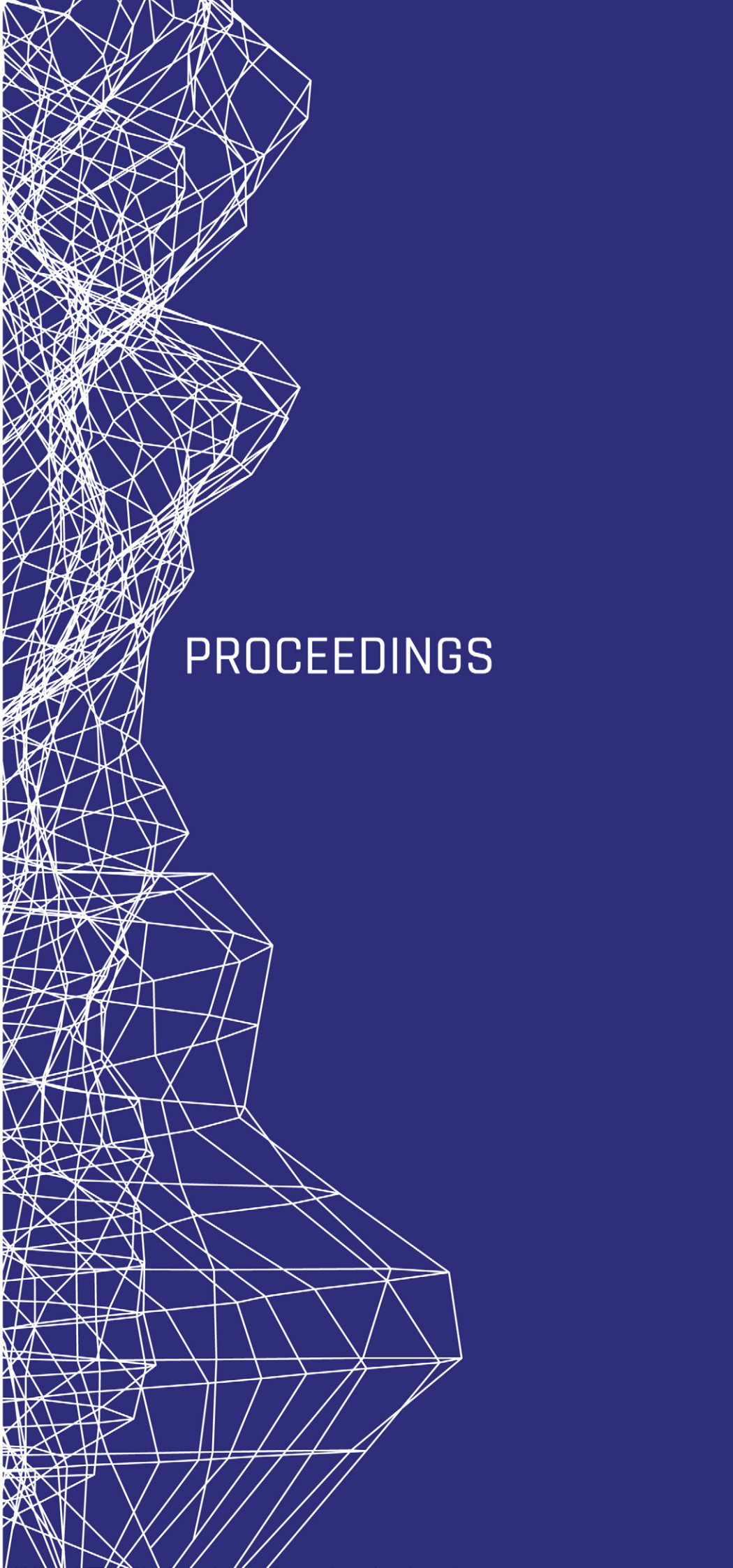
RSD7 2018

RELATING SYSTEMS THINKING AND DESIGN 7th SYMPOSIUM

CHALLENGING COMPLEXITY BY SYSTEMIC DESIGN TOWARDS SUSTAINABILITY



PROCEEDINGS

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WORKING PAPER

Sustainable Product Service System Design applied to Distributed Economies: a New Sustainable System Design Approach

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Abstract (150 words) One major issue attached to the transition towards a sustainable society is improving social equity and cohesion in low and middle-income contexts, while empowering locally-based enterprises and initiatives for sustainability, characterised by a democratisation of access to resources, goods and services.
Two promising and interwoven offer models coupling environmental with economic and social sustainability are the Sustainable Product-Service System (S.PSS) and the Distributed Economies (DE). The coupling of these two models is a new promising Research Hypothesis of the LeNSin (the international Learning Network of networks on Sustainability) for contributing to the transition towards a sustainable society for all, aiming at the diffusion of design for sustainability worldwide with a learning-by–sharing, open and copy-left ethos.
Within this framework, a new system design approach with method and tools have been developed, tested, and articulated. They are now part of the first open learning e-package on S.PSS applied to DE design.

Keywords: Sustainable Product-Service System (S.PSS), Distributed Economies (DE), Design for Sustainability (DfS), open and copyleft

1. Sustainable Product-Service Systems (S.PSS): A Win-Win Offer Model for Sustainability

A key contemporary query is the following: within the environmental and economic crisis which are the opportunities? Do we know any offer/business model capable of creating (new) value decoupling it from the materials and energy consumption? In other words, significantly reducing the environmental impact of traditional production/consumption systems?

In fact, Sustainable Product-Service System (S.PSS) has been studied since the end of the 90th as (one of) the most promising offer/business models in this perspective (Gpedkoop, van Halen, Riele et al.,1999; Mont, 2002; Tischner, Rayan, Vezzoli et al., 2009; UNEP, 2002; Vezzoli, Kohtala, Srinivasan, 2014). S.PSS has been recently 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 ownership of the product/s and/or its life cycle responsibilities remain by the provider/s, so that the economic interest of the providers continuously seeks environmentally and/or socioethically beneficial new solutions."* (Vezzoli, 2018).

1.1. S.PSS types

Three majors S.PSS approaches to system innovation have been studied and listed as favorable for eco-efficiency (Vezzoli, Kohtala, Srinivasan, 2014; Tukker & van Halen, 2003):

1. Product-oriented S.PSS: services providing added value to the product life cycle
2. Use-oriented S.PSS: services providing 'enabling platforms for customers'.
3. Result-oriented S.PSS: services providing 'final results' for customers.

Product-oriented S.PSS: adding value to the product life cycle (type I)

Product-oriented S.PSS innovation adding value to the product life cycle is defined as:
a company (alliance of companies) that provides additional services to guarantee an extended life cycle performance of the product/semi-finished product (sold to the customer).

A typical service contract would include maintenance, repair, upgrading, substitution and product take-back services over a specified period.
This reduces the user's responsibility in the use and/or disposal of the product/semi-finished product (owned by her/him), and the innovative interaction between the company and the customer drives the company's economic and competitive interest in continuously seeking environmentally beneficial new solutions, i.e. the economic interest becomes something other than only selling a larger number of products.

Use-oriented S.PSS: offering enabling platforms for customers (type II)

A use-oriented S.PSS innovation offering an enabling platform to customers is defined as:
a company (alliance of companies) offering access to products, tools, opportunities or capabilities that enable customers to meet the particular satisfaction they want (in other words efficiently

satisfying a particular need and/or desire). The customer obtains the desired utility but does not own the product that provides it and pays only for the time the product is actually used.

Depending on the contract agreement, the user could have the right to hold the product/s for a given period (several continuous uses) or only for one use. Commercial structures for providing such services include leasing, pooling or sharing of certain goods for a specific use.

The client thus does not own the products and does not operate them to obtain the final satisfaction (the client pays the company to provide the agreed results). Again, in this case the innovative interaction between the company and the client drives the company's economic and competitive interest to continuously seek environmentally beneficial new solutions, e.g. to design highly efficient, long-lasting, re-usable and recyclable products.

Result-oriented S.PSS: offering final results to customers (type III)

A result-oriented S.PSS innovation offering final results to customers can be defined as:
a company (alliance of companies) that provides a customized mix of services (as a substitute for the purchase and use of products), in order to provide an integrated solution to meet a particular customer's satisfaction (in other words a specific final result). The mix of services does not require the client to assume (full) responsibility for the acquisition of the product involved. Thus, the producer maintains the ownership of the products and is paid by the client only for providing the agreed results.

The customer does not own the products and does not operate them to achieve the final satisfaction; the client pays the company to provide the agreed results. The customer benefits by being freed from the problems and costs involved in the acquisition, use, and maintenance of equipment and products. The innovative interaction between the company and the client drives the company's economic and competitive interest to continuously seek environmentally beneficial new solutions, e.g. long-lasting, re-usable and recyclable products.

2. Distributed Economies (DE)

Distributed Economies (DE) is another model studied since 2005 (Johansson, Kisch, Mirata, 2005; Van Del Dool, Marchington, Ripken et al., 2009) as an alternative economic structure to the dominant Centralised one promising for locally-based sustainability (Johansson, Kisch, Mirata, 2005); DE has been recently defined as *"Small-scale production units, located by or nearby the end-users, whether individuals, entrepreneurs and/or organisations/institutions, i.e. the producers are the same end-users or nearby them. If the small-scale production units are connected with each other to share various forms of resources and/or goods (physical and knowledge-based ones), they become a Locally Distributed Economy Network, which may in turn be connected with nearby similar networks. If properly designed they are promising to promote locally-based sustainability, i.e. Sustainable Distributed Economies (S.DE)"* (LeNSin Polimi Team, 2018).

2.1. Types of Distributed Economies

There are different types of Distributed Economies (DE). Here below is a classification so far proposed within the LeNSin project classified in two groups: *hardware/natural resources-based DE* and *knowledge/information-based DE* (LeNSin Polimi Team, 2018)*:*

HARDWARE/NATURAL RESOURSES-BASED DISTRIBUTED ECONOMIES (DE) TYPES

Distributed energy Generation (DG)
An example of Distributed energy Generation (DG) system is (the shift from *centralized coal power plant* to) a *home-based solar energy plants connected in mini-grid.*

Distributed Manufacturing (DM)
An example of Distributed Manufacturing (DM) system is (*the shift from centralized furniture production to) a 3D printed furniture production.*

Distributed production of Food (DF)
An example of a Distributed production system of Food (DF) is (the shift from *intensive farming/ supermarket* to) *a urban gardening.*

