Lecture Notes in Mechanical Engineering

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Designing Sustainability for All

The Design of Sustainable Product-Service Systems Applied to Distributed Economies

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ISSN 2195-4356 ISSN 2195-4364 (electronic)
Lecture Notes in Mechanical Engineering
ISBN 978-3-030-66299-8 ISBN 978-3-030-66300-1 (eBook)
https://doi.org/10.1007/978-3-030-66300-1

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

With the support of the
Erasmus+ Programme
of the European Union

The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Foreword

During the last few decades, the history of design culture and practice, when dealing with the issue of sustainability, has moved from individual products to systems of consumption and production, and from strictly environmental problems to a complex blend of socio-ethical, environmental and economic issues. In this context, a clear challenge is to provide Sustainability for All (accessible even within low- and middle-income contexts), coupling environmental protection with social equity, social cohesion and economic prosperity. Within this framework, it is crucial that design can take a proactive role and become an agent to extend access to sustainable solutions. Design can do so because within its genetic code, by principle its role is to improve the quality of the world: an ethical–cultural component that, though not generally apparent, can be found in a deeper examination of the majority of designers' motivations. Finally, it is evident that a key role has to be played by Higher Education Institutions, both in researching and defining the new roles designers may play, as well as in curricular proposals where a new generation of design should grow. A challenging journey is ahead of us. And from this perspective, we believe this book will contribute to a larger change in the design community invited to meet this challenge.

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Acknowledgements

This volume is a collaboration of the following authors representing all partners in the LeNSin project.

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Introduction

One major issue attached to the transition towards a sustainable society is that of improving **social equity and cohesion**, while empowering **locally based** enterprises and initiatives, for an **environmentally** sustainable re-globalization process characterized by a **democratization of access to resources**, **goods** and **services**. For a just and sustainable world, this necessitates attention to capacitating low- and middle-income contexts, regions or social groups and enabling access to resources, at the same time as enhancing local capabilities in high income regions in a way that does not exploit the poor and vulnerable. Two promising and interwoven offer models coupling environmental with economic and social sustainability are Sustainable Product-Service Systems (S.PSS) and Distributed Economies (DE). In relation to these two models, a new promising Research Hypothesis has been proposed, studied and characterized during the LeNSin Erasmus+ European Union funded project[18] and a new promising role of and for design has been envisioned. The outcomes of this research endeavour are elaborated in this book.

Firstly, the concept of Sustainable Product-Service Systems (S.PSS) is introduced as a known win-win offer model for sustainability. The idea of Distributed Economies (DE) is then introduced as a promising offer model for locally based sustainability. This is followed by an elaboration of the following scenario: S.PSS applied to DE as an opportune approach to diffusing sustainability for all. A scenario of S.PSS applied to DE is presented together with illustrative case studies. Finally, a new role for design in developing the S.PSS applied to DE model is presented, i.e. System Design for Sustainability for All (SD4SA).

[18] LeNSin, the International Learning Networks on Sustainability is an EU-supported (ERASMUS+) project. It aims to promote a new generation of designers and educators capable of effectively contributing to the transition towards a sustainable society for all. The partnership includes 36 universities and institutions (14 partners and all other associated partners) from Brazil, China, India, Mexico, South Africa and, in Europe, Finland, Italy, The Netherlands and the United Kingdom. It is part of the LeNS network established in 2007, now involving more than 150 Higher Education Institutions from all continents, that adopt a learning-by-sharing approach to knowledge generation and dissemination, with an open access ethos. www.lens-international.org.

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Product-Service Systems Development for Sustainability. A New Understanding

Carlo Vezzoli, Fabrizio Ceschin, and Jan Carel Diehl

1 The Role of PSS in Addressing Sustainability

1.1 The Sustainability Challenge

In 1972 the book *Limits to Growth* was published based on a first computerized simulation of the effects on nature of the ongoing system of production and consumption [19]. It was the first scientific forecast of a possible global eco-system collapse. Fifteen years later, in 1987, the United Nations (UN) World Commission for Environment and Development (WCED) provided the first definition of Sustainable Development: A social and productive development that takes place within the limits set by "nature" and meets the needs of the present without compromising those of the future generation within a worldwide equitable redistribution of resources. This also incorporates the fundamental challenge of social equity and cohesion (i.e. the socio-ethical dimension of sustainability). In the autumn of 2015, the UN updated the commitments, goals and actions for sustainable development by approving the "Agenda 2030 for Sustainable Development" [28] as a mutual commitment to global development, in favour of human well-being and to preserve the environment. The main outputs of the Agenda are the 17 Sustainable Development Goals (SDGs), which gather together the main challenges to be achieved by 2030 in relation to the three dimensions of sustainable development, i.e. the environmental protection, the social inclusion and the economic prosperity.

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C. Vezzoli et al. (eds.), *Designing Sustainability for All*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-3-030-66300-1_1

It is within this framework that this book presents Sustainable Product-Service System (S.PSS) and Distributed Economies (DE) as key promising and interwoven offer models coupling environmental and social with economic sustainability. Moreover, S.PSS applied to DE is a promising approach to diffuse sustainability in low- and middle-income contexts. This volume also elaborates on the role design can play to generate new ideas and solutions addressing S.PSS applied to DE, as well as develop and diffuse related solutions, i.e. designing sustainability for all. This chapter presents an updated understanding of how PSS addresses Sustainability and the role of design.

1.2 Sustainable Product-Service System: A Win-Win Opportunity for Sustainability

A key contemporary query is the following: within the entangled and complex environmental, social and economic crises, where are the opportunities? Do we know any offer or business model capable of creating (new) value, decoupling it from material and energy consumption? In other words, significantly reducing the environmental impact of traditional production/consumption systems? In fact, the concept of Sustainable Product-Service System (S.PSS) has been studied since the end of the 1990s [10, 12, 18, 20, 23, 29] as a promising offer/business model in this regard. More recently, S.PSS has been demonstrated [32, 36] to be a clearly promising offer model to extend the access to good and services even to low- and middle-income contexts, thus enhancing social equity and cohesion as well. Finally, it is a win-win offer model combining the three dimensions of sustainability, the economic with the environmental and the socio-ethical. An S.PSS can be defined as follows [36]:

> Sustainable Product-Service System (S.PSS) is an offer model providing an integrated mix of products and services that are together able to fulfil a particular customer/user 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 the life cycle services costs/responsibilities remain with the provider/s, so that the same provider/s continuously seek/s environmentally and/or socio-ethically beneficial new solutions, with economic benefits.

S.PSSs are value propositions introducing considerable innovation on different levels (see also Fig. 1):

- They shift the business focus from selling (only) **products** to offering a so-called "**unit of satisfaction**",[1] i.e. a combination of products and services jointly capable of achieving an ultimate user satisfaction.
- They shift the value perceived by the customer/end-user from **individual ownership** to **access** to goods and services.
- They shift the primary innovation from a **technological** one to an innovation on a **stakeholder interaction** level.

This approach is also supported by the European Union in its action plan on the Circular Economy, when stating that: "incentivising product-as-a-service or other models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle" [10]. Finally, in the key understanding of our discourse, S.PSSs are offer models with a win-win sustainability potential, i.e. they are offer/business models capable of creating (new) value, decoupling it from resource consumption and increase of negative environmental impact whilst extending access to good and services to low- and middle-income people and, at the same time, enhancing social equity and cohesion.

1.3 PSS Types

Three main S.PSS approaches to system innovation have been studied and listed as favourable for eco-efficiency [13, 26, 29, 37]:

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)

Let us start with an example of an eco-efficient system innovation adding value to the product life cycle.

Fig. 1 S.PSS: a paradigm shift from a traditional product offer

[1] A satisfaction unit can be defined as [36] "a defined (quantified) satisfaction of a customer that could be fulfilled by one or more mix of products and services, used as a reference unit to design and to evaluate the sustainability benefits and impacts".

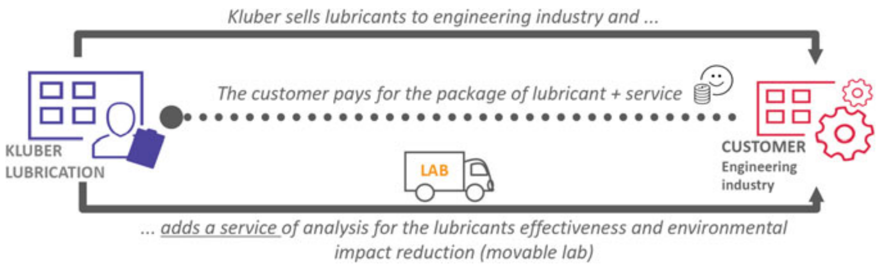

Fig. 2 Klüber lubricants service. Main company-customer interactions

Klüber lubricants service
Klüber offers lubricants plus the service for on-site identification of equipment inefficiency, and the potential reduction of emissions' impact (see Fig. 2). This innovative interaction between the company and the customer adding all-inclusive life cycle services allows the company's economic interest to be different from only selling more lubricants.

In summary, a ***Product-oriented S.PSS*** *innovation* adding value to the product life cycle is defined as:

> a company/organization (alliance of companies/organizations) that provides all-inclusive life cycle services – maintenance, repair, upgrading, substitution and product take-back – to guarantee the life cycle performance of the product/semi-finished product (sold to the customer/user).

A typical service contract would include maintenance, repair, upgrading, substitution and product take-back services over a specified period of time. The customer/user responsibility is reduced to the use and/or disposal of the product/semi-finished product (owned by the customer), since she/he pays all-inclusively for the product with its life cycle services, and the innovative interaction between the company/organization and the customer/user drives the company/organization's economic interest in continuously seeking environmentally beneficial new solutions, i.e. the economic interest becomes something other than only selling a larger amount of products.

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

The following box describes an example of an eco-efficient system innovation as enabling platforms for customers.

Riversimple. Pay-per-month mobility solution
Riversimple provides a pay-per-month ownerless car with all-inclusive energy, maintenance, repair, insurance and end-of-life collection (see Fig. 3). This

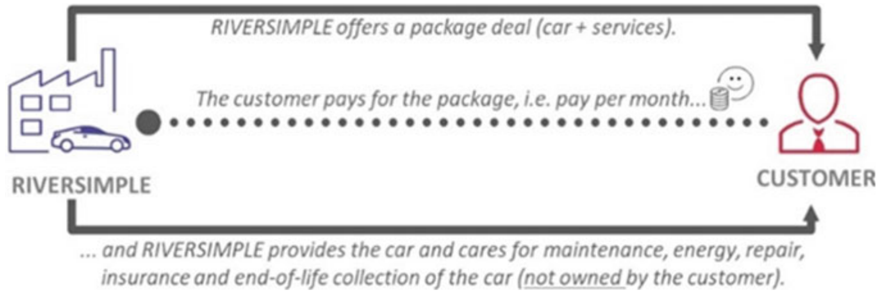

Fig. 3 Riversimple. Pay-per-month mobility solution

type of innovative interaction between the company and the customer (ownerless car with all-inclusive life cycle services) promotes the provider's economic interest to foster the design or offer of a long-lasting, energy-efficient and recyclable car.

In summary, a ***use-oriented S.PSS*** *innovation* offering an enabling platform to customers is defined as:

> a company/organization (alliance of companies/organizations) that provides access to products, tools and opportunities enabling the customer to get their "satisfaction". The customer/user does not own the product/s but operates them to obtain a specific "satisfaction" (and pays only for the use of the product/s).

Depending on the contract agreement, the customer/user could have the right to hold the product/s for a given period of time (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 customer/user consequently does not own the products, but operates on them to obtain a specific final satisfaction (the client pays for the use of the product). Again, in this case, the innovative interaction between the company/organization and the customer/user drives the company/organization to continuously seek environmentally beneficial new solutions together with economic benefits, e.g. to design highly efficient, long-lasting, reusable and recyclable products.

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

The following describes an example of an eco-efficient system innovation providing final results to customers.

Philips. Pay-per-Lux
The customer pays to have an agreed amount of lighting (lux) in its building. Philips is responsible for (paying for) the installation, upgrading, repair and

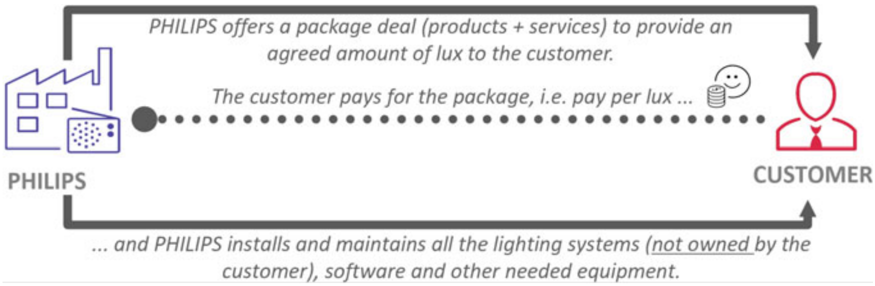

Fig. 4 Philips. Pay-per-Lux

end-of-life collection of all products/equipment (owned by Philips) (Fig. 4). This kind of innovative interaction between the company and the customer (an ownerless lighting system with all-inclusive life cycle services) encourages the provider's economic interest to foster the design/offer of long-lasting, reusable and recyclable lighting systems.

A ***result-oriented S.PSS*** *innovation* offering final results to customers can be defined as:

> a company/organization (alliance of companies/organizations) that offers a customized mix of services, instead of products, in order to provide a specific final result to the customer. The customer/user does not own the products and does not operate on them to obtain the final satisfaction (the customer pays the company/organization to provide the agreed results).

The customer/user 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 customer/user drives the company's economic and competitive interest to continuously seek environmentally beneficial new solutions, e.g. long-lasting, reusable and recyclable products. Moreover, if properly conceived, S.PSS can offer to low- and middle-income people the possibility to have access to services that traditional product sales models would not allow (i.e. by lower initial costs).

In fact, it has been argued that in low- and middle-income contexts "an S.PSS innovation may act as a business opportunity to facilitate the process of socio-economic development by jumping over the stage characterized by individual consumption/ownership of mass-produced goods towards a 'satisfaction-based' and 'low resource-intensity' advanced service-economy" [29].

1.4 S.PSS Environmental Benefits

When is an S.PSS eco-efficient? Better still, when is an S.PSS decoupling the economic interests from both an increase in resource consumption and a decrease of demaging environmental impacts?

In other words, why and when is an S.PSS producer/provider economically interested in design for environmental sustainability? The following S.PSS environmental and economic win-win benefits could be highlighted (adapted from [36]):

(a) *Product lifetime extension*: As far as the S.PSS provider is offering the products retaining the ownership and being paid per unit of satisfaction, or offering all-inclusive the product with its maintenance, repair, upgrade and substitution, the **longer** the product/s or its components last (environmental benefits), and the **more** the producer/provider avoids or postpones the disposal costs plus the costs of pre-production, production and distribution[2] of a new product substituting the one disposed of (economic benefits). Hence the producer/providers are driven by economic interests to design (offer) for lifespan extension of product/s (with eco-efficient product Life Cycle Design (LCD) implications) (Fig. 5).

(b) *Intensive use of product*: As far as the S.PSS provider is selling a shared use of products (or product's components) to various users, the **more** intensively the product/s (or some product's components) are used, i.e. the more time (environmental benefits), the **higher** the profit, i.e. proportionally to the overall use time (economic benefits). Hence, the producer/providers are driven by economic interests to design for intensive use of product/s (eco-efficient product LCD implications) (Fig. 6).

(c) *Resource consumption minimization*: As far as the S.PSS provider is selling all-inclusive the access to products and the resources it consumes in use, with payment based on unit of satisfaction (product's ownership by the producer/provider), the **higher** the product/s resource efficiency in use is (environmental benefits), and the **higher** the profit, i.e. the payment minus (among others) the costs of resources in use (economic benefits). Hence, the producer/provider is driven by economic interests to design/offer product/s minimizing resource consumption in use (eco-efficient product LCD implications) (Fig. 7).[3]

(d) *Resources' renewability*: When the S.PSS provider has an all-inclusive offer of a utility, with pay per period/time/satisfaction (e.g. energy production unit ownership by the producer/supplier), the **higher** the proportion of passive/renewable sources is in relation to non-passive/non-renewable (environmental benefits), and the **higher** the profit, i.e. the payment minus (among others) the costs of non-passive/non-renewable sources (economic benefits). Hence, the producer/provider is driven by economic interests to design (offer) for

[2]Even marketing and advertisement costs could be avoided.

[3]Resource efficiency might include the end-of-life stage (recycling, re-use, composting, etc.) where it would be of interest to the S.PSS provider to make this stage also economically relevant.

passive/renewable resource optimization (eco-efficient product LCD implications) (Fig. 8).

(e) *Material life extension*: As far as the S.PSS provider is selling the product all-inclusive with its end-of-life treatment/s, the **more** the materials are either recycled, incinerated with energy recovery or composted (environmental benefits), the **more** costs are avoided of both landfilling and either the purchase of new primary material, energy or compost (economic benefits). Hence, the producer/provider is driven by economic interests to design for material life extension, i.e. recycling, energy recovery or composting (eco-efficient product LCD implications) (Fig. 9).

