorities, and SE4All Idea Tables to generate solutions towards Sustainable Energy for All. The most promising system ideas generated, were used to generate a more defined concept, which was characterized in terms of: network of providers, customer/s, type of S.PSS (Product-oriented, Use-oriented, Result-oriented), products + services offered, configuration of the system and as well type/s

[45] *The tool was developed by Francois Jégou during the MEPSS European research project (Methodology for Product Service Systems) Growth Programme / European 5th Framework).*

[46] *The tool was developed by Daniela Sangiorgi during the MEPSS European research project (Methodology for Product Service Systems) Growth Programme / European 5th Framework).*

of renewable resources within the Innovation Diagram for S.PSS&DRE. Several System Design tools were used by the students to detail the concept in term of: what is offered (Offering Diagram tool), which are the interactions among stakeholders (Energy System Map, Interaction Table and Storyboard), what are the touchpoints of the concept (Touch-Points/Evidences tool), which can be the motivations/contributions/benefits from and for each of the (potential) stakeholders (Stakeholders' Motivation and Sustainability Table tool). Each group, during the last day of the course, presented its concept of S.PSS applied to DRE related to its topic and location, and built on the outcomes of each tool used e.g. description of the concept with information from the Innovation Diagram for S.PSS&DRE, representation of stakeholder's interaction through the System Map.

Evaluation:
This was the first design experience where design approach, process and tools were tested. So forth, inputs where fundamental to start the improvement and refinement process. The students were asked to evaluate the tools through a questionnaire aimed to verify *comprehension and usability* of each tool, and its *impact in the design process*. Emerged inputs have been elaborated and combined with observations from the researcher.

The students evaluated all tools they used, anyhow here are presented the evaluations only for those designed/updated by the researcher. To increase readability of the outcomes, the tools are presented as per the process stages: Exploring Opportunities, Design system Concept, Design (and engineering) the system.

Exploring opportunities stage:
The tools used were the *Sustainability Design Orienting Scenario for S.PSS & DRE* and the *Sustainable Energy for All Idea Tables (and cards)*.

The students evaluated quite positively the *Sustainability Design Orienting Scenario for S.PSS & DRE*. In term of comprehension and usability of the tool feedback highlighted that some of the stories were too similar in some points, thus reducing the communication potentials. As general comment, a guide on how to use the tool e.g. an introductive video, could be useful to clarify how to make the first interaction with the tool. Both comments have been address: the stories have been reviewed; an introductory video is now available to introduce the tool. Below the table with student's evaluation.

TOOL: *Sustainability Design Orienting Scenario for S.PSS & DRE*	*No answer*	*No*	*More no than yes*	*More yes than no*	*Yes*
1. COMPREHENSION AND USABILITY OF THE TOOL	3%	0%	13%	42%	42%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	3%	30%	67%

Table 4. student's evaluation on Sustainability Design Orienting Scenario for S.PSS & DRE.

The evaluation on the *Sustainable Energy for All Idea Tables (and cards)* was quite positive, anyhow some "no" have been received. In term of comprehension and usability of the tool the feedback highlighted that the interface of the tool was not so easy to understand e.g. not clear where to post the ideas; as well as some of the guidelines to orient the idea generation were too similar. In relation to the cards with the examples, the graphic did not facilitate readability. To address the feedback, the guidelines have been reviewed, as well as the graphic of the cards have been improved. Below the table with student's evaluation.

TOOL: *Sustainable Energy for All Idea Tables (and cards)*	*No answer*	*No*	*More no than yes*	*More yes than no*	*Yes*
1. COMPREHENSION AND USABILITY OF THE TOOL	7%	1%	1%	35%	56%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	9%	0%	4%	30%	57%

Table 5. student's evaluation on Sustainable Energy for All Idea Tables (and cards).

Design system concept stage:
The tool used was the *Innovation Diagram for S.PSS & DRE.*

The students evaluated quite positively the *Innovation Diagram for S.PSS & DRE*, anyhow some "no" have been received. In term of comprehension and usability of the tool, feedback highlighted that the interface of the tool was complex due to the high number of elements e.g. polarity diagram, profile with labels, thus reducing usability of the tool. To address the feedback, the structure of the tool has been revised redefining priorities in the use of the space. Below the table with student's evaluation.

TOOL: *Innovation Diagram for S.PSS & DRE*	*No answer*	*No*	*More no than yes*	*More yes than no*	*Yes*
1. COMPREHENSION AND USABILITY OF THE TOOL	3%	2%	12%	28%	55%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	3%	0%	5%	35%	57%

Table 6. student's evaluation on Innovation Diagram for S.PSS & DRE.

Design (and engineering) the system stage:
The tool used during was the *Concept Description form for S.PSS & DRE*.

The evaluation on the *Concept Description form for S.PSS & DRE* was quite positive, anyhow some "no" have been received. Main aim of the tool, at first sight, was not so clear according to feedback. In fact, its impact in the design process was perceived more to communicate the concept, instead to detail it. Other feedback referred to the small room for customization. To address the feedback, the interface of the tool has been simplified. The use of the tool has been discussed to be tested during other design-research activities. Below the table with student's evaluation.

TOOL: *Concept Description form for S.PSS & DRE*	*No answer*	*No*	*More no than yes*	*More yes than no*	*Yes*
1. COMPREHENSION AND USABILITY OF THE TOOL	7%	1%	5%	34%	53%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	3%	0%	5%	35%	57%

Table 7. student's evaluation on Concept Description form for S.PSS & DRE.

7.3 Vocational course for Stakeholders for energy (Botswana - 2016)

Introduction:

The first vocational course *"Designing Sustainable Product-Service System (S.PSS) offer models for Distributed Renewable Energy (DRE) systems"* was conducted by the University of Botswana (Botswana - 2016) in collaboration with Politecnico di Milano (the researcher was in the board), involving six representatives[47] from five Small and Medium Enterprises (SMEs) for energy, and one Research Center from Botswana. Participants, organized in groups, were asked to innovate and increase sustainability of their existing businesses, through a design simulation, where to design Sustainable Product-Service System applied to Distributed Renewable Energy solutions. So forth, attention was mainly addressed to defining new concepts, and to define the new (internal/external) actors needed to make the innovation to work e.g. energy supplier, products manufacture, service providers and the potential involvement of local public authorities. For the researcher, the aim was to present the model and design approach and to test and evaluate the tools with energy practitioners to receive feedback and observations.

Figure 19. Collage from the first vocational course on Sustainable Product-Service System (S.PSS) Offer Models for Distributed Renewable Energy (DRE) systems vocational course – University of Botswana (Botswana).

[47] *The 6 participants, involved in the vocational course, represented the following SMEs: So Solar, Biosys Botswana, Bostrich Projects, Sunshine Eaglesworth, SIAB/Energy Systems Group, and the BITRI Research center.*

Description of activities:
The vocational course duration was 12 hours divided in 2 days (6 hours each). The groups were made of 3 practitioners, dealing with different Distributed Renewable Energy (DRE) such as, biogas, sun, hydropower, and cook-stove technologies.

The course was based on both theory and practice. Theoretical lectures, aimed to provide an introduction on sustainable development and System Design for Sustainability (SDS); and basic knowledge on Sustainable Product-Service System (S.PSS), Distributed Renewable Energy (DRE) and their coupling (S.PSS applied to DRE). Case studies on S.PSS applied to DRE, to give examples from the field, were presented and discussed with participants. The acquired notions were put into practice within the design simulation. Design approach and an overview of the tools, were presented to the participants during a dedicated lecture before the design simulation. Each tool was presented before its use during the specific stage of the simulation. Below, the schedule of the course, and a short description of the design simulation are provided.

Course schedule:
Day 0:
- Closed meeting for staff only, a pre-test of lectures was made to share and discuss the available knowledge. Last details on the course, both in terms of structure and contents were discussed.

Day I:
- Lectures to introduce participants in the topics of the course:
    - Course welcome and introduction;
    - Sustainable Energy for Sustainable Development;
    - Distributed / decentralized generation;
    - Sustainable Product-Service System (S.PSS) innovation;
    - Sustainable Product-Service System applied to Distributed Renewable Energy;
    - Case studies of Sustainable Product-Service System applied to Distributed Renewable Energy;
    - System Design for sustainable Energy for All;
- Introduction to the Design simulation: presentation of expectancies, schedule and material distribution.
- Lectures to introduce participants in the topics of the course:
    MSDS Method for System Design (for Sustainable energy for All) (method and tools overview)

Day II:

- Design Exercise:
    - Positioning and characterization of the existing business of each participant within the *Innovation Diagram for S.PSS & DRE*;
    - Get inspiration, watching of the *Sustainable Design Orienting Scenario (SDOS) for S.PSS and DRE* (4 main videos + 12 sub-videos), to immerse in innovative and win-win offer model;
    - Session of sustainable ideas generation, adopting the *Energy for All Idea Tables with case study cards* (ideas towards sustainable energy for All);
    - Draft concept, through the selection, positioning and clustering of generated ideas; as well as filling the profile of the new concept within the *Innovation Diagram for S.PSS and DRE.*
    - Draft the stakeholders to be involved and their relations, using the *System Map*;
    - Sustainability check (environmental and socio-ethical), using the *Stakeholders' Sustainable Motivation Table;*
    - Design the *Animatic* for the final presentation, which included the concept presentation, and outcomes from previous tools: *System Map*.
- Plenary presentation of designed concept. Each group had 5 mins to present the developed concept, emphasizing: concept characteristics, stakeholders' relations, benefits and roles, and sustainability values of the concept;
- Discussion on future steps e.g. possible collaborations with the local University;
- Evaluation questionnaire.

The first activity of the design simulation, aimed to understand the business of each SME, was conducted with the use of the Innovation Diagram for S.PSS&DRE tool. It was evidenced that the current businesses of SMEs and research center, were proposing Product-oriented solutions, thus selling their DRE products with (eventually) additional services included, such as maintenance and repair. To give inspirations to the participants, the Sustainability Design Orienting Scenario (SDOS) tool was used. Each group used the Sustainable Energy for All Idea Tables to generate system ideas. Among others, ideas generated were, locally managed solutions for energy access, fresh food and drinks delivery to local communities, etc. The most promising ideas were copied and clustered by each group in the Innovation Diagram for S.PSS&DRE, and defined the concept in terms of: providers, customer/s, type of S.PSS (Product-oriented, Use-oriented, Result-oriented), products + services offered, configuration of the system and as well type/s of renewable resources. The interactions of stakeholders of the system, as well as their motivations/contributions/benefits to be part of the concept, were refined through the Energy System Map tool, and the Stakeholders' Motivation and Sustainability Table one. Each group, had 5 mins to present its concept during the last day of the course. A concept was *"A B2C solution, based on solar energy movable kiosk, aimed to provide fresh drinks and food to the local community in Botswana. The service providers own the kiosk and all related energy using equipment and products e.g. fridge, lights. The customers pay an entry fee to become members of the system and later only as a pay-per-use. The service providers are currently importing the solar panels, but are interested to build local partnerships at least to locally manufacture some spare parts"*.

Evaluation:
This design experience, gave to the researcher the opportunity to design structure and (part of) the contents of the course, thus increasing her understanding on the entire course. The participants were asked to evaluate, both the tools and course through a questionnaire aimed to verify *comprehension and usability* of each tool, and its *impact in the design process*, as well as its *potential conditions of use*. The course evaluation, was based on the course *contents*. The structure of the course was discussed among the researcher and the board of the course. Emerged inputs were elaborated and combined with observations from the researcher.

The participants evaluated all tools they used, anyhow here are presented the evaluations only for those designed/updated by the researcher. To increase readability of the outcomes, the tools are presented as per the process stages: Strategic Analysis, Exploring Opportunities, Design system Concept.

Strategic Analysis stage:
The tool used was the *Innovation Diagram for S.PSS & DRE*.

The participants expressed their interest in the *Innovation Diagram for S.PSS & DRE*, and evaluated it positively. In term of comprehension and usability of the tool feedback highlighted that due to the complexity of the tool, time restriction was an issue. Satisfaction was expressed regarding the potential use of the tool, especially to present the business to potential partners. The tool was also used during the System concept design stage, this evaluation comprises both the uses. Below the table with participant's evaluation.

TOOL: *Innovation Diagram for S.PSS & DRE*	*No answer*	*No*	*More no than yes*	*More yes than no*	*Yes*
1. COMPREHENSION AND USABILITY OF THE TOOL	0%	0%	0%	50%	50%

2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	0%	20%	80%
3. POTENTIAL CONDITIONS OF USE	0%	0%	0%	20%	80%

Table 8. participant's evaluation on Innovation Diagram for S.PSS & DRE (vocational course Botswana).

Exploring opportunities stage:
The tools used were the *Sustainability Design Orienting Scenario for S.PSS & DRE* and the *Sustainable Energy for All Idea Tables (and cards)*.

The participants evaluated positively the *Sustainability Design Orienting Scenario for S.PSS & DRE*. In term of comprehension and usability of the tool, was proposed to give them to the participants in advance, thus giving more time to understand all communication levels of the narrations. Furthermore, was suggested to outline definitions (within the videos) more concisely. To address the feedback, a review of the texts was made. Below the table with participant's evaluation.

TOOL: *Sustainability Design Orienting Scenario for S.PSS & DRE*	*No answer*	*No*	*More no than yes*	*More yes than no*	*Yes*
1. COMPREHENSION AND USABILITY OF THE TOOL	0%	0%	0%	50%	50%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	0%	10%	90%
3. POTENTIAL CONDITIONS OF USE	0%	0%	0%	10%	90%

Table 9. participant's evaluation on Sustainability Design Orienting Scenario for S.PSS & DRE (vocational course Botswana).

The evaluation on the *Sustainable Energy for All Idea Tables (and cards)* was very positive, and no specific indications were provided. Below the table with participant's evaluation.

TOOL: *Sustainable Energy for All Idea Tables (and cards)*	*No answer*	*No*	*More no than yes*	*More yes than no*	*Yes*
1. COMPREHENSION AND USABILITY OF THE TOOL	0%	0%	0%	10%	90%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	0%	10%	90%
3. POTENTIAL CONDITIONS OF USE	0%	0%	0%	10%	90%

Table 10. participant's evaluation on Sustainable Energy for All Idea Tables (and cards) (vocational course

Botswana).

Within the questionnaire, participants were asked to evaluate the contents delivered during the course. The 80% of participants were satisfied by the course, and 2 persons didn't answer. Main feedback emerged from the course evaluation, were related to: the willingness to re-use the acquired knowledge and know-how into strategic conversations with (potential) partners. Furthermore, an interest into learn more about all tools was declared, to be able next times to use them focusing more on the design-research activities rather than to practical issues in their use.

7.4 Vocational course for Small and Medium Enterprises for energy (Uganda - 2016)

Introduction:

The second vocational course *"Designing Sustainable Product-Service System (S.PSS) offer models for Distributed Renewable Energy (DRE) systems"* was conducted by the Makerere University (Uganda - 2016) as a collaboration between the Centre for Research in Energy and Energy Conservation (CREEC) of the University, in collaboration with Politecnico di Milano (the researcher was in the board), involving ten representatives[48] from nine Small and Medium Enterprises (SMEs) for energy from Uganda. Participants were asked to innovate and increase sustainability of their existing businesses, through a design simulation, where to design Sustainable Product-Service System applied to Distributed Renewable Energy solutions. Attention was mainly addressed to defining new concepts, and to properly communicate them to external audiences using dedicated tools e.g. involving new stakeholders, or requesting permission from local administrations with the support of narrative tools. For the researcher, the aim was to present the model and design approach and to test and evaluate the tools with energy practitioners for (further) feedback and observations.

Figure 20. Collage from the first vocational course on Sustainable Product-Service System (S.PSS) Offer

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[48] *The 10 participants, involved in the vocational course, represented the following SMEs: Contragen ug, Green Heat Uganda, Reo-Uganda, Mandulis Energy, Marma Technical Services, Village Power, Awamu-Biomass Energy ltd, Good fire manda, Clean Tech ltd.*

Models for Distributed Renewable Energy (DRE) systems vocational course - Makerere University (Uganda).

Description of activities:
The vocational course duration was 21 hours divided in 3 days (7 hours each), plus a final half-day of plenary presentation. The groups were made of 3-4 practitioners, dealing with different Distributed Renewable Energy (DRE) such as, biogas, sun, hydropower, and cook-stove technologies.

The course was based on both theory and practice. Theoretical lectures, aimed to provide basic knowledge on Sustainable Product-Service System (S.PSS), Distributed Renewable Energy (DRE) and their coupling (S.PSS applied to DRE), and with an introduction on sustainable development and System Design for Sustainability (SDS). Case studies on S.PSS applied to DRE, were presented directly from case studies representatives and from different members of the board, to be discussed with participants. Within the design simulation, the acquired notions were put into practice. Design approach and an overview of the tools, were presented to the participants during a dedicated lecture before the design simulation. Each tool was deeply presented before its use during the specific stage of the simulation. Below, the schedule of the course and a short description of this design simulation are provided.

Course schedule:
Day 0:
- Closed meeting for staff only, to share and discuss last details on the course, both in terms of structure and contents.

Day I:
- Lectures to introduce participants in the topics of the course:
    - Course welcome and introduction;
    - Sustainable Energy for Sustainable Development;
    - Distributed / decentralized generation;
    - Sustainable Product-Service System (S.PSS) innovation (with exercise);
    - Sustainable Product-Service System applied to Distributed Renewable Energy;
    - Case studies of Sustainable Product-Service System applied to Distributed Renewable Energy (with exercise);
- Introduction to the Design simulation: presentation of expectancies, schedule and material distribution.

Day II:

- Lectures to introduce participants in the topics of the course:
  - System Design for sustainable Energy for All;
  - MSDS Method for System Design (for Sustainable energy for All) (method and tools overview)
- Design Exercise:
  - Positioning and characterization of the existing business of each participant within the *Innovation Diagram for S.PSS & DRE*, plus short plenary presentation using the same tool;
  - Get inspiration, watching of the *Sustainable Design Orienting Scenario (SDOS) for S.PSS and DRE* (4 main videos + 12 sub-videos), to immerse in innovative and win-win offer model;
  - Session of sustainable ideas generation, adopting the *Energy for All Idea Tables with case study cards* (ideas towards sustainable energy for All);
  - Draft concept, through the selection, positioning and clustering of generated ideas; as well as filling the profile of the new concept within the *Innovation Diagram for S.PSS and DRE.*

Day III:
- Sum-up of previous days
- Design Exercise:
  - Detail the concept, using the *Concept Description form for S.PSS and DRE* to fill the (draft) profile of the new concept, and to write a (draft) short description;
  - Draft the stakeholders to be involved and their relations, using the *System Map*;
  - Sustainability check (environmental and socio-ethical), using the *Stakeholders' Sustainable Motivation Table;*
  - Design the *Animatic* for the final presentation, which included the concept presentation, and outcomes from previous tools: *System Map* + *Stakeholders' Sustainable Motivation Table*.

Day IV:
- Plenary presentation of designed concept, using the *Animatic*. Each group had 10 mins to present the developed concept, emphasizing: concept characteristics, stakeholders' relations, benefits and roles, and sustainability values of the concept.
- Discussion on future steps e.g. possible collaborations with the local University;
- Evaluation questionnaire.

In this design simulation, as in the one implemented in Botswana, the first activity conducted was the used of the Innovation Diagram for S.PSS&DRE tool, which gave an understanding of the business of each SME. To innovate the current Product-oriented and Use-oriented solutions provided by the SMEs, the Sustainability Design Orienting Scenario (SDOS) tool was used, giving more inspirations, as well as Sustainable Energy for All Idea Tables to generate system ideas, which supported several system ideas such as community kitchens, local biogas digesters and so on. The most promising ones were copied and clustered in the Innovation Diagram for S.PSS&DRE to setup the concept. The Energy System Map tool, and the Stakeholders' Motivation and Sustainability Table one, were used to detail the roles and perspectives of the (potential) stakeholders to be involved. Each group presented its concept during the last day of the course. To give an example, one of the concepts was *"A business to customer (B2C) solution, based on a community bio-digester, owned by the Renewable Energies Ltd (REL), who is responsible for its installation, training, repair and maintenance. REL offers to its customers biogas stored in bags to facilitate cooking activities, and charged batteries for lanterns. Customers pay-per-use to use the energy services (biogas refill/battery charging). REL owns biogas bags and the batteries, customers own the stoves and the lights. To gain extra-money and Customers can provide bio-waste to support the function of the bio-digester, that will be paid from REL"*.

Evaluation:
This design experience, gave to the researcher the opportunity to design the structure and (part of) the contents of the course, thus increasing her understanding on the entire course and the needed knowledge and know-how needed by the board and the participants to work on it. The participants were asked to evaluate, both the tools and course through a questionnaire aimed to verify *comprehension and usability* of each tool, and its *impact in the design process*, as well as its *potential conditions of use*. The course evaluation, was based on the course *contents*. The structure of the course was discussed among the researcher and the board of the course. Emerged inputs have been elaborated and combined with observations from the researcher.

The participants evaluated all tools they used, anyhow here are presented the evaluations only for those designed/updated by the researcher. To increase readability of the outcomes, the tools are presented as per the process stages: Strategic Analysis, Exploring Opportunities, Design system Concept.

Strategic Analysis stage:
The tool used was the *Innovation Diagram for S.PSS & DRE*.

The participants expressed their interest in the *Innovation Diagram for S.PSS & DRE*, and evaluated it positively. In term of comprehension and usability of the tool feedback highlighted the complexity of the tool. Consequently, time availability was a crucial issue. High satisfaction was expressed regarding the potential use of the tool, mainly as to internally analyze a company, train other companies or to open new businesses. The tool was also used during the System concept design stage, this evaluation comprises both the uses. Below the table with participant's evaluation.

TOOL: *Innovation Diagram for S.PSS & DRE*	*No answer*	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1. COMPREHENSION & USABILITY OF THE TOOL	0%	0%	0%	20%	80%	0%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	0%	50%	50%	0%
3. POTENTIAL CONDITIONS OF USE	0%	0%	10%	0%	50%	40%

Table 11. participant's evaluation on Innovation Diagram for S.PSS & DRE (and cards) (vocational course Uganda).

Exploring opportunities stage:
The tools used were the *Sustainability Design Orienting Scenario for S.PSS & DRE* and the *Sustainable Energy for All Idea Tables (and cards)*.

The participants evaluated quite positively the *Sustainability Design Orienting Scenario for S.PSS & DRE*. In term of comprehension and usability of the tool was underlined the potential difficulty in the use of a video format in specific situations e.g. rural communities, or in absence of video and audio appliances. Possible improvement of the tool, in low technology perspectives, could be to present the visions in written narrations, no exploration in this direction have been (currently) conducted. Below the table with participant's evaluation.

TOOL: *Sustainability Design Orienting Scenario for S.PSS & DRE*	*No answer*	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1. COMPREHENSION & USABILITY OF THE TOOL	20%	0%	0%	30%	50%	0%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	20%	0%	10%	10%	40%	20%
3. POTENTIAL CONDITIONS OF USE	20%	0%	10%	10%	30%	30%

Table 12. participant's evaluation on Sustainability Design Orienting Scenario for S.PSS & DRE (vocational course Uganda).

The evaluation on the *Sustainable Energy for All Idea Tables (and cards)* was mainly positive. In term of comprehension and usability of the tool the feedback suggested improvement in the editing e.g. check the color of the text to ensure visibility in writing ideas on the post-it. To highlight the different sections a differentiation with color e.g. one color per each section, was proposed. To address the feedback, graphic check and change in the color of the post-it was given. To differentiate sections, the title of each section was made more visible. Below the table with participant's evaluation.

TOOL: *Sustainable Energy for All Idea Tables (and cards)*	*No answer*	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1. COMPREHENSION & USABILITY OF THE TOOL	10%	0%	0%	20%	70%	0%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	10%	0%	0%	20%	30%	40%
3. POTENTIAL CONDITIONS OF USE	10%	0%	0%	20%	50%	20%

Table 13. participant's evaluation on Sustainable Energy for All Idea Tables (and cards) (vocational course Uganda).

Design system concept stage:
The tool used were *Innovation Diagram for S.PSS&DRE* (evaluated above) and *Stakeholders Sustainability and Motivation Table*.

Participants gave mainly a positive evaluation of the *Stakeholders' Sustainability and Motivation Table*. Feedback highlighted some difficulties in defining the contribution to sustainability, particularly to identify the direct contributor. To address the feedback, more detailed examples have been included in the form to be used, thus strengthening the base to build the new information. Below the table with participant's evaluation.

TOOL: *Stakeholders' Sustainability and Motivation Table*	*No answer*	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1. COMPREHENSION & USABILITY OF THE TOOL	20%	0%	0%	10%	70%	0%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	20%	0%	0%	0%	30%	50%
3. POTENTIAL CONDITIONS OF USE	20%	0%	0%	10%	40%	30%

Table 14. participant's evaluation on Stakeholders' Sustainability and Motivation Table (vocational course Uganda).

Within the questionnaire, participants were asked to evaluate the contents delivered during the course. The 40% of participants were very satisfied by the course, 50% completely satisfied, and 1 person didn't answer. Main feedback emerged from the course evaluation, were related to: the willingness to include more possibilities to design S.PSS applied to DRE solutions for cook-stoves and not only for energy/electricity generation; and the interest to include a market analysis for the concept of S.PSS applied to DRE, generated during the course. To address the feedback, is notable that all tools are open-source and copy-left materials which can be modified and updated freely. Furthermore, as no tools are mandatory or forbidden, a market analysis for the concept of S.PSS applied to DRE, could be included in the design process case by case.

7.5 Workshop with a cooperative for energy (Italy - 2017)

Introduction:
The workshop was organized by the researcher and held by Politecnico di Milano. The workshop was a collaboration with Retenergie, the first cooperative working on Renewable Energy in Italy. As the recent partnership settled between Retenergie and ènostra, an Italian provider of Renewable Energy, a representative from ènostra participated to the workshop. The goal of the workshop was to test the tools to analyze the structure of the participant's offers, as well as to design new opportunities where the S.PSS applied to DRE model is adopted. This design experience was fundamental for the researcher, on one side, to experiment design approach and tools out from the African context (see previous design-research activities) opening the scope to a wider audience; as well as to collaborate with one single client (Retenergie), deepening benefits and limit of such choice.

Description of activities:
The workshop duration was 8 hours in 1 day. The participants were two representatives of Retenergie, and one representative from ènostra.

The workshop was based on both theory and practice. Theoretical lectures, provided basic knowledge on Sustainable Product-Service System (S.PSS), Distributed Renewable Energy (DRE) and their coupling (S.PSS applied to DRE). An introduction on sustainable development was also provided. The acquired notions were put into practice through the design simulation. Design approach and an overview of the tools, were presented to the participants during a dedicated lecture. Each tool was deeply presented before its use during the specific stage of the simulation. The course (and materials) were translated and used in Italian due to the nationality of participants. Below, the schedule of the workshop and a short description of this design simulation are provided.

Workshop schedule:
Morning:
- Lectures to introduce participants in the topics of the workshop:
    - welcome and introduction;
    - Sustainable Energy for Sustainable Development;
    - Sustainable Product-Service System applied to Distributed Renewable Energy (with exercise);
    - MSDS Method for System Design (for Sustainable energy for All) (method and tools overview)

Afternoon:

- Introduction to Design simulation: presentation of expectancies, schedule and material distribution;
- Design Exercise:
  - Positioning and characterization of Retenergie and ènostra within the *Innovation Diagram for S.PSS & DRE*;
  - Session of sustainable ideas generation, adopting the *Energy for All Idea Tables with case study cards* (ideas towards sustainable energy for All);
  - Draft concept, through the selection, positioning and clustering of generated ideas; as well as filling the profile of the new concept within the *Innovation Diagram for S.PSS and DRE.*
- Discussion on further opportunities of collaboration;
- Evaluation questionnaire.

The businesses of Retenergie and ènostra were explored through the Innovation Diagram for S.PSS&DRE tool. It was evidenced the complexity of both businesses and time was dedicated to make them clear. Then, the participants generated system ideas with the Sustainable Energy for All Idea Tables, moving a step further in the collaboration between Retenergie and ènostra, which was represented by the definition of two possible concepts using again the Innovation Diagram for S.PSS&DRE. A first concept generated was related to energy efficiency in buildings as strategy to reduce energy losses. This brought Retenergie to include in its offer a set of products with services (Product-oriented S.PSS) for building insulation, to be sold to the customers (B2C – B2B). A second concept was dedicated to the setup of smart-grids, which could bring opportunities to distributed renewable energy.

Evaluation:
The participants were asked to evaluate, both the tools and workshop through a questionnaire aimed to verify *comprehension and usability* of each tool, and its *impact in the design process*, as well as its *potential conditions of use*. The workshop evaluation, was based on *contents*. The structure of the workshop was discussed among the researcher and the client. Emerged inputs have been elaborated and combined with observations from the researcher.

To increase readability, the tools are presented as per the process stages: Strategic Analysis, Exploring Opportunities, Design system concept.

Strategic Analysis stage:
The tool used was the *Innovation Diagram for S.PSS & DRE*.

The clients expressed their interest in the *Innovation Diagram for S.PSS & DRE*, and evaluated it positively. In term of comprehension and usability of the tool, potential improvements were suggested. First, more automation in the tool e.g. substitute labels with a menu, was proposed. More flexibility e.g. wide the vertical axis boundaries of the innovation diagram, was also suggested to respond more precisely to the variety of the market. The tool was also used during the System concept design stage, this evaluation comprises both the uses. At this regard, a suggestion to include a SWOT analysis of the designed concept was proposed. To address the feedback: more automation in the tool is perceived as one of the goal to improve the tool. Anyhow, due to high costs and competences required for automation, the process is still at the beginning. The axes boundaries were defined from the case studies analysis, an in the perspective of orientating the design of new concepts in such directions. Anyhow, due to the variety of actors who can deal with energy solutions, e.g. consultancies, public entities, the boundaries meaning has been widened, so forth all actors can play in the polarity diagram. Below the table with participant's evaluation.

TOOL: *Innovation Diagram for S.PSS & DRE*	*No answer*	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1. COMPREHENSION & USABILITY OF THE TOOL	0%	0%	34%	0%	66%	0%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	0%	0%	100%	0%
3. POTENTIAL CONDITIONS OF USE	0%	0%	0%	34%	0%	66%

Table 15. participant's evaluation on Innovation Diagram for S.PSS & DRE (workshop Retenergie – ènostra).

Exploring opportunities stage:
The tools used was the *Sustainable Energy for All Idea Tables (and cards)*.

The evaluation on the *Sustainable Energy for All Idea Tables (and cards)* was mainly positive. In term of comprehension and usability of the tool, the feedback suggested to clarify e.g. with a legend, the energy vocabulary, to facilitate readability, especially in the guidelines. To address the feedback, a review of the guidelines was provided. Below the table with participant's evaluation.

TOOL: *Sustainable Energy for All Idea Tables (and cards)*	*No answer*	*Not at all satisfied*	*Slightly satisfied*	*Moderatel y satisfied*	*Very satisfied*	*Completel y satisfied*
1. COMPREHENSION & USABILITY OF THE TOOL	0%	0%	0%	0%	66%	34%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	0%	33%	33%	34%
3. POTENTIAL CONDITIONS OF USE	0%	0%	33%	0%	33%	34%

Table 16. participant's evaluation on Sustainable Energy for All Idea Tables (and cards) (workshop Retenergie – ènostra).

Within the questionnaire, participants were asked to evaluate the contents delivered in the workshop. Two clients were very satisfied by the workshop, one was completely satisfied. Due to short time of the workshop, a suggestion was to concentrate more on the design exercise to dedicate time for the use of the tools. Such feedback will be addressed by the researcher for the next design-research activities. High interested was expressed from the client (and shared by the researcher) to continue the collaboration.

7.6 Workshop with an association for energy (Italy - 2017)

Introduction:
The workshop was organized by the researcher as a collaboration with Energoclub onlus, Energoclub onlus, an Italian association working on Renewable Energy. The workshop was held in the Energoclub onlus headquarters in Treviso (Veneto). The goal of the workshop was to use the tools to analyze the existing association as well as to design new opportunities for an existing project in-progress led by the association in collaboration with Confindustria Veneto[49], where the S.PSS applied to DRE model was applied. This last design experience was fundamental for the researcher, having the opportunity to test design approach and tools within an existing project; as well as to collaborate with one single client, deepening benefits and limit of such choice.

Description of activities:
The workshop duration was 8 hours in 1 day. The participants were two representatives of Energoclub onlus.

The workshop was based on both theory and practice, providing basic knowledge on Sustainable Product-Service System (S.PSS), Distributed Renewable Energy (DRE) and their coupling (S.PSS applied to DRE), and with an introduction on sustainable development and System Design for Sustainability (SDS). To test design approach and tools, they were presented to the participants during a dedicated lecture and used during the design exercise. Each tool was deeply presented before its use during the specific stage of the exercise. The course (and materials) were translated and used in Italian due to the nationality of participants. Below, the schedule of the workshop and a short description of this design simulation are provided.

Workshop schedule:
Morning:

- Lectures to introduce participants in the topics of the workshop:
    - welcome and introduction;
    - Sustainable Energy for Sustainable Development;
    - Sustainable Product-Service System applied to Distributed Renewable Energy (with exercise);
    - MSDS Method for System Design (for Sustainable energy for All) (method and tools overview)

[49] *Confindustria Veneto is the regional section of the Italian employee's federation and chamber of commerce.*

- Introduction to the Design simulation: presentation of expectancies, schedule and material distribution;

Afternoon:

- Design Exercise:
  - Positioning and characterization of Energoclub onlus within the *Innovation Diagram for S.PSS & DRE*;
  - Session of sustainable ideas generation (for the existing project), adopting the *Energy for All Idea Tables with case study cards* (ideas towards sustainable energy for All);
  - Draft concept, through the selection, positioning and clustering of generated ideas; as well as filling the profile of the new concept within the *Innovation Diagram for S.PSS and DRE.*
  - Draft of stakeholder's interactions, within the *System Map.*
  - Draft sustainability check of the designed concept by using the *Stakeholder's Sustainability and Motivation Table.*
- Discussion on further opportunities of collaboration.
- Evaluation questionnaire.

This last design simulation, was based on an existing project in-progress led by Energoclub in collaboration with Confindustria Veneto. In this case, the Innovation Diagram for S.PSS&DRE tool, was filled in relation to the current project, thus evidencing available and missing competences from the stakeholders currently involved. It was evidenced the need of several external stakeholders to cover the project need, so forth time was spent in the use of the System Map, to clarify the potential interactions, as well as to fill the Stakeholder's Sustainability and Motivation Table, which gave a clear overview of motivations/contribution/benefits for and from each (potential) stakeholders.

Evaluation:

The participants were asked to evaluate, both the tools and workshop through a questionnaire aimed to verify *comprehension and usability* of each tool, and its *impact in the design process*, as well as its *potential conditions of use*. The workshop evaluation, was based on *contents*. The structure of the workshop was discussed among the researcher and the client. Emerged inputs have been elaborated and combined with observations from the researcher.

To increase readability, the tools are presented as per the process stages: Strategic Analysis, Exploring Opportunities, Design system concept.

Strategic Analysis stage:
The tool used was the *Innovation Diagram for S.PSS & DRE*.

The evaluation of the *Innovation Diagram for S.PSS & DRE* was positive. To increase usability of the tool, the use of the excel format was proposed. In term of possible re-use condition, the clients expressed their interest in the use the tool as a way to present their project to (potential) partners and external actors e.g. during promotion campaigns to attract new customers. To address the feedback: to increase usability of the tool using other supports (software) is set as one of the goal to improve the tool. Anyhow, due to limited resources and competences, the process is still at the beginning. The tool was also used during the System concept design stage, this evaluation comprises both the uses. Below the table with participant's evaluation.

TOOL: *Innovation Diagram for S.PSS & DRE*	*No answer*	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1. COMPREHENSION & USABILITY OF THE TOOL	0%	0%	0%	0%	100%	0%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	0%	0%	50%	50%
3. POTENTIAL CONDITIONS OF USE	0%	0%	0%	0%	100%	0%

Table 17. participant's evaluation on Innovation Diagram for S.PSS & DRE (workshop Energoclub).

Exploring opportunities stage:
The tools used was the *Sustainable Energy for All Idea Tables (and cards)*.

The evaluation on the *Sustainable Energy for All Idea Tables (and cards)* was mainly positive. In term of comprehension and usability of the tool, the feedback suggested to improve translation as some English terms were still in use. To address the feedback, a review of the text was provided. Below the table with participant's evaluation.

TOOL: *Sustainable Energy for All Idea Tables (and cards)*	*No answer*	*Not at all satisfied*	*Slightly satisfied*	*Moderatel y satisfied*	*Very satisfied*	*Completel y satisfied*
1. COMPREHENSION & USABILITY OF THE TOOL	0%	0%	0%	0%	100%	0%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	0%	0%	50%	50%
3. POTENTIAL CONDITIONS OF USE	0%	0%	0%	0%	100%	0%

Table 18. participant's evaluation on Sustainable Energy for All Idea Tables (and cards) (workshop Energoclub).

Design system concept stage:
The tools used were the *Innovation Diagram for S.PSS & DRE* (evaluated above) and the *Stakeholders Sustainability and Motivation Table*.

Participants gave a positive evaluation of the *Stakeholders' Sustainability and Motivation Table*, no specific suggestions were indicated. Below the table with participant's evaluation.

TOOL: *Stakeholders' Sustainability and Motivation Table*	*No answer*	*Not at all satisfied*	*Slightly satisfied*	*Moderatel y satisfied*	*Very satisfied*	*Completel y satisfied*
1. COMPREHENSION & USABILITY OF THE TOOL	0%	0%	0%	0%	50%	50%
2. IMPACT OF THE TOOL IN THE DESIGN PROCESS	0%	0%	0%	0%	0%	100%
3. POTENTIAL CONDITIONS OF USE	0%	0%	0%	0%	50%	50%

Table 19. participant's evaluation on Stakeholders' Sustainability and Motivation Table (workshop Energoclub).

Within the questionnaire, participants were asked to evaluate the contents delivered in the workshop. One representative was very satisfied by the workshop, one was completely satisfied. An interest to see more case studies, to get a deep knowledge in the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model and dynamics was outlined. Another observation was to insert such workshop in more complete collaborations as: one meeting to give a deep introduction of the existing project to the research team; one preliminary meeting with all partners of the project to introduce the (potential) collaboration with methodology, goals and objectives, definition of the collaboration proposal and the contractual conditions, definition of the activities plan and set of the collaboration. A final consideration suggested the use of free supports (software) e.g. open office, to furtherly increase accessibility of the resources. Some feedback will be addressed by the researcher for the next design-research activities; regarding the use of free supports (software) first steps are in-progress to verify compatibility. Based on the above positive considerations, and high interested expressed from the client (and shared by the researcher) to continue the collaboration, first steps are in-progress.

7.7 Conclusion and lesson learned

The chapter illustrated *five design-research activities* conducted by the researcher, aimed at testing and get insights for the refinement of the design approach, design process and related tools, and also on provided contents. The design-research activities included: a design exercise for design master students in Italy, two vocational courses for Small and Medium Enterprises (SMEs) and stakeholders dealing with energy from Botswana and Uganda, and two workshop with Italian entities working on Renewable Energy.

The design exercise led to:

- first refinement on the tools such as, *Sustainability Design Orienting Scenario for S.PSS & DRE*, *Sustainable Energy for All idea tables (and cards)*, and *Innovation Diagram for S.PSS & DRE.*
- refinement on the design process e.g. order of the use of the tools.

The vocational training courses led to:

- conscious use of digital artefacts e.g. tools, which need to be planned in relation to audience and context; but, if correctly facilitated, they have potentialities in the design process, as to increase confidence of participants with digital interfaces;
- time definition for the use of each tool, particularly when the co-design activity is for participants without previous design competences;
- refinement on the tools such as, *Concept Description form for S.PSS & DRE*, *Stakeholders' Sustainability and Motivation Matrix.*

The workshops led to:

- refine the role of the designer as facilitator of the design process, but also as facilitator (depending on the audience), to guarantee a proper transfer of knowledge and know-how.

The outcomes generated from the design-research activities, together with the inputs from evaluations and observations, brought the researcher to develop the *open course on System Design for sustainable energy for All*, as a sample of a course, for both professionals, researchers, academics and students, to get the (base) knowledge-base and know-how, to deal towards sustainable energy for All, adopting the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model. The module, as one of the tangible contributions from the research, is presented in chapter 9.

Chapter 8 – Open course on System Design for sustainable energy for All

The chapter presents the open course on System Design for sustainable energy for All, as one of the main tangible results of the research. An introduction to the open learning platform of the LeNSes project where the open course is available is firstly given.

8.1 Introduction

The previous chapter introduced five design-research activities conducted by the researcher in collaboration with students, practitioners, designers, researchers and academics from Africa and Italy. To guide and support these design-research activities (and other within the LeNSes project), a series of learning resources e.g. slides, video-lectures, tools, were developed as a collaboration among researchers from the design and the energy fields. During each design-research activity these were continuously improved in an iterative process of test, improvement, re-design and refinement. In fact, each design-research activity, as well as external exchanges of views, gave insights to further improve quality and contents of the learning resources, to provide anytime a better toolbox of knowledge-base and know-how for the participants. Moreover, at technical level, basic insights were provided from the METID (Metodi e TEcnologie Innovative per la Didattica) group of Politecnico di Milano, which deals with innovative methods for e-learning and teaching.
Given the value of being equipped with a proper knowledge-base and know-how, both for the designers and those contributing in the process to design Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions, an *open course on System Design for sustainable energy for All*, has been developed within this research. The open learning LeNSes platform where the open course in uploaded is firstly presented.

8.2 The open learning platform of the LeNSes project

The open learning platform developed by the LeNSes project (www.lenses.polimi.it), and main tool of the project, has been designed as a *modular e-package* of teaching resources (slide shows, texts, audio, video, etc.) and tools for designers, students, designers, professional and those interested into overcome the energy challenge. From the platform all the interested customers can *visualize*, *download*, *modify, remix and reuse* all resources in an open-source and copy left logic. In fact, all contents of the platform are: *downloadable for free* (free-access); developed with an *open-source* and *copy left* logic, so with intellectual property rights (authorship), but without restrictions to diffusion (i.e. Creative Commons license). The aim is to both let anyone to follow a complete course on-line, or to access specific resources according to her/his interest; as well as to support new courses activation by any interested teacher worldwide, adapting, using and re-uploading the learning resources (s)he finds useful, according to her/his specific (didactic) needs, institutional requirements or local context characteristics. In this perspective, the overall aim is to speed up the diffusion of knowledge and know-how on System

Design for Sustainable Energy for All, thus contributing from the design field to overcome the energy challenge, with sustainable energy solutions.

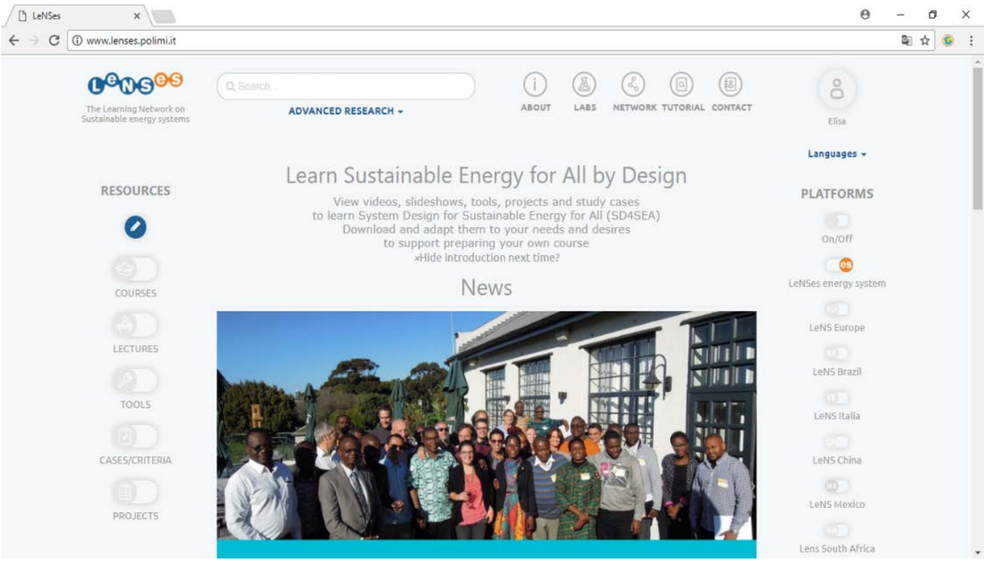

Figure 21. The open learning LeNSes platfrom. (www.lenses.polimi.it).

Finally, the LeNSes platform, and not only the contents, is downloadable as open-source and copy left artefact so forth:

- any educational institution, teacher, sustainability-focused network, can generate a new *LeNS-based* online platform, reconfiguring it by re-defining partners (the scientific board), the sustainability focus, the geographical representation;
- any new generated online platform will upload and manage learning resources independently (controlling also the scientific reliability);
- any new generated online platform will be linked to the others.

8.3 The open course on System Design for Sustainable Energy for All

The *open course on System Design for sustainable energy for All*, made available on the LeNSes open learning platform, is a sum-up of theoretical and practical contributions and findings provided by this research (and the LeNSes project), to be accessed everywhere with an internet connection, thus supporting the diffusion of System Design for sustainable energy for All (Vezzoli & Bacchetti, 2014) among designers, (energy) professionals, research and academics, or other actors dealing with sustainable energy for All.

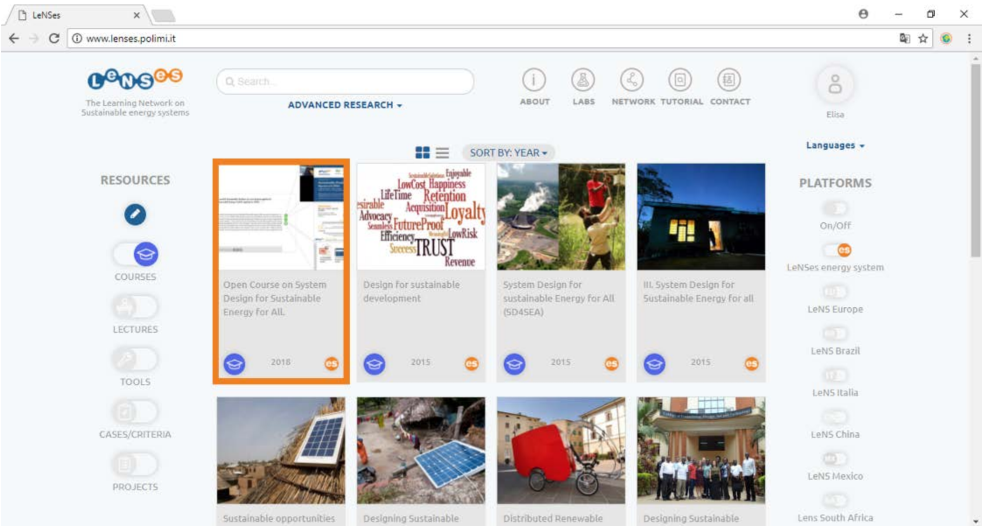

Figure 22. The open course on System Design for Sustainable Energy forAll on the LeNSes platform.

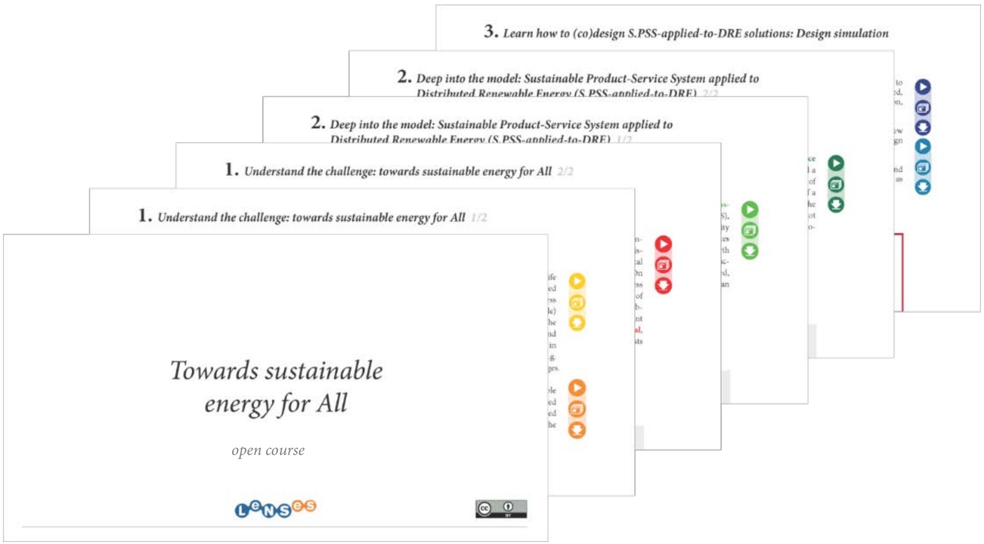

Figure 23. Open course on System Design for sustainable energy for All (cover and the three core sub-sections).

8.3.1 Aims and audience

The specific aim of the open course is to equip the readers dealing with sustainable energy for All, in an accessible way on the topic; as well as to facilitate the readers supporting their strategic conversations with other actors, using the open course as common-ground.

Moreover, the general aim of the open course is to freely diffuse the developed knowledge-base and know-how as much as possible, thus speeding up (potential) conversations with actors dealing with energy, both within and outside from the scientific community dealing with sustainable development, thus this makes the expected audience to include designers, (energy) professionals, students, as well as researchers and academics.

8.3.2 Structure and contents

The open course is divided in two main sections (with sub-sections).

First section, is the introduction, that welcome the reader into the open course. Main scope of the open course, the (expected) audience, and the willingness to be an open tool, freely accessible and in-progress, are presented. Then the open course gives an overview of the available contents, and on how to interact with them e.g. a legend of icons to work with (video-lecture, slideshow, download) is provided, so forth supporting the reader to get the most complete experience.

Second section, is the core of the tool, that illustrates the contents of the open course. It is divided in three sub-sections, *Understanding the challenge: towards sustainable energy for All*, *Deep into the model: Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE)*, and *Learn how to (co)design with the model*. They refer to the capabilities needed by the designers (or other actors contributing in the process) to deal with sustainable energy for All, and particularly with the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model.

A short description of each sub-section is provided below:

- *Understanding the challenge: towards sustainable energy for All:* this sub-section gives an overview of the current energy challenge we are facing, and to the needed shift we need to make from centralized and non-renewable energy consumption to a distributed renewable energy generation, thus enabling sustainable energy access for All. A focus is provided on the Distributed Renewable Energy (DRE) concept, with its characteristics, benefits and limits, as promising concept towards sustainable energy for All. The contents of this sub-section will support the designers (or other actors) to have an overview of the challenge to overcome;

- *Deep into the model: Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE):* this sub-section introduces the Sustainable Product-Service System (S.PSS) model, as promising to support the diffusion of Distributed Renewable Energy (DRE). Then, it presents the Sustainable Product-Service System applied to Distributed Renewable Energy (DRE) model, as coupling of the two models, as win-win solution to overcome the energy challenge we are facing, and to bring energy for All. The contents of this sub-section will support the designers (or other actors) to have an deep understand on the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model, with its characteristics, benefits and limits;

- *Learn how to (co)design with the model:* this sub-section is dedicated to the design role to support the path towards sustainable energy for All, and particularly through the design of the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model. The design approach and tools to be equipped with, are presented through a (simplified) design simulation to (co)design solutions towards sustainable energy for All. The contents of this sub-section will support the designers (or other actors) to design Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions, and as well to facilitate the design process with other actors.

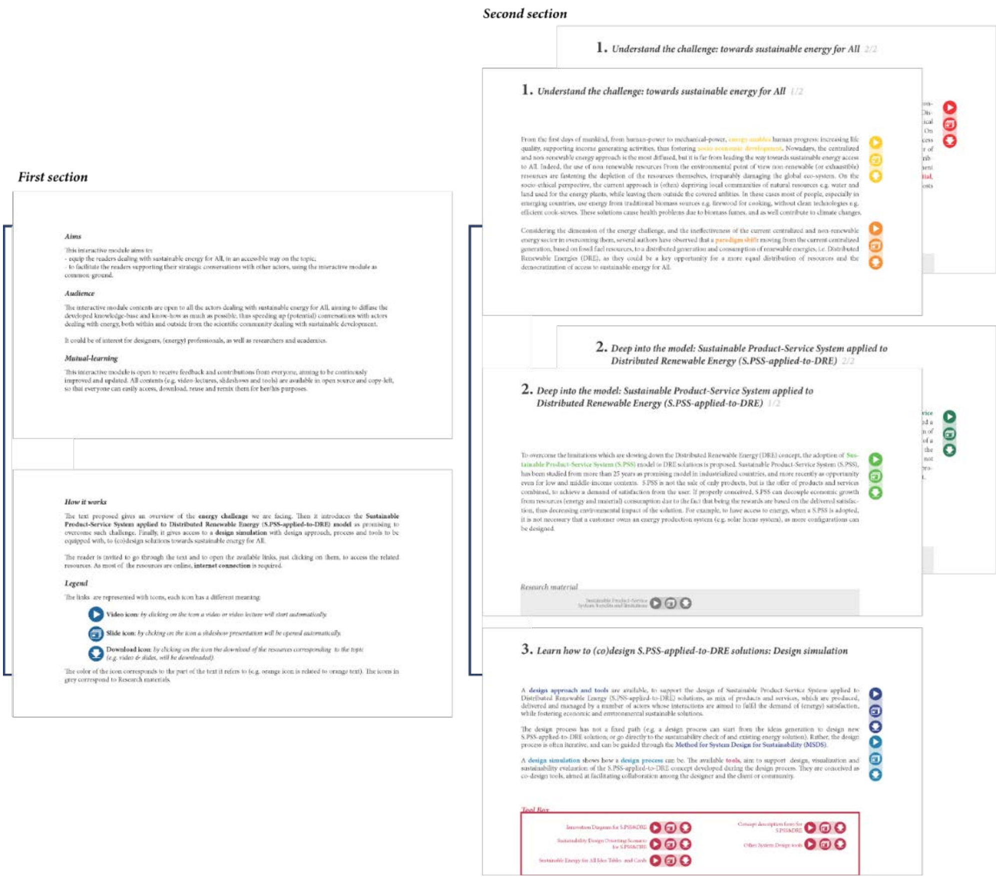

Figure 24. Overview of the two main sections of the open course on System Design for Sustainable Energy for All.

To deep the contents presented as a text in each sub-section, the interactive model includes additional research materials, which are accessible from the icons (video-lecture, slideshow, download) in each page. These contents were developed by the researcher and other researchers, professionals and academics within the LeNSes project. Such contents, followed an iterative process, so forth they were designed, presented, evaluated and refined. The video-lecture were recorded for the specific purpose of being used as online contents, to show the key-point of the specific topic, and without a specific audience. Guidelines in this direction were provided by the METID (Metodi e TEcnologie Innovative per la Didattica) group of Politecnico di Milano, from those used to make Massive Open Online Courses (MOOC).

All contents (e.g. video-lectures, slideshows and tools) were made and are available in open source and copy-left, so that everyone can easily access, download, reuse and remix them for her/his purposes.

Figure 25. Overview of the use of links, within the open course on System Design for Sustainable Energy for All.

Table 20. Index of sub-sections, resources and typologies (Video-lecture, Slide. Tool, Web).

Sub-section	Resource	Video-lecture	Slide	Tool	Web
Understanding the challenge: towards sustainable energy for All	1. Sustainable energy for Sustainable development;	X	X		
	2. Paradigm shift: from centralized/non-renewable energy to distributed/renewable one	X	X		
	3. Distributed Renewable Energy (DRE): concept, benefits and limits	X	X		
	4. Distributed Renewable Energy (DRE): sources and technologies		X		
Deep into the model: Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE)	5. Sustainable Product-Service System (S.PSS) model	X	X		
	6. Sustainable Product-Service System (S.PSS) model: benefits and limits	X	X		
	7. Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE)	X	X		
	8. Scenario for S.PSS applied to DRE	X	X		
	9. S.PSS applied to DRE: case studies				X
Learn how to (co)design with the model	10. Designing S.PSS applied to DRE solutions (method and tools)	X		X	
	11. Design simulation	X		X	
	12. Innovation diagram for S.PSS&DRE	X		X	
	13. Sustainability Design Orienting Scenario for S.PSS&DRE	X		X	
	14. Sustainable Energy for All Idea Tables and Cards	X		X	
	15. Concept description form for S.PSS&DRE	X		X	
	16. Stakeholder's motivation and sustainability Table	X		X	

8.3.3 Why and how to use it

The open course can be downloaded from the LeNSes project website (www.lenses.polimi.it section courses). Once the open course is downloaded the reader can start to work on it. As the resources are online, internet connection is required.

Depending on the aims of the reader, the open course can be red and used in different ways. Anyhow, the main function, is to provide an understanding and support, to deal towards sustainable energy for All, and to design Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions. Below, two potential situations are presented:

- *Access to explore the contents:* after downloading the open course, full-screen view is suggested. Then, the reader is invited to carefully read the instructions available in the introduction section, with specific indications on how to use the open course and the icons (links). After, the reader can go to the core of the open course where, according to her/his goals (s)he can: learn more on the energy challenge (sub-section 1); learn more on the Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) model (sub-section 2); or learn how to (co)design the S.PSS applied to DRE model to obtains sustainable energy solutions (sub-section 3). To get further insights on the various themes, the reader is invited to use (click) the available icons which provide direct links to: watch a video or video-lecture, see a slideshow, download all resources of the specific are e.g. the download icons related to "Distributed Renewable Energy", allows to download video-lecture and slideshow on the topic. As introduced, there is not a compulsory path, and the reader is invited to explore the tool with no limits in viewing the available resources;
- *Access to support a strategic conversation with other actors:* in this case, the reader is expected to have already a general idea on System Design for sustainable energy for All (acquired from the open course or other sources) and also a certain confidence with the open course. So forth, the reader can use the open course going directly to the sub-section of interest, and then use the text and available icons to deep the contents useful for the conversation;
- *Access to support practice through the open course:* in this case, the reader is firstly invited to read the whole text to have a general idea on System Design for sustainable energy for All (if not already acquired). Then, to have a focus on sub-section 3 of the open course, which is dedicated to how to (co)design the S.PSS applied to DRE model. There the reader will have the opportunity to check the design approach, to follow a simulation of design process, and to watch and download the available tools to support the (co)design activities;

Although the tool has been designed to be used for different purposes and contexts, if used in workshops and (co)design sessions a projector is preferable. The time required could vary according to the expected experience. The result from the use of the open course, according to the goal/s of the reader, can vary from an in-depth understanding on the explored topics, to the acquisition of new know-how, as well as the development of (co)design activities.

8.4 Conclusions

The *open course on System Design for sustainable energy for All*, even if discussed and assessed with user experience designers, it is only an initial support for Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) knowledge and know-how. In fact, as open course, it is a work in progress, aimed to receive further inputs involving its future readers, such as designers, (energy) professionals, students, researchers and academics. Thus, promoting an open and mutual-learning process, while increasing views exchanges opportunities; as well as favoring the upgrade of the available resources.

Coherently with the ethos of this research and of the LeNS network and projects (LeNSes, LeNSin – more on both projects in chapter 1), all contents (e.g. video-lectures, slideshows and tools) are available in open source and copy-left, so that everyone can easily access, download, reuse and remix them for her/his purposes.

Part IV – Future research

Chapter 9 - Conclusions and further research directions

The chapter presents findings and innovative aspects of the research, as well as the lesson learnt by the researcher within the research path. Limits and generalizations, as well as potential directions for future researches are described.

9.1 Main research findings

RQ1. Is S.PSS applied to DRE a promising and relevant model for sustainable development?

The first part of this research aimed to explore and characterize the promising models of S.PSS and DRE for low and middle-income (all) contexts.
To do this, RQ.1 included the following sub-question:
a. what are the dynamics and characteristics that facilitate development of S.PSS applied to DRE within low and middle-income (all) contexts?

During this research (and still now), the researcher has extensively explored the S.PSS and DRE models, focusing on their coupling. The potential (environmental, socio-ethical, economic) benefits for each model have been presented respectively on chapters 3 and 2. Here, the main potential (environmental, socio-ethical, economic) sustainability benefits derived from the coupling of S.PSS & DRE are illustrated (see more in chapter 5). In fact, the coupling of the two models represents a win-win approach to deliver sustainable energy solutions in low and middle-income (all) contexts.

<u>Environmental benefits:</u>
The adoption of S.PSS approach in DRE solutions, makes energy providers economically interested in providing environmentally beneficial solutions. In fact, the provider is paid by the customer to access her/his (energy) satisfaction, so forth for the performance and not per unit of product sold. It is interest of the provider, who owns or has some responsibilities on the product i.e. DRE micro-generator and potentially of the Energy Using Products/Equipment, to offer resource (energy and material) efficient products, which provide the needed satisfaction at a lower cost. This could entail different strategies such as longer and optimized utilization, which can reduce the environmental impact of energy provision. So forth, to make the provider or better the manufacturer of the included products, to owns or have some responsibilities on the DRE micro-generator and Energy Using Products or Equipment is a crucial point to encourage the design environmentally sustainable products.
<u>Socio-ethical benefits:</u>
S.PSS & DRE gives the opportunity to individuals and local communities to access their (energy) satisfaction, thus increasing equity in the redistribution and democratization of (energy) resources. This is possible as S.PSS offers access to (energy) satisfaction rather than mere (energy) product ownership. This avoids the

initial investment cost and running costs e.g. operation & maintenance of energy products to the customers, which are frequently unaffordable in low and middle-income contexts. Additionally, the opportunity to access S.PSS & DRE through small payments i.e. one shot solutions, can increase the answer to unsatisfied, customized energy demands. Furthermore, the access to services and products combines for DRE, can increase reliability for small businesses/local entrepreneurs' businesses, reducing the risk of business failures or drop-off. Finally, both S.PSS and DRE are labor and relationship-intensive solutions, this can favor the involvement of local rather than global stakeholders with a consequent development of skills, hence increasing potential employment opportunities and a consequent socio-cultural development.

Economic benefits:

From a customer perspective, the opportunity to access (energy) satisfaction instead of products ownership avoids the initial investment and unexpected life-cycle costs, guarantying the economic feasibility of the offer.

From a provider perspective, a S.PSS approach can increase competitiveness of the offer as more customized on customer needs, and creates longer term relationship with the clients, thus ensuring a stable income for the provider. Furthermore, the offer of access instead of ownership could open new market opportunities for the provider, towards unexplored target i.e. those unable to pay a DRE in one instalment. Finally, as S.PSS applied to DRE solutions require to be managed at local level, this can offer opportunities to strengthen the local economy and increase local employment.

It is clear, that the above potential benefits must be verified case-by-case to correctly respond to local needs and habits, and to reduce potential rebound effects. For this reason, S.PSS applied to DRE, it should be verified and properly designed contextually to give value to its role towards sustainable development.

The above win-win benefits of S.PSS & DRE, were observed by the researcher in the case studies research, and from literature review on both models. Then, they have been (and are) explored, discussed and refined in an open-learning process with the international scientific community of the LeNSes project, which took place through meetings, workshops, skype call and mail exchanges. This continuous process, gave room to the development of a shared preliminary research.

To test the above findings and to share them in a learning process with (energy) professionals, academics and students, eight official courses (four pilots for students and four vocational training for energy professionals) were developed from 2013 to

2016. The researcher conducted, with other professors, *two vocational training courses* in Botswana and Uganda involving more than 15 SMEs for energy, who were aimed to learn on the S.PSS approach to DRE, and to bring it back to their own renewable energy businesses. Furthermore, the researcher conducted *two workshops* on S.PSS and DRE for SMEs in Italy; as well as a *design exercise* for design students. Finally, she presented in the Conference on *Circular Perspectives on Product/Service-Systems* (Denmark), increasing her findings with contributions from other EU funded project on similar topics. From 2015, the debate has been open to the wider worldwide LeNS scientific community dealing with sustainable development. The researcher has presented S.PSS & DRE in Brazil and Mexico, opening room for discussion in new countries and contexts, and contributing to the current way of presenting S.PSS for innovative perspectives.

RQ2. Can Sustainable Product-Service System Design have a role in the development of such model?

The second part of this research was aimed to develop the needed know-how for the designers, to entail the design of S.PSS and DRE for low and middle-income (all) contexts.

To do this, RQ.2 included the following sub-questions:

a. And if so, what kind of knowledge-base and know-how are needed by a designer?

b. From an operational point of view, what are the design approaches, the methods and the tools that can be used?

The adoption of a S.PSS approach to DRE solutions, brought to the development of a new design role entailing: *"the design of a **Distributed Renewable Energy Sustainable Product-Service System**, 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 - based on the design of innovative interactions of the stakeholders, in which economic and competitive interest of the providers, continuously seek after both socio-ethically and environmentally beneficial new solutions".*

This new role, required the designer to: design environmentally sustainable products and services together to fulfil the (energy) satisfaction; design and facilitate new configurations (interactions/partnership) between stakeholder to achieve their convergence of economic and environmental interests in relation to the sustainable energy solution; operate/facilitate a participatory process among entrepreneurs, users, NGOs, etc. It should be highlighted that, the so-called *System Design for Sustainable Energy for All (SD4SEA)*, is a new role for designers, which derives from S.PSS Design and is declined to design DRE with its characteristics.

As illustrated in chapter 6, to support the practice towards Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions, this research (and the LeNSes project) has developed a design approach, with a design process and related tools. The researcher had a key role in the development of the following tools: *Sustainability Design Orienting Scenario for S.PSS & DRE; Sustainable Energy for All Tables & Cards; Innovation diagram for S.PSS & DRE; Concept Description form for S.PSS & DRE; Stakeholder Motivation and Sustainability Table*.

To test, verify and refine the new design role, and its potential operational contribution, they have been adopted and assessed within courses for (energy) practitioners and students (see above) among Africa and Europe. These design-research activities gave room for verification and simplification especially on tools, and for the refinement of the design role both as designer of such S.PSS & DRE innovations, as well as facilitator in the co-design process with participants. At the end of each design-research activity, the participants were asked to fill a questionnaire on each tool used, as well as on contents, thus giving room for improvement to the researcher and the entire LeNSes project. Within the LeNSin project, further tests have been conducted by the researcher in Brazil and Mexico, aimed to verify the potential of the design role in other countries and contexts.

Coherently with the ethos of this research, all contribution to the new design role (knowledge-base and know-how) are available in open source and copy-left, so that everyone can easily access, download, reuse and remix them for her/his purposes, thus speeding the learning process towards Sustainability and Sustainable energy for All. On the same ethos, the researcher has developed an *open course* on System Design for Sustainable Energy for All aimed to equip the designers with an accessible tool, comprehensive of knowledge-base and know-how towards sustainable energy for All. The resources adapted in the open course, were developed all along the LeNSes project, as open-production of knowledge (see more below), so forth they are not a finite product, but they can be updated with new resources, findings, etc. to come.

9.2 Innovative aspects of the research

The research is based on the promising models of Sustainable Product-Service System (S.PSS) and Distributed Renewable Energy (DRE). S.PSS, has been studied from more than 25 years, and more recently as opportunity even in low and middle-income contexts, and towards sustainable development. DRE is a growing concept, and during last years has increased its relevance, especially within the debate on access to sustainable development, where the topic of sustainable energy for All is recently become a priority. Even though the two models are well known in the scientific community dealing with sustainable development, they have never been coupled and studied as a combined strategy toward sustainable development. Thus, this research (and the LeNSes project) can be considered pioneer in this direction, proposing and testing the model the S.PSS approach to diffuse DRE for the first time.

It has been observed through case studies research and literature review, that product design is only briefly introduced in the challenge towards sustainable energy for All, and mainly as product design for DRE products. Anyhow, even the product design contribution is limited, as DRE solutions are (for now) mainly based on technology development, thus predominantly preferring an engineer to work on them. The new Design Role for System Design for Sustainable Energy for All integrates to *product design* the *Product-Service System design* for Sustainable energy for All. So forth, the contribution from the design field can become more relevant and, if properly supported with knowledge-base and know-how, could increase both product and system sustainability potential of DRE solutions.

As introduced in chapter 8, this research fits in the international scientific community of LeNSes, and shares its open-knowledge ethos. This implies that all contribution from this research are available in open source and copy-left, so that everyone can easily access, download, reuse and remix them for her/his purposes. This gave room for great improvements in the research process, through the opportunity of exploring, share and discuss knowledge which is collaboratively produced. For example, the case studies collected by this research, are available on the LeNSes platform. They can be downloaded, updated and uploaded again. Furthermore, they can be used by other academics or (energy) professionals to show the state of the art on S.PSS & DRE and give inspiration within design-research activities and much more. This example was aimed to show the potentiality of open-knowledge adopted by this research, allowing a faster open-learning process, which is in continuous evolution through it development, share, refinement.

9.3 Research limits and generalization

9.3.1 Research limits

Some limits on this research could be discussed, both in term of context of application and methodology.

This research has focused on low and middle-income contexts, seen as main priorities to work to speed up the process towards sustainable energy for All. Coherently, the outcomes developed were aimed to reflect on how S.PSS & DRE can act on these contexts, its characteristics and potential successful factors. Anyhow, data collected from case studies research and the literature review are in continuous evolution. For example, some of the case studies have evolved in time, thus changing their offer and structure from the first studies. According to this continuous evolution, and to slow the obsolescence of learning resources, tools, case studies and open course, they are available in open-source and copy-left to be freely *visualized, downloaded, updated* and *re-uploaded*.

A second limit of this research, was the need of customization of video-lectures, slides, tools and case studies while working in different countries, and especially in the emerging ones. For example, in Africa it was required to transform online tools into paper based one to be used more efficiently without problems on the internet connection. In Brazil, translation of video-lectures, slides, tools and case studies was required to be locally accessible. On one side, this brought to a higher customization of the knowledge-base and know-how for the specific case. On the other side, this was a limit for the sharing of the outcomes for mutual-learning worldwide.

9.3.2 Research Generalization

This research focused on the adoption of Sustainable Product-Service System (S.PSS) to diffuse Distributed Renewable Energy (DRE), as opportunity in low and middle-income (all) contexts towards sustainable energy for All, as enabler for sustainable development.

As most of the activities were conducted in Africa, the results could be tested and adapted in other countries, to verify similarities and differences. This is currently happening in China, within the LeNSin project (the researcher is involved). In a wider perspective, previous researches and EU funded projects on Sustainable Product-Service System (S.PSS), as well as the outcomes of this research and the LeNSes project, gave room to expect a potential role in the adoption of Sustainable Product-Service System (S.PSS), to other type of Distributed Economies (DE), beyond Distributed Renewable Energy (DRE). To clarify, 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). The EU funded project LeNSin – the international Learning Network on Sustainability (more in section 1.3), identified five main type of Distributed Economies, such as: Distributed Renewable Energy (DRE), Distributed Production (DP), Distributed Information (DI), Distributed manufacturing (DM), Distributed Software (DS).

The LeNSin project, currently in progress, is already testing the adoption of Sustainable Product-Service System (S.PSS) to such different Distributed Economies (DE). However, it should be noticed that some differences may arise between the different types, so forth both the knowledge-base and know-how with related design approach and tools developed within this research, they should be tested, improved and refined accordingly to the selected Distributed Economy (DE). The open course on System Design for sustainable energy for All, could be also adapted for other type of Distributed Economies (DE), particularly in this case several differences among types could be observed, asking for re-design or improvement of the current structure and contents.

9.4 Reflections and future research directions

Future directions for the research, can be narrowed to the research outcomes, such as, to improve the emerged results or translate them to other research fields, or can entail broader implications of this research in the field of S.PSS and DRE education. These options are presented below.

9.4.1 Improving the results of the research

First, to refine the achieved results of the research *and define characteristics for other countries*, it could be valuable to make new design-research activities on sustainable energy for All, to be conducted and facilitated without the intervention of the researcher, thus opening to feedback from experts from the (energy and design) fields, and increasing reliability of the results. The design-research activities could be valuable also to tests on the developed design approach and tools, giving the room to discuss, improve and refine them. Same path could be proposed regarding the *open course on System Design for sustainable energy for All*.
Second, as for now the design process is aimed at designing Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) concepts, a valuable improvement could be to extend the intervention to support the design of the implementation paths for the S.PSS applied to DRE solutions. A good starting point in this direction could be to test and adapt what available as transition path for Sustainable Product-Service System (S.PSS) innovations (Ceschin, 2012).

9.4.2 Exploring the results of the research in new fields

As introduced in the generalization paragraph, one hypothesis can be to explore and characterize Sustainable Product-Service System (S.PSS) to support different Distributed Economies (DE). However, it should be considered that some differences may arise between the different types, so forth both the knowledge-base and know-how with related design approach and tools developed within this research, they should be tested, improved and refined accordingly to the selected Distributed Economy (DE). The LeNSin project is already working in this direction (the researcher is involved) (more in section 1.3).

A second option, could be to open the field of intervention, not only seeking to permanent solutions e.g. setup access to energy, but as strategy to satisfy (or prevent) the (energy related) needs in emergency situations such as, earthquakes, floods or migrations. In fact, being Sustainable Product-Service System applied to Distributed Renewable Energy (S.PSS applied to DRE) solutions, based on satisfaction instead of ownership, thus having high flexibility in configuration, they could act as promising opportunities in such conditions. Some practices in this direction are already on-going. As an example, the Solarkiosk AG company in partnership with United Nations, has recently promoted an E-Hubb e.g. solar powered station offering energy services, as solution for refugee camps, where children, despite their unsecure condition, can meet, follow e-classes, use IT services to proceed in their education. In this perspective, must be noted that knowledge-base and know-how developed within this research, must be revise and need to include further notions and capabilities to be investigated. Anyhow, this type of intervention could correspond to an "end-of-pipe" approach, so to when the catastrophe is already there, and energy access is a temporary measure. So forth, if to reason in this direction is necessary, on the other hand as researcher the believe is to act in advance, to contribute to prevent climate change and the consequent catastrophes.

9.4.3 Implications of this research in the field of S.PSS and S.PSS and DRE education.

Within the academic field, the potential contribution of S.PSS and DRE in teaching activities has been tested and verified. To complement feedback from participants, evaluation reports were provided by professors invited to, in the role of observer of the design-research activities and aimed to verify impact and relevance of S.PSS and DRE, related resources, tools and case studies, within the open-learning process. Currently, within the universities involved in the LeNSes project, curricular courses for BSc/master students, which include S.PSS applied to DRE as teaching material have been accredited. Furthermore, the open course provided by this research, as well as other online courses on SD4SEA for BSc/master students, as well as life-long learning modules for vocational training of (energy) professionals are available online with video recorded lectures, slides, tools and case studies freely accessible. As open-process of collaborative knowledge, video recorded lectures, slides, tools and case studies are expected to evolve on time both as contents and modalities. Further research, tests and verification will be needed in this perspective.

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ANNEXES I:

Annex Ia – Study cases format and slide

Annex Ib – Slides of collected case studies

PROJECT NAME, PROVIDER, PROJECT LOCATION

Picture source ...

GENERAL INFORMATION

Project name	-
Producer/provider	-
Designer	-
Start (year)	-
State	choose among on-going/concluded
Project location	-
Source of information	-
Main contact	-
E-mail	-
Website	-

SYSTEM CHARACTERISTICS

SYSTEM CONFIGURATION:	
Provider/s (role)	indicate provider/s and related roles
Customer/s (type)	indicate the type of costumer: consumer (e.g. community, household)/business (e.g. small enterprise)
S.PSS CHARACTERISTICS:	
Type of S.PSS	choose among: Product-oriented User-oriented Result-oriented/hybrid (in case of hybrid please specify the combination)
Offered product/s (related producer/s)	-
Offered service/s	-
Ownership of the offered product/s	-
Energy access payment	-
DRE system configuration	choose among: distributed (off-grid/mini-grid/main-grid)

	decentralized (off-grid/mini-grid/main-grid)
DRE resource type	choose among: solar/wind/hydro/biomass/biogas/hybrid/other

DESCRIPTION

How the S.PSS applied to DRE offer works?
Who are the provider/s and customer/s of the offer?
What is offer to the customer?
What and how is paid within the service?
…

COMPETITIVE FACTORS

Why is the offer innovative? What differs from competitors?
What are the impacts of the offer on the community?
Is it easily replicable in other contexts?
…

BARRIERS AND CONTRAINS ENCOUNTERED

Which barriers and/or constrains you faced during service design, introduction, and running?
Describe barriers and constrains you faced in relation to:
Provider/s (e.g. difficulties in scalability, etc.)
Customer/s (e.g. difficulties in acceptance, etc.)
Context (e.g. norms, etc.)

BUSINESS MODEL

Describe the Business Model of the service.

Net profit	Turnover	Employees	Energy produced
Please write the total amount in €	*Please write the total amount in €*	*Please consider only full time employees or specify the relationship e.g. volunteer, part time employees, etc.*	*Please write the data referring to 1 year production.*

SUSTAINABLE BENEFITS

Environmental Benefits
Describe environmental benefits starting from the following categories.
System life optimization
Transportation/distribution reduction
Resource reduction
Waste minimization/valorization
Conservation/biocompatibility
Toxicity reduction.

Socio-ethical Benefits
Describe socio-ethical benefits starting from the following categories.
Improve employment/working conditions
Improve equity and justice in relation to stakeholders

Enable a responsible/sustainable consumption
Favor/integrate the weaker and marginalized
Improve social cohesion
Empower/enhance local resources.

Economic Benefits
Describe economic benefits starting from the following categories.
Market position and competitiveness
Profitability/added value for companies
Added value for customers
Long term business/development risks
Partnership/cooperation
Macro-economic effect.

REPRESENTATIVE PICTURE OF THE PROJECT

PROJECT NAME, PROVIDER, PROJECT LOCATION

SHORT DESCRIPTION OF THE PROJECT

How the S.PSS applied to DRE offer works?

Who are the provider/s and customer/s of the offer?

What is offer to the customer?

What and how is paid within the service?

...

PROVIDER/S:

CUSTOMER:

S.PSS TYPE:

PRODUCTS:

SERVICES:

OWNERSHIP:

PAYMENT:

DRE CONF.:

RESOURCE:

HUSK POWER, HUSK POWER, INDIA

The Husk Power company provides energy solutions by designing and installing biomass power plants (from 25 kW to 100 kW) and wiring villages of up to 4000 inhabitants to deliver electricity. Households pre-pay a fixed monthly fee, ranging from 2 to 3 euro, to light up their Energy Using Products e.g. fluorescent lamps or a mobile charging station. The company retains ownership of the plants and employs local agents for operation, maintenance and fee collection. A partnership with local farmers is established to provide rice husk to power the local plant.

PROVIDER/S: Husk Power (design, installation) local agents (maintenance & operation, fee collection) farmers (provide rice husk)
CUSTOMER: Households (B2C)
S.PSS TYPE: Result-oriented (B2C)
PRODUCTS: Biomass power plants, decentralized mini grid, EUP (fluorescent lamps, one mobile charging station).
SERVICES: Installation, maintenance.
OWNERSHIP: Husk Power (plant) customer (EUP)
PAYMENT: (Pre)-pay per period (monthly fee)
DRE CONF.: Decentralized mini-grid
RESOURCE: Biomass Energy

OMC POWER, OMC POWER, INDIA

The OMC Power company offers energy solutions to telecommunication companies in India, through stand-alone power plants running on solar, wind and biogas. Telecommunication companies get the power plant installed on site and pay per the energy they use (kWh). OMC Power retains the ownership of the energy system and provides installation, operation & maintenance, repair. As complementary service OMC Power offers charged lanterns to local communities (pre-payment or pay-per-use).

PROVIDER/S: OMC Power (owner) and local agents (operations, maintenance and fee collection)
CUSTOMER: Companies (B2B) Households (B2C)
S.PSS TYPE: Result-oriented (B2B – B2C)
PRODUCTS: Power plants (B2B), solar lanterns (B2C)
SERVICES: Design, installation, maintenance and repair
OWNERSHIP: OMC Power
PAYMENT: Pay per time
DRE CONF.: Decentralized mini-grid
RESOURCE: Hydro/Solar/Wind/Hybrid Energy

OFF-GRID: ELECTRIC, M-POWER ,TANZANIA

M-POWER company, owner of OFF-GRID ELECTRIC, offers Solar Home Systems (SHS) which include the hardware to generate energy (Solar panel + Storage + Wires) and related Energy Using Products (EUP - two lights + phone charger), to rural people in Tanzania. Customers pay a pay-per-period fee, usually on daily basis. OFF-GRID Electric retains the ownership of the SHSs and the EUPs, and provides installation, operation & maintenance, end of life services. The offer can be upgraded in relation to the energy needs. OFF-GRID Electric organizes training for installation for local dealers and customers. Recently has been opened the first OFF-GRID Academy for technical training.

PROVIDER/S: M-POWER (management, training) Fosera company (design) local agents (installation, operation & maintenance, end of life services) investors programs (economic and technology support)
CUSTOMER: Households (B2C)
S.PSS TYPE: Result-oriented
PRODUCTS: SHS: 1 solar panel + 2 lights + 1 phone charger (the kit can be upgraded)
SERVICES: Installation, operation & maintenance, end of life treatments
OWNERSHIP: M-POWER
PAYMENT: (Pre)pay per period (monthly fee)
DRE CONF.: Distributed off-grid
RESOURCE: Solar Energy

SOLAR TRANSITION, IKISAYA ENERGY GROUP, KENYA

Solar Transition is a project implemented in Ikisaya Village, offering a village recharging station that provides energy for a range of services: lantern charging and renting, battery charging, charging mobile phones, IT-services (typing, printing and photo-copying), television and video shows.

The energy center is not directly connecting the households of the community but is an off-grid recharging station where customers can buy electricity and bring at home through batteries or access to services offered at the center. Customers have firstly to pay an initial membership fee and a specific service fee as a pay per use payment.

PROVIDER/S: Ikisaya Energy Group (Cooperative Based Organization)
CUSTOMER: Iksaya Village (single users)
S.PSS TYPE: Product-oriented PSS (B2B), Result-oriented PSS (B2C)
PRODUCTS: Charging point, lanterns
SERVICES: Maintenance and repair of the service point & lanterns; charging, printing/scanning, TV shows
OWNERSHIP: Ikisaya Energy Group (Cooperative Based Organization)
PAYMENT: Hybrid: Initial membership + pay per use
DRE CONF.: Decentralized off-grid
RESOURCE: Solar Energy

SHARED SOLAR, UGANDA

Shared Solar connects houses and small businesses of Ruhira village through a decentralized mini-grid based on solar energy. Users pre-pay per time through scratch cards or mobile phones (without fee). The solar station (micro generator + its accessories) are all owned by Shared Solar, as donation from the Millennium Village project (sponsoring the project). All energy using products and equipment (i.e. sewing machine) are owned by the users. Added services as installation and in use services (i.e. maintenance, repairing) are all in charge to Shared Solar.

PROVIDER/S: Shared Solar (owner), vendors (collect payments, sell new meters), technicians (installation, maintenance and repair)
CUSTOMER: household and small enterprises (B2C)
S.PSS TYPE: Result-oriented
PRODUCTS: Production station and Mini-grid
SERVICES: Installation, maintenance and repair, training for vendors/technicians
OWNERSHIP: Shared Solar (Production station and Mini-grid), customers (Energy Using Products and Equipment)
PAYMENT: (Pre)Pay per time
DRE CONF.: Decentralized mini-grid
RESOURCE: Solar Energy

GRAMEEN SHAKTI, BANGLADESH

The company offers Solar Home Systems (SHS) with a service package inclusive of end-user credit, installation, maintenance and repair services. End-users, low-income households and small businesses living in rural isolated communities, can purchase the product with microcredit services and be able to repay the loan in 2-3 years. In order to ensure an effective after-sale service, Grameen Shakti trains women as local technicians for repairs and maintenance of systems and for assemble solar accessories such as LED lights and charge controllers.

PROVIDER/S: Grameen Shakti (microcredit, training), technicians (assembly, maintenance & repair)
CUSTOMER: Households, small businesses (B2C-B2B)
S.PSS TYPE: Product-oriented
PRODUCTS: Solar Home Systems (10-130 Wp), battery and appliances (2-11 lamps, TV, charger)
SERVICES: Initial invest. (micro credit), installation, maintenance & repair, training, end of life treatments.
OWNERSHIP: Customer (after payback – usually 2-3 years)
PAYMENT: Initial investment (micro credit), pay per period (fixed fee until the customer pays the SHS)
DRE CONF.: Distributed Off-grid
RESOURCE: Solar Energy

M-KOPA SOLAR, M-KOPA KENYA LTD,KENYA

M-Kopa Solar provides a Solar Home System (SHS) including the photovoltaic panel, the lights, the radio and a phone charging. Customers pay small, flexible installments over time. By collaborating with a technology provider (d.Light) and using the existing network of mobile money M-PESA, the company allows customers to pay an initial deposit and then process payments via mobile money-transfer. If the payment does not occur, the system is blocked. After the credit period, the customer owns the system and benefits from free and sustainable energy provision.

PROVIDER/S: M-KOPA Kenya Ltd in partnership with Safaricom (network provider), d.Light (manufacturer)
CUSTOMER: Households (B2C)
S.PSS TYPE: Product-oriented
PRODUCTS: SHS: 1 Solar panel + 4 LED lights + 1 torch + 1 radio + wires to charge phones
SERVICES: Training for employees.
OWNERSHIP: Customer (after payback)
PAYMENT: Pay per period (fixed fee until the customer pays the SHS)
DRE CONF.: Distributed off-grid
RESOURCE: Solar Energy

BBOXX ENERGY KIOSK, BBOXX, ETHIOPIA-KENYA

Bboxx sells its own Solar Home Systems (SHS) and related accessories, including a platform called SMART Solar to monitor energy use and the performance of the system. Customers pay a monthly fee (from 10 to 20 euros) to access energy whole day. After around 3 years of payment the Solar system is owned by the customer. Installation, maintenance and repair are included in the fee and done by BBOXX's local technicians. After complete repayment, the customer can go for a maintenance contract which means he/she continues to get support and replacements for the unit.

PROVIDER/S: Bboxx (design, kiosk installation, manufacture, training), Local entrepreneur (installation, maintenance and repair)
CUSTOMER: household (B2C) small entrepreneur (B2B)
S.PSS TYPE: Product-oriented
PRODUCTS: BBOXX unit
SERVICES: Installation, maintenance and repair, training for employees
OWNERSHIP: customer (after payback – 2/3 years)
PAYMENT: Monthly payment (until complete payback)
DRE CONF.: Decentralized off-grid
RESOURCE: Solar Energy

SOLARKIOSK, SOLARKIOSK AG, KENYA – RWANDA - TANZANIA

Solarkiosk, targets local intermediaries to manage and guarantee the provision of energy services in rural areas of Kenya, Rwanda and Tanzania. Solarkiosk designs, installs and owns the E-Hubb, a charging station provided with solar panels and Energy Using Products, that provides a wide range of energy services such as, internet connectivity, copying, printing and scanning, etc. Customers pay per use e.g. pay to print, or they can buy some offered Energy Using Products such as solar lanterns, or other consumables. Local intermediary receives training for management, selling and accountability of the E-Hubb, and as well to solve basic maintenance and repair.

PROVIDER/S: Solarkiosk AG (E-HUBB and related equipment), local intermediary (selling, installation, maintenance and repair)
CUSTOMER: single customers (B2C)
S.PSS TYPE: Product-oriented (B2C)
PRODUCTS: E-Hubb, Solar lamps
SERVICES: Design, installation and maintenance
OWNERSHIP: Solarkiosk AG (provider)
PAYMENT: Pay per use (B2C)
DRE CONF.: Decentralized off-grid
RESOURCE: Solar Energy

DOMESTIC BIOGAS, BSP, NEPAL

Biogas Sector Partnership (BSP) installed biogas plants in households, providing biogas for cooking and lighting. A plant costs between 350 and 450 €; about one third of this is paid in-kind, through the family providing labor and materials. The remaining is paid usually in 18 months, with opportunity of micro-financing plans. Customers are trained for minor repairs and operations on plants; a three-year guarantee period is included. Same biogas plants are built for schools and hospitals.

PROVIDER/S: Biogas Sector Partnership - BSP (coordination, training, quality control), customer (installation, basic repairs), partnership with private companies (installation together with customers)
CUSTOMER: HouseholdS (B2C)
S.PSS TYPE: Product-oriented
PRODUCTS: Domestic biogas plants
SERVICES: Installation, maintenance and repair
OWNERSHIP: Customer (after payback – 18 months)
PAYMENT: pay in-kind + pay per period (until payback)
DRE CONF.: Distributed off-grid
RESOURCE: Biomass Energy

INDIGO, AZURI TECHNOLOGIES, KENYA

Indigo sells Solar Home System (SHS) for only 10 euro; composed by a 3-watt solar panel, battery, two LED lamps and one phone charge unit with cables. Customers pay on a pay-as-you go system: buying 1 euro scratch card from local vendors to access electricity for a week inserting the code in their system battery. The power generated from these solar panels provides nearly eight hours of light each evening and supports mobile phone charging. Furthermore, the SHS can be upgraded: from simple systems to full home electrification.

PROVIDER/S: Azuri Technologies (provider of SHS, management) local dealer (selling, installation and maintenance of products)
CUSTOMER: Households (B2C)
S.PSS TYPE: Product-oriented
PRODUCTS: SHS: 1 (3watt) solar panel + storage + 2 LED lamps + 1 phone charge unit with cables
SERVICES: Installation, maintenance
OWNERSHIP: Customer (after payback)
PAYMENT: Initial fee + (Pre)pay per time
DRE CONF.: Distributed off-grid
RESOURCE: Solar Energy

GRAM, GRAM POWER, INDIA

Gram Power provides energy services in rural India through the installation and operation of mini grids. Target customers are rural communities who gets connected to the mini grid and pre-pay for the energy they need. Households gets smart meters installed at their home and have the possibility to prepay electricity through local entrepreneurs. The entrepreneur, in fact, purchases in bulk energy credit from Gram Power and transfer the credit into the consumer's smart meter through a wireless technology.

PROVIDER/S: Gram Power (installation, operation, maintenance, training), local entrepreneurs (fee collection)
CUSTOMER: Household (B2C)
S.PSS TYPE: Result-oriented
PRODUCTS: Mini-grid
SERVICES: Installation, maintenance, training.
OWNERSHIP: Local community
PAYMENT: (Pre)pay per time (donors support)
DRE CONF.: Decentralized mini-grid
RESOURCE: Hydro/Solar/Biomass energy

Onergy solar, Onergy solar, INDIA

ONergy company provides energy solutions such as: solar lanterns, Solar Home Systems, solar irrigation systems, solar water heating systems, solar street lighting, cooks-toves, micro-grid for households and institutions. ONergy establishes Renewable Energy Centres (RECs) which operate through a network of local (trained) entrepreneurs to sell repair and maintain the offered solutions. ONergy's developed high quality products (certified), strong after sales service network (e.g. warranty is included), while facilitating consumer financing for solar systems.

PROVIDER/S: Onergy (design, manufacturing, installation, operation, training), local entrepreneur (selling, maintenance)
CUSTOMER: Rural communities (B2C)
S.PSS TYPE: Product-oriented
PRODUCTS: solar lanterns, Solar Home Systems,solar irrigation systems, solar water heating systems, solar street lighting, cook-stoves, mini-grid for households and institutions
SERVICES: Installation, maintenance, training
OWNERSHIP: Customer
PAYMENT: micro-credit (financial support)
DRE CONF.: Decentralized off-grid/mini-grid
RESOURCE: Solar

TERI_LIGHTING A BILLION LIVES, TERI, INDIA

TERI provides clean technology solutions, managed by Village Level Entrepreneurs (VLEs) who receive training and financing to become operators of a Charging station (5 solar panels + 50 LED lanterns) to offer energy services. Offered energy services are: Lantern Rent, Solar Micro Grid (solar panel + 2 light points + 1 mobile charging facility); Solar Home Lighting System- SHLS (solar panel + 2 light points + 1 mobile charging facility); Integrated Domestic Energy Systems - IDES (solar panel + 2 light points + 1 mobile charging facility + cook-stove). Every household pays a nominal charge per day or per month according to the selected use.

PROVIDER/S: TERI (coordination), manufacturer (design, production, installation, end of life treatment) Village Level Entrepreneurs (operation & maintenance), management) Entrepreneurs (spare part provision)
CUSTOMER: Village Level Entrepreneurs B2B) households/communities (B2C)
S.PSS TYPE: Product-oriented (B2B) Result-oriented (B2C)
PRODUCTS: Charging station, **Lanterns,** Solar Micro Grid, SHLS, IDES
SERVICES: financing, training, operation & maintenance, end of life treatment
OWNERSHIP: TERI
PAYMENT: Pay per use or Pay per period
DRE CONF.: Decentralized off-grid
RESOURCE: Solar Energy

Sunlabob, Sunlabob, LAOS

Sunlabob company provides energy-services through a renting model. Sunlabob leases a charging station with Energy Using Products (EUP - e.g. solar lanterns) to an established village committee who rents the products to the individual households. The committee is in charge of setting prices, collecting rents and perform basic maintenance. Sunlabob retains ownership and maintenance responsibilities, and offers training services. Final customers can rent the recharged lantern for 0.50 euro and it will last for 15 hours of light. To use the charging station, the committee pays around 1.70 euro per month.

PROVIDER/S: Sunlabob (installation, training) village committee (fee collection, basic maintenance)
CUSTOMER: village committee (B2B) local community (B2C)
S.PSS TYPE: Use-oriented (B2B) Result-oriented (B2C)
PRODUCTS: Charging station and Energy Using Products (lanterns)
SERVICES: Installation, training, maintenance
OWNERSHIP: Sunlabob
PAYMENT: Pay per period (B2B) Pay per use (B2C)
DRE CONF.: Decentralized off-grid
RESOURCE: Solar energy

Annex II - Evaluation Questionnaire

The questionnaire used in the design-research activities has been updated in time. Indeed, the questions were the same for all design-research activities, while the evaluation rate has been improved for the second vocational courses. The questionnaire proposed is the last updated from the vocational course in Uganda.

MAKERERE UNIVERSITY

POLITECNICO MILANO 1863

the Learning Network on Sustainable energy systems

Designing Sustainable Product-Service System (S.PSS) Offer Models for Distributed Renewable Energy (DRE) systems

Date: *18-22 July 2016,*
Venue: *Makerere University, College of Engineering Design Art and Technology (CEDAT),CEDAT boardroom,4th floor, Room 5002*

Evaluation Questionnaire_tools & course

A. Tools evaluation
B. Course evaluation

A. Tools evaluation is based on two main factors: comprehension and usability of the tool, impact of the tool on the process. Further questions on potential reuse are proposed.

TOOL 1: S.PSS&DRE Innovation Diagram					
1. COMPREHENSION AND USABILITY OF THE TOOL					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1.1 Was the tool self-explanatory?					
If not, in which section/part/… needs to be more clear? ………………………………………………………………………… …………………………………………………………………………					
1.2 Was the tool easy to use?					
If not, could you please indicate where the tool may needs to be improved? ………………………………………………………………………… …………………………………………………………………………					
1.3 Was the section of ideas positioning/clustering easy to use?					
If not, could you please indicate where the tool may needs to be improved? ………………………………………………………………………… …………………………………………………………………………					
1.4 Was the section of label/characterization easy to use?					
If not, could you please indicate where the tool may needs to be improved? ………………………………………………………………………… …………………………………………………………………………					
2. IMPACT OF THE TOOL IN THE PROCESS					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
2.1 Was the tool aim and objective clear?					
2.2 Was the tool use relevant to design the concept for a new business on S.PSS&DRE?					
If not, could you please indicate what make it useless in the process? ………………………………………………………………………… …………………………………………………………………………					
3. POTENTIAL CONDITIONS OF USE					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
3.1 Could be your interest to use the tool in other context?					
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? …………………………………………………………………………					

………
Did you think some potential improvement needed in the tool? e.g. online/offline structure, language, etc. ……… ………
Since the tool is downloadable from the website (www.lenses.polimi.it) which format could be the most suitable for you? ……… ………
OTHER Please write here free suggestions/comments ……… ……………………………………………………………………………………………………

TOOL 2: Sustainability Design Orienting Scenario on S.PSS&DRE					
1. COMPREHENSION AND USABILITY OF THE TOOL					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1.1 Was the tool self-explanatory?					
If not, in which section/part/… needs to be more clear? ……… ………					
1.2 Was the tool easy to use?					
If not, could you please indicate where the tool may needs to be improved? ……… ………					
2. IMPACT OF THE TOOL IN THE PROCESS					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
2.1 Was the tool aim and objective clear?					
2.2 Was the tool use relevant to design the concept for a new business on S.PSS&DRE?					
If not, could you please indicate what make it useless in the process? ……… ……………………………………………………………………………………………………					
3. POTENTIAL CONDITIONS OF USE					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
3.1 Could be your interest to use the tool in other context?					
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? ……… ………					
Did you think some potential improvement needed in the tool? e.g. online/offline structure, language, etc. ……… ………					
Since the tool is downloadable from the website (www.lenses.polimi.it) which format could be the most suitable for you? ……… ………					
OTHER Please write here free suggestions/comments ……… ……………………………………………………………………………………………………					

TOOL 3: Sustainable Energy for All (SE4A) Idea Tables					
1. COMPREHENSION AND USABILITY OF THE TOOL					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1.1 Was the tool self-explanatory?					

If not, in which section/part/… needs to be more clear? ………………………………………… …………………………………………					
1.2 Was the tool easy to use?					
If not, could you please indicate where the tool may needs to be improved? ………………………………………… …………………………………………					
1.3 Were the guidelines easy to understand?					
If not, could you please indicate where the they may need to be improved? Language, etc. ………………………………………… …………………………………………					
2. IMPACT OF THE TOOL IN THE PROCESS					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
2.1 Was the tool aim and objective clear?					
2.2 Was the tool use relevant to design the concept for a new business on S.PSS&DRE?					
If not, could you please indicate what make it useless in the process? ………………………………………… …………………………………………					
3. POTENTIAL CONDITIONS OF USE					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
3.1 Could be your interest to use the tool in other context?					
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? ………………………………………… …………………………………………					
Did you think some potential improvement needed in the tool? e.g. online/offline structure, language, etc. ………………………………………… …………………………………………					
Since the tool is downloadable from the website (www.lenses.polimi.it) which format could be the most suitable for you? ………………………………………… …………………………………………					
OTHER Please write here free suggestions/comments ………………………………………… …………………………………………					

TOOL 3.1: Case study CARDS					
1. COMPREHENSION AND USABILITY OF THE TOOL					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1.1 Was the tool self-explanatory?					
If not, in which section/part/… needs to be more clear? ………………………………………… …………………………………………					
1.2 Was the tool easy to use?					
If not, could you please indicate where the tool may needs to be improved? ………………………………………… …………………………………………					
1.3 Was the tool supportive for the SE4A Idea Tables?					
If not, could you please indicate where the tool may needs to be improved? Language, etc. ………………………………………… …………………………………………					

2. IMPACT OF THE TOOL IN THE PROCESS					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
2.1 Was the tool aim and objective clear?					
2.2 Was the tool use relevant to design the concept for a new business on S.PSS&DRE?					
If not, could you please indicate what make it useless in the process? …… ……………………………………………………………………………………………………					
3. POTENTIAL CONDITIONS OF USE					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
3.1 Could be your interest to use the tool in other context?					
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? ……… ………					
Did you think some potential improvement needed in the tool? e.g. online/offline structure, language, etc. ……… ………					
Since the tool is downloadable from the website (www.lenses.polimi.it) which format could be the most suitable for you? ……… ………					
OTHER Please write here free suggestions/comments …… ……………………………………………………………………………………………………					

TOOL 4: Stakeholder System Map					
1. COMPREHENSION AND USABILITY OF THE TOOL					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1.1 Was the tool self-explanatory?					
If not, in which section/part/… needs to be more clear? …… ……					
1.2 Was the tool easy to use?					
If not, could you please indicate where the tool may needs to be improved? …… ……					
1.3 Were the icons easy to use?					
If not, could you please indicate where they may need to be improved? ……… ………					
2. IMPACT OF THE TOOL IN THE PROCESS					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
2.1 Was the tool aim and objective clear?					
2.2 Was the tool use relevant to design the concept for a new business on S.PSS&DRE?					
If not, could you please indicate what make it useless in the process? …… ……………………………………………………………………………………………………					

3. POTENTIAL CONDITIONS OF USE					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
3.1 Could be your interest to use the tool in other context?					
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? …… ……					
Did you think some potential improvement needed in the tool? e.g. online/offline structure, language, etc. …… ……					
Since the tool is downloadable from the website (www.lenses.polimi.it) which format could be the most suitable for you? …… ……					
OTHER Please write here free suggestions/comments …… …………………………………………………………………………					

TOOL 5: S.PSS & DRE Concept Description form					
1. COMPREHENSION AND USABILITY OF THE TOOL					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1.1 Was the tool self-explanatory?					
If not, in which section/part/… needs to be more clear? …… ………………………………………………………………………………………………					
1.2 Was the tool easy to use?					
If not, could you please indicate where the tool may needs to be improved? …… ………………………………………………………………………………………………					
2. IMPACT OF THE TOOL IN THE PROCESS					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
2.1 Was the tool aim and objective clear?					
2.2 Was the tool use relevant to design the concept for a new business on S.PSS&DRE?					
If not, could you please indicate what make it useless in the process? …… …………………………………………………………………………					
3. POTENTIAL CONDITIONS OF USE					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
3.1 Could be your interest to use the tool in other context?					
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? …… ……					
Did you think some potential improvement needed in the tool? e.g. online/offline structure, language, etc. …… ……					
Since the tool is downloadable from the website (www.lenses.polimi.it) which format could be the most suitable for you? …… ……					
OTHER Please write here free suggestions/comments …… …………………………………………………………………………					

TOOL 6: Stakeholder Sustainable Motivation Table					
1. COMPREHENSION AND USABILITY OF THE TOOL					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1.1 Was the tool self-explanatory?					
If not, in which section/part/… needs to be more clear? …… ……					
1.2 Was the tool easy to use?					
If not, could you please indicate where the tool may needs to be improved? …… ……					
1.3 Were the column easy to understand?					
If not, could you please indicate where they may need to be improved? …… ……					
2. IMPACT OF THE TOOL IN THE PROCESS					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
2.1 Was the tool aim and objective clear?					
2.2 Was the tool use relevant to design the concept for a new business on S.PSS&DRE?					
If not, could you please indicate what make it useless in the process? …… ……………………………………………………………………………………………………					
3. POTENTIAL CONDITIONS OF USE					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
3.1 Could be your interest to use the tool in other context?					
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? …… ……					
Did you think some potential improvement needed in the tool? e.g. online/offline structure, language, etc. …… ……					
Since the tool is downloadable from the website (www.lenses.polimi.it) which format could be the most suitable for you? …… ……					
OTHER Please write here free suggestions/comments …… ……………………………………………………………………………………………………					

TOOL 7: Interaction Storyboard					
1. COMPREHENSION AND USABILITY OF THE TOOL					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1.1 Was the tool self-explanatory?					
If not, in which section/part/… needs to be more clear? …… ……					
1.2 Was the tool easy to use?					
If not, could you please indicate where the tool may needs to be improved?					

…… ………………………………………………………………………………………………………					
2. IMPACT OF THE TOOL IN THE PROCESS					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
2.1 Was the tool aim and objective clear?					
2.2 Was the tool use relevant to design the concept for a new business on S.PSS&DRE?					
If not, could you please indicate what make it useless in the process? …… …………………………………………………………………………………					
3. POTENTIAL CONDITIONS OF USE					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
3.1 Could be your interest to use the tool in other context?					
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? ……… ………					
Did you think some potential improvement needed in the tool? e.g. online/offline structure, language, etc. ……… ………					
Since the tool is downloadable from the website (www.lenses.polimi.it) which format could be the most suitable for you? ……… ………					
OTHER Please write here free suggestions/comments …… …………………………………………………………………………………					

TOOL 8: Animatic – final delivery					
1. COMPREHENSION AND USABILITY OF THE TOOL					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
1.1 Was the tool self-explanatory?					
If not, in which section/part/… needs to be more clear? …… ………………………………………………………………………………………………………					
1.2 Was the tool easy to use?					
If not, could you please indicate where the tool may needs to be improved? …… ………………………………………………………………………………………………………					
2. IMPACT OF THE TOOL IN THE PROCESS					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
2.1 Was the tool aim and objective clear?					
2.2 Was the tool use relevant to design the concept for a new business on S.PSS&DRE?					
If not, could you please indicate what make it useless in the process? …… …………………………………………………………………………………					
3. POTENTIAL CONDITIONS OF USE					
Please tick the option which represents your opinion	*Not at all satisfied*	*Slightly satisfied*	*Moderately satisfied*	*Very satisfied*	*Completely satisfied*
3.1 Could be your					

interest to use the tool in other context?					
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? ……… ………					
Did you think some potential improvement needed in the tool? e.g. online/offline structure, language, etc. ……… ………					
Since the tool is downloadable from the website (www.lenses.polimi.it) which format could be the most suitable for you? ……… ………					
OTHER Please write here free suggestions/comments ……… ………………………………………………………………………………………………					

B. Course evaluation is based on course contents.

COURSE										
Please mark a cell with your answer	*Not at all satisfied*		*Slightly satisfied*		*Moderately satisfied*		*Very satisfied*		*Completely satisfied*	
1. COURSE CONTENTS										
1.1 Were the presented contents clear?										
If not, in which section/part/… it needs to be more clear? ……… ……										
1.2 Were there some sections you would like to explore more?										
If so, which? ……… ……										
1.3 Was the design exercise helpful?										
Otherwise, How would you improve it? ……… ……										
1.4 Could you be interested to use the contents in other contexts?										
If not interested, why? If interested, where/with whom would you reuse it, and with which purpose? ……… ……										