Distributed Water management (DW)
An example of Distributed Water management (DW) system is (the shift from *centralized urban water supply* to) *a decentralized access to clean water from underground.*

KNOWLEDGE/INFORMATION-BASED DISTRIBUTED ECONOMIES (DE) TYPES
Distributed production of Software (DS)
A well-known example of a Distributed production of Software (DS) is (the shift from *proprietary software* to) *an open source software "Linux".*

Distributed production of Information/knowledge (DI)
A well-known example of a Distributed production of Information/knowledge (DI) is (the shift from *traditional encyclopaedia* to) *open encyclopaedia "Wikipedia". In fact, the same LeNS network of HEIs network could be classified into this category.*

Distributed Design (DD)
An example of a Distributed production of Information/knowledge (DI) is (the shift from *Design department of multinational car manufacturer* to) *an open source car design platform e.g. the OSVehicle a Modular Open Source Electric Car Platform that enable businesses and startups to design, prototype, and build electric vehicles and transportation services. https://www.osvehicle.com. Other examples of a Distributed Design (DD) are: the Open IDEO platform https://openideo.com/; the Innonative platform developed with the support of the Life+ programme of the European Union www.innonative.com.*

2.2. Distributed Economies configuration

Distributed Economies (DE) are in fact **small**-scale **locally-based** offer models, eventually **network-structured**, defining a paradigm shift from dominant centralized production systems (see Figure 1).

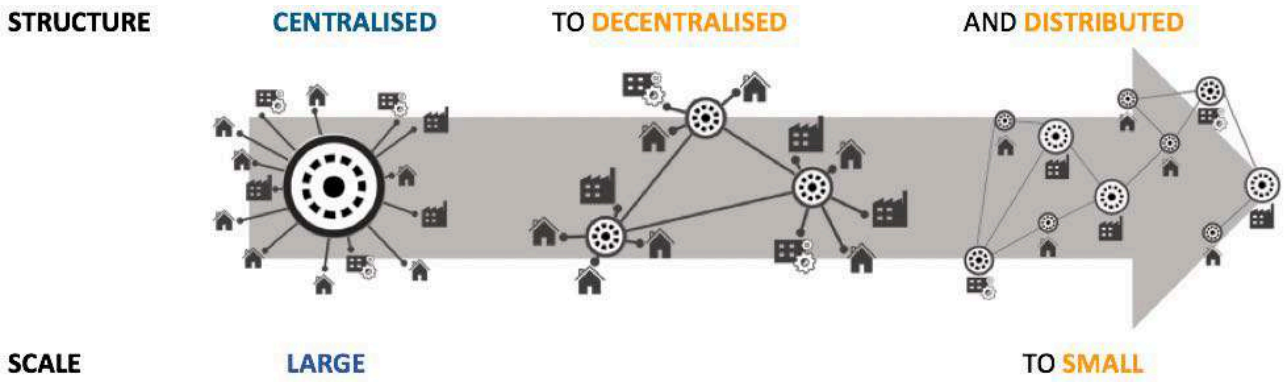


Figure 1. The paradigm shift from centralized to distributed locally-based systems

Centralized Economies could be defined as large-scale production units that controls essential activities and deliver their goods (physical and/or knowledge-based) via great distribution networks, to very many (often) far away customers, whether individuals, entrepreneurs or other organizations/institutions.

Figure 2. The structure of the production unit of Centralized Economies

Decentralised Economies could be defined as small-scale production units that deliver their goods (physical and/or knowledge-based ones) directly to nearby customers, whether individuals, entrepreneurs or other organizations/institutions. These production units could be standalone or connected to each other to share various forms of resources and/or goods (physical and/or knowledge-based ones); e.g. to share the energy surplus). In the latter case, they become Decentralized Economy Local Network, which may in turn be connected with nearby similar networks.

Figure 3. The structure of the production unit of Decentralized Economies

Distributed Economies (DE) could be defined as (very) small-scale production units of goods (physical and/or knowledge-based ones) located by the end-users (that become the producers, i.e. prosumer) that have the control on essential activities, whether individuals, entrepreneurs or organizations/institutions. These production units could be standalone or connected to each other to share various forms of resources and/or goods (physical and/or knowledge-based ones). In the latter case, they become Distributed Economy Local Network, which may in turn be connected with nearby similar networks.

Figure 4. The structure of the production unit of Distributed Economies

Distributed Economies in comparison to Centralised Economies (as shifting from Centralised Economies to Distributed Economies) could be distinguished in term size, proximity, structure, resilience, responsiveness, diversity of solutions, locally-based sustainability potential.

In fact, the DE configuration could be characterised by one of the following sub-structures:

- Stand-Alone DE systems
- A DE network
- A DE network of networks
- A DE connected to a Centralized Network.
-

Stand-Alone DE systems

They are, either distributed or decentralised production unit without any local delivery system (network) with nearby customers and/or production units.

A *Stand Alone Distributed* system is an isolated production unit by the user; either an individual or an enterprise (see the examples in Table 2).

A *Stand Alone Decentralised* system is an isolated production unit where customer go to benefit from the outcomes of the production unit (see examples in Table 2).

A DE network

They are either distributed, decentralised or centralised production unit or hybrid of more than one such type of production units with a delivery system (network) with customers and/or production units.

A *Centralised network system* is a network of production unit far from the user with a large delivery system for various forms of resources (physical and/or knowledge-based ones) towards either individuals or enterprises distributed in a large scale of area such as a state/s, country/ies, continent/s or worldwide.

A *Decentralised network* system is a production with a local delivery system (network) for various forms of resources (physical and/or knowledge-based ones) towards either nearby individuals or nearby enterprises (see the figure in Table 1).

A *Distributed network* system is a network of production unit by the user; either an individual or an enterprise(see the figure in Table 1) to share locally various forms of resources (physical and/or knowledge-based ones; e.g. to share the energy surplus) with nearby individuals.

A *Hybrid network system* is a network of production unit that consists of two or more type of centralised, decentralised, or distributed network systems.

A DE network of networks

They are either centralised, distributed or decentralised production units or local networks *connected to a other Networks* to share various forms of resources (physical and/or knowledge-based ones; e.g. to share the energy) (see the figure in Table 1).

A DE connected to a Centralized Network

They are either distributed or decentralised production units or local networks *connected to a Centralized Network* to share various forms of resources (physical and/or knowledge-based ones; e.g. to share the energy) (see the figure in Table 1).

The tab below summarizes the main possible configurations of DE systems.

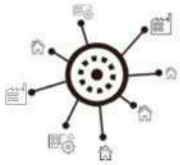
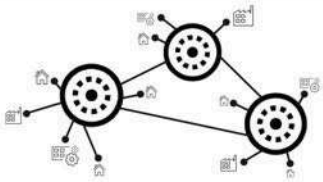
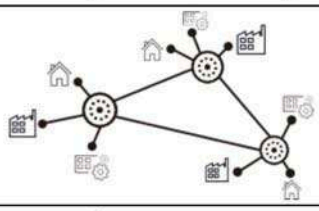
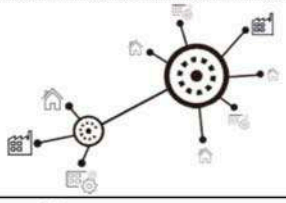
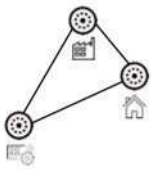
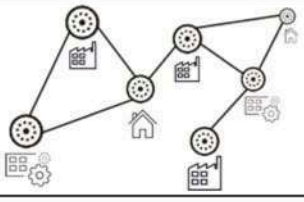
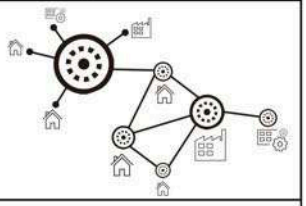
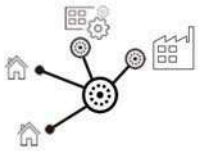
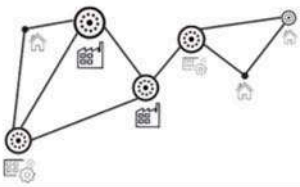
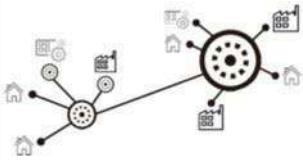
	Stand Alone	NEtwork	Network of Networks	Centralized Connected
CEntralized				
DeCentralised				
DiStributed				
Hybrid				

Table 1. Possible DE systems configurations

In the following table, various key network-DE structure configurations are exemplified with different DE classifications:

	Stand-alone - distributed	Stand-alone - decentralised	Network - distributed	Network - decentralised
DG	a small wind farm which provides energy to a village with a local mini-grid	solar powered energy charging station, where people go to charge their phone, etc.	set of solar panels for home use, connected via a local-mini grid to share the energy surplus	solar panel for a single household energy production
DF	local baker which delivers bread to the houses in the neighbourhood every morning	local producer of organic vegetables and fruits selling directly to consumer in a shop by the fields	neighbourhood club for home gardening for private use, enabling the sharing of production surplus	home gardening for private use
DW	water gathered from a local spring water source distributed to the households in the village through a local piping infrastructure	medium size water collector where local people access with their tanks to get the water	roof rain water harvesting for private use, with neighbourhood piping infrastructure for surplus sharing	harvesting rain water from the home roof for private use
DM	an entrepreneur locally delivering 3D printed items made on request	maker selling 3D printed artefacts directly to final user in a shop by the workshop	a local 3D printer owner produces items for home use while producing for the local community on request during the unused time of the printer	making clothes at home using sewing machines for own use
DS	a software developer providing service installing the home security system she developed going to the homes	a software developer selling the home security system she developed from her office to the local community	developing open source software collaborating with a local community of developers at home to create a home security system	developing software at home to create a home security system
DI	providing a local consultancy service about gardening, by going to the customers' gardens in the town	a farming expert providing a consultancy service in her office about farming for the region	small weather station for forecast located at home for your own use + sharing the information with your local community	(very) small weather station for home forecast
DD	an architect providing a service for the local community to improve the houses going to the location of the houses	providing a service in your studio for the local customers to design custom furniture	Designing your own clothes at home and sharing your design with your local community	designing your own clothes at home

Table 2. Different DE Classification Examples for network-DE structure configurations

3. S.PSS Applied to DE: a Promising Approach to Diffuse Sustainability in Low/Middle-Income (All) Contexts

The paper discusses an innovative system approach to sustainability, i.e. the win-win potential of coupling S.PSS and DE for a sustainable society for all, which is the Research Hypothesis of the LeNSin (the international Learning Network of networks on Sustainability) project, funded by the EU Erasmus+ programme involving 36 universities from Italy, Finland, Netherlands, United Kingdom, China, India, Brazil, Mexico and South Africa. The Research Hypothesis runs as follow: (LeNSin Polimi Team, 2015).

A S.PSS applied to DE is a promising approach to diffuse sustainability in low/middle-income (all) contexts, because it reduces/cuts both the initial (capital) cost of DE hardware purchasing (that may be unaffordable) and the running cost for maintenance, repair, upgrade, etc. of such a DE hardware (that may cause the interruption of use), while increasing local employment and related skills, as well as fostering for economic interest of the producer/provider to design low environmentally impacting DE products, i.e. resulting in a key leverage for a sustainable development process aiming at democratizing the access to resources, goods and services.

Below in Figure 5 it is given an example of a win-win S.PSS model applied to DRE (one of the type of DE) in a low income context.

Figure 5. An example of S.PSS. applied to DE (DRE)

Let us specify a bit further the above Research Hypothesis, i.e. let us see in a more schematic way the main reasons why a Sustainable Product Service System model offer applied to Distributed Economies should open new opportunities for a sustainable development (even) in low and middle-income contexts:

- selling to **final users** the **access** rather than **DE product** ownership, reduces/**avoids** the **purchasing costs** of those DE hardware (frequently too high for low and middle-income people), making goods and services more easily accessible
- selling to **final user** all-inclusive **life cycle serv**ices with **DE product** offer, reduces/**avoids running cost** for maintenance, repair, upgrade, etc. (frequently too high for low and middle-income people) avoiding the interruption of DE product use
- selling to to **entrepreneur** the **access** rather than **DE equipment** ownership, reduces/**avoids** initial (capital) **investment costs** (frequently too high for low and middle-income entrepreneurs), facilitating new business start-up
- selling to **entrepreneur** all-inclusive **life cycle serv**ices with **DE equipment** offer, **r**educes/**avoids running cost** for maintenance, repair, upgrade, etc. (frequently too high for low and middle-income entrepreneurs), avoiding the interruption of DE equipment use, i.e. interruption of working activities
- offering goods and services without DE product/equipment purchasing costs, open **new market opportunities** as new potential customers form low and middle income contexts (BoP), i.e**. potentially empowering locally-based economies.**

For what concern the environmental benefits we could highlights that applying an S.PSS model foster an environmentally sustainable DE diffusion, because a DE producer/provider selling it to a final user/entrepreneur as an S.PSS offer model to is economically interested in designing it for DE product/equipment:

- lifespan extension and use intensification;
- material life extension (recycling, energy recovery, composting);
- materials minimizations;
- energy minimizations;
- resources (materials and energy) renewability/biocompatibility;
- resources (materials and energy) toxicity/harmfulness minimizations.

It is useful to highlight that the Research Hypothesis is, in fact, the coupling of two paradigm shifts (see the Figure 6):

- the shift from traditional product sale model to S.PSS, i.e. the shift of customer perceived value from individual ownership to access to a mix of products and services (systems) fulfilling a given unit of satisfaction;
- the shift from centralized to decentralized/distributed systems in which a small scale unit of production is locally-based, i.e. nearby or at the point of use, and where the user can become a producer.

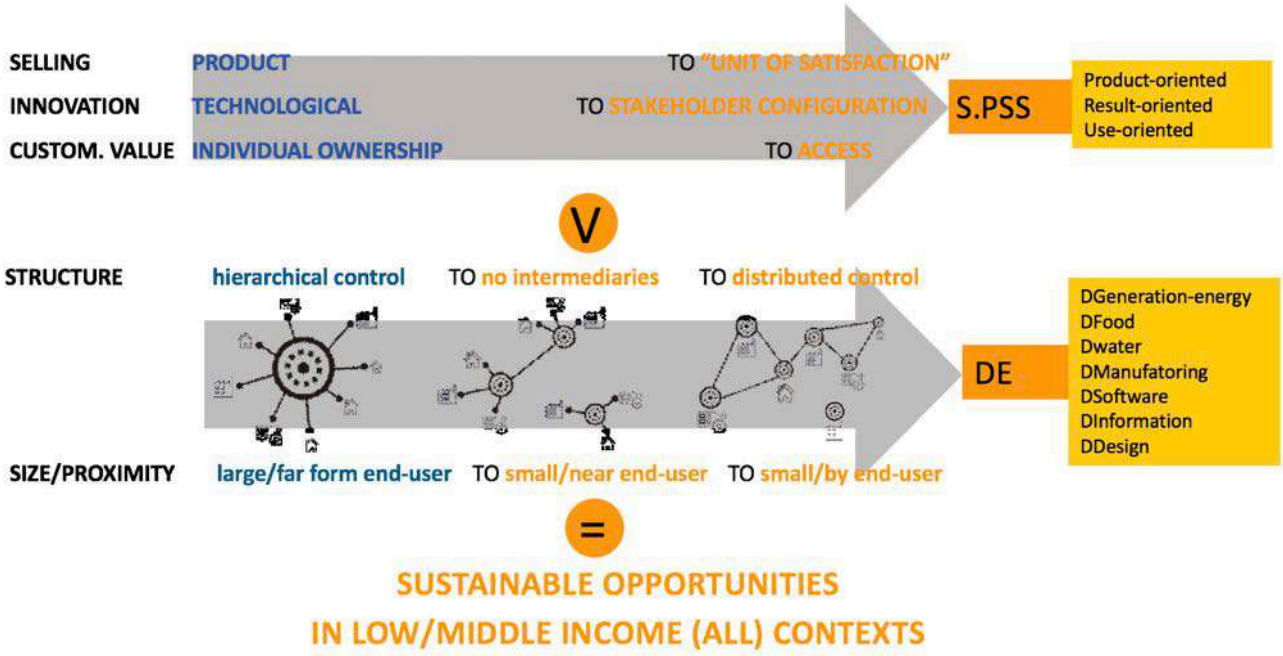


Figure 6. The coupling the 2 paradigm shifts represented by S.PSS and DE

Shifting the concern of the design role, the following Research Hypothesis (LeNSin Polimi Team, 2015) has been studied by envisioning a new system design role to design for S.PSS applied to DE.

4. Methodology

S.PSS applied to DE Design Approach, method and tools have been explored and characterised mainly within the LeNSin project with the following process:

State of the Art: each of the 36 partner institutions carried out literature review on the Design for Sustainability (DfS) topic, current practices and approaches in DfS, followed by a coordinated case study analysis. The results of those activities were shared between all partners in a meeting and trough the project web platform.

Design of the new method and tools: A new method and design tools for S.PSS applied to DE has been designed and developed within the LeNS Lab Polimi as well as by the other project partners in relation to their own sustainability agenda. These activities were followed by 5 seminars held in Brazil, South Africa, Mexico, China and India, where the partners gathered academics, companies, NGOs, governmental institutions, etc. All developed until that point has been shared in these seminars, in which the input from the attendees have been collected. All the activities of the project were video-recorded and uploaded on the project website to be made accessible to all the researchers in the project, which made possible to gather feedback from a large group of researchers. All these activities led to a refinement and characterisation of the Research Hypothesises (that includes the approach), and the developed methods and tools.

Testing and further development: All produced that far were the bases for the design and implementation of the first round of 5 pilot courses held in the non-European partner countries, where local and European teachers were involved in the teaching and evaluating boards. All of the learning resources (syllabus, videos of the lectures, slides, case studies, tools, etc.) have been shared with other partners right after the end of each course. A second round of pilot courses was then carried out with the same logic in different universities and with different guest EU teachers and observers. At the end, a total of 10 pilot courses were carried out, each of them evaluated by a questionnaire given to both students and professors. All the pilot courses were also video-recorded and shared on the project platform.

Development of the final version: In parallel to the activities in the LeNSin Projects, the method and design tools for System Design for Sustainability for All have also been used and tested in the System Design for Sustainability course at Politecnico di Milano by Polimi LeNS Lab, where the final working versions of the method and tools have been developed. Nevertheless, their update and development are continuing by Polimi LeNS Lab through testing-by-using in the System Design for Sustainability course at Polimi as well as through synergies among the course materials developed by the other LeNS partners since all the course materials developed on the topic by the partners of the project are uploaded on the LeNS Platform as open source.

5. Sustainability Design-Orienting Scenario for S.PSS Applied to DE

A Sustainability Design-Orienting Scenario for S.PSS applied to DE has been developed within the project, which is composed by a polarity diagram with 4 visions (see Figure 7), each representing a Sustainable win-win configuration; combining socio-cultural, organizational and technological factors, fostering solutions with a low environmental impact, a high socioethical quality and a high economic and competitive value. It is polarised on the vertical axis by the type of DE structure, **distributed** or **decentralised**, and on the horizontal axis on the type of customer, **B2C** (final user or small communities) or **B2B** (small entrepreneur or small business). The crossing of those polarities produced the 4 vision that are shown in the diagram below:

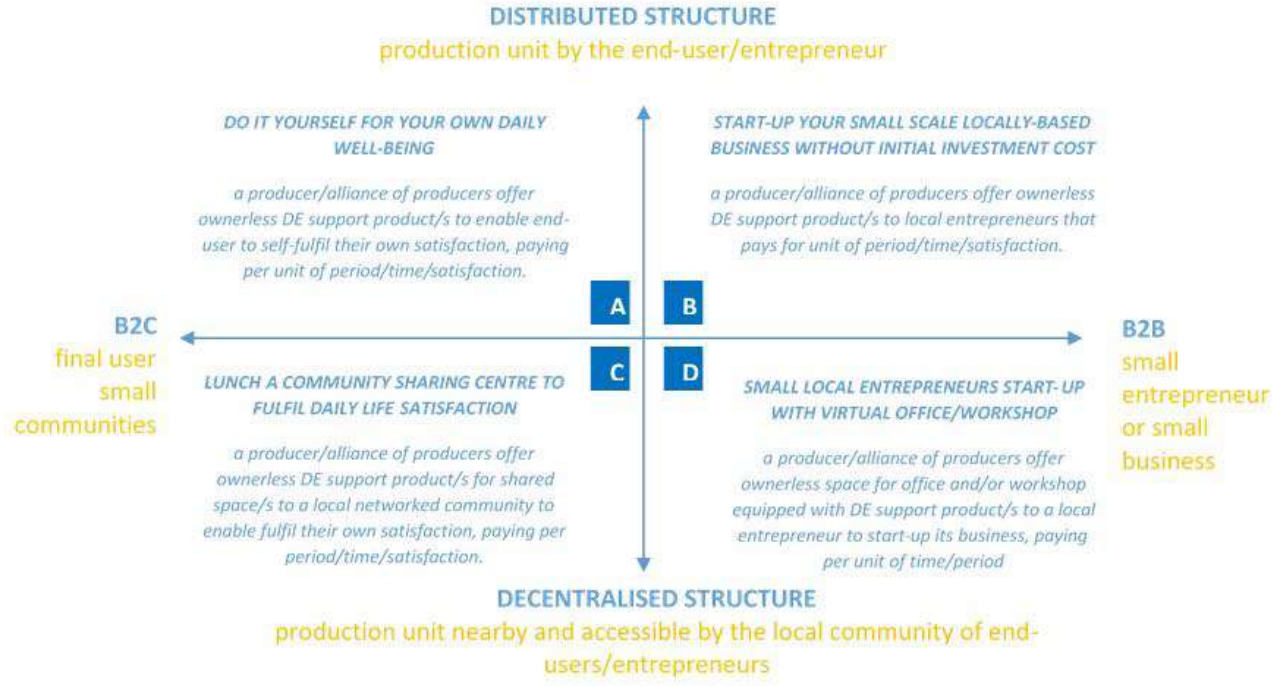


Figure 7. The design-orienting scenario for S.PSS applied to DE

6. System Design for Sustainability for All: a New Role Designing S.PSS Applied to DE

Finally, for ***Designing Sustainable Product-Service System applied to Distributed Economies,*** the following new role of designer is envisioned as defied below: (LeNSin Polimi Team, 2015)

SD4SA:
"design of S.PSS applied to DE, i.e. the design of the Systems of Products and Services that are together able to fulfil a particular customer demand (deliver a "unit of satisfaction"), within the DE paradigm; based on the design of innovative interactions among locally-based stakeholders, where

the ownership of the product/s and/or its life cycle responsibilities remain by the provider/s, so that economic interests of the provider/s continuously seek both environmentally and socio-ethically beneficial new solutions, i.e. solutions accessible to all".

Within this framework there is the need to develop the new knowledge-base and know-how for the new competences in Designing and implementing Sustainable Product-Service System applied to Distributed Economies.

Based on the key approaches/skills of S.PSS design (Vezzoli, Kohtala, Srinivasan et al., 2017) the following could be derived as a first tentative description for System Design for Sustainability for All:

A. "satisfaction-system" approach: *design the satisfaction of a particular demand ("satisfaction unit") and all its related DE products and services;*
B. "stakeholder configuration" approach: *design the interactions of the stakeholder of a particular DE satisfaction-system;*
C. "system sustainability4all" approach: *design sustainable for all DE (offer model) where the economic and competitive interests of the providers continuously seek for environmental and socioethical beneficial new solutions.*

In fact, this new role in (System) Design for Sustainability for All, moves from mere "appropriate technologies" design to "appropriate stakeholder configuration" design, to address S.PSS applied to DE.

In this framework, the two key disciplinary grounds to be merged, redefined and up-dated are those of Product-Service System design for Sustainability and that of Distributed Economies (DE) design and development.

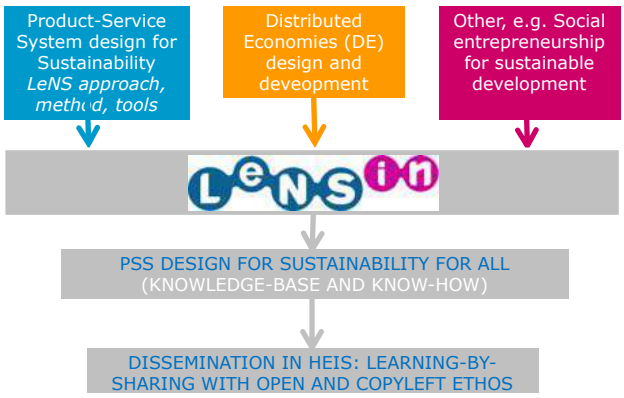


Figure 8. Knowledge area sources for the building of the new discipline of System Design for Sustainability for All

7. Tools Developed for System Design for Sustainability for All Approach

A set of design tools for System Design for Sustainability for all (SD4SA) are developed to support design processes for the development of S.PSS, applicable to DE at the LeNS Lab at Politecnico di Milano. These tools are adaptable to specific design requirements and usable in existing design processes. In the figure below, the main phases and tools are listed.

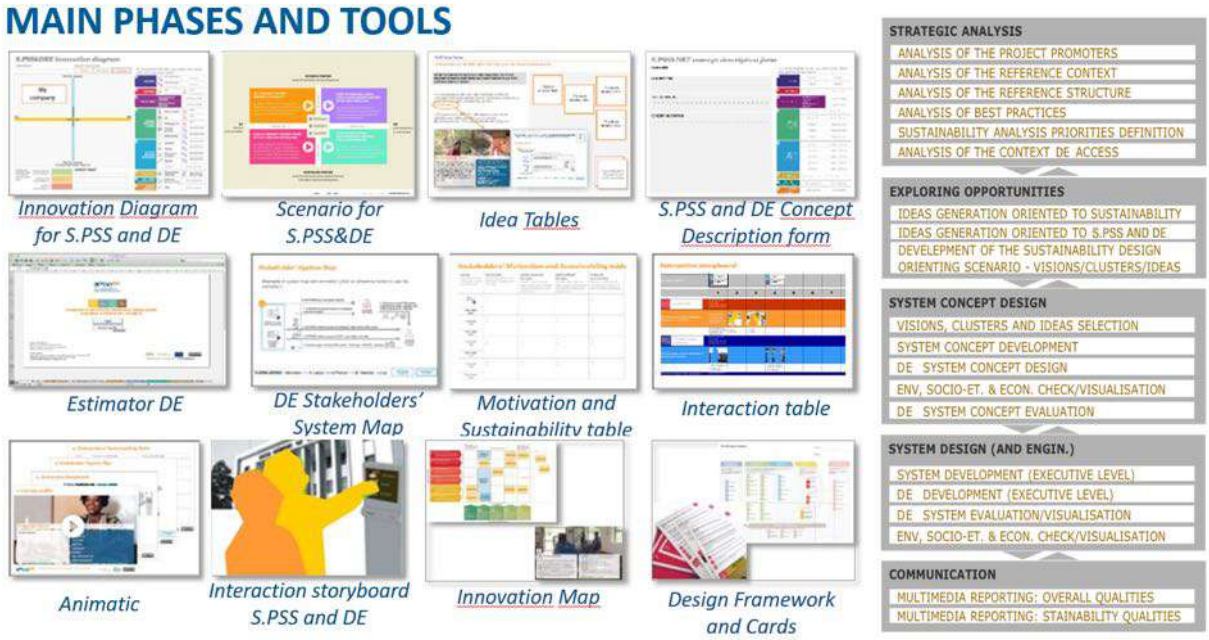


Figure 9. SD4SA main design phases and tools

In particular, the following tools are developed for S.PSS applied to DE:

- **Sustainability Design-Orienting Scenario _S.PSS&DE** for inspiring Sustainability For All ideas generation (S.PSS applied to DE)
- **Sustainability Design-Orienting (SDO) Toolkit** for orientating system design process towards sustainable solutions (environmental, socio-ethical, economic)
- **SDO Idea Table** for orientating DE idea generation process towards S.PSS offer model
- **Innovation Diagram** for positioning and characterizing existing offer and competitors; selecting promising ideas and starting characterizing S.PSS&DE concept profile
- **System Map** for visualizing (design and co-design) the configuration of the system, describing actors involved and their interactions

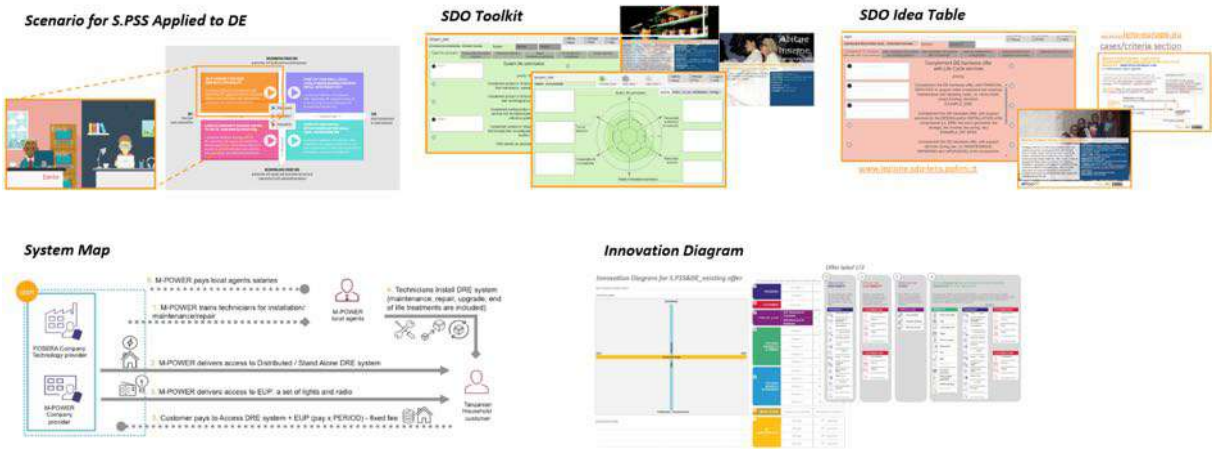


Figure 10. Tools developed for S.PSS applied to DE

8. Conclusion

The paper contents are innovative as both the understanding (and the description) of the win-win potentials of S.PSS applied to DE; and the related system design approaches, skills and tools are new. Those outcomes resulted from a process where their validity and characterisation have been carried out by a well-integrated groups of multidisciplinary and multicultural worldwide researchers. Finally, all the learning resources on the knowledge-base and know-how developed in the project are uploaded on the LeNS web platform, where they could be downloaded free of charge, with an open and copy-left ethos. The outcomes achieved are already innovative and relevant, but at the same time, it is clear that new research activities are needed to better identify the win-win characteristics of S.PSS applied to DE as well as the approaches and the skills for a new generation of designer adopting a system approach to effectively address the sustainability challenge.

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