(f) *Minimization of toxicity and harmfulness*: As far as the S.PSS provider is selling toxic or harmful product/s all-inclusive with use and/or end-of-life toxicity/harm management services, the **lower** the potential toxic or harmful emissions are in use and/or at the end-of-life (environmental benefits), the **more** costs are avoided of both toxic/harmful treatments in use and/or at the end-of-life. Hence, the producer/provider is driven by economic interests to design (offer) for toxicity/harm minimization (eco-efficient product LCD implications) (Fig. 10).

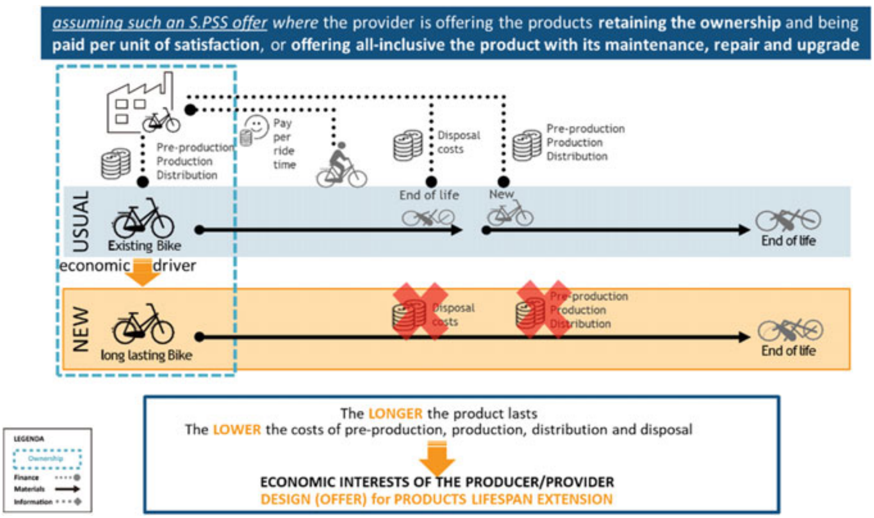

Fig. 5 S.PSS model fostering the design (offer) for product lifespan extension

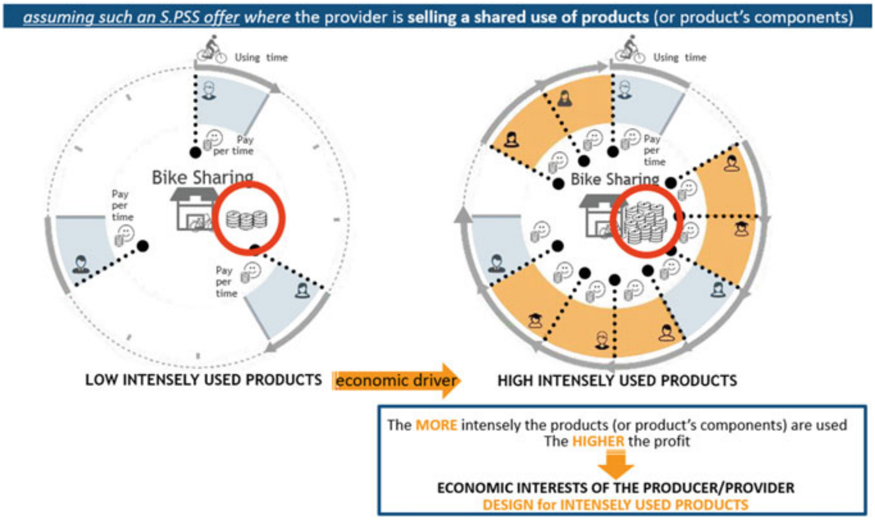

Fig. 6 S.PSS model fostering the design (offer) for intensive use of the product

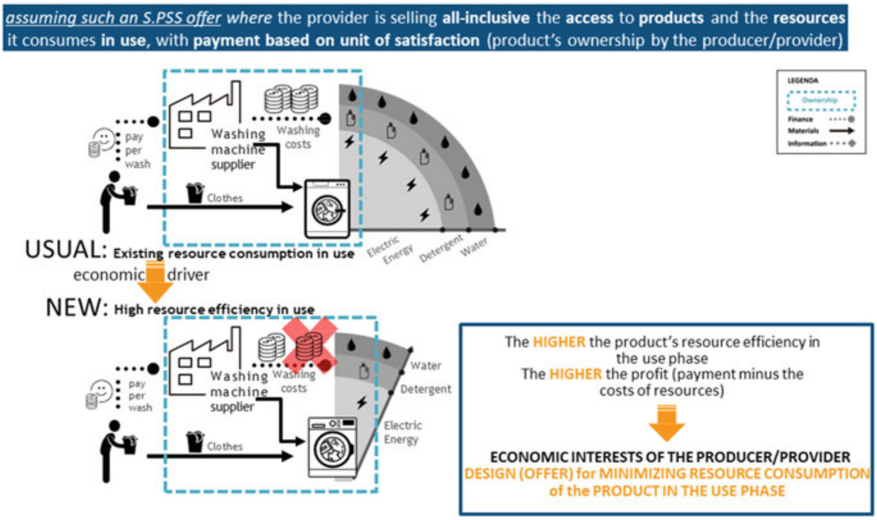

Fig. 7 S.PSS model fostering the design (offer) of products minimizing resource consumption in the use phase

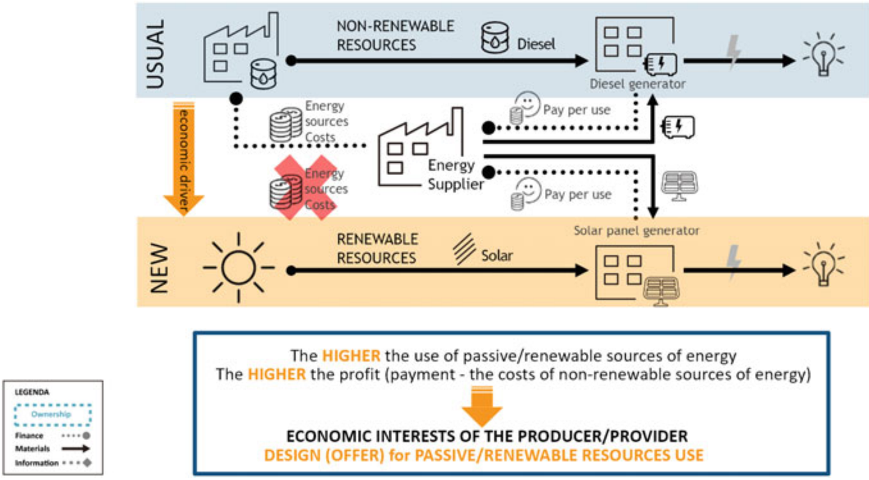

Fig. 8 S.PSS model fostering the design (offer) for passive/renewable resource optimization

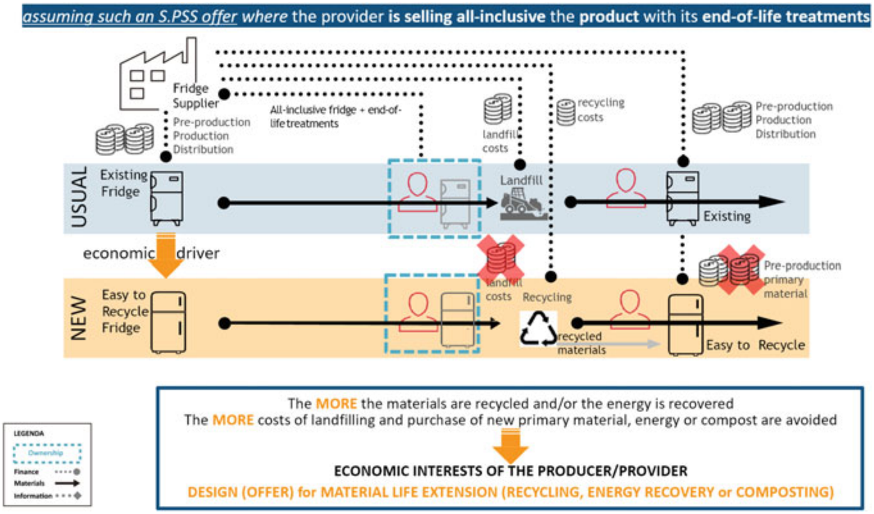

Fig. 9 S.PSS model fostering the design (offer) for material life extension (recycling, energy recovery or composting)

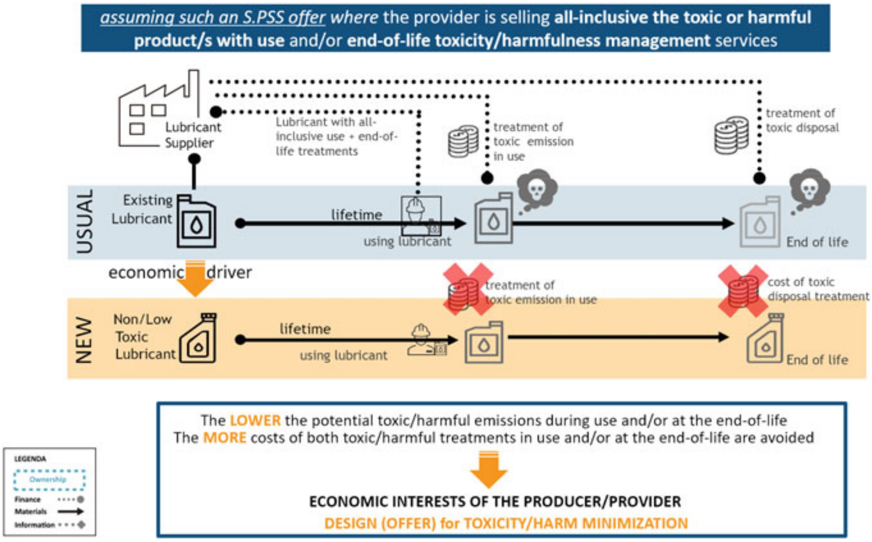

Fig. 10 S.PSS model fostering the design (offer) for toxicity/harm minimization

Fig. 11 S.PSS as a model making product Life Cycle Design economically relevant for the manufacturer/provider

To conclude, when is an S.PSS eco-efficient? When the product ownership and/or the economic responsibility for its life cycle performance remains with the producers/providers who are selling a unit of satisfaction rather than (only) the product. And why does this happen? Because this way, we shift or allocate the direct economic and competitive interest to reduce the products' and/or the services' environmental impacts, onto the stakeholder responsible for their design and development. Consequently, within an S.PSS model, a product LCD/eco-design approach is economically beneficial (Fig. 11).

In other words, an S.PSS producer/provider is economically interested in design for:

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

1.5 S.PSS Socio-Ethical Benefits

Why may S.PSS foster socio-ethical benefits? Because S.PSS make goods and services economically accessible to both final users and entrepreneurs, also in low- and middle-income contexts. The following S.PSS socio-ethical and economic win-win benefits could be highlighted (updated from [36]): The first two are related to end-users and the third, fourth and fifth are related to entrepreneurs/organizations.

(a) *End-user product accessibility*: As far as the S.PSS model is selling the access rather than mere product ownership, this reduces or avoids purchasing costs of products that are frequently too high for low- and middle-income end-users *(economic benefits),* i.e. making goods and services more easily accessible (*socio-ethical benefits*) (Fig. 12).

(b) *Reduction of interrupted product use*: As far as the S.PSS model is selling the 'unit of satisfaction' including life cycle services costs, this reduces or avoids running costs for maintenance, repair, upgrade, etc. that are too high for low- and middle-income end-users (economic benefits), i.e. who can avoid interruption of product use (socio-ethical benefits) (Fig. 13).

(c) *Enterpreneurs/organizations' equipment accessibility*: As far as the S.PSS model is selling access rather than the (working) equipment itself, this reduces or avoids initial (capital) investment costs of equipment, which are frequently too high for low- and middle-income entrepreneurs/organizations (economic benefits), i.e. facilitating new business start-ups in low- and middle-income contexts (socio-ethical benefits) (Fig. 14).

(d) *Reduction of interrupted equipment use*: As far as the S.PSS model is selling all-inclusive life cycle services with the equipment offer to entrepreneurs, this reduces or avoids running costs for equipment maintenance, repair, upgrade, etc. that are frequently too high for low- and middle-income entrepreneurs/organizations (economic benefits), i.e. this avoids interruption of equipment use and subsequently working activities (socio-ethical benefits) (Fig. 15).

(e) *Local employment and competencies improvement*: As far as the S.PSS model is offering goods and services without product purchasing costs, they open new

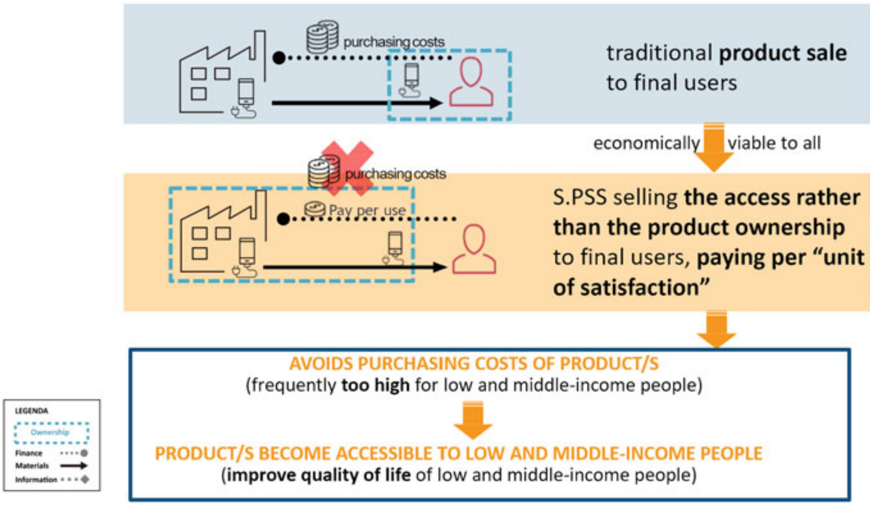

Fig. 12 S.PSS model making product/s accessible to low- and middle-income end-users

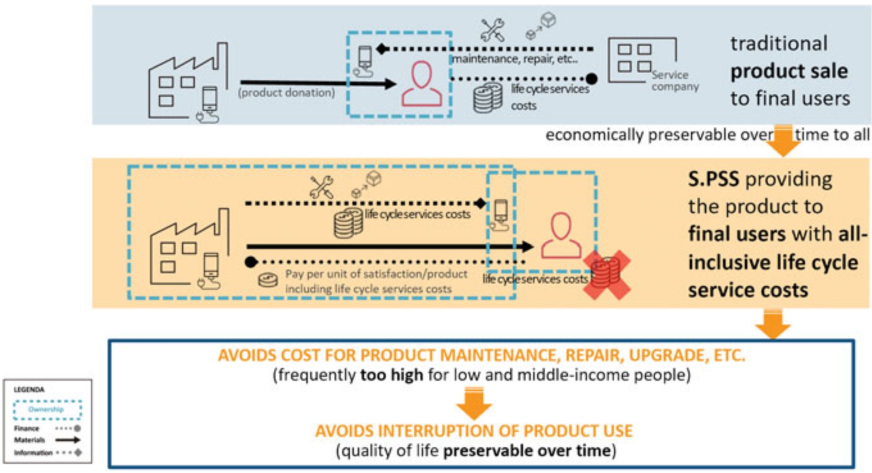

Fig. 13 S.PSS model making quality of life preservable over time in low- and middle-income contexts

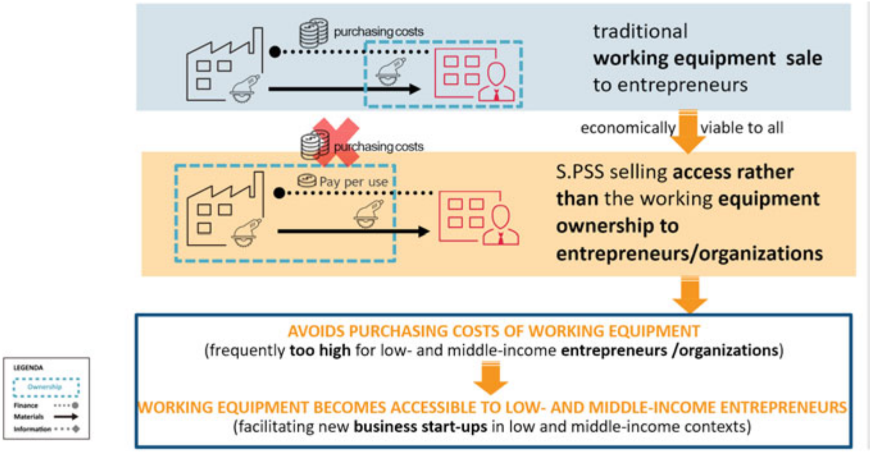

Fig. 14 S.PSS model facilitating new business start-ups in low- and middle-income contexts

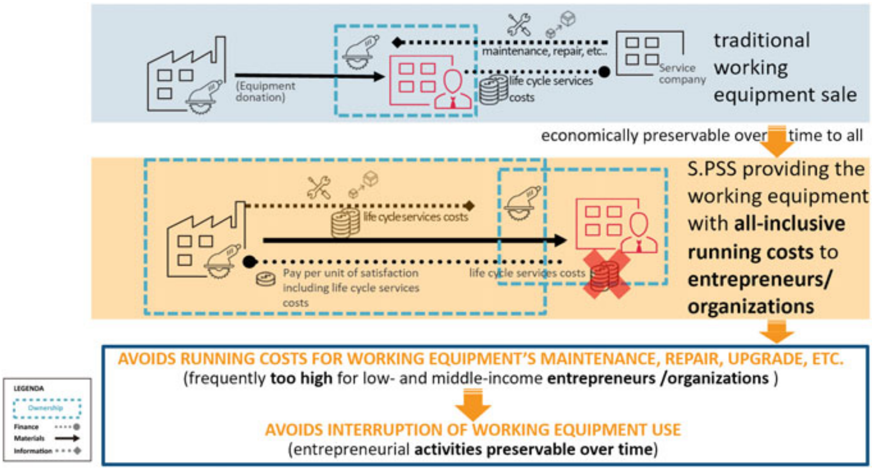

Fig. 15 S.PSS model making entrepreneurial activities preservable over time

market opportunities for local entrepreneurs via new potential low- and middle-income customers (such as Bottom of the Pyramid, or BoP), i.e. potentially empowering locally based economies and life quality (socio-ethical benefits) (Fig. 16).

The service dimension of an S.PSS demands local providers, thus generating local jobs. This contributes directly to social cohesion, as it reduces the need for migration or long commutes; increases the likelihood of better balance between work and social life; and thus provides a context where the social fabric can be built up and/or consolidated.

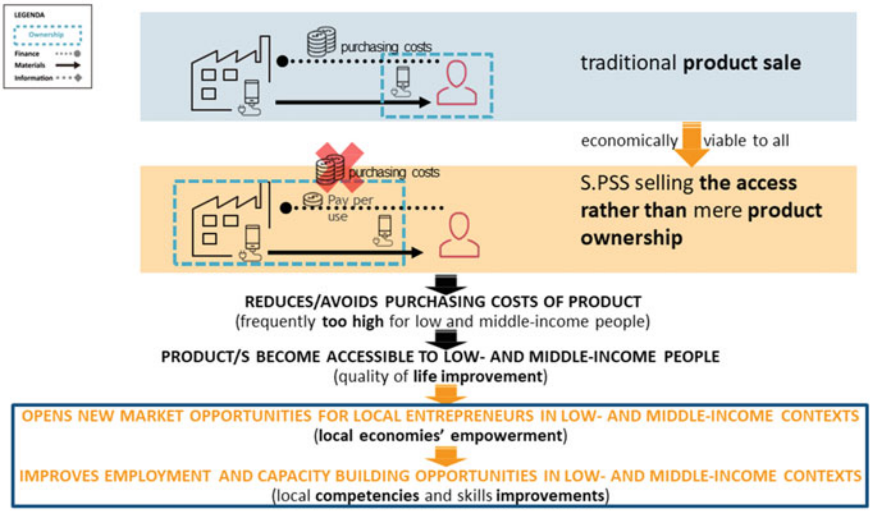

Fig. 16 S.PSS model improving local employment, competencies and skills

Fig. 17 S.PSS model improving local life quality, competencies and skills

Finally, within an S.PSS model the producer/provider is economically interested in design for social equity, i.e. to extend sustainable access to products/equipment for low- and middle-income people (see Fig. 17), by designing for:

- improving the quality of life of low- and middle-income people through economically accessible goods and services preservable over time;
- supporting new business start-ups and their survival over time in low- and middle-income contexts;
- empowering local economies by improving competencies and skills.

1.6 S.PSS Economic and Competitive Benefits

What are the main economic and competitive benefits of S.PSS? The following S.PSS economic and competitive benefits could be highlighted [36]:

- As far as the S.PSS model offers service along all its life cycle, organizations can establish longer and stronger relationships with customers, i.e. increasing customer loyalty;
- As far as the S.PSS models are different offers from traditional product sales, which are nowadays in saturated markets, they can open up new business opportunities, i.e. empowering strategic positioning;
- As far as the S.PSS model offers goods and services without initial investment costs, they open new market opportunities for middle- and low-income people (BoP), i.e. empowering locally based economies.

2 PSS Design for Sustainability

The introduction of PSS innovation for sustainability into design has led design researchers to work on defining new skills of a more strategic nature [2, 3, 18, 25, 37], which aim at system sustainability through a convergence of stakeholder interests and are coherent with the satisfaction-based approach. 'Strategic' here also refers to the necessary acknowledgement of cultural contexts and inherent opportunities and barriers built into the social fabric.

In relation to the characteristics of S.PSS described in the previous section, three main approaches and related skills for Product-Service System Design for Sustainability could be highlighted [36]:

- a "**satisfaction-system**" approach: calling for skills to design the satisfaction of a particular demand (a "satisfaction unit") and hence all its related products and services;
- a "**stakeholder configuration**" approach: calling for skills to design the interactions of the stakeholders of a particular satisfaction-system;
- a "**system sustainability**" approach: calling for skills to design such stakeholder interactions (offer model) that make the providers economically interested to continuously seek both environmentally and socio-ethical new beneficial solutions.

The first key point lies in the satisfaction-based approach, where the focus is no longer on delivering a single product. It is thus inadequate to merely design or assess a single product, but instead we consider the whole process of every product and service associated with satisfying certain needs and/or desires. The second key task is to introduce a stakeholder configuration approach. If we want to design the stakeholder interactions, the system design approach should project and promote innovative types of interactions and partnerships between appropriate socio-economic stakeholders, while responding to a particular social demand for satisfaction. Therefore, designing the configuration of a system means understanding what stakeholder profiles should be in place and what the best interrelationships are, in the sense of financial, resource, information or labour flows. Last but not least, it must be emphasized that, as stated by various authors [3, 20, 29–31], not all PSS innovations are driven by the economic interest to have a reduced environmental impact, nor do they necessarily promote social equity and cohesion. For this reason, it is expedient to operate and adopt appropriate criteria and guidelines in the design process towards sustainable stakeholder interactions/relationships. Having understood this, **Product-Service System design for sustainability** can be defined as follows (adapted from [36]):

> the design of the system of products and services that are together able to fulfil a particular customer demand (to deliver a "unit of satisfaction"), based on the design of innovative interactions between the stakeholders of the value production system (satisfaction system), where the ownership of the product/s and/or the life cycle services costs/responsibilities remain with the provider/s, so that the same provider/s continuously seek/s environmentally and/or socio-ethically beneficial new solutions, together with economic benefits.

3 S.PSS in Relation to Other Design for Sustainability Approaches

This book focuses on S.PSS and the role it can play in fostering Distributed Economies. However, it remains essential to discuss the linkages between S.PSS and other Design-for-Sustainability (DfS) approaches. In fact, in order to exploit the sustainability potential of PSS solutions, other DfS approaches should be adopted and used in combination with S.PSS design [7].

To begin with, it is important to highlight that the sustainability profile of a PSS strictly depends on how the products included in the offer have been designed. It is true that through an S.PSS approach it is possible to develop business models in which the manufacturer and the other stakeholders involved in the solution have a potential economic incentive to take responsibility for the PSS life cycle and optimize material and energy consumption (see Sect. 1.4). However, in order to exploit this sustainability potential, the products need to be correctly designed. For example, in a use-oriented PSS (see Sect. 1.3), in which manufacturers keep ownership of products and offer access to them, products need to be designed to be long-lasting (considering also the shared use), easy to maintain and repair. At the same time, products should be designed to be remanufactured and ultimately to be recycled at the end of their life cycle. Thus, S.PSS design requires the integration of **product eco-design** (or **Life Cycle Design**), which focuses on reducing the environmental impact of a product looking at its different life cycle stages, from the extraction of raw materials, through manufacturing, distribution and use, and on to final disposal [24, 33, 38].

Looking more at the user-related aspects, it should be mentioned that some S.PSSs require a certain degree of change in patterns of consumption and user habits. Typically, this involves a shift from consumption based on ownership to consumption based on access and sharing goods. Even if we are generally used to not owning and sharing certain products (for example, of the products linked to mobility services like a car or bicycle), for some product categories (e.g. appliances) there are still substantial barriers for the adoption of S.PSS-oriented offers [35]. For this reason, it becomes crucial to design S.PSS offers able to stimulate changes in user behaviour and thus support the adoption of these kinds of solutions. **Design for sustainable behaviour** (e.g. see [15, 16]), and its ability to shape and influence human behaviour to support the adoption of sustainable innovations and habits, can thus play an important role in fostering the diffusion of S.PSSs. Design for sustainable behaviour can be applied to both the product and service elements of an S.PSS (e.g. services should be designed in a way that "sharing" should be seen positively throughout the user experience).

Emotionally durable design (e.g. see [8, 21]) can also be used to support S.PSSs. Emotionally durable design focuses on enhancing and strengthening the emotional tie between the user and the product so that the user–product relationship remains satisfactory over time. In those S.PSSs in which users have individual and long-term access to a product (e.g. product-lease) it might be beneficial to create a strong emotional connection between the user and the product, and thus adopt emotionally durable design strategies.

It is also important to note the potential linkages between S.PSS and social innovations. We must acknowledge that PSS design can take inspiration from social innovations to develop new product-service offerings (e.g. commercial vegetable box subscription services that mimic similar solutions developed at a local level by communities and farmers) [7]. Thus, **design for social innovation** (defined as "a constellation of design initiatives geared toward making social innovation more probable, effective, long-lasting, and apt to spread" [17]) can enable designers to gather inspirations from community-based solutions to ideate and develop S.PSSs. On the other hand, an S.PSS design can be used as an approach to foster social innovation by triggering, sustaining and/or guiding the direction of action. Finally, we need to highlight that S.PSS innovation can be complex to implement and bring to the mainstream, as they are hindered by a range of barriers [5, 20, 27, 35]: cultural barriers (e.g. the cultural shift necessary to value ownerless offers as opposed to owning products), corporate barriers (e.g. the need to implement changes in the business mindset and strategy) and regulative barriers (e.g. lack of internalization of the environmental and social costs in market prices). **Design for sustainability transitions**, which focuses on the transformation of socio-technical systems through technological, social, organizational and institutional innovations [7], can be used to support a successful implementation of S.PSSs. In particular, it can be adopted to understand the process of the introduction and diffusion of S.PSSs and how it can be more effectively designed, managed and oriented (e.g. see [3–5, 14, 34]).

At this point, it is also useful to discuss the relationship between S.PSS and the concept of the **circular economy**. The Ellen MacArthur Foundation [9] defined circular economy as "an industrial economy that is restorative or regenerative by intention and design". Its key principles are the creation of closed-loop systems of material flows and the 3R concept (reduction, reuse and recycling of resources)

[11]. As noted by Ceschin and Gaziulusoy [6, 7], even if the concept of the circular economy has been popularized and branded by Dame Ellen MacArthur, it can be considered as an umbrella concept that encompasses different principles that have been around for a long time (e.g. industrial ecology, biomimicry and cradle-to-cradle).

S.PSS design is crucial to support a circular economy; it can lead to business models that enable and foster circularity. As noted by Ceschin and Gaziulusoy [7], with the popularization of the circular economy concept, the term circular business model (e.g. see [22]) has gradually emerged. Bocken, Pauw, Bakker and van der Grinten [1] have proposed six circular business model strategies, grouped into two main categories:

- *strategies for slowing loops*, which include access and performance models, extending product value, classic long-life model and encouraging sufficiency; and
- *strategies for closing loops*, which include extending resource value and industrial symbiosis.

Apart from the different terminology and classification, the concept of S.PSS overlaps with the concept of circular business models. However, the circular business models include additional broader aspects, such as extending resource value (e.g. collection of otherwise 'wasted' materials/resources and turning them into new forms of value; [1]) and industrial symbiosis. Circular business models have a strong focus on the economic and environmental dimension of sustainability and less on the socio-economic dimension. In any case, it is clear how the concept of S.PSS represents a fundamental component of any circular economy. In fact, as stated in the recently published "EU Circular Economy Action Plan" [10], moving towards "product-as-a-service or other models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle" is considered a key principle for sustainability, and a necessary condition to incentivize the design of sustainable products.

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Distributed Economies

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1 Reframing the Economy Towards Sustainability

There is an urgent need to reframe the economy towards a new paradigm where economic evolution occurs fairly and ethically, in conjunction with the development of human well-being achieved in harmony with nature. This emerging paradigm presents profound divergences from the orthodox paradigm, which is based on economic rationality (characterized by a continuous pursuit of economic efficiency

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C. Vezzoli et al. (eds.), *Designing Sustainability for All*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-3-030-66300-1_2

Table 1 Comparing two economic paradigms [57]

Orthodox paradigm	Promising sustainability paradigm
Individualism	Solidarity
Growth	Development
Large scale	Small scale
Competition	Cooperation
Centralization	Distribution
Profit	Well-being
Tangible	Intangible
Product based	Service based
Reduced ethics	Ethical and fair
Consumerism	Sharing

in resource exploitation) [13, 17, 39, 55, 60, 66]. In a sustainable approach, solutions should jointly promote the improvement of welfare, social cohesion and social equity, while significantly reducing environmental impact and resource depletion. Table 1 illustrates the main differences between these economic paradigms.

This new economic paradigm includes cooperative work in the production of goods and services, solidarity finance, fair trade and solidarity consumption (MTE 2012). An initiative or enterprise is guided by the generation of work and income and, at the same time, seeks to achieve social inclusion and respect for ecosystems. The economic, political and cultural results obtained from value creation are shared among participants, thus constituting a strategy to overcome the pattern of subordination and vulnerability observed in conventional practices prevalent in the orthodox economy [27]. The implementation of such a vision has the excessive centralization of the economy as one of its key barriers, as explained in the next section.

2 How Centralization Hinders Sustainability and Resilience

The rationale for centralizing, mass production for economies of scale has been based on the ideals of efficiency and cost-savings, ideals that are rarely tested for their real efficiency or efficacy [11, 31, 43]. For example, in the case of electricity, a certain percentage is always lost in transmission, particularly in grids that are not well maintained. Manufacturing of goods by centralized mass production becomes efficient particularly when the social and environmental costs of manufacturing, from waste and pollution to decent working conditions, are externalized. In the worst case, overcapacity may be pushed onto consumers through aggressive marketing as well as planned obsolescence strategies, and nature is seen only a provider of 'resources', raw materials and raw land to be exploited. Much critique of current industrial mass production thus centres on tendencies to promote consumerist values, overconsumption and throwaway products. Large firms are also less likely to answer to consumer pressure for environmental and social responsibility; simultaneously, the large distances between consumers and manufacturing supply chains means consumers are not always fully aware of sustainability issues [5].

In the fast fashion industry, for instance, production efficiency, low wages and dangerous working conditions in many regions have radically reduced the prices of apparel for consumers, which in turn has increased consumption—and its negative social and environmental impacts—by even 40% [46]. Negative environmental impacts from the production of fast fashion include substantial use of water and chemical pollutants, especially in regions of water scarcity and less capacity for environmental protection measures, not to mention impacts from transportation, retail distribution and disposal [46]. Such impacts are usually experienced in low- and middle-income regions far from where the clothing is purchased. Moreover, there are negative environmental impacts from waste in many industries, which includes not only pre-consumer waste produced during manufacturing, but also "deadstock"—finished goods such as fast fashion and luxury goods that are disposed of before they even reach the consumer [45]. Deadstock is surplus output, a direct result of overproduction in centralized, large-capacity, capital-intensive mass production, in contrast to other models such as production-on-demand. The principle of Distributed Economies therefore calls for an analysis of what products and services in a specific region deliver social and environmental harms by virtue of being produced in large-scale, centralized modes. The objective is to become sensitive to and work to change systems that have become an "ever-faster once-through flow of materials from depletion to pollution" [11, 28].

Critique of 'centralization' is not limited to tangible products and their manufacturing. In the fast fashion example, attention is also paid to what consumer behaviours are encouraged as a result of low prices in a consumerist society, which impose barriers to other experimental models such as sharing, renting and upcycling that would extend product and material lifetimes. These alternative models also connect actors in other ways than fiat money, connections that are not visible or valued in models that emphasize capital-intensive, efficient, centralized industrial systems [38, 44, 54] . At the same time, one must also be wary of centralizing tendencies in the "sharing economy". As the largest peer-to-peer platforms for "collaborative consumption" gain critical mass, while retaining ownership in centralized corporate hands far from local users, there is uncertainty and controversy over how such "platform capitalism" delivers social benefits, local value and positive environmental impacts for their diverse stakeholders [20, 44, 53, 59].

Another critique of institutional centralizing relevant to design relates to expertise and legitimacy: who has the authority to produce, design, innovate and distribute. Centralized production, geographically and/or via patents and Intellectual Property Rights regimes, separates the authority to repair and maintain from the knowledge to repair and maintain, for instance. Such barriers can affect actors who contribute to a local economy and ensure circular material flows (through product longevity)—such as repair hackerspaces—but are not accounted for in neoclassical economics indicators [31, 54]. Analysis according to DE principles would therefore examine where economic activities threaten local resilience and the ability to satisfy local needs, cases where "one industrial production process exercises an exclusive control over the satisfaction of a pressing need and excludes nonindustrial activities from competition" [29]. It is beneficial for environmental, social and economic sustainability that knowledge of design and abilities to innovate are not removed from communities, but are rather enhanced.

Centralized systems and the accompanying extreme focus on efficiency must thereby be examined in terms of sustainability because of the impact on societies' and systems' resilience. If resilience is understood as the ability for a system (such as a city, region or neighbourhood, including natural systems and industrial systems) to be flexible, agile, adaptive and able to absorb shocks from a disturbance [24, 26, 50], an excessive focus on efficiency leads to structures that are fragile and brittle [50]. Both ecosystems and human systems absorb shocks and deal with disturbances by "allowing the existence of some redundant and not-so-efficient pathways" [9, 50]. From the point of view of a city, resilience would address dependence on global supply networks and the need for diversified economic activities, which requires examination of the role of mass manufacturing and services in the region [24].

The shift to a network society [12] appears to embed new potential: new ways societies can meet their needs and express themselves creatively, which call into question—and actively dismantle—harmful systems [6]. Walter Stahel suggests shifting emphasis from production optimization to use optimization, and that large-scale, capital-intensive production units be gradually or partially replaced by "smaller-scale labour-intensive, independent, locally integrated work units" [62]. This "distributed" model is the focus of the next section.

3 Distributed Economies (DE) as a Strategy Towards Sustainability

Distributed Economies consists of small-scale value-adding units (e.g. manufacturing, services) where there is a shift in the control of core activities towards the user/client. Johansson et al. [31] first defined Distributed Economies as a "selective share of production distributed to regions where activities are organized in the form of small scale, flexible units that are synergistically connected with each other" in a network.

These local units serve local needs near or at the point of use, including artefact and service demands across the product life cycle and business process, shifting the control of essential activities towards or by the end-user, whether individuals, entrepreneurs or organizations. Hence, in such contexts, local units are more capable of offering on-demand solutions and having a higher level of multi-user participation, including those situations where the user her/himself can also take the role of manufacturer or service provider.

In a Distributed Economy, these small-scale units could be stand-alone or peer-to-peer, connected with other nearby units to share various forms of products, semi-finished products, resources, knowledge/information and other types of services. These local units are sometimes organized as multiple providers to the same order, forming a much more resilient network (e.g. cooperatives). Hence, this local network can be connected to nearby networks, resulting in an expanded network of networks, i.e. they become a Distributed Economy Network (DEN). If properly designed taking sustainability principles into account, they have potential to promote locally based sustainability, i.e. Sustainable Distributed Economies (S.DE). They share or jointly use various forms of local resources, including skills, knowledge and manufacturing/service capabilities.

When we discuss the concept of Distributed Economies, we do so in contrast to Centralized Economies for simplicity and clarity in analysis. With that in mind, we can identify two types of small-scale locally-based production units where we find a shift in the control of core activities towards the user/client. The first we (also) call *Distributed*, which are *by the end-user*, and the second *Decentralized*, which are *nearby the end-user*, as illustrated in the diagram below (Fig. 1).[1]

In contrast to DE, a **Centralized Economy** is *characterized by* ***large production units*** *located (often) far from its customers (individuals or organizations), with production capacity geographically concentrated, delivering products/services* via ***large distribution networks****. Their large-scale, stand-alone production units demand high control of essential activities and, thus, decision making is often centralized*. Due to their scale, implementation of changes is often costly and time-consuming (Fig. 2).

Meanwhile, a **Decentralized Economy** is *characterized by* ***small****-scale* ***production units*** *that deliver their goods and services* via ***light distribution*** *networks, directly to* ***customers,*** *whether individuals, entrepreneurs or other organizations/institutions, increasing* ***customers' control over*** *essential* ***activities;*** *they could be* ***stand-alone*** *or* ***connected*** *to each other to* ***share*** *various forms of* ***goods*** *and* ***services****. Thus, the cost and time for implementing or changing them is also variable. Their decision-making process is decentralized, with some customer/user control over essential activities* (Fig. 3).

Finally, a **Distributed Economy** ***involves (very) small****-scale* ***production units*** *of goods (physical and/or knowledge-based artefacts) located* ***near or at the same place of the end-users*** *(who become the producers, i.e. prosumers) that have* ***control over*** *essential* ***activities****, whether individuals, entrepreneurs or organizations/institutions. They could be* ***stand-alone*** *or peer-to-peer* ***connected*** *to each other to* ***share*** *various forms of* ***goods*** *and* ***services*** (see Fig. 4).

A Distributed Economy (DE) could be further characterized by its life cycle localization depth, i.e. whether it is centralized, decentralized or distributed along all its life cycle stages (pre-production, production, distribution, use and disposal). The relevance and configuration of these stages could differ from case to case, as exemplified in the right-most diagram in Fig. 5, which describes the life cycle localization

[1] We thereby use this terminology and conceptualization in this volume, acknowledging that these terms have different definitions in various fields.

depth of a solar panel produced and distributed by a multinational company (Centralized), installed and used by an individual, e.g. having it installed on the roof of their home (Distributed), and disposed of locally (Decentralized). An in-depth analysis of this example shows the system is Centralized in its pre-production, production and distribution phase, Distributed in its use phase and Decentralized in its disposal phase.

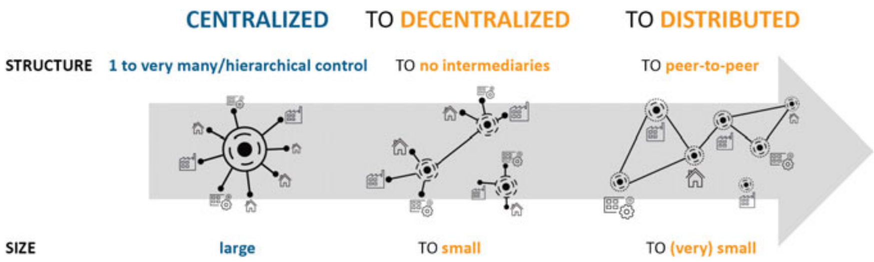

Fig. 1 The paradigm shift from centralized, to decentralized, to distributed economies

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

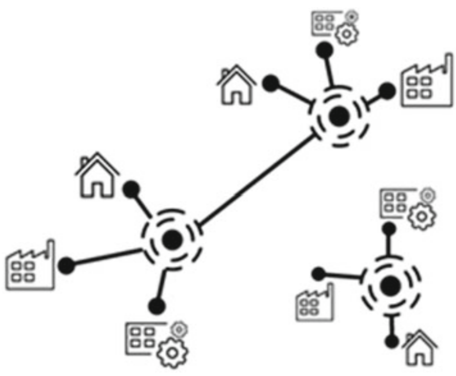

Fig. 3 The structure of the production unit of Decentralized Economies

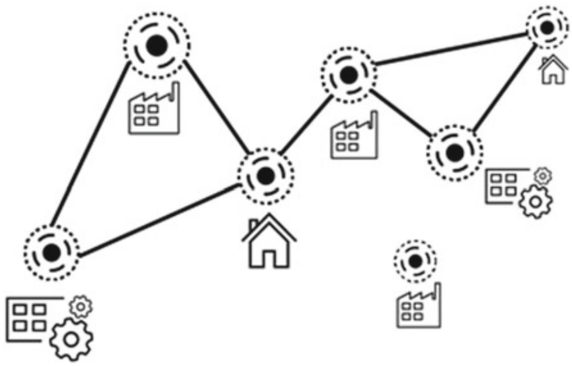

Fig. 4 The structure of the production unit of Distributed Economies

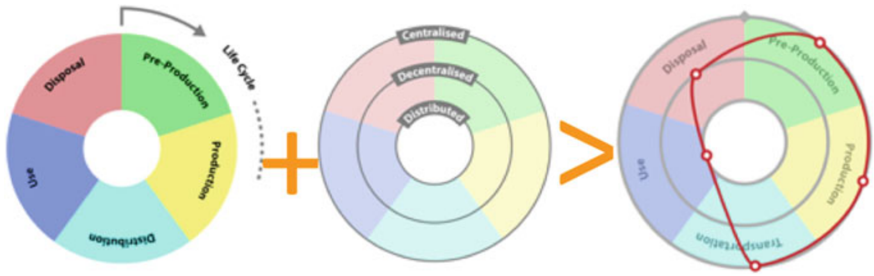

Fig. 5 Example of how a system should be characterized according to how Distributed/Decentralized/Centralized it is in its various life cycle stages

When compared to the Centralized approach, Distributed Economies is a promising offer model for enhancing cohesion to the same goals and more equitable distribution of power at a local level, distributing the activities based on expertise, resource availability and accessibility. Furthermore, these flexible units may have less emphasis on economic growth and more on the achievement of well-being. Therefore, its adoption implies a rupture to the unsustainable foundations of neoclassical economics, which is often driven by the idea that large-scale production makes better economic sense.

It is useful to observe, furthermore, that Distributed Economies (DE) is nothing new. What we have experienced over the course of decades has been and is a process of centralization, especially in industrialized countries. For example, preparing a meal at home is a distributed activity with its home-based production units (ovens, etc.). Nevertheless, even in this case, we may observe an evolution towards a life cycle centralization (in industrialized and emerging contexts): to cook we buy electricity/gas from the main grid (centralized), while in the past we collected nearby biomass (distributed, though with highly toxic combustion fumes); we can purchase food in a supermarket (centralized), while in the past much was cultivated in our gardens or bought from neighbourhood shops (distributed); finally, nowadays we can buy “almost ready meals” (centralizing most cooking activities).

Furthermore, DE already exists in many low- and middle-income contexts. In Kenya, for instance, according to the International Labor Organization, 90% of businesses are informal, which would mean that a large percentage of the population is familiar with the distributed and networked nature of the informal sector. Such a population could already be familiar with the open and networked relationships that S.PSS and DE offer [67]. Hence, Sustainable Distributed Economies (S.DE) need to be seen not as a return to the past, but as a transition towards socially, environmentally, economically and technically advanced sustainable distributed economies.

4 Practical Implications of DE in Various Fields

We may identify different types of Distributed Economies (DE). Below is a classification organized in two groups:

Hardware/natural resource-based DE:

- Distributed energy Generation (DG),
- Distributed Food production (DF),
- Distributed Water supply/management (DW)
- Distributed Manufacturing (DM).

Knowledge/information-based DE:

- Distributed Software development (DS),
- Distributed Knowledge generation (DK),
- Distributed Design (DD).

These DE types are described in the following sections.

4.1 Distributed Design (DD)

A Distributed Design (DD) system is an open design system where solutions are conceived and/or developed by a small-scale design unit, e.g. one person/computer being the end-user or located nearby the end-users, whether individuals, entrepreneurs and/or organizations/institutions. If the small-scale production units are also connected with other DD (e.g. to share the open design technical drawings), they become a Distributed Design Network (DDN), 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 Design (S.DD) systems. Through participatory design practices in the context of digital technologies, such as open design and crowd-design [19], designers can access widely dispersed or demographically segmented user groups and suppliers, engaging them directly to contribute with ideas and solutions, and encouraging them to engage in the outcome configuration. In this way, the development of a new product, service or Product-Service System can be done by laypeople, prosumers, producers, creative communities, experts in various fields, designers and companies, or even by the interaction between these groups [18]. The collaboration between the people involved in the development of these projects can occur through crowd-based platforms, FabLabs, makerspaces, hackerspaces, or iteratively between these spaces [15].

4.2 Distributed Manufacturing

Distributed Manufacturing (DM) can be described as a production system made of small-scale manufacturing units equipped with physical and digital technologies, which enable the localization of manufacturing facilities and comprehensive communication between all supply chain actors in order to facilitate customer-oriented production [49]. Key DM features can be summarized into three categories: the localization of manufacturing units, the application of physical and digital technologies, and the customer orientation [7, 34, 61]. The localization of manufacturing units addresses the proximity between manufacturing facilities (e.g. factories, workshops, personal fabrication labs or makerspaces, in-house and in-store suites, mobile manufacturing units, etc.) and end customers and/or manufacturing resources. The application of physical and digital technologies refers to hardware, tangible manufacturing equipment needed to produce products (e.g. 3D printers, laser cutters, Computer Numerical Control (CNC) routers) and the application of computer systems and the use of the Internet (e.g. Industry 4.0, Cloud Computing, Internet of Things, ICT, etc.) used to collect and process data and enable communication between key actors. The customer orientation refers to the level of product or service customization (e.g. mass customization, personalization, bespoke production, etc.) and the level of customer involvement in design and production processes.

Implementation of DM brings multiple benefits for companies and their customers, including companies' resilience to changes in market demand [51], enablement of personalized production [32], facilitated movement and relocation of manufacturing facilities [61], reduction of supply chain actors [4], and many more. However, the transition towards DM requires companies to change organizational mindset [8], adopt new ways of managing business processes [47] and invest in new manufacturing and communication technologies [4].

4.3 Distributed Energy Generation (DG)

Decentralized and distributed energy generation systems (DG systems) are typically powered by renewable energy sources. These include solar, wind, small hydro, biomass, biogas and geothermal power.

There is no consensus on a shared definition of decentralized generation and distributed generation [22]. For some authors, these two terms are synonymous [33]. For others, the difference is that in decentralized systems, the energy generation units have no interactions with each other [2, 36]. At any rate, from a technical perspective we can distinguish between [21, 65]:

(a) Stand-alone energy systems: these are off-grid systems, thus not connected to each other or to the main grid;
(b) Grid-based systems: these are energy generation systems which supply power at a local level, using local-wide distribution networks [52].

DG systems are associated with a range of potential sustainability benefits [21, 65]:

- From the economic perspective, DG systems are characterized by lower transmission costs for remote regions and lower energy prices in the long-term compared to centralized systems [48]. They can also enhance the flexibility and resilience of the system [31]. A system can easily cope with individual failures (i.e. fault in an energy generation unit) since each energy-using node can be served by multiple energy production units. DG systems require relatively low investments, making it easier for small economic entities such as single individuals and/or local communities to become prosumers (consumers but also producers of the energy).
- In relation to the environmental aspects, the use of renewable and locally available energy sources results in a lower environmental impact compared to the use of fossil fuels (and the related extraction, transformation and distribution processes) [58]. Moreover, local energy production reduces the energy distribution losses that characterize centralized systems.
- Regarding the socio-ethical dimension, the fact that DG systems are relatively easy to be installed and managed (and thus enable users to become prosumers) fosters the process of democratization of energy access, thus enhancing community self-sufficiency and self-governance [14]. Additionally, being locally distributed, they can lead to an increase in local employment (e.g. in relation to installation and maintenance activities) and thus dissemination of competences, which can foster local economies.

However, despite their potential benefits, there are also some barriers to be taken into consideration (for a more detailed discussion see [65], Sect. 5): technical (e.g. resource availability, skill requirement for design and development), economic (e.g. users' purchasing power and spending priorities, energy pricing, incentives), institutional (e.g. policy and regulations), socio-cultural (e.g. norms and value system, behavioural or lifestyle issues), and environmental (e.g. impact on ecosystems and wildlife).

An example of Distributed Energy Generation is the solution offered by IBEKA, a non-profit organization operating in Indonesia. IBEKA provides hydro mini-grids to communities. This includes the design and installation of the energy generation plant as well as support to enable the local community to manage the plant. IBEKA sets up a community-managed enterprise to run the system and trains it on how to operate, maintain and manage it. The grid-connected system allows communities to sell surplus energy to the national energy supplier. Revenues cover operation, maintenance, loan repayments and a community fund. End-users pay according to a tariff which could be based on a pay-per-energy consumed (meter) or an agreed amount of energy per day.

4.4 Distributed Water Supply/Management

A Distributed management system of Water (DW) is a small-scale management unit, located by or nearby the end-users, whether individuals, entrepreneurs and/or organizations/institutions. If the small-scale Water supply/management unit (DW) is also connected with other DWs (e.g. to share the water surplus), they become a Distributed Water supply/management Network (DWN), which may, in turn, be connected with similar networks nearby. If properly designed, they have potential to promote locally based sustainability, i.e. Sustainable Distributed Water supply/management (S.DW) systems. An example of a Distributed Water supply/management (DW) system is the shift from a centralized urban water supply to distributed access to clean groundwater.

Compared with water supply/management systems based on centralized systems, distributed systems are smaller in scale. In structure, the relationship between production units is more equal. It is also more flexible and proactive; compared to the central type, the production unit of the distributed system is closer to the user and more open, which can motivate users to actively participate and develop customized solutions to effectively meet individual needs [68].

For example, P1MC is a charity project initiated by the Brazilian NGO ASA in early 2000 to help residents of the arid regions of north-eastern Brazil to build home rainwater storage facilities. P1MC abandoned the traditional water tank product sales model, but supported local villagers to build their own reservoirs, provided training on routine maintenance methods and provided follow-up technical support. This model of ‘collaborative construction’ plus ‘services and training’ has a significant role in promoting project implementation in poor areas. Through professional planning and design, local organizations are encouraged to collaborate with individuals, significantly reducing the cost of building and operating hardware facilities and making local water supply solutions more flexible and agile.

4.5 Distributed Food Production (DF)

Distributed Food production (DF) is a small-scale value-added unit (production/service) associated with food, located by or nearby the end-users, whether individuals or organizations. If the small-scale Food production units (DF) are also connected with other DF (e.g. to share food overproduction), they become a Distributed Food production Network (DFN), which may, in turn, be connected with similar networks nearby. If properly designed they have potential to promote locally based sustainability, i.e. Sustainable Distributed Food production (S.DF) systems.

Centralized food systems evolved along with the advances of the industrial revolution, adopting production and consumption practices based on industrial, mass production logic, that is, introducing elements that aim for system optimization and production efficiency, prioritizing financial gain over quality of food produced. In a period of little more than 200 years, in order to guarantee the expansion of the agricultural frontier and the volume of food production, agro-industrial practices have progressively been adopting mechanization, introducing chemical substances and promoting genetic modification as support pillars of the system. This has put the survival of millenary practices and traditions that revolve around food at risk, without taking into consideration the impact of such practices on the natural and social systems that sustain it, resulting in the consequent socio-environmental degradation of the planet.

Alternatives as Distributed Food production encompass a comprehensive set of ideas that have put into practice the diffusion of community networks and the quest for small-scale and flexible sustainable solutions, making use of local resources. Initiatives include Experiential Agribusiness, Community Supported Agriculture, Urban Farming and the Slow Food movement.

Experiential Agribusiness is based on the offer of gastronomic experiences as a value proposition. It can be considered a decentralized, small-scale system that appropriates traditional food production techniques and cultural practices, reconfiguring new gastronomic propositions strongly influenced by user experience under the name of food design. Community Supported Agriculture focuses on the production of high-quality foods for a local community, often using organic or biodynamic farming methods and a Decentralized or Distributed structure. It connects the producer and consumers within the food system by allowing the consumer to get involved in the different activities related to the harvest of a certain farm or group of farms. Urban farming is the practice of cultivating, processing and distributing food and the raising of animals for food and other uses within and around cities and towns. It takes advantage of vacant and underutilized private or public spaces within the city and the suburbs that might have a potential use for farming purposes. Slow Food is a global movement present in more than 150 countries. It is a reference in debates on biodiversity, local food communities and genetically modified food [3]. It was initiated with the aim to protect regional traditions, good food, gastronomic pleasure and a slow pace of life from the perceived domination of agribusiness, supermarkets and fast food chains.

4.6 Distributed Software Development (DS)

Distributed Software development (DS) is a small-scale production unit (i.e. a computer is the basic hardware for such production), located by or nearby the end-users, whether individuals, entrepreneurs and/or organizations/institutions. If the DS small-scale production units is also connected with other DS (e.g. to share information, open data or open code), they become a Distributed Software Network (DSN), which may, in turn, be connected with similar networks. If properly designed, they hold promise to promote locally based sustainability, i.e. Sustainable Distributed Software development (S.DS) systems. A well-known example of a Distributed production of Software (DS) is the shift from proprietary software to open-source software 'Linux'.

4.7 Distributed Production of Knowledge (DK)

A Distributed production of Information/Knowledge (DK) system is a small-scale production unit (i.e. a computer is the basic hardware for such production), located by the end-users or peer-to-peer connected with the end-users, whether individuals, entrepreneurs and/or organizations/institutions. If the DK small-scale production unit is also connected with other DK (for example, to share open information and data), they become a Distributed Knowledge generation Network (DKN), which may, in turn, be connected with similar networks nearby. If properly designed, they hold promise to promote sustainability on a multilocal level, i.e. Sustainable Distributed Knowledge generation (S.DK) systems. A well-known example of Distributed Information/Knowledge generation is the shift from the traditional encyclopaedia to the open encyclopaedia 'Wikipedia'. In fact, the LeNS Learning Network on Sustainability of HEIs could be classified into this category.

5 Alternative System Configurations

5.1 Stand-Alone Configurations

A stand-alone DE configuration occurs in those systems characterized by the use of either distributed or decentralized production units, without any local delivery system (network) with nearby customers and/or production units. These isolated production units are run by and for the user, either by an individual or an enterprise/organization. A Stand-Alone Distributed system is an isolated production unit by the end-user, while a Stand-Alone Decentralized System is an isolated production unit reached by near-by customers to benefit from the outcomes (of the production unit) (see Fig. 6 below).

5.2 Network Configurations

There are four types of Network Configuration, as described below:

- A *Centralized Network System* is a network of production units far from the user with an extensive delivery system for various forms of resources (physical and/or knowledge-based) to individuals or enterprises/organizations distributed in a large-scale area such as a state/s, country/ies, continent/s or worldwide (see Fig. 6 below).
- A *Decentralized Network System* is production with a local delivery system (network) for various forms of resources (physical and/or knowledge-based) to nearby individuals or nearby enterprises/organizations (Fig. 6).
- A *Distributed Network System* is a network of production units run by the user, either an individual or an enterprise/organization (Fig. 6), sharing various forms of resources (physical and/or knowledge-based) locally with nearby individuals and/or organizations.
- A *Hybrid network* system is a network of production units that consists of two or more types of centralized, decentralized or distributed network systems (Fig. 6).

Beyond these four configurations, there can also be a **Network of Networks**, which are either centralized, distributed or decentralized production units or local networks connected to other networks to share various forms of resources (physical and/or knowledge-based) (Fig. 6).

Finally, a **DE can also be connected to a Centralized Network**. In this case, either distributed or decentralized production units or local networks are connected to a Centralized Network to share various forms of resources (physical and/or knowledge-based) (Fig. 6).

5.3 Summary and Examples of System Configurations

Figure 6 visually summarizes the main system configurations described in the previous section.

The following table gives examples from the different DE classifications for these alternative system configurations (Table 2).

6 Main Drivers and Win-Win Benefits of DE

Table 3 presents a wide range of win-win benefits of DE according to the three dimensions of sustainability [56]. Changes in customer behaviour and demands, including the quest for greater well-being and more democratic practices, are opening opportunities for a wider adoption of Distributed Economies. The proximity between

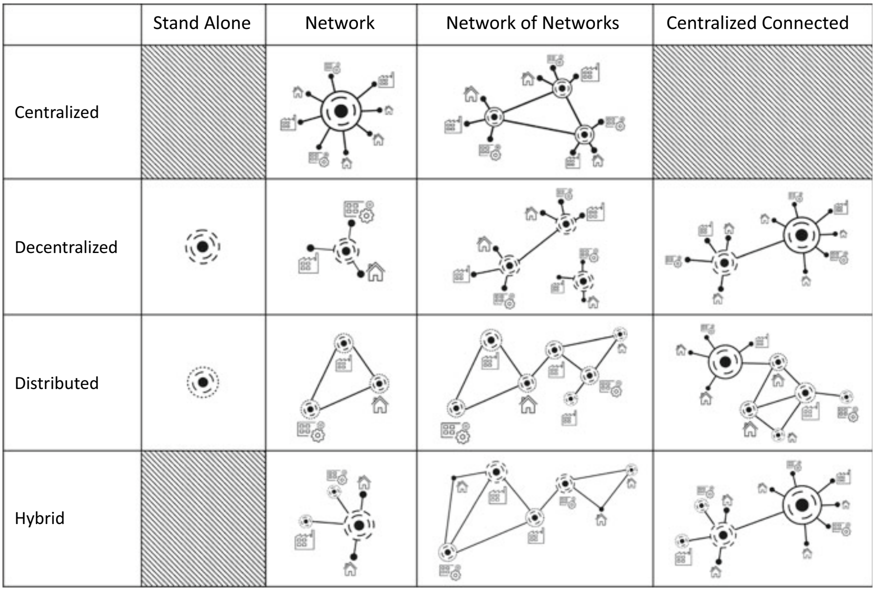

Fig. 6 Possible production/delivery system configurations

producers and consumers enables the provision of solutions with a better fit to local needs. By re-connecting people and producers, Distributed Economies also provide an opportunity for poverty alleviation, with people providing for their needs in alternative ways. Various authors [16, 31] argue that DE offers advantages in the pursuit of social diversity, respect for local culture, increased local quality of life and collective spirit, and focus on regional assets expanding the bargaining power for local actors beyond the maximization of social capital.

Some of the main economic drivers to adopt DE characteristics include the growing interest in customization and the reduction of logistics, lead time and labour costs due to shorter distances. In addition, the embedded characteristics of DE enable more collaborative design and production, with optimal distribution and use of resources. It is aligned to the expectations of a young generation that is increasingly in search for jobs with more freedom and creativity.

Emerging technologies have also opened new avenues and opportunities to implement DE. The possibilities provided by technologies such as IoT (Internet of Things), AI (Artificial Intelligence) and digital fabrication (such as Additive Manufacturing technologies), have aligned with a growing level of internet access and broader options for communication technologies. This has opened new avenues for merging digital and physical technologies, resulting in more flexible and agile manufacturing/services as well as knowledge sharing approaches.

Table 2 Examples of the main DE structure configurations

	Stand-alone—distributed	Stand-alone—decentralized	Network—distributed	Network—decentralized
DG (Distributed Energy Generation)	Solar panel for single household energy production	Hydro-powered charging station, where people go to charge phones, etc.	Solar panels for home use, connected via local mini-grid, sharing an energy surplus	Wind farm which provides energy to a village with a local mini-grid
DF (Distributed Food)	Home gardening for private use	Organic producer selling food directly to local consumers near or from the fields	Neighbourhood gardening club sharing of production surplus	Local baker delivering organic bread to the neighbours every morning
DW (Distributed Water)	Rainwater harvesting from the home roof for private use	Medium-sized water collector that local people access with their tanks to get the water	Roof rainwater harvesting for private use, with neighbourhood piping infrastructure for surplus sharing	Water from a local spring distributed to the households in the village through local infrastructure
DM (Distributed Manufacturing)	An individual making clothes at home using sewing machines for own use	A maker selling 3D printed artefacts directly to the final user in a shop beside the workshop	A digital fabricator supplying own needs while producing and delivering to locals during unused time	An entrepreneur locally delivering 3D printed items made on request
DS (Distributed Software)	A developer developing software at home to create a home security system	A software developer team selling the security system they developed from their office to local enterprises/organizations	A local community of developers collaborating on open-source software to create and install a home security system	A software developer providing a service installing the home security system she/he developed
DK (Distributed Knowledge)	A (very) small weather station for home forecast	A farming expert providing a consultancy service in her office about farming for the region	A small weather station located at an individual's home for their own use and sharing the data with the local community	A local consultancy providing a gardening service by going to the customers' gardens

(continued)

Table 2 (continued)

	Stand-alone—distributed	Stand-alone—decentralized	Network—distributed	Network—decentralized
DD (Distributed Design)	An individual designing his/her family clothes at home	A studio providing an onsite service for the local customers to design custom furniture	An individual designing their own clothes at home and sharing the designs with their local community	An architect studio providing services for a local community by going to their houses

Table 3 Main Win-Win Benefits of DE

Social benefits	Environmental benefits	Economic benefits
• Fosters a culture of mutual help and empowerment, enhancing the social resilience of the system; • Fosters higher socio-economic equity, offering more opportunity to marginalized people, thus accepting diversity; • Encourages the sharing of knowledge and skills, providing a better environment for wide competence building; • Values local culture, knowledge and capabilities by using local skills and native knowledge, enabling higher customer/user involvement in the design process; • Promotes social cohesion among local stakeholders, with a better cultural fit of products/services, creating meaningful and long-lasting relationships with customers, promoting mutual trust at the local level.	• Enables a shift towards a circular economy, making easier the collection of products at the end of their life cycle due to shorter distances; • Reduces environmental impact due to shorter distances, increasing system efficiency, with a decrease in the demand for resources and, at the same time, more emphasis on the use of renewable resources and conserving resources; • Increases the possibility to prioritize the environment over pure financial gains as users/clients can keep direct contact with the environmental impacts resulting from their choices; • Delivers a higher rate of shared services and resources, leading to better resource use and democratization of access to resources.	• Enables better fulfilment of local needs, allowing on-demand production and reduction of marketing costs due to customer proximity; • Provides a higher level of customization and enables faster delivery of product/service changes; • Features shorter, more flexible and smaller supply chains, with sharp reduction in logistics costs, lead-time, waste and capital investment; • Enables better monitoring of product performance, with higher local control over production; • Valorizes the local economy, integrates local competencies and infrastructure into the design process, increasing the bargaining power of local providers and encouraging open source innovation.

7 Potential Unsustainability of DE

'Distributed' does not automatically mean 'good' or anti-centralized, and these concerns are immediately apparent in the most extensive online peer-to-peer platforms, from sharing of services to social media [38, 40, 54, 59]. Even when people are seen as 'members of communities' socially connected to each other (compared to being mere providers of physical labour in a factory), they have nevertheless become providers of data that is sold by centralized media giants to other parties for profit. Individuals acting within these platforms do not become part of collective local economies, nor is their resilience necessarily enhanced by their participation.

As the notion of Distributed Economies emerged from Lund University's International Institute for Industrial Environmental Economics in the mid 2000s, IIIEE publications from that time have helped clarify what it is we *do not want* in our current global mass production-consumption system by emphasizing DE [31, 41]. The negative characteristics of 'centralization' discussed in this literature still hold true for products, services or platforms that appear to be decentralized, distributed and peer-to-peer, and analyses must account for this. Table 4 summarizes these and other main potential unsustainabilities of DE.

The shift to a network society has not yet been accompanied by a generalized knowledge of how to govern ourselves in horizontal networks that embed market-oriented, public-sector-oriented and civic-society oriented actors and actions—particularly when trying to keep ecological impacts in mind. Decentralizing and distributing too easily ends up as more business-as-usual. "[L]ocal actors' possibilities to have ownership and control over their immediate economic environment" may be strengthened in appearance, while weakened in operation [41]. It is thus essential to pay attention to what remains centralized, when limited conceptions of market value predominate, and when discussions on the nature of economic collaboration is depoliticized. Communities that strive to repoliticize the discussion on decentralizing, from Transition Towns to indigenous land defenders to open design groups working on sustainable solutions, make visible what is 'centralized' and why it is undesirable, and they actively prototype and prefigure new modes of production. By examining their examples, and how they interplay with mass production and consumption from the 'orthodox economy' (see Sect. 1), we see that characteristics such as standardization and modularity, for instance, are still useful, but useful for community autonomy and resilience, not for financial profit for a selected few.

Table 4 Potential unsustainabilities of DE

Potential environmental unsustainabilities	Potential social unsustainabilities
Large-scale centralized production units could optimize resource consumption and emissions (per production outcome)	DE production units are not necessarily empowering local economies and well-being
In centralized production units, labour practices could be more specialized ("expert"), i.e. optimizing resource consumption and emissions (per production outcome)	DE production units, particularly the increase of do-it-yourself, could at the same time decrease employment, as far as doing something by oneself reduces the opportunities to employ local experts
DE production units are not necessarily (designed) with a low environmental impact (e.g. to use renewable resources)	DE production units could be used merely as a strategy to outsource locally, without proper care for safety standards and the quality of life in workplaces
DE outcomes do not necessarily have a low environmental impact	An increase in the amount of local production or services may jeopardize social habits or routines
DE practices that involve increased digitalization may contribute to greater volumes of e-waste, increased electricity consumption, greater embodied energy of electronic system components and increased consumption of scarce resources such as rare earth metals	Local production or services may require expert knowledge and/or material or cultural resources that are not locally available

Especially in the last five to ten years, internet-enabled, open, peer-to-peer connectedness has enhanced our ability to participate and radically distribute tasks and activities. However, it has also weakened our physical and mental health, accelerated throughput of e-waste, increased our global need for energy, further marginalized the already marginalized, and threatened our very democracies. It appears, then, that we need to not only re-visit the literature but continually update our alternative conceptualizations of the economy and its role in structuring our relationship to the living earth and webs of life. For more resilient communities, the DE concept has emphasized good environmental performance, local people's preferences, quality of life and well-being [30], while particularly examining privileged regions in northern Europe. The Stockholm Resilience Centre has emphasized how humans and nature are intertwined in complex social-ecological systems, where resilience-building needs to nurture diversity, combine different types of knowledge for learning and create opportunities for self-organization [26], while remaining within the paradigm of 'development'. From the perspective of post-development and post-coloniality, acknowledging that global inequities are only increasing, Escobar [23] and others have emphasized plurality, community autonomy and self-determination.

To conclude, despite its potential unsustainabilities, DE still stands as a useful framework for understanding how we want to shape our local economies, even within a rapidly transforming, global environment with many industrial and post-industrial trajectories.

8 Understanding DE from Different Contexts

8.1 A Brazilian Perspective

The service sector is the largest component (70%) of the Brazilian national Gross Domestic Product (GDP). However, there is an uneven development pattern of the sector across the country. Service activities are concentrated in the same large poles with a North-South divide: the South concentrates the most dynamic sectors and providing greater diversity of services, as well as larger sizes of firm, i.e., greater economies of scale. The North, particularly in the northeast region, shows lower diversification of services and an intense concentration of the 'Public Administration' sector [10]. The inequalities in the country are particularly relevant when it comes to access to basic sanitation, sewage treatment and potable water [63]. The provision of services on items such as water and electricity still follow a poorly effective and highly centralized approach. According to Lepre and Castillo [35], in the Northeast region, one of the poorest in the country, many communities still live in the dark and distant from sources of drinking water. Whilst Brazil is one of the world's leading producers of hydroelectric power, with a current capacity of about 260,000 megawatts, the most relevant initiatives in the energy sector are those directed towards large-scale facilities [63].

In order to reverse this situation, there is a growing number of community-based initiatives, start-ups and NGOs that are investing in more decentralized or distributed approaches, deploying and implementing water and energy solutions with small and flexible localized units. New regulation is stimulating the construction of small-scale hydroelectric plants, which in Brazil are defined as those with a capacity of 5 to 30 MW and an area of reservoir limited to 13 km^2. From 331 small-scale plants in 1999, the country reached 1129 in 2019, according to ABRAPCH [1].

Industry in Brazil follows a Distributed Economy in those sectors with lower demands on technology or with lower demands on capital investment, enabling individuals or small companies to start their own business. This is the case in the clothing and textile sector, for instance. Brazil is a country where all stages of the clothing supply chain can be found within the country borders, from fibre production to semi-processed products (yarn and fabrics with their finishing processes) and final products. Industrial clusters in this sector are good examples of decentralized or distributed approaches to the economy. These clusters are composed of a variety of company sizes and types, including cooperatives and/or craftworkers, organized in close proximity to customers and suppliers, contributing to optimize their production and logistic processes.

In contrast, in the agricultural sector, there is a mix of centralized, decentralized and distributed approaches, operating simultaneously across the supply chain. Part of the expansion of the agribusiness sector occurred at the expense of the environment, including the Amazon. It is quite common that investment in this sector prioritizes large-scale farms, huge silos that often stock grains for more than a year waiting for better international prices, and large ports with correspondent large ships to transport commodities across the oceans. However, in this same agricultural sector there are federal, state and municipal initiatives directed towards family agriculture, which is highly distributed in its essence, with around 800 thousand rural inhabitants being assisted with credit, research and extension programmes [42]. These small-scale local farmers supply food to rural communities, schools and on urban street markets, in direct contact with their final consumers.

8.2 A Chinese Perspective

In China, sustainable development has become a social consensus. Meanwhile, the relevant concepts of sustainable development have been widely recognized at all levels of society, and these concepts are consistent with the principles of the DE to a certain extent. On the other hand, China can benefit from its development in the Internet field, and the promotion and implementation of a distributed economy are possible. We can see that technological advances are rapidly affecting and changing China's consumption patterns. Manufacturing, energy, water, food and information/knowledge production industries are showing decentralized/distributed trends and potentials to varying degrees and will bring challenges to the mainstream economic model. However, it should also be noted that China's current development success has actually relied on a central development model. Therefore, for a long time to come, in China, the status of this central economic development model will remain unshakable. All stakeholders committed to promoting China's sustainable transformation need to think carefully and rationally about the role of the distributed economy.

We also need to acknowledge that the sustainable development of various regions in China is not balanced, and there is a clear difference in sustainable development between second/third-tier cities and first-tier cities (Beijing, Shanghai, Guangzhou and Shenzhen). Especially in terms of sustainable production and consumption, although China has been actively promoting cleaner production and green consumption lifestyles, China's economic development mode is still in a relatively extensive stage. Consumption and high pollutant emissions still exist. On the other hand, the public's awareness of green consumption and production needs to be further improved. From another perspective, this can also be seen as an excellent opportunity for a distributed economy to realize its sustainable potential. As a large and dynamic country, China is likely to have extensive and in-depth development and actions in many areas of the distributed economy in the future [68].

8.3 A Finnish Perspective

In Finland, certain concepts related to a more sustainable society have become prominent, which are grounded on principles that are compatible with those of Distributed Economies. This is not surprising, as DE was developed in the neighbouring country of Sweden, and much of northern Europe has experienced the negative economic effects of manufacturing that has moved offshore to regions with cheaper labour and raw materials while recognizing that our consumption patterns are also outsourcing pollution and bad working conditions to these regions. In Finland, this was especially visible in the fashion and textiles sector. DE principles related to revitalizing the economy, regional collaboration on high-value-added, high-quality products using local raw materials and resources (knowledge, manufacturing capabilities and skills), are therefore easily applied. The most popular economic revitalization concept that robustly embeds sustainability considerations in Finland is that of a Circular Economy (or Circular Bio-Economy). In this vision, local resources related to biomass circulate as biological nutrients in the organic cycle of the economy, adding value where possible through upcycling and cascading. Stakeholders, companies, research institutes, investors and customers, collaborate in production, research and innovation, in order to diversify the Finnish economy and strengthen its resilience. Therefore, Finland as a region with a particular industrial history would find many aspects of Distributed Economies strategically attractive.

8.4 An Indian Perspective

Pre-colonial industrialization in India was largely based on distributed, village-based economies, even for global trade in manufactured goods like textiles and handicrafts. However, colonization and the subsequent post-colonial industrialization created a push towards centralized global and monopolistic manufacturing systems which denuded the network of local production economies. Over the last few decades, there has been cross-sectoral movement back towards distributed economies motivated mainly by issues of livelihood generation and economic empowerment by tapping into urban markets to develop opportunities for rural economies.

Distributed production systems were revived on a large scale through cooperative dairy companies like Amul and traditional food companies like Lijjat Papad, formed in the late 1940s and early 1950s, which have managed to develop vast networks of village-based production units. These companies set the template for distributed economies which, over the past two decades, have developed in diverse sectors like fashion and textiles, handicrafts, food processing, energy production and water management among others, resulting in tens of thousands of people being financially empowered and in a shift towards more environmentally and socio-ethically conscious consumption patterns, as well as a growing interest in traditional and indigenous aesthetics and lifestyles.

In urban India, distributed economies have been powered by technological aggregator platforms mainly in the service sector in industries ranging across design and architecture, construction and maintenance, transportation, food and beverages and hospitality. Environmentally sound practices are increasingly being incorporated into these platforms.

While these developments are varied and exciting, their theorization within the discourse of distributed economies remains at a nascent stage. The challenge will be to understand how these economies function in relation to each other and how they can work within larger economic and ecological systems.

8.5 A Mexican Perspective

We can distinguish three important factors in the Mexican economy:

1. Large investments are made by transnational industries that are concentrated in specific states. According to INEGI (National System of Statistical and Geographical Information in Mexico), the manufacturing industry has made the largest contribution to state GDP in Coahuila de Zaragoza, Querétaro, State of Mexico, Aguascalientes, Guanajuato, Puebla and San Luis Potosí, which coincides with the investment plans reported by a survey published by Manufactura MX [37].
2. The traditional production models that have been able to resist Mexico's incursion into global markets are those oriented towards a Distributed Economy.

3. The informal sector takes an important role, both because of its scale and because it mainly focuses on the satisfaction of local markets, one of the key characteristics of Distributed Economy models.

In Mexico, the industrialization process has focused on development poles in specific geographical areas, which has created impoverished regions where economic activities develop with difficulty. The industrialization process in Mexico has not always been the result of an international state policy; sometimes it has responded to industry push and the changing conditions of the environment [25]. On the other hand, after the entry into force of NAFTA (North American Free Trade Agreement), industrialization has been driven by the creation of global supply chains, where the strategy focuses on opening up to foreign trade [25] and not to the satisfaction of local markets.

The investment plans of the manufacturing sector are settled in eight states (national regions). It is not yet a priority to enter the three special economic zones (EEZs) declared in 2015 by the federal government to boost development in regions with greater social and economic lags in the country, according to the study [37]. This indicates that although there are public policy efforts to generate development poles that move closer to the decentralized model, the investment plans of the companies are oriented towards maintaining a traditional industrialization model. The survey applied to 812 Mexican business leaders nationwide, of large and medium-sized companies from various industries, established in the country, reveals that 55% of those interviewed are taking their company to a state in Mexico. In 2015, that estimate was 63 percent [37].

However, it is possible to find cases of models closer to distributed economies that respond to the satisfaction of local markets. Nevertheless, they are currently in danger because of public policy trends aimed at impacting global markets. To take one example, the Colonia Morelos neighbourhood in Mexico City is so large that it contains two important boroughs: the Cuauhtémoc and the Venustiano Carranza. It is currently one of the most important areas for drug trafficking, which has made it a violent area; however, its commercial activities dating from the last century (1881) still prevail. At that time, its inhabitants were engaged in the manufacture of shoes, a trade of great tradition and which continues in one of its neighbourhoods, Tepito. Currently, along the principal avenue of that zone, several supply stores related with the manufacture of shoes and bags are established, as well as workshops that offer Product-Service Systems i.e. manufacturing parts of the shoe production process are offered. In other words, shoemakers who do not have sewing machinery, for example, can send their pre-cut pieces to local workshops, which offer sewing services. In this way, finished products are offered in the local Granaditas Market.

In Mexico, local markets are served not only by the formal sector: 76 out of every 100 pesos generated from GDP are produced by 42% of all formal jobs and 24 pesos are generated by 58% of informal jobs. Informality in Mexico is widespread and, in particular, much more widespread than in other countries in the region. High informality is worrying because it denotes an inadequate distribution of resources (in particular labour) and an extremely inefficient use of government services, which can compromise the country's growth prospects. Mexico's principal challenge would be focused on finding an efficient strategy to turn back to local markets through DE.

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Integrating S.PSS and DE

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1 Introduction to S.PSS Applied to DE: Sustainable Opportunities

The combination of Sustainable Product-Service Systems (S.PSS) and Distributed Economies (DE) has been considered as a promising mode of developing sustainability through regional resilience and by empowering a shift to a more localized economic model [11]. Especially in regions with significant middle- and low-income populations, DE provides possibilities for increased localized employment generation, and many such schemes have been implemented in both urban and rural areas. In underserved regions, this could help decrease emigration and develop better services in these economies. The LeNSin project studied the shift to S.PSS as a mode of DE designing and delivering. The win-win sustainability benefits could be summarized as follows.

S.PSS is a promising approach to diffuse DE in low/middle-income (all) contexts, because it reduces/cuts both the initial (capital) cost of DE product/equipment purchasing (that may be unaffordable) and the running cost for maintenance, repair, upgrade, etc. of such DE hardware (that may cause

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C. Vezzoli et al. (eds.), *Designing Sustainability for All*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-3-030-66300-1_3

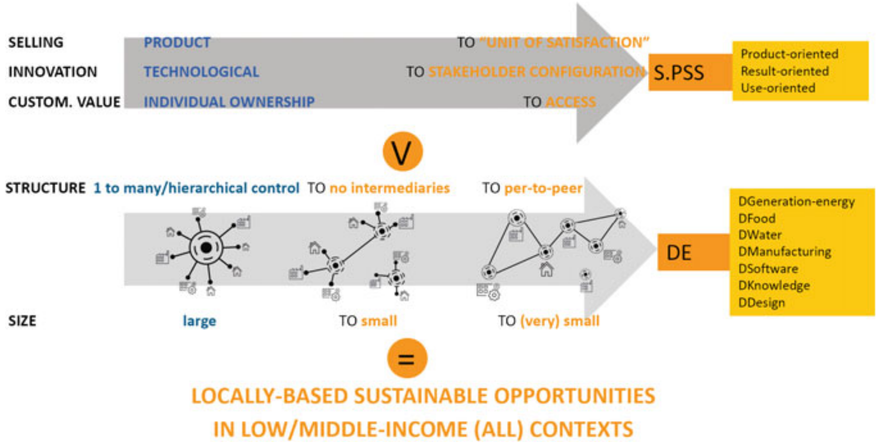

Fig. 1 The coupling of the two win-win sustainability paradigm shifts represented by S.PSS and DE

the interruption of use) increasing local employment and related skills. Furthermore, by offering a DE system adopting an S.PSS model, the producer/provider is economically incentivized to design low environmentally impacting DE products/equipment. Finally, S.PSS applied to DE is a promising key leverage for a sustainable development process for all aiming at democratizing access to resources, goods and services.

These win-win potentials are based, in fact, on the coupling of the two win-win sustainability paradigm shifts of S.PSS and DE we have already discussed in the previous chapters of S.PSS and DE we have already discussed in the previous chapters (see Fig. 1):

1. The shift from a 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;
2. 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.

Further consideration could be made in relation to the increased access to the internet and digital infrastuctures and tools combined with the projected development of distributed technologies, such as 3D printing, which significantly increase the potential and ease of setting up these Distributed Economies. In areas with low income, even basic internet penetration has opened up possibilities to access knowledge and know-how to set up distributed networks. A number of organizations and governments are supporting the set-up of such networks in low- and middle-income regions, and the main focus is to develop affordable systems with the aid of technology that requires lower investment cost. In middle- to higher-income regions, the likelihood of using more capital-intensive processes (like 3D printing manufacturing) is higher and there is a push to develop DE networks with the aid of technology. However, it seems that technology and access to information sharing systems will be key to developing scalable and replicable DE. With the accelerated pace of technological penetration, it is possible to envision what an S.PSS would look like applied in a DE format.

Sustainable value-adding PSS can only be created taking into account every life cycle stage of products and services [8]. Distributed Manufacturing, for example, applied to *near-future* scenarios addresses each S.PSS life cycle stage, thus showing the potential to improve PSS development from the sustainability point of view:

- The *design* stage predominantly benefits from collaboration between PSS provider and customer, enabled by connectivity through digital channels and physical interaction in local production facilities, which results in better S.PSS acceptance.
- The *material production (pre-production)* and *production* stages benefit from the distribution of manufacturing facilities, equipped with digitally connected manufacturing technology. The ability to send digital production files to remote locations, for example, allows PSS companies to produce products and spare parts in close proximity to customers and/or resources, thus reducing the environmental impact of distribution.
- The *use* stage is supported with the largest number of near-future scenarios tackling on-site and on-time provision of maintenance services and empowering customers to maintain, repair, update, upgrade and re-manufacture the products included in the S.PSS solution.
- The *end-of-life* phase is facilitated by the application of sensor technology, which helps to indicate products' and components' end-of-life by alerting PSS providers and customers. Finally, a distributed network of localized recycling facilities eases product collection, recycling and/or energy recovery.

This chapter examines case studies of S.PSS applied to DE (both Distributed and Decentralized production units) from across the globe. It is important to note nevertheless that it is challenging to clearly define and categorize the case studies, as most of them consist of varying degrees of PSS or DE with different types of interactions. These could, however, be used to develop a categorical understanding of S.PSS applied to DE.

2 Case Studies of S.PSS and DE Integration

2.1 S.PSS and Distributed Energy Generation (DG)

As discussed in Chap. 2, Distributed energy Generation (DG) represents a promising strategy to provide energy access with a range of sustainability benefits. However promising, the implementation of DG solutions should not only focus on the technical

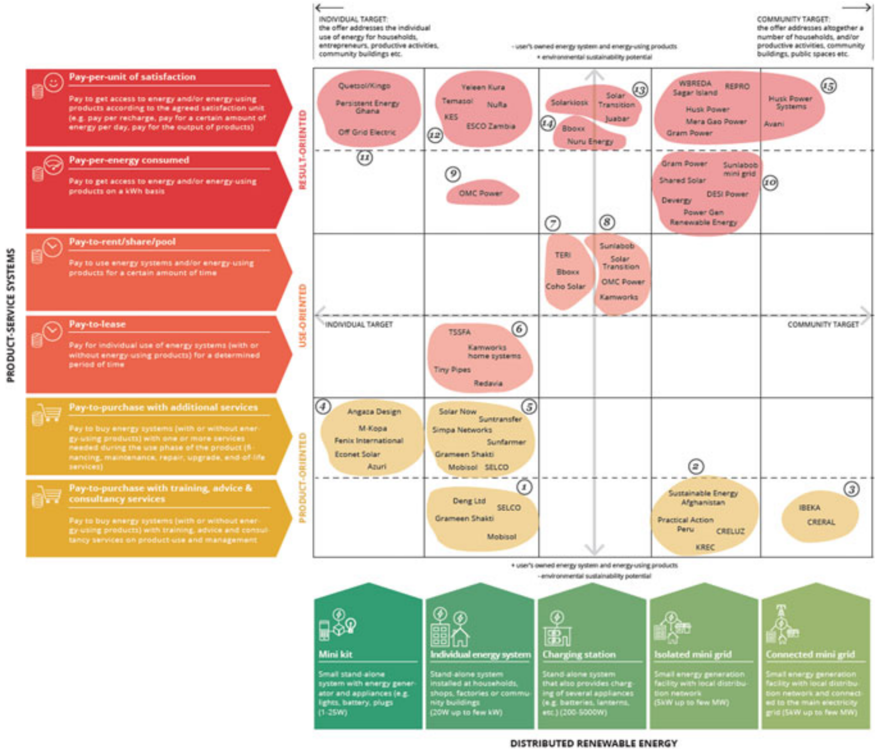

Fig. 2 Archetypal models of PSS applied to DG in low- and middle-income contexts [2, 3]

aspects. There are other aspects which are crucial for the success of DG solutions. Most of the unsuccessful cases of DG are linked to problems such as the lack of a maintenance and repair network, lack of understanding of user needs or lack of a proper business model [3, 10]. For this reason, an S.PSS system design approach should be adopted. This means that, in addition to energy technology, the stakeholder value chain, the product-service combination and the business model aspects should be taken into consideration and integrated into systemic solutions [6, 9]. S.PSS applied to DG can be categorized in 15 archetypal models (Fig. 2) [2, 3]:

1. Selling individual energy systems with advice and training services;
2. Offering advice and training services for community-owned and-managed isolated mini-grids;
3. Offering advice and training services for community-owned and-managed connected mini-grids;
4. Selling mini-kits with additional services;
5. Selling individual energy systems with additional services;
6. Offering individual energy systems (and energy-consuming products) in leasing;
7. Renting energy-using products through entrepreneur-owned and-managed charging stations;

8. Renting energy-using products through entrepreneur- or community-managed charging stations;
9. Offering access to energy (and energy-using products) on a pay-per-consumption basis through individual energy systems;
10. Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids;
11. Offering access to energy & energy-using products on a pay-per-unit of satisfaction basis through mini kits;
12. Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through individual energy systems;
13. Offering access to energy-using products through community- or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis;
14. Offering recharging services through entrepreneur-owned & -managed charging stations;
15. Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini-grids.

Several case studies of S.PSS and Distributed energy Generation (DG) are presented below.

SELCO (example of archetypal model 1 and 5)

Active since: 1995
Provider/s: SELCO and local community agents
Customers: Rural Households/Communities, Institutions
S.PSS Type: Product-oriented S.PSS
DE configuration: Distributed and Decentralized energy Generation
Products: Solar Home Lighting, Solar Water Heater, Solar Inverter Systems, DC Home Appliances like Butter Churners, Grinders, etc.
Services: Product customization, installation, maintenance and repair, community training, tailoring financing options, advisory and capacity building.
Payments: Pay for product-service-system
Resource: Solar Energy
Location: India

SELCO is a rural energy service social enterprise that provides affordable and environment-friendly energy services to rural households. SELCO produces solar Product-Service Systems for individuals, communities or institutions. The ultimate aim of the company is to provide affordable rural electrification through renewable sources and to achieve this, SELCO provides services that include financing consultancy, customized product configurations, training, maintenance and repair.

The company also creates additional distributed economies by training local youth for maintenance of the systems, supporting local entrepreneurs who can buy the

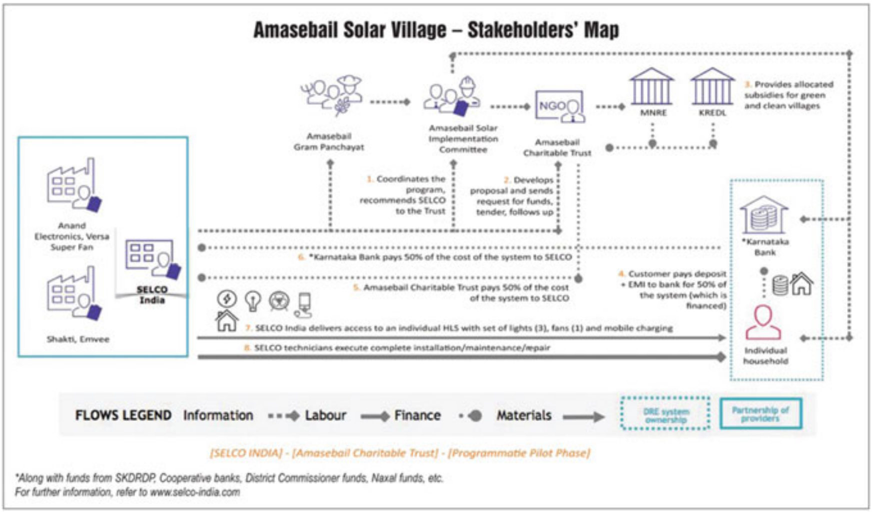

Fig. 3 System map of a SELCO S.PSS for a village in India. (*Source:* renewablewatch.in)

system and develop a livelihood by providing charging services and connecting them to financial services. The company has also diversified into producing solar energy-powered products like sewing machines and photocopy machines which can further develop into opportunities for distributed manufacturing.

The most striking characteristic of the company is its targeted user group and diversified Product-Service System in a standard distributed format, involving multiple relevant stakeholders (Figs. 3 and 4).

Solarkiosk (example of archetypal model 15)

Active since: 2011

Provider/s: Solarkiosk Solutions GmbH (E-HUBB and related equipment); local subsidiary (installation, maintenance and repair)

Customers: Solarkiosk local subsidiaries (own model), international organizations (B2B)

S.PSS Type: Use-oriented (B2B), Result-oriented (B2C)

DE configuration: Decentralized energy Generation

Products: E-HUBB, Solar Pico systems, Solar Home Systems, PAYG systems, other products

Services: Project based design, production, installation, maintenance, engineering

Payments: E-HUBB is in ownership of Solarkiosk (own model), Project budgets (B2B sales)

Fig. 4 Solar powered cow milking unit. (*Source* SELCO)

Payments: E-Hubb is given for free (B2B), Pay per use (B2C)

Resource: Solar Energy

Location: Ethiopia, Kenya, Rwanda, Tanzania, projects realized in 11 other countries

The company targets local entrepreneurs, especially women, for the provision of energy services through charging stations. Solarkiosk designs and installs the E-Hubb, a charging station provided with solar panels and energy-consuming products and recruits a local entrepreneur who manages the system and appliances. Due to the modular configuration of the station, he/she can provide a wide range of energy-dependent services such as internet connectivity, water purification, copying, printing and scanning. Customers pay for the service they need: pay to print, pay to get purified water, pay for internet access and other services (Figs. 5 and 6).

2.2 S.PSS and Distributed Food Production (DF)

If small-scale Food production units (DF) are connected with other DF (e.g. to share food overproduction), they become a Distributed Food Production Network (DFN), which may in turn be connected with nearby similar networks. If properly designed they hold promise to promote locally based sustainability, i.e. Sustainable Distributed Food production (S.DF) systems.

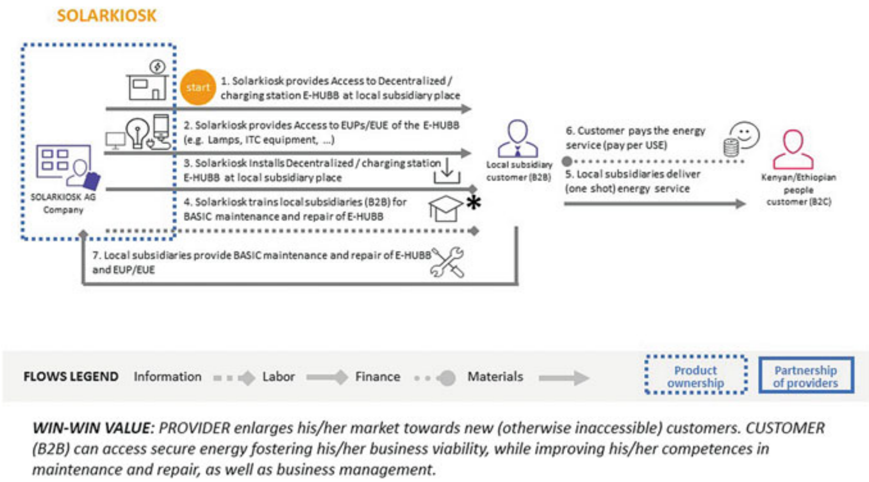

Fig. 5 Solarkiosk system map

Fig. 6 Solarkiosk Ethiopia, 2011

The new configuration results in reducing the need for transportation of food from outside the city. It also minimizes the use of packaging and storage. Producers and consumers connect with each other, and consumers assume a new role as co-producers who have the opportunity to learn more about local food production, while they get involved in the process of growing food and raising animals. In this way, urban farming empowers communities to share knowledge and diversity, keeping alive food traditions and local food heritage.

Several case studies of S.PSS and Distributed Food production (DF) are presented below.

PickYourOwn

Active since: 2008

Provider/s: Farmers

Customers: Home users (B2C), Commercial Business (B2B)

S.PSS Type: Use-oriented S.PSS

DE configuration: Decentralized Food production

Products: Fruits and vegetables

Services: Use of kitchen and canneries facilities, channel for collaboration, education, consultancy and certified production.

Payments: Pay per period/time or pay per produced unit or each process for the use of kitchen/caning facilities. Pay per product (farm)

Location: USA

Pick-your-own is an idea for home or commercial users to pick their own fruit from the local farms near them and use them in distributed food production. The website PickYourOwn.org lists farms located all around the country who provide their products to be sold with the pick-your-own concept. On the website there is also a calendar of the harvesting time of different products. The home users or commercial users can pick fresh vegetables and fruits on these farms and produce canned/bottled/packed products using the kitchen/canning facilities that are in shared/community/commercial kitchens and canneries. The users can produce products for their own use as well as to sell or exchange. While most of the facilities are more oriented towards home users, some are oriented towards commercial users. In most sites, they also provide information and education for production in their facilities. Some have licenses that enable users to produce for commercial use. They also function as a hub for users to meet, collaborate and learn from each other. The two common payment methods are pay per period, pay per produced unit/each process or a combination of both. In this case, while the production and consumption of vegetables is distributed, the production also includes the service of fresh food combined with the customer experience of handpicking it. It also reduces the need for packaging and transportation for the producer as well as ensuring a fair price for the produce (Figs. 7 and 8).

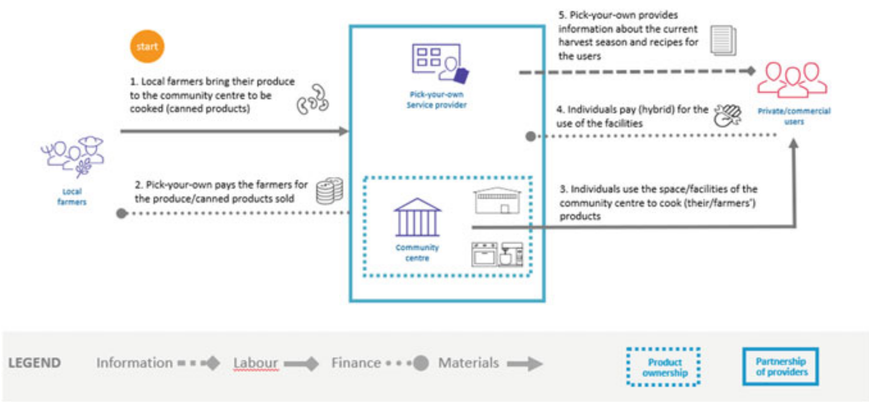

Fig. 7 Pick-your-own system map

Fig. 8 Example of a Pick Your Own farm, 2008

FoodyBuddy

Active since: 2017

Provider/s: Home Chefs

Customers: Hungry Individual Consumers

S.PSS Type: Use-oriented S.PSS

DE configuration: Decentralized Food production

Products: Fresh Cooked Meals

Services: Aggregator platform connecting home-based chefs to customers

Payments: Pay per product delivered

Location: India

Foodybuddy is a neighbour food network that connects home-based chefs to customers at a hyper-local level. The app allows home chefs to decide upon the menu, number of portions, days of sale, timings and pricing of meals, allowing for flexible income generation. The consumer has the advantage of viewing a daily menu of food on offer in their neighbourhood or apartment complex and communicate with the seller on the app.

Since this system works at a hyper-local level, it eliminates the need for transportation. The food is either delivered by the seller or picked up by the consumer. This also allows the seller and the customer to interact personally and develop connections within the neighbourhood. There is an opportunity to connect this service with existing delivery services if it is so required, as an example of a networked distributed system (Fig. 9).

Fig. 9 Service onboarding on the Foodybuddy App. (*Source* Foodybuddy App)

2.3 S.PSS and Distributed Water Management (DW)

Water management is an area that is increasingly witnessing the dangers of the failure of excessive centralization. With the development of regional scale systems of water management like large dams and reservoirs—primarily for agriculture and power generation—there is evidence of increasing negative impacts on ecosystems [1].

Decentralized solutions for water collection, storage, treatment and use are being revived from traditional systems or developed as new solutions to cater to the needs of vast populations underserved by centralized water management projects. In many parts of the world, limited access to fresh water is also becoming an issue of political contention which disenfranchises vast numbers of people from the process of water management and access. In this scenario, provision of clean water as a service has great potential for developing distributed models of management and access that also empowers communities to be self-sufficient and fosters community-based income generation models. There are organizations that work with community-based catchment management, water storage and treatment.

Several examples of organizations that provide potable water to underserved communities in an S.PSS and Distributed Water management (DW) are presented below.

Piramal Sarvajal

Provider/s: Piramal Sarvajal with local franchisees

Customers: Underserved rural and urban communities

S.PSS Type: Use-oriented S.PSS

DE configuration: Decentralized Water Management Network

Products: Water ATMs, Water purifiers, Water Quality Monitoring Units

Services: Community awareness and training, centralized water quality monitoring, water delivery system

Payments: Pay per use

Location: India

Piramal Sarvajal sets up community-level solutions that are locally operated but centrally managed on a market-based pay-per-use system. The last-mile operational accountability is ensured by developing and deploying remotely monitored and controlled drinking water purification systems. Piramal Sarvajal's other product is the Water ATM: a solar-powered, cloud-connected, smart card-based automatic water vending machine.

While the water purification and delivery systems follow a pay-per-use S.PSS model with an emphasis on socio-ethical and economic sustainability, the distributed system of water purification also allows for developing distributed economies through community-based franchisees (Fig. 10).

Ecosoftt and Gram Vikas

Provider/s: Ecosoftt and Gram Vikas (Partner NGO)

Customers: People from villages without access to clean water

S.PSS Type: Use-oriented S.PSS

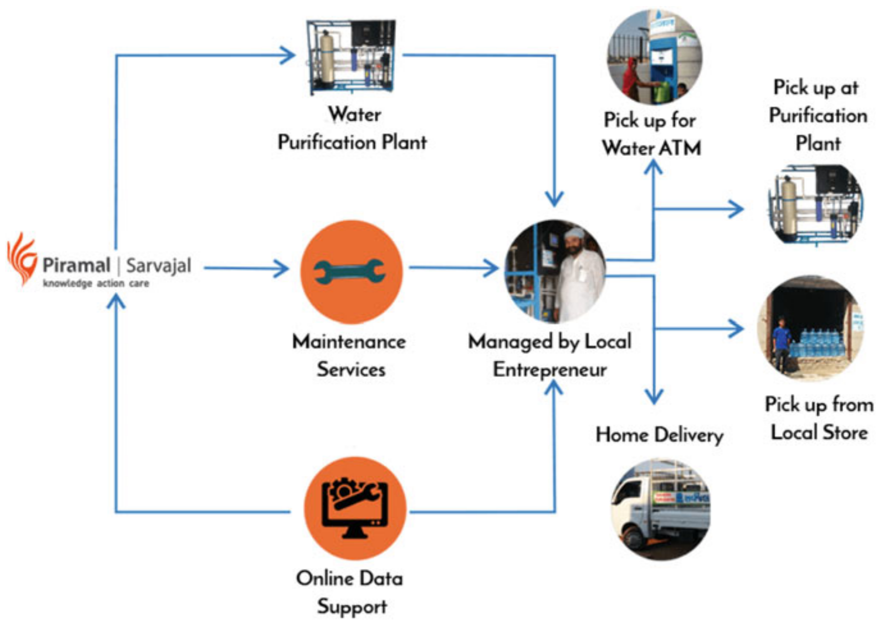

Fig. 10 System map of Piramal Sarvajal. (*Source* Piramal Sarvajal)

Fig. 11 Decentralized clean water systems for villages

DE configuration: Decentralized Water Management

Products: Equipment to build infrastructure

Services: Access to drinking water, toilets, bathing rooms and wastewater management systems

Payments: Pay per use

Location: India

Ecosoft in collaboration with Gram Vikas (an NGO) provides equipment + training for local users to build infrastructure to take water from underground and provide decentralized access to clean water in the village. The package consists of access to drinking water, toilets, bathing rooms and a wastewater management system. There is no investment cost for the local community; they pay to Ecosoft according to the amount of water they consume. The package also includes training for maintenance and providing equipment in case of replacement needed (Fig. 11).

2.4 S.PSS and Distributed Manufacturing (DM)

Current manufacturing and supply chains have become extremely efficient global systems that draw labour, material, production and assembly from centres around the world. These supply chains have been honed to function at maximum efficiency. However, it is also notable that this efficiency comes at the cost of redundancy and resilience. Global events like pandemics are proving that there is a dire need for developing more resilient and localized systems of production and distribution.

As mentioned in Chap. 2, three key features of digital manufacturing have been identified as:

- Localization of manufacturing units;
- Application of physical and digital technologies;
- Customer orientation.

Distributed manufacturing allows more people to develop local livelihood opportunities that can contribute towards building economic sustainability. A movement away from extractive global manufacturing processes marks a potential to develop ecological and socio-ethical sustainability in local communities.

Several case studies of S.PSS and Distributed Manufacturing (DM) are presented below.

StrataSys Leasing

Active since: 2011

Provider/s: StrataSys

Customers: Small and large enterprises, makers, designers, engineers (B2B)

S.PSS Type: Use-oriented and Result-Oriented S.PSS

DE configuration: Decentralized Manufactoring

Products: 3D printers, start-up supplies, support removal system, cleaning agent

Services: Optional services (system operation, inhouse support, education, project implementation, consulting)

Payments: Pay per period (fixed cost)

Location: USA and Israel (headquarters), Canada, Brazil, Mexico, Germany, Japan, Korea, China, Singapore, India

StrataSys manufactures 3D printers and offers 3D production systems for office-based additive manufacturing, rapid prototyping and direct digital manufacturing solutions. The company offers leasing service of some models of their manufactured commercial 3D printers and bundled 3D-printer packages in the United States. Besides the printer, the 3D Print Packs include start-up supplies, a support-removal system and cleaning agent. StrataSys also provides various separate services such as system operation, in-house support, education, project implementation and consulting (Figs. 12 and 13).

Fig. 12 StrataSys direct digital manufacturing solutions leasing, 2012

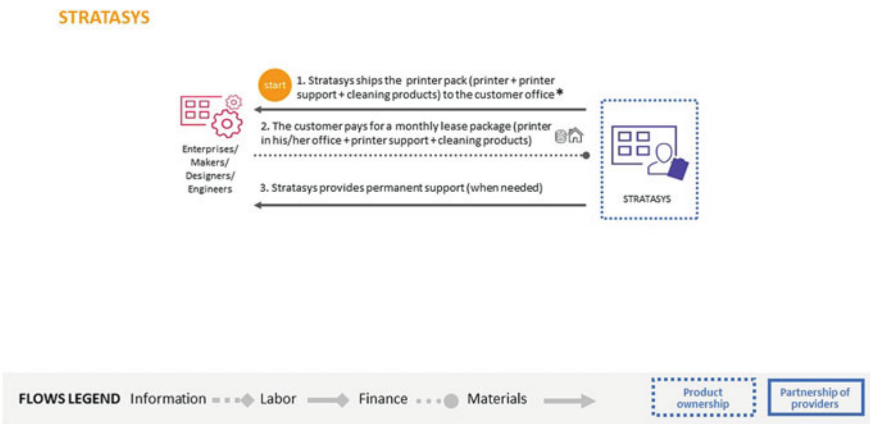

Fig. 13 StrataSys system map

Industree Foundation

Active since: 2000

Provider/s: Industree Foundation

Customers: Farmers, Artisans

S.PSS Type: Result Oriented

DE configuration: Decentralized Manufacturing

Products: Sustainable Producer Owned Enterprises

Services: Training enterprise leaders in business management, soft skills and hard skills, connecting to academia and designers, creating access to capital and markets, providing digital connectivity

Location: India, Ethiopia

The Industree foundation organizes rural communities in a distributed value chain yet integrated through an aggregated national level marketing and sourcing enterprise, with whom producer-owned enterprises have the choice to interact for some or all their transactions. The company holistically tackles the root causes of poverty by creating an ownership-based, organized creative manufacturing ecosystem for micro-entrepreneurs, most of whom are women. Distributed Design and Manufacturing that is equitable and sustainable can be viable only if there is an enabling ecosystem of support. Industree works to co-create an enabling platform using its 6C principle:

1. **Construct**: Business model innovation through producer ownership and inclusive entrepreneurship. Producer members earn through fair wages for production and shared profits from production and marketing. Aggregation for viability in material sourcing, professional management, productivity, access to market and capital.

2. **Capacity**: Training encompasses a grassroots business academy that trains producers and micro-enterprise leaders, paraprofessionals who work in the unit as professional support and service, and enterprise leadership. Training of professionals and enterprise leaders for broad handholding for replication and adaptation beyond Industree.

3. **Create**: Co-creation of design by professional designers who are part of the professional management group, alongside master artisans, designers would also be part of the professional management team. The efforts of the inhouse team will be bolstered by students and academic institutions from the region and beyond convened by Industree.

4. **Capital**: Creating access to capital through partnerships with Non-Banking Financial Company (NBFC) and working capital pools. A revolving working capital pool will be created along with funds offered through schemes of the Micro, Small and Medium Enterprises (MSME) sector and access to loans from banks based on purchase orders received.

5. **Channel**: Markets, connecting to markets both B2B and B2C, creating the awareness among buyers through meets and workshops, using brands to connect with

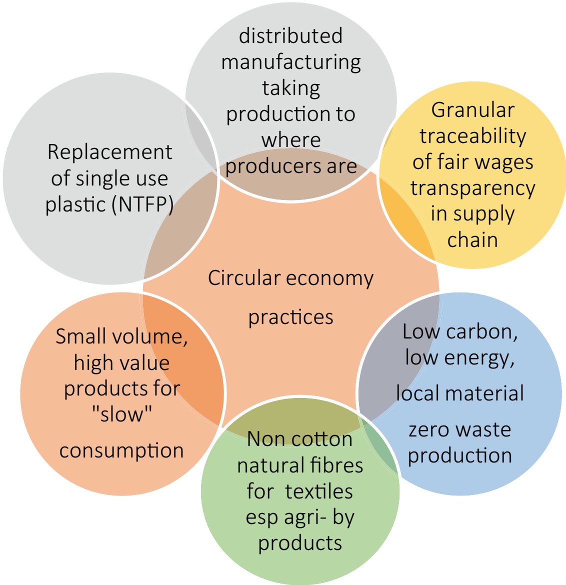

Fig. 14 An example of Circular Economy practices of Industree

brands. Participation in fairs and exhibitions to promote the products, nationally and regionally.

6. **Connect**: Digital connectivity primarily through mobile applications, through which sustainable enterprises in the creative manufacturing can be supported, serviced, incubated and accelerated (Figs. 14 and 15).

2.5 *S.PSS and Distributed Software (DS)*

While the internet began as a decentralized network of servers accessed by a network of users, there has now been a shift towards an increasingly centralized net through intermediaries like Google and Facebook whose servers handle a significant portion of all data on the internet. This has led to concerns over individual and organizational privacy, data protection and data ownership and agency. There is also a growing realization that these intermediaries have disproportionate control over information flows. Since online media now encompass critical sectors like finance, social networking and business, there are emerging alternatives that seek to develop networks of distributed and localized data storage and application embedded in communities rather than global corporates.

The case studies of S.PSS and Distributed Software (DS) presented below demonstrate a movement towards community-based and community-led online services. However, it is to be noted that although distributed software and in particular the

Fig. 15 Bangalore GreenKraft—one of the enterprises set up by Industree

case studies chosen show potential opportunities for developing S.PSS models, they have not yet actively incorporated it into their current form.

Secure Scuttlebutt

Active since: 2014

Provider/s: Secure Scuttlebutt

Customers: Community

S.PSS Type: Result-Oriented

DE configuration: Decentralized Software

Products: Offline Friendly Secure Gossip Protocol

Services: Data Ownership, End to End encryption, Agency over interaction

Payments:-

Location: Worldwide (origin New Zealand)

Secure Scuttlebutt is a localized but distributed social network that works with a peer-to-peer mesh network where user data is stored locally on user devices rather than a centralized server [7]. The data is exchanged between devices through data replication on a shared WiFi or local area network or even with a USB stick. It is also possible to connect to the network using public servers called “Pubs”. The intent of Secure Scuttlebutt is to eliminate the need for connection to centralized servers while still having the network intact through a localized community of devices. This develops a resilient system that is upheld through the distributed network.

On a voluntary basis, it is possible for users to engage monetarily using the Secure Scuttlebutt Consortium. As an S.PSS model, in exchange for a voluntary donation, the developers are able to provide an opportunity for an alternate social media network that protects user data and allows the user to choose terms of engagement with the network. It connects people who do not have access to a regular internet service and can also be used in emergency situations.

Holochain

Active since: 2006

Provider/s: Holochain is a technology that can be used by multiple providers

Customers: Communities of users and developers

S.PSS Type: Product- or Use-oriented S.PSS (depending on the application)

DE conf.: Distributed Software

Products: HoloPort device for hosting (optional)

Services: Framework and protocol for app development

Payments: Hosts are paid in crypto; Holo takes a percentage transaction fee

Location: Worldwide

Holochain is a framework for building distributed peer to peer applications that is based on a shift from data centric computing of the Blockchain to an agent centric model. Holochain is a way of building and running applications on the user’s own devices and without using an intermediary server. Users within a community that have spare computing capacity on their devices can host the applications of others. In exchange for this, the contributor gets paid in Holo Fuel, a crypto-currency that can be used to buy applications or hosting services within the community. Another characteristic of Holochain’s agent-centric approach is that the users determine the terms of engagement within their own communities and this cannot be disrupted by others.

As a distributed computing system, parallels can be drawn with a two-way power grid, except here computing capacity is shared by users. It is possible to envision ways in which this peer-to-peer sharing system can allow users to build a sharing ecosystem of online and offline services in future (Fig. 16).

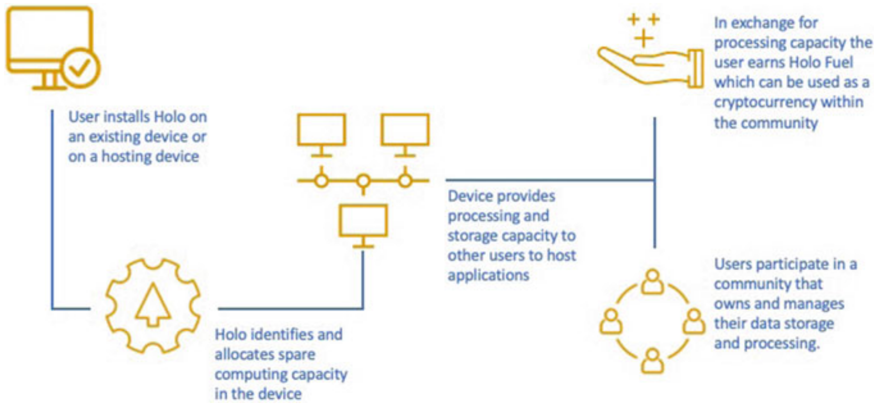

Fig. 16 Holochain system (Adapted from [5])

Linux

Active since: 1991

Provider/s: Community of developers

Customers: Community

S.PSS Type: Use-oriented S.PSS

DE conf.: Distributed Software

Products: Computer code

Services: -

Payments: Free

Location: Worldwide

Linux is an open-source operating system that is used in smartphones, personal computers, netbooks, supercomputers, servers, embedded devices, home appliances, cars and so on. The source code can be used, modified and distributed by anyone under the GNU General Public License, with the condition that whoever distributes software using a source code under the GNU license must make the original as well as the modified source code available under the same terms. Thus it can be said that Linux is software produced by a network of developers e.g. small-scale producers that are connected with each other locally and globally (Fig. 17).

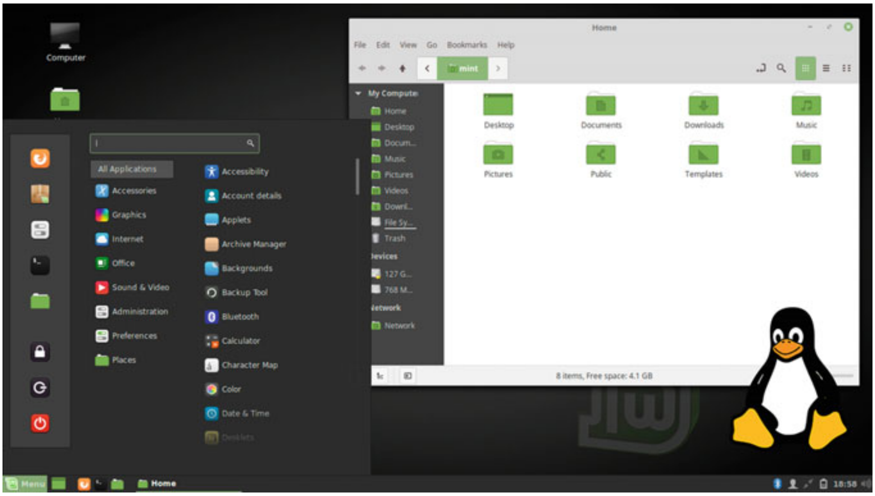

Fig. 17 Examples of Linux application

2.6 S.PSS and Distributed Knowledge (DK)

Internet and web technology has revolutionized learning by providing a vast amount of learning resources across disciplines that are easily accessible and very affordable, often only at the cost of the internet service. One of the main ways in which this has influenced education in universities and schools is bringing ways of learning, thinking and doing to the forefront since it is now fairly common to be able to pick up skills through online resources. There is also a shift towards self-directed learning where students decide which subjects and skills are most appropriate to support their own goals and interests.

A number of online learning platforms like EdX and Coursera provide online courses from universities across the world and in a range of subjects that can be freely accessed by anyone with internet access. Additionally, on passing a course, it is also possible to pay a nominal fee for receiving a certificate from the respective university.

There are also attempts to draw a link between online learning communities and physical communities in distributed knowledge production and application. The case study of S.PSS and Distributed Knowledge (DK) in this section illustrates one such attempt.

Project DEFY (Design Education for Yourself)

Provider/s: Project DEFY

Customers: Community

S.PSS Type: Use-oriented S.PSS

DE configuration: Decentralized Knowledge

Products: Nooks

Services: Induction Program for new learners

Payments: Income generation through innovation and projects

Location: India, Uganda, Rwanda, Zimbabwe

Location: India

Project DEFY sets up self-designed learning centres or 'Nooks' across marginalized communities in India and Africa (Uganda, Rwanda, Zimbabwe). Nooks are free-for-all 'schools without teachers' that provide everyone in the local community with access to technology, tools, resources and information to design their own education. As such, Nooks are a primary example of distributed education design where learning is decentralized, contextualized, localized and individualized.

This process is supported through a 45-day long induction programme for new learners in which they get exposed to new areas of skills and learning through hands-on practice as well as through fostering and providing a safe, inclusive space for meaningful conversations to take place among the Nook community. At the end of the induction programme, the learners are enabled (individually or in groups) to identify and write down their own, individual goals and help to break them down into concrete, hands-on projects they pursue in order to achieve their goals.

As opposed to schools and colleges where decision-making follows an authoritarian top-down approach, Nooks are managed by the community members themselves. This includes administrative decisions such as the opening times of the Nook, the responsibility for a monthly resources budget, as well as—of course—being in charge of the learning process itself.

Whereas in schools and colleges the learners are separated from the means and resources of learning—having their relations to those means mediated, appropriated, circumscribed and severed by teachers, textbooks, curriculum, etc.—Nook learners are enabled to take control of and directly own the means and resources

Fig. 18 Nook enabled by Project DEFY (Source: Project DEFY)

of learning. Importantly, Nooks do this on a scale and cost that fits within the economy of even low-income communities. In the long run, the Nooks aim to become self-sufficient and completely community-run by capitalizing on the creations, innovations, products and skills that emerge out of them (Fig. 18).

2.7 S.PSS and Distributed Design (DD)

The complex nature of contemporary design problems has led towards an increasingly collaborative and heterogeneous approach to knowledge production and design. There is a recognized need for bringing together experts and stakeholders across disciplines to fully understand the nature of dependencies of a system and to then design appropriate systemic solutions [4, 12].

A number of design platforms and collectives have emerged over the last decade. Some are along the lines of an Uber model, where designers, manufacturers and suppliers are connected with customers to enable distributed design service. In disciplines like architecture and interior design, for example, multiple companies have emerged which provide end-to-end services of design, fabrication, installation and finish with additional options such as home products and maintenance services using distributed networks of local businesses. Other distributed design models such as Local Motors are more topical and specific.

Several case studies of S.PSS and Distributed Design (DD) are presented below.

Quirky

Active since: 2009

Provider/s: Quirky (platform, online tool and connection between members and manufacturers), Partners, e.g. General Electric, PepsiCo, Mattel (manufacturing)

Customers: Designers, inventors, individuals with specific skills

S.PSS Type: Result-oriented S.PSS

DE configuration: Distributed Design

Products: -

Services: Provides a network of skilled users and access to product creation enterprises

Payments: Free (use of the platform)

Location: New York City.

Quirky is an invention platform that connects inventors with users who have other skills for developing the idea and with companies specialized in a specific product category for manufacturing. The offer is therefore access to complete product creation. Quirky's business model pays designers part of the profits that their products yield. The users do not need to pay for using the platform. The users can submit their ideas and connect with others to make a team for collaboration. Once the developed idea is accepted by Quirky through a voting system by the Quirky community at Eval (Quirky's live weekly product evaluation), it is pitched to the manufacturers. If it is manufactured, Quirky shares the profit with the team members according to their influence evaