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System Design for Sustainable Energy for all

A new challenging role for design to foster sustainable development

Abstract
This paper argues that Product-Service System Design for Sustainability applied to Distributed Renewable Energy DRE) is a promising approach to help achieve the goal of "Sustainable energy for all" (United Nation). Firstly, two understandings are presented: 1) Distributed Renewable Energy (DRE) is a key leverage for sustainable development and; 2) Product-Service System (PSS) is a promising model for sustainable development. Based on those understandings two consequent research hypotheses are presented: 1) S.PSS is a promising model for DRE and is particularly relevant for the distributed and informal economies in low-middle income (all) contexts; 2) (Product-Service) System Design for Sustainable energy for all is a new challenging role for design. The recently awarded LeNSes (Learning Network on Sustainable energy system) EU project (bi-regional with Africa) is based on these hypotheses and it is introduced in terms of its aims and expected results, i.e. to deepen and diffuse the knowledge-base and know-how of system design for sustainable energy for all. Finally, two best practices of DRE-based S.PSS are described, one is the recently awarded (2014 International Ashden) project 'M-POWER Off-grid electric services in Arusha, Tanzania' and the second is the pilot implementation of the 'Sunride sustainable mobility system in Cape Town'.

Keywords: Product-Service System, design for sustainability, Distributed Renewable Energy, energy for all, low and middle-income contexts.

1. Distributed Renewable Energy (DRE): key leverage for a sustainable development

1.1 Sustainable development is not possible without sustainable energy for all

Energy is the world's largest industrial sector, whose output is an essential input to almost every good and service provided in the current global economy. Yet 1.3 billion people -one in five globally- lack electricity to light their homes or conduct business. Twice that number -nearly 40% of the world's population- rely on wood, coal, charcoal, or animal waste to cook their food. These sources of energy for cooking produce toxic smoke that causes lung disease and kills nearly two million people a year, most of them women and children (Sustainable Energy for All, 2012). These poor health outcomes along with the lack of access to electricity exacerbate the plight of the poor.

The lack of access to modern energy therefore makes it difficult to achieve the Millennium Development Goals[1] of reducing poverty, improving women's and children's health, or broadening the reach of education (Sustainable Energy for All 2012).

In this regard, this paper argues that the availability of energy will have a reverberating effect on productivity, health, education, climate change, food security and communication services (Colombo et al. 2013). Accordingly, access to sustainable energy can increase self-sufficiency, power and interdependency to individuals and local communities in a process of resource democratisation and inequality reduction (Rifkin 2011; Vezzoli 2010). If so, then the opportunity to overcome the development divide strongly depends on the availability of energy.

In other words, *sustainable development is not possible without sustainable energy for all*. This importance of energy for sustainable development has been recognized within the international arena, i.e. the United Nations General Assembly has designated, by its resolution 65/151, the year 2012 as the International Year of Sustainable Energy for All; and in 2012 the

Rio+20 UN Conference held in Rio de Janeiro contributed as well to the recognition that energy is a key driver for sustainable development.

1.2 Distributed Renewable Energy (DRE): key leverage for sustainable development

Even though energy is the world's largest industrial sector (Colombo et al. 2013; Rifkin 2011), the dominant energy system is far from being the right one to take energy in a sustainable way to all. Authors therefore agree that a paradigm shift is needed to lead to a new era driven more by decentralized or distributed systems, rather than by the dominant centralized energy generation systems. Such decentralized and distributed systems are proposed as being more democratic and inclusive, as opposed to the monopolistic and exclusive regimes of centralised energy systems. Additionally, decentralized systems will be driven more by the people than by the market and will be based on renewable energy sources as opposed to the prevailing non-renewable resources such as fossil fuels (Rifkin, 2011; Vezzoli, 2010; Colombo et al., 2013).

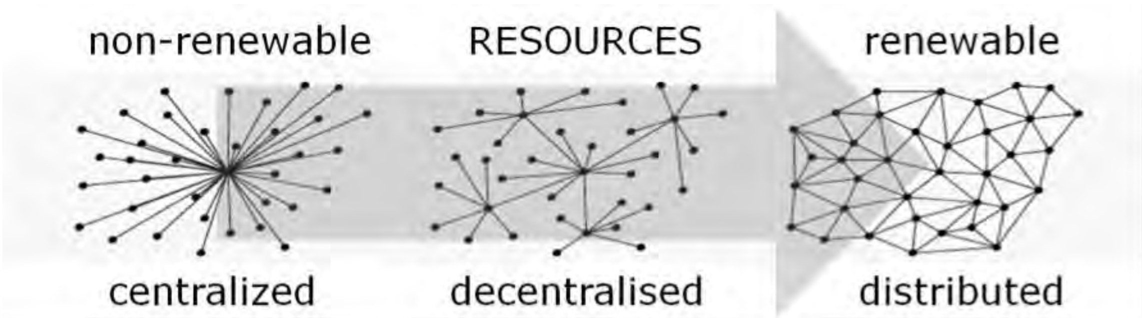


Fig. 1 The paradigm shift from non-renewable/centralized to distributed/renewable energy generation systems

A Distributed Renewable Energy (DRE) generation it is characterized by:

- renewable resources: *sun, wind, water, biomass, geothermal energy*
- small-scale generation plants
- generation at/near the point of use
- users is the producer: individuals, small businesses and/or communities
- if connected with each other to synergistically share the energy surplus, they
- become Renewable Local Energy Network; eventually connected with nearby similar Networks.

Finally a *Distributed Renewable Energy (DRE) generation* could be defined as:

> A small-scale generation plants sourced by renewable energy resources (such as sun, wind, water, biomass and geothermal energy), at or near the point of use, where the users is the producer, whether an individual, a small businesses and/or a local community and if a small-scale generation plants is connected with each other (to synergically share the energy surplus), they become Renewable Local Energy Network; eventually connected with nearby similar Networks.

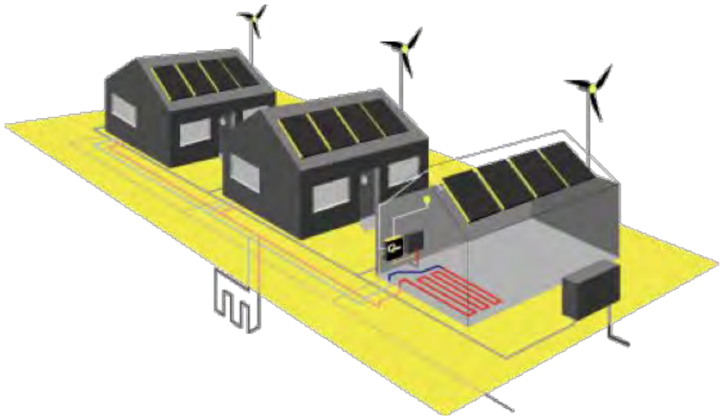


Fig. 2 A schematic representation of a Distributed Renewable Energy (DRE) generation (source www.qurrent.nl)

Several authors (Colombo et al., 2013; Rifkin, 2002 and 2010; Johansson, Kisch & Mirata, 2004; Vezzoli, 2010; Sustainable Energy for All 2011) have observed that the transition from centralized and non-renewable fossil fuel resources (oil, coal, etc.) to Distributed Renewable Energies (DRE) play a key role in the transition towards sustainable development, as far as they allow the use of local resources while preserving the environment, creating employment, promoting income generation, capacity building and local empowerment.

To clarify the above assumptions let's now look at the fossil resources model from an economic and socio-ethical point of view. Resources from fossil fuels – due to their localization and the complexity of extraction and transformation processes – have led to a series of highly centralized production and distribution infrastructures. The consequence has been a widespread centralization of the economic infrastructure, which has resulted in reduced opportunities for access to resources, above all to energy, and particularly electricity. This is a key factor in perpetuating poverty in the world[2]. It is therefore said that the enlarging rift between rich and poor can to a large extent be attributed to the very nature of the fossil fuel energy regime (Rifkin, 2002 and 2011). Without access to resources and to energy in particular, individuals have little control over their own destiny. Only by freeing themselves from oil, coal and natural gas imports, can low-income and middle-income contexts emerge, improving the economic conditions and quality of life of their populations.

From a strictly environmental point of view, using fossil resources determines most of the carbon dioxide emissions that have their fair share in causing global warming. There are also many widely-known problems and environmental risks associated with the various extraction and transformation processes, and the transport of these resources (Vezzoli 2010).

As an alternative to fossil fuel, the use of locally-based - distributed and eventually network-structured - renewable resources, such as sun, wind, water, biomass and geothermal energy, presents indubitable environmental advantages, due to their reduced greenhouse effect (and its impact), inexhaustibility and lower environmental cost compared to the various processes of extraction, transformation and distribution when using fossil fuels. Consequently, the expansive usage of distributed generation of renewable resources could lead to an extensive redistribution of power towards many single individuals, which is necessary to establish conditions that would allow the Earth's riches to be shared more fairly. This is the essence of a policy for bottom-up re-globalization. Briefly, let's see why.

The renewable resources can be used locally through relatively simple processes. Technology for these renewable resources has however not been developed in a significant way though the installation and management of photovoltaic (sun) technologies is still infinitely less complex than plants for oil wells and refineries. Photovoltaic technologies are therefore installable and manageable by *small-scale economic entities* such as a single residential complex or single individuals. If adequately exploited then, such renewable resources would enable every human being to have more power and move towards a democratic regime of resource management. These sources would allow micro-plants to be set up close to the end-user, who would no longer be only a consumer but also producer of the energy he uses. Autonomous photovoltaic panels and combustion cells could supply electricity rapidly and at a favourable cost. When a sufficient number of such micro-plants have been installed (whether purchased or managed), they could be connected together into micro energy-grids, and therefore into a constantly expanding (potentially global) energy grid. Individuals, residential complexes and local communities could in this way share and exchange energy, achieving self-sufficiency and consequently increased power, in a framework of greater interdependence. Ultimately, they could challenge the traditional centralized energy generating plants (born and developed during the age of fossil fuels), and escape the grip of the huge, powerful, energy and electricity companies, causing a radical change in important flows of power: no longer from top downwards, but from bottom upwards.

In short, such a decentralized infrastructure supplied by renewable sources, usually referred to as *Distributed Energy Generation (DEG)*, or *Distributed Renewable Energy (DRE)*, on the one hand would reduce environmental impact, and on the other could facilitate a democratization of resources and energy, enabling individuals, communities and nations to reclaim their independence while accepting the responsibility that derives from their reciprocal interdependence (self-sufficiency and interdependence). Giving access and power to local communities also contributes to enhancing the positive aspects of humanity's cultural plurality, where local cultural forms would aspire less and less to being possessions to defend, and more and more to being opportunities for positive cross-fertilization towards a general improvement in the conditions of life on earth.

Finally, Distributed Renewable Energies (DRE) are increasingly seen (Colombo et al. 2013) as vital catalysts to achieve universal access to energy and a wider social and economic development by enabling education, health and sustainable agriculture, by creating green jobs and by promoting equity. In other terms, the dissemination of distributed generation based on renewable energies represents an economically viable and effective way to promote sustainable development in low-income and middle-income contexts. Furthermore, the experience gained in developing countries could also contribute to the paradigm shift needed in the energy sector at global level (Colombo et al. 2013).

One of the most committed and known researcher on this topic is Jeremy Rifkin, who talks about the Third Industrial Revolution (Rifkin 2010). Rifkin's core idea is the creation of a renewable energy regime, loaded by buildings, partially stored in the form of hydrogen, distributed via an energy internet -a smart intergrid- and connected to plug in zero emission transport. Rifkin highlights 5 pillars for this transition:

- Shifting to renewable energy (solar, wind, hydro, geothermal, ocean waves and biomass)
- Buildings as power plants
- Deploying hydrogen and other storage technologies in every building and throughout the infrastructure to store intermittent energies
- Using internet technology to transform the power grid of every continent into an energy sharing intergrid that acts like the internet
- Transitioning the transport fleet to electric, plug in and fuel cell vehicles that can buy and sell electricity on a smart continental interactive power grid.

2. Product-Service System (PSS): a promising model for sustainable development

2.1 Product-Service System: eco-efficiency opportunities for industrialized contexts

The realisation of a renewable energy regime can gain from the creative and generative impulse of design. This impulse to create new things affords design a prime position in the innovation of DRE. To achieve this, the focus in design will have to shift from simply creating new products, to creating new production and consumption systems, i.e. innovative ways into which the various systems stakeholder may interact. In this regard, some design research centres have reset part of the debate on design for sustainability by focusing attention even on system innovation. They have done so through a stringent interpretation of environmental sustainability that requires a systemic discontinuity i.e. radical innovation in production and consumption patterns. Accordingly, a significant ambit in which to promote radical changes for sustainable consumption seems to be the widening possibilities for innovation beyond the product. More specifically, this entails innovation of the *system,* which entails an integrated mix of products and services that together are able to satisfy a particular demand of the customer (Goedkoop, van Halen, Riele, Rommes, 1999; Brezet, 2001; Charter, Tischner, 2001; Manzini, Vezzoli, 2001; Bijma, Stuts, Silvester, 2001).

This integrated mix is referred to in this context as a *Product-Service System* (PSS) which can be defined as 'a system of products, services, network of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower impact than traditional business models' (Mont O., 2002). More recently, in the United Nations Environment Program publication (UNEP, Tischner, Vezzoli, 2009), a PSS is defined as 'a system of products and services (and related infrastructure) which are jointly capable of fulfilling client needs or demands more efficiently and with higher value for both companies and customers than purely product based solution'. The following case exemplifies what written above.

> Pay Per Page Green—Ricoh
> Ricoh offers a package deal (Pay per Page Green) and installs, maintains and collects at the end-of-life the printers and photocopiers (not owned by the customer); the customer pays for the number of delivered pages and copies. The innovative interaction between the company and the client provides the company's economic interest to provide (and design) long-lasting, re-usable and recyclable photocopiers.
>
> Components are tested and functional parts are re-manufactured or directly re-used in a new photocopier. Damaged components are directed to material recycling. Ricoh products are designed to allow component compatibility between different models and to facilitate the whole processes of re-using or re-manufacturing.

A commonly shared opinion is that "PSS could decouple the creation of value from consumption of materials and energy and thus significantly reduce the life-cycle environmental load of current product systems". Eco-efficient PSS can be said to derive from a new convergence of interest between different stakeholders, where innovation is not only happening at a product (or semi-finished) level, but at the interactive and partnership level. In this way, a value production system includes the value chains of a firm's supplier (and their suppliers all the way back), the firm itself, the firm's distribution channels, and the firm's buyers and is presumably extended to the buyers of their products as well (Porter, 2006).

In summary, the characteristics of a PSS innovation are the following (Vezzoli, 2010):

- They are rooted in a *satisfaction-based* economic model, i.e. each offer is developed/designed and delivered in relation to a particular customer "satisfaction" (unit of satisfaction);
- They are *stakeholder interaction-based* innovations, i.e. they are radical innovations, not so much in technological terms as in new interactions/partnerships between the stakeholders of a particular value/satisfaction production system;
- They have an *intrinsic eco-efficiency potential*, i.e. they are innovations in which it is the company/companies' economic and competitive interest that may lead to a reduction in environmental impact (system eco-efficiency: decoupling the creation of value from resources consumption).

2.2 PSS a promising approach for sustainable innovations in emerging and low-income contexts

Most of the research efforts investigating PSS have been focused mainly on the environmental and economic dimensions of sustainability and have mainly considered industrialized contexts. Nevertheless, an emerging hypothesis proposes that such innovations are also favourable for emerging or low-income contexts and help to tackle the socio-ethical dimension of sustainability together with the environmental (and economical) one, i.e. coupling eco-efficiency with social equity, cohesion and inclusion.

In year 2000 the United Nations Environment Program (UNEP) set up a group of international researchers[3] to both disseminate world-wide the concept of Product-Service Systems innovation, and start exploring new PSS potentialities, which can be summed up in the following queries.

Is PSS also applicable in emerging and low-income contexts?

This question arises simply because the development of Sustainable Product-Service Systems, studied, said and achieved thus far did not refer to the socio-ethical dimension of sustainability nor to emerging and low-income contexts (which are by statute within the concern of the United Nation Environment Program). This question was the forerunner of another.

(If the answer to the first is affirmative) can a PSS approach favour social equity, cohesion and inclusion within these contexts together with eco-efficiency?

The response to the former two questions, given by the international group of experts engaged by UNEP, has been the following research-working hypothesis (UNEP, 2002; UNEP, 2009):

> PSS may act as business opportunities to facilitate the process of social-economic development in emerging and low-income contexts - by jumping over or by-passing the stage of individual consumption/ownership of mass produced goods - towards a "satisfaction-based" and low resources intensive advanced service-economy.

The case below exemplifies this finding.

> The Virtual Station (offices), based in Fortaleza, Brazil, supplies a full range of products, infrastructure (owned by virtual station) and services for a complete office. Clients only pay for the periods of use; spaces are equipped with computers, printers, scanners, access to internet, TV, copiers, reception, personalised phone answer, answering and remittance of fax reception/transmits. It is environmentally sustainable because it uses the solar energy. It is

socio-ethically sustainable because it provides poor people with access to useful services. It is also economically sustainable because is a business for TSSFA (The Sun Shines For All) company.

Following are some arguments that can be highlighted in support of this hypothesis that Product-Service System innovation is an approach that is applicable even in emerging and low-income contexts (UNEP, 2002)[4]. First, if PSS are eco-efficient at system level it means that they may represent opportunities, for a context with fewer economic possibilities, to respond with a lower overall cost (more easily) to unsatisfied social demands.

Secondly, PSS offers are more focused on the context of use, because they do not only sell products, but they open relationships with the end user. For this reason, an increased offer in these contexts should trigger a greater involvement of (more competent) local, rather than global, stakeholders; thus fostering and facilitating the reinforcement and prosperity of the local economy. Furthermore, since PSS are more labour/relationship intensive, they can also lead to an increase in local employment and a consequent dissemination of skills.

Finally, since the development of PSS is based on the building of system relationships and partnerships, they are coherent with the development of network enterprises on a local basis for a bottom-up re-globalization process, i.e. Distributed Economies (DE).

2.3 Informal Distributed Economies and networks already exist in low-income contexts

A further elaboration of DE may strengthen the argument for adopting S.PSS in emerging and low-income contexts. DE is currently described as a vision that brings together networks to take advantage of scale while remaining distributed and flexible. Unlike in centralised economies, consumers in DE remain connected to the producers who can respond better to their needs. Furthermore, in DE small-scale production systems can thrive through an open network of innovation (Johansson et al., 2004). Taking this description into account, emerging and low-income contexts can be conceptualized as informal DE because they are proliferated by small, informal and networked businesses. These types of businesses are a common feature in Sub-Saharan Africa, where the economies are largely informal (Verick, 2006).

According to the International Labour Organisation (ILO), 90% of businesses in a country like Kenya are informal. This would mean that a large percentage of the population is familiar with the distributed and networked nature of the informal sector. If so, then such a population, that is typical in Africa, would be attuned to the open and networked relationships that PSS and DRE offer. Further, a PSS approach would be able to take advantage of existing informal relationships that are characteristic of social groups in emerging and low-income economies. According to Trærup (2012), the informal network in social groups facilitates collective action for communities. As already argued, PSS would plug into these informal networks and possibly produce greater benefits for those communities. Setting up PSS that can distribute renewable energy is therefore emphasised as an appropriate approach because it will link into the existing informal networks to maximise on reach and affordability.

Vivid examples of distributed informal networks can be found in the ‘Jua kali’ in Kenya or the ‘second economy’ in South Africa[5]. In Kenya, the *Jua kali* (Swahili for *hot sun*) is used as a term to refer to the once, open-air activities of the informal sector traders. Today, those traders, many of them being small-scale producers, are recognised and supported by the government of Kenya. In South Africa, the second economy has not received the same privilege but it has been allowed to flourish now, much more than during the Apartheid period. The traders in these types of informal sectors continue to face many challenges, whose solutions are thought to be in formalising these businesses. This paper argues that such formalisation should not necessarily seek to create large-scale, centralized models. Instead, focus should be on strengthening the existing networks that can create further opportunities for partnerships and cooperation. For instance, *Jua kali* producers working in *Gikomba* open-air market are already well connected as they work in close proximity. This proximity means that the competition amongst the traders is very high. In a PSS model, this competitive nature of their work can be turned into co-competition so that the producers find ways to collectively: improve their products, working conditions and access to markets. They could in this way, reduce their personal costs while increasing their collective benefits. If a DRE dimension was introduced, these traders can take advantage of renewable energies regimes whose benefits are shared amongst them.

Finally, informal economies are a lifeline for the poor and so creating further opportunities through their existing networks will have immediate and direct benefits for low-income earners. Some of these earners are themselves producers of their own energy from non-renewable sources such as charcoal. DRE can now offer them the chance to produce energy more sustainably to improve their livelihoods and to better their environments. The survivalist, existing informal networks that are distributed amongst these poor can therefore become symbiotic relationships that remain flexible and accessible to the majority. Adopting a PSS approach is therefore proposed here as a worthwhile consideration for low-income contexts.

3. Product-Service System design for Sustainability: an emerging role for design

In this section, we look at the implications of PSS in design, by recalling the definition (of the role) of *Product-Service System Design for sustainability*, and the Method for System Design for Sustainability (MSDS) as elaborated within the EU funded *Learning Network for Sustainability* (LeNS) project (2007-2010).

3.1 Product-Service System Design for Sustainability

The definition of *Product-Service System Design for Sustainability* as emerged from the LeNS EU funded project runs as follow (Vezzoli et al. 2014):

> the design of the 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 innovative interactions of the stakeholders (directly and indirectly linked to that "satisfaction" system) where the economic and competitive interest of the providers continuously seeks after both environmentally and socio-ethically beneficial new solutions**.**

In relation to the characteristics of a PSS innovation described in the previous chapter, the approaches and skills for system design for sustainability could be articulated as follows (Vezzoli et al. 2014, to be published):

- *"satisfaction-system" approach*: design a particular demand of satisfaction (satisfaction unit) and the mix of products and services fulfilling it
- *"stakeholder configuration" approach:* design the interactions of the stakeholders of a particular satisfaction system
- *"PSS sustainability" approach:* design the interactions of the stakeholders (offer model) leading them for economic and/or competitive reasons towards those innovations that will improve social equity, cohesion and inclusion as well as reduce the environmental impact.

3.2 The Method for System Design for Sustainability (MSDS): the LeNS approach

Some methods and tools have been developed in the last decade to support the aforementioned *System Design for Sustainability* approaches. Among those is the *Method for System Design for*

Sustainability **(***MSDS)*. The *MSDS* method aims to support system innovation design and to orient it towards sustainability. It is conceived for designers working for or within a company but also for public institutions and NGOs. It can be used by an individual designer or by a wider design team. In all cases special attention has been paid to facilitating co-designing procedures both within the company itself (between people from different disciplinary backgrounds) and outside, bringing different stakeholders and end users into play.

The MSDS method has been elaborated within the MEPSS[6] EU project, integrated with outcomes from the HiCS[7] EU project and refined within the LeNS[8] EU project. It has been used and refined during a series of company consultancy, with Tetrapack company and Kone company[9] and recently in a process of participated design within the Towards a new Intergenerational openness (TANGO) EU funded project (Culture program); four Sustainable Product-Service System has been designed for four suburban districts of Milan, and a set of videos describing them are visible at the following website: www.designtango.eu.

The MSDS method is modular and flexible in order to be adapted to the specific needs of the designers/companies and to different context's conditions, nevertheless it is organised in the following phases:

- strategic analysis
- exploring opportunities;
- designing system concepts;
- designing system details;
- communication.

The table below shows the MSDS aims and processes related the above mentioned phases.

MSDS method		
Phases	**Aim**	**Processes**
Strategic Analysis	To obtain the information necessary to facilitate the generation of sustainable ideas	Analyse project proposers and outline the intervention context
		Analyse the context of reference
		Analyse the carrying structure of the system
		Analyse best practices
		Determine priorities for the design intervention in view of sustainability
Exploring opportunities	To make a "catalogue" of promising strategic possibilities available, and/or a sustainability design-orienting scenario	Generate ideas orientated towards sustainability
		Outline a sustainability oriented design scenario (visions, clusters and individual ideas orientated towards sustainability)
Designing system concepts	To determine one or more system concepts oriented towards sustainability	Select clusters and single ideas
		Develop system concepts (consisting of one or more product and service mixes that characterize the offer; the relative interaction system between the actors involved; potential environmental, socio-ethic and economic improvements)
		Environmental, socio-ethic and economic appraisal
Design (and engineering) a system	To develop the most promising system concept(s) into the detailed version necessary to its/their implementation	Detailed system design
		Environmental, socio-ethical and economic assessment
Communication	Draw up documentation to communicate the general, and above all sustainable,	Draw up documentation in various formats

	characteristics of the system designed	

Table 1. Overall scheme of the MSDS phases, aims and processes, partly adopted by the TANGO Milan design project.

The main tools of MSDS method are available for free on the LeNS web site: www.lens.polimi.it tool section.

The MSDS main design tools are as follow.

The *Sustainability Design-Orienting* (SDO) toolkit that aims at orientating the system design process towards sustainable solutions (environmental, socio-ethical, economic).

Fig. 3. Two snapshots of the Sustainability Design-Orienting toolkit

The *Sustainability interaction story-spot* that aims at visualising (only) key interaction in relation to criteria of sustainability: environmental, socio-ethical, economic. Could be animated.

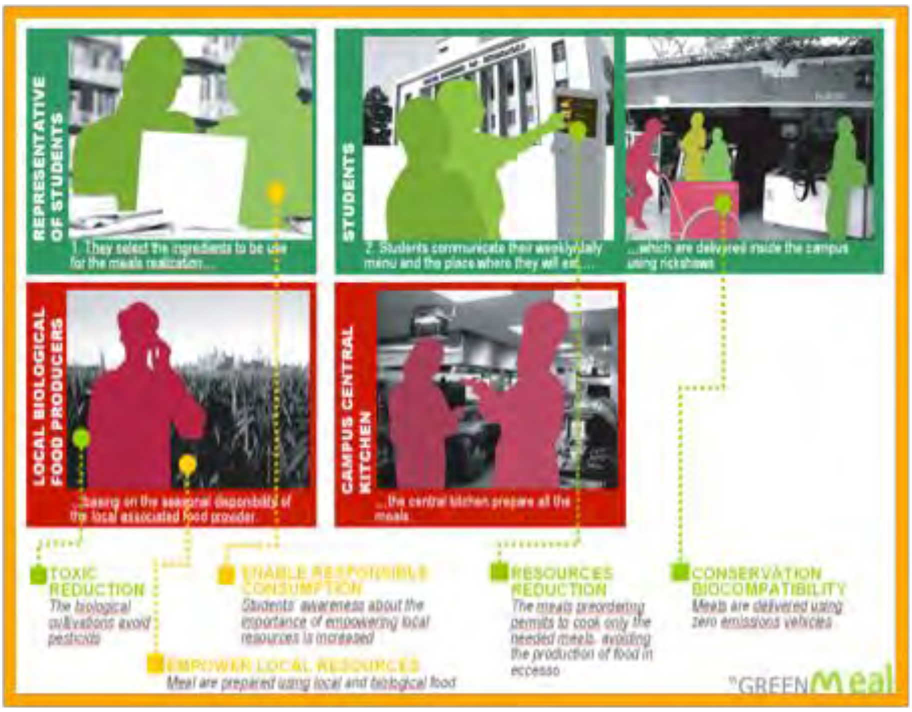


Fig. 4. Example of the sustainability interaction story-spot

The *system map* that aims at visualising (design and co-design) the configuration of the system, describing actors involved and their interactions.

Fig. 5. Example of the system map

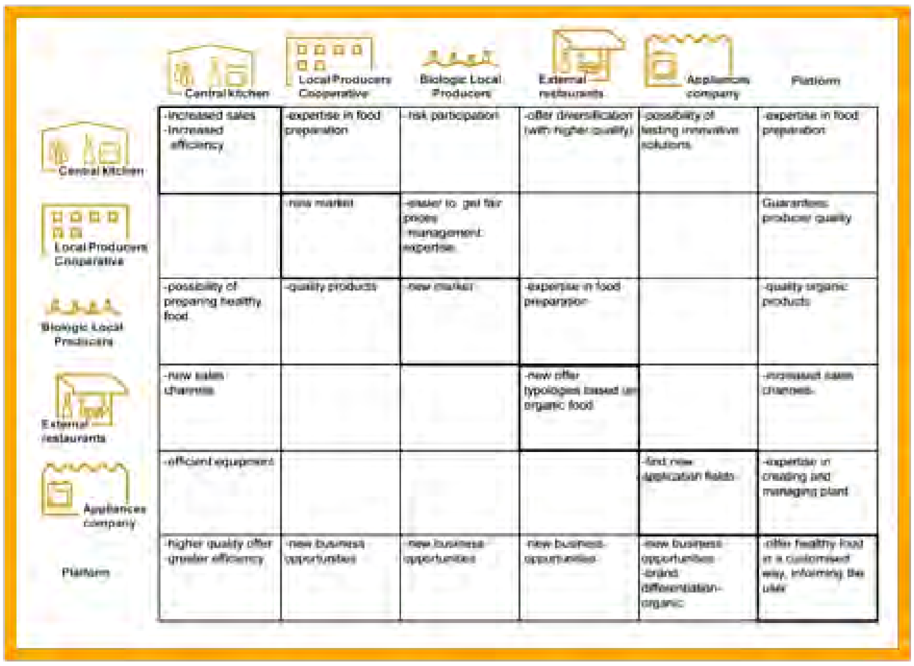
The *interaction table* and *story-board* that aims at visualising (design and co-design) the functioning of the system in time: the narratives (stories) of the front-desk (with the clients) and back-stage interactions between other stakeholders. The interaction story-board could be animated.

Fig. 6. Example of the interaction table

The *satisfaction offering diagram* that aims at visualising (design and co-design) the satisfaction offered by the system, and how this is delivered to the user/customer.

Fig. 7. Example of the offering diagram

The *stakeholders motivation matrix* that aims at visualising (identifying) the motivations that actors have in being involved in the system.



	Central kitchen	Local Producers Cooperative	Biologic Local Producers	External restaurants	Appliances company	Platform
Central kitchen	-increased sales -increased efficiency	-expertise in food preparation	-risk participation	-offer diversification (with higher quality)	-possibility of testing innovative solutions	-expertise in food preparation
Local Producers Cooperative		-rural market	-easier to get fair prices -management expertise			Guarantees producer quality
Biologic Local Producers	-possibility of preparing healthy food	-quality products	-new market	-expertise in food preparation		-quality organic products
External restaurants	-new sales channels			-new offer typologies based on organic food		-increased sales channels
Appliances company	-efficient equipment				-find new application fields	-expertise in creating and managing plant
Platform	-higher quality offer -greater efficiency	-new business opportunities	-new business opportunities	-new business opportunities	-new business opportunities -brand differentiation-organic	-offer healthy food in a customised way, informing the user

Fig. 8. Example of the stakeholders motivation matrix

4. Sustainable Product-Service System: a promising model for Distributed Renewable Energy

4.1 Product-Service System: sustainable opportunities even in the energy sector

In the energy sector cases of Sustainable PSS based on distributed renewable energy are particularly promising as shown in the following examples.

An example of S.PSS based on DRE in *industrialized contexts.*

The 'solar heat service', AMG, Palermo, Italy

The 'solar heat service' is a full-service providing a final result, consisting in 'selling' hot water as a finished product. Hot water is produced by new equipment that combines solar energy and methane, with economic and energy savings. Hot water is measured by means of a specific heat meter and the whole system is monitored, in order both to control in real time how the system works and also to apply the Guarantee of Solar Results. AMG has tested this service in a Tennis Club in Palermo city (Italy), providing hot water for the dressing rooms. The innovative feature of this Product-Service system is that AMG will not invoice the client for the methane consumed to obtain hot water, but rather, hot water is sold as an entire service. With AMG the consumer pays to receive a comprehensive service covering installation, thermal-energy meters and transportation of methane to the boilers. With equipment maintenance provided as well, the customer is buying a 'final result'.

Billing is by unit of service and not per unit of consumed resources, the company becomes motivated to innovate in order to minimize the energy consumed in use: the less methane consumed (the higher the use of solar energy and the greater the efficiency of the system) the higher the income for AMG.

An example of S.PSS based on DRE in *low-income context*

Distributed Solar Energy and electrical devices as an all-inclusive package, Brazil.

Fabio Rosa founded both a for-profit corporation, Agroelectric System of Appropriate Technology (STA) and a not-for profit organization, the Institute for Development of Natural Energy and Sustainability (IDEAAS). TSSFA developed a basic photovoltaic solar home system and in 2001, Rosa began exploring a new business model to provide Brazils rural people with what they needed: energy services, not just solar energy. To that end TSSFA developed a leasing structure whereby customers pay a monthly fee for the use of cost-effective solar energy packages. TSSFA customers sign a three-year service contract but can end the contract at any time by paying the cost of un-installation. Solar home kits, as TSSFA calls them, include the hardware needed to generate energy, while also providing the installation service and products that use the electricity generated by the solar home system, such as lighting and electrical outlets. All of the tangible inputs are owned by STA and only the service provided by these materials are leased to customers. It is environmentally sustainable because it uses the solar energy; it is socio-ethically sustainable because give to poor people access to useful services; it is economically sustainable because is a business for TSSFA company.

4.2 S.PSS applied to DRE is a sustainable opportunity in low/middle income (all) contexts: a research hypothesis (I)

In the previous sections, we discussed the two concepts of Distributed Renewable Energy (DRE) and Sustainable Product-Service System (S.PSS) as applied to energy-powered systems are worth considering in the diffusion of sustainable development through sustainable energy for all

In this paragraph, we propose to couple (in a differentiated way) the energy-powered *S.PSS to the DRE to reach challenging PSS sustainable model.*

Both models, as well as their combination, are win-win strategies since they can potentially couple multiple sustainable benefits: economic (reduced cost of energy, due to increased resiliency and reliability), environmental (efficiency gains, reduced emissions), and socio-ethical (democratization of access to energy, increased participation and independence of local people).

In other terms, the following research-working hypothesis could be formulated (LeNSes EU proposal, 2013):

> A S.PSS approach may act as a business opportunity to facilitate the diffusion of DRE-based value production system (satisfaction system) in low and middle-income (all) contexts, , reducing the (initial) cost of access to energy, resulting in a key leverage for a sustainable development process aiming at democratizing access to resources, goods and services.

5. System Design for Sustainable energy (for all): a design research working hypothesis for the LeNSes EU project

5.1 System Design for Sustainable energy (for all): a design research working hypothesis (II)

The above described role for system design for sustainability could be adapted to formulate a research working hypothesis on a new challenging role focused on “unit of satisfaction” powered by a Sustainable Distributed Renewable Energy (Vezzoli, Delfino, 2013).

> *System design for sustainable energy (for all):*
> the design of the system of products and services for an on-site Distributed Renewable Energy (DRE) generation able to “power” the fulfillment of customer demand/s (“unit of satisfaction” powered by that energy) with accessible cost; an offer model based on an innovative interactions of the stakeholders (of the “satisfaction” production system) where the economic and competitive interest of the providers continuously seeks after both environmentally and socio-ethically beneficial new solutions; eventually including the offer of a local energy network.

5.2 LeNSes, the Learning Network for Sustainable energy systems

The above working hypothesis has been proposed in a recently (10.10.2013) activated project, the *Learning Network for Sustainable energy systems* financed by EU Edulink II bioregional project. Promoted and coordinated by the Design and system innovation for Sustainability research group of the Design department of the Politecnico di Milano University it involves 6 other partners: the Brunel University, UK, the Delft University of Technology, the Netherlands, the Cape Peninsula University of Technology, South Africa, the Makerere University, Uganda, the University of Botswana, Botswana and the University of Nairobi, Kenya.

It is a Multi-polar and open network for curricula and lifelong learning capacity development focused on locally-based Sustainable Energy System Design & Engineering (SES.DE). In fact, it is based on the on the research working hypothesis highlighted in the previous chapters. Coherently with what has been discussed above, the focus will be on innovative solutions to improve access to cleaner and stable energy services. And in particular on locally-based, renewable, secure, cleaner and economically viable (even to marginalized persons) energy services, based on the promising models of Sustainable Product-Service Systems (PSS) and Distributed Renewable Energy (DRE). In this framework the focus is on extending the access to those people/communities that do not have yet access to energy services (e.g. rural communities) and improving the offer for those who already have access to it (e.g. urban contexts), integrating, in both of the cases, gender equity issues. Moreover there will be a focus also on the use of modern (energy) technologies, and in particular on the most effective and appropriate technologies to manage the generation, storage, distribution and use of renewable energies in locally-based systems. Finally, these issues will be approached from a multidisciplinary and systemic perspective, focusing on: the proper configurations of the socio-economic actors (appropriate partnerships alongside with appropriate technologies) to locally produce, deliver and maintain the energy systems; co-design approaches involving stakeholders including final users.

Its focus on access to Distributed Renewable Energy (DRE) systems is in line with the target countries' national and regional plans. In *Uganda,* one of the goals of the Renewable Energy Policy is "to promote the decentralized (distributed), off-grid electricity supply models […] by the deployment of locally available renewable energy sources". In Botswana the National Development Plan 10 (2009-2016) underscores the need to achieve national "energy security" and "self-reliance"; in addition *Botswana* is planning to have a renewable energy feed-in tariffs for electricity generation. In *Kenya* the Energy Plan states that the Government shall: "designate a Renewable Energy Lead Agency to promote and accelerate the exploitation of this resource"; "building programmes for players in renewable energy technologies in collaboration with training institutions"; "develop a tariff for net metering for electricity generated from renewable energy sources […] [and] encourage consumers sell excess power generated from the renewable energy systems"; "Open up off-grid areas in order to ease connectivity to electricity by constructing transmission lines to link them up to the national grid". In *South Africa* the Renewable Energy Market Transformation Programme focuses on removing the barriers and reducing the costs of renewable energy technologies and promoting independent renewable energy producers to feed into the national grid.

The *Overall objective* of the project is to contribute to curriculum and lifelong learning capacity development in *System Design for sustainable energy for all*, to favour the building up a new generation of practitioners capable of extending the access to locally-based, secure and cleaner energy services, based on the promising models of Product-Service Systems (PSS) and Distributed Renewable Energy (DRE), and addressing equity and gender issues. So forth based on the working hypothesis that has been articulated in the previous chapters.

The *specific objective* is to create a multi-polar network among African and European HEIs, to support African HEIs teachers to deliver didactic curricular courses and lifelong learning modules: a network promoting an open source and copyleft ethos for knowledge building and sharing - supported by an Open Learning E-Platform (OLEP) - aimed at: (i) jointly promoting a new shared disciplinary ground on *System Design for sustainable energy for all*; (ii) jointly developing courses/modules, learning resources, tools and guidelines to support educators; (iii) supporting exchanges among HEIs and practitioners in Africa and Europe; (iv) ensuring the endurance of the action after the project end.

The estimated results are:

- The Open Learning E-Platform (OLEP) for a decentralized production/fruition of knowledge in a open and copyleft ethos, with a modular e-package of learning resources (slide shows, texts, audio, video, etc.) and tools to be freely downloaded, modified, remixed, reused, and up-loaded.
- 4 pilot and 4 permanent curricular courses in the 4 African partner HEIs.
- 4 lifelong learning modules in the 4 African partner HEIs.
- A copyleft didactic book on locally-based *System Design for sustainable energy for all*.
- An international conference; a teachers-targeted workshop; an international students' design award.
- A catalogue of sustainable energy solutions, displaying best practices, and new concepts and ideas.

6. Best practices of system design for sustainable energy for all in low/middle-income contexts

6.1 M-POWER Off-grid: Electric

Off-grid Electric[10] is a California and Tanzania based company, recently awarded by the *'2014 International Ashden[11] Awards winners',* with the aim of provide affordable and reliable energy to communities that currently lack such power energy.

The company uses Distributed Renewable Energy to sell power as a service to customers who suffer from an expensive grid, an unreliable grid, or have no electrical grid access at all. The aim is to deliver a complete technical, operational and financial model that makes high quality renewable electrical services affordable to millions of homes.

A first pilot phase has been implemented in 2012 in the region around Arusha, Tanzania. The company provides energy services, rather than selling a product, under the designation of M-POWER, which enables customers to conveniently use solar energy. These plug-and-play home systems are installed in the homes of the customers. The provider takes care of installation, maintenance and repair, while customer pays only for the service including different electrical appliances, such as provided LED lamps and mobile phone charging adapter. Therefore the customers take no risks.

There are different levels of the service, the cheapest costs $ 1.2 per week plus a one-time installation fee of 6 USD to be paid at the beginning of the contract. This fee in a way also serves as a commission for the sales agents. Besides the basic service level, which includes lighting and mobile phone charging, upgrades can be booked (at higher prices), which allow radio, TV or other additional lamps.

The payment method is based on the pre-paid concept using M-PESA[12], the user receives an unlock code via SMS, inserts the code and the system get unlocked for the paid period, and it starts generate electricity. The system automatically turns off when no credit is left. To ensure that systems do not remain long periods unused, Off-Grid Electric local agents can confiscate these energy generator systems. Currently, about 80 % of systems are constantly used.

Fig 9. The first M-POWER energy hub in Arusha, Tanzania.
Here potential customers can learn about the service and sign up.

M-POWER represents an innovative approach to the market, whereby customers pre-pay for energy services and do not buy hardware they merely pay a fee for the service. This radically reduces both the cost and the risk to each user because the provider company maintains the ownership of the energy generator systems and the energy using products and provides support and technical services during the entire contract. Those innovative system that are offering full-service can be considered more accessible and less risky for customers, but they require an upfront big investment and an appropriate business model and stakeholder configuration in order to reach the break-even point of the project and ensure sustainable energy for all. However the implementation of the pre-paid (or pay-as-you-go) concept, taken from the mobile industry that had great success even in developing countries, somehow can solve or at least reduce the problem of arrears payment. The M-POWER service both ensures sustainable energy access for all but even benefits the local labor market, providing job opportunities where locals are trained and employed to become dealers and technicians.

Fig. 10. Local agents install the Solar Home Kit

6.1 The Sunride sustainable mobility system in Cape Town

Project background: the MULO system

MULO System (system for Urban Mobility for Labour purposes) is a family of light working vehicles for urban contexts powered by solar, electric and human power, convertible in four variants: freight transport, people transport, green areas maintenance and hawkers. The first version of the vehicle was prototyped in 2009 by the high school IPSIA ‘A. Ferrari’ Maranello in collaboration with DIS (Design and system Innovation for Sustainability) unit of research of Politecnico di Milano on the base of a design by Fabrizio Ceschin (Design Master Thesis).

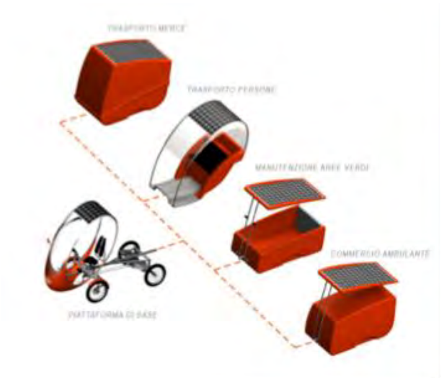


Fig.11. Rendering Mulo in four different variants Fig.12. First prototype of the Mulo on road

Mulo system: an open project of sustainable DRE-based mobility for all

The DIS research group has for a couple of years promoted the Mulo project as an *open project* to diffuse sustainable (mobility) and as a PSS powered by a DRE system. Currently, the design and activation of various socio-technical experiments (pilot projects) developed in low and middle-income contexts in collaboration with local universities, as well as local companies, NGOs and administrations have been carried out.

Fig. 13. Mulo system an open project developed in different contexts

Sunride: the pilot project implementation of the S.PSS applied to DRE

The *Sunride pilot project*[13]*,* is an example of sustainable DRE-based mobility project designed and pilot implemented for the transportation of people with physical disabilities in Cape Town, South Africa. *Sunride* is the result of the collaboration between Politecnico di Milano, IPSIA "A. Ferrari" di Maranello and Cape Peninsula University of Technology (CPUT) in Cape Town, Shonaquip, a south African social enterprise which produce aids for people with disabilities, and Bicycle Empowerment Network (BEN) a NGO based in Cape Town aimed to reduce poverty and improve mobility through the promotion of the bicycle in all its forms. This network of Italian and South African stakeholders has started the design and engineering of the vehicle to fit local circumstances and type of use. At the same time, the stakeholder configuration was designed as an S.PSS based on DRE.

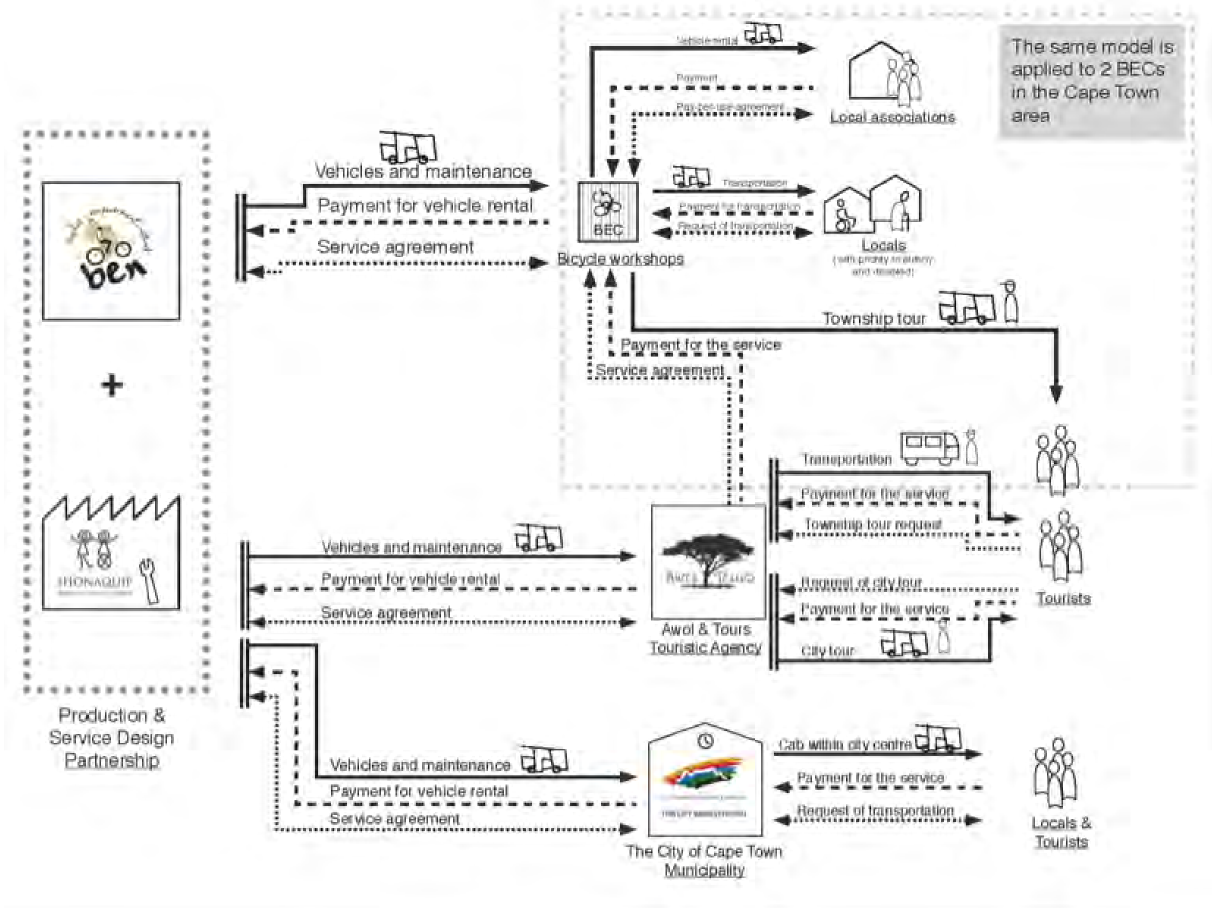


Fig. 14. Project stakeholder system map designed in its full operative phase

The mobility service system, at its full operative phase, is designed to be environmentally, socio-ethically and economically sustainable.

The designed system is based on the partnership between a vehicles company manufacturer (so far Shonaquip) and a local NGO (so far BEN bikes), which represents the Product-Service System (PSS) provider; they keep the ownership of the solar powered vehicles and offer an integrated mobility service, on *a pay-per-move* base.

The PSS provider signs agreements with associations/companies - such as local community, local clinic, touristic companies, public transportation companies - interested in renting the vehicles to give access to mobility to people in their specific context of action.

Each solar vehicle generates renewable energy directly used to assist the riding. While if the vehicle is not used, the energy produced can be sold to recharge small electrical devices. The project has been addressed for Cape Town suburbs, where the public transportation is limited or even absent and not always affordable due to high percentage of unemployment.

The company that manufactures the solar powered vehicles, instead of selling them is paid on a *pay-per-move* base, keeping the ownership on all tangible products and providing, within the cost, an integrated maintenance and repairing service. The customers are not exposed to high initial investment cost and the providers are economically interested to improve continuously the tangible products, in terms of their longevity and recyclability, as well as their energy efficiency and solar power capacity. Furthermore, the designed stakeholder configuration foresees the creation of job opportunities for marginalized people while satisfying the needs of mobility for low-income people with motor disabilities as well as for all.

Simultaneously, in order to identify how to overcome implementation barriers and help achieve its dissemination, a *transition path* was designed based on a series of *socio-technical experiment* (pilot projects)[14]. Finally a prototype of the vehicle was manufactured in Cape Town, to carry up to two passengers and one wheelchair user (see figure 13). The prototype of the vehicle was used for the implementation of the *socio-technical experiments*.

Fig. 15. Prototype of the vehicle – Features

The first DRE-based S.PSS pilot project, was carried out in Lavender hill, Cape Town suburbs by the Bicycle Empowerment Centre (BEC) of Lavender Hill, BEN bikes, Shonaquip and with the supervision of CPUT and Politecnico di Milano.


Fig. 16. Transporting a wheelchair user during the pilot project

Shonaquip, Politecnico di Milano and CPUT (co-owners of the prototype of the vehicle) gave over the management of the vehicle to BEC Imfundo cycling, to take care of the mechanical maintenance and management of elderly sick and disabled transportation, from their home to

any point of interests around Lavender Hill community, such as to the Hospital, to the Church or the post office.
During the pilot project the transportation service did not charge any specific fee, but donations were accepted. The Imfundo Cycling club, a group of young cyclist formed around the BEC, have a means to gain income and exercise by driving the vehicle, which will keep them away from *negative* influences in the community.

A rental service took place so that NGO's in the community, in particular the local Mediclinic and Philza Abafazi Bethu NGO, have rented the vehicle for their own excursions such as carrying their patients around in the community or delivering food at homes. The beginning of the pilot project was outlined by a Launch event organized in collaboration with BEN Bikes. The event was aimed to show to the audience the working prototype of the vehicle and to the community where the pilot project will run as well as incubating new projects, with new partners. After the event a small meeting between the most important actors took place in order to define the further steps of the project. After a first testing period the DRE-based S.PSS was refined and a business plan proposal was developed (for the system at its full operative phase). In order to make the service economically self-sustainable the system has been broaden to other type of transportations creating profitable businesses such as the transportation of tourists or commuters around the city centre (Delfino, Remotti, 2012). The next steps are to broaden the network of stakeholders even more and diffuse the S.PSS in different context around the Cape Town metropolitan area, creating many independent but connected local mobility systems.

7. Conclusion

During the Learning Network on Sustainability (LeNS) project, funded few years ago by the EU, the relevance of PSS design for sustainability in middle and low-income context has emerged, especially when this offer is merged with the model of Distributed Economies (Vezzoli et al. 2014). Furthermore, it has been argued that S.PSS applied to DRE is a promising approach in low and middle-income contexts where the population is already familiar to the distributed and networked nature of the informal sector and would be attuned to the open and networked relationships that S.PSS and DRE offer.

The recently awarded EU funded project *Learning Network on Sustainable energy system (LeNSes)*, is working on a declination of the former research hypothesis with a focus on the important energy sector, with the aim of building up a knowledge-base and know-how for system design for sustainable energy for all. In operative terms, the system design approaches, skills, method and tools (i.e. the MSDS introduced previously) proposed by the former LeNS project will be adjusted, specified and merged to properly tackle the incorporation of Distributed Renewable Energy systems.

On the other hand the Sunride sustainable mobility open project (in Cape Town and elsewhere), will continue to be a privileged testing ground of the theoretical and methodological outcomes of the LeNSes project, i.e. a testing ground of the system design for sustainable energy (for all) approach; while best practices such as M-POWER will be analysed in order to outline guidelines and key characteristics of a successful S.PSS applied to DRE model.

Finally, a new system design approach will be developed and tested as a promising contribute to the needed and key paradigm shift in the energy sector, seen by the most as the essential leverage for the transition towards a sustainable society.

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[1] The eight Millennium Development Goals (MDGs) – which range from halving extreme poverty rates to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015 – form a blueprint agreed to by all the world's countries and all the world's leading development institutions. http://www.un.org/millenniumgoals.

2 For example, many have observed (Stiglitz, 2002) that the rise in oil prices during the seventies and eighties was the main cause of debt increase in the third world. These nations were forced into debt, for billions of Euro, with international monetary institutions and with banks, to guarantee oil imports. In many of the world's poorest countries, the cost of paying interest and settling debts is today greater than the amount needed to provide essential services for their own populations.

3 The work involved a group of researchers (including the author) from industrialized, emerging and low-income countries; it was set up in 2000 and ended in 2002 presenting the main achievements within the publication UNEP, 2002. *Product-Service System. Opportunities for Sustainable Solutions*.

4 This hypothesis has also been examined in a series of case studies, collected by the group engaged by the UNEP.

[5] See: http://www.industrialization.go.ke/index.php?option=com_content&view=article&id=144&Itemid=161 from Department of Micro and Small Industries (MSI), Republic of Kenya and http://www.economic.gov.za/about-us/programmes/economic-policy-development/second-economy from Economic development department, Republic of South Africa

[6] MEPSS MEthodology for product Service System development (2002-2005: European project, 5th Framework Program GROWTH).

[7] HiCS Highly Customerised Solutions (2001-2004: European project, 5th Framework Program GROWTH).

[8] LeNS, the Learning Network on Sustainability, project funded by the European Union, Asia link programm (2007-2010); in particular by the Design and system Innovation for Sustainability (DIS) research group of the Design department of the Politecnico di Milano, head by Carlo Vezzoli has been the project coordinator.

[9] See Cortesi S., Vezzoli C., Donghi C. 2010. Case study of the design of Eco-Efficient Product-Service-System for KONE Corporation, using the MSDS method and tools in Ceschin F., Vezzoli C., Jun Z. (edit by), Proceedings Sustainability in Design: Now! Challenges and Opportunities for Design Research, Education and Practices in the XXI Century. Greenleaf Publishing Inc, Sheffield, 2010.

[10] http://offgrid-electric.com/

[11] http://www.ashden.org/winners/OffGrid14

[12] M-Pesa is a mobile-phone based money transfer and microfinancing service, launched in 2007 for Safaricom and Vodacom, the largest mobile network operators in Kenya and Tanzania.

[13] See: sunrideproject.wordpress.com

[14] A socio-technical experiment can be defined a partially protected environment where a broad network of actors can learn and explore (I) how to incubate and improve radical innovations and (II) how to contribute to their societal embedding. Socio-technical experiments in order to contribute to transition processes should be

conceived to act as: - *Labs*, to test, learn and improve the innovation on multiple dimensions (technical, usability, regulative, political, economic, socio-cultural ones), and in relation to different contexts; - *Windows,* to raise interest on the innovation project and the related actors, disseminate results, build-up synergies with existing similar projects/initiatives, and attract and enroll new potential actors; - *Agents of change,* to influence contextual conditions in order to favor and speed-up the societal embedding process. Experiments should be conceived to introduce and diffuse new ideas and knowledge to the community, and stimulate various social groups (users, public institutions, companies, etc.) to change their perspectives, beliefs, and lifestyles. (Ceschin, 2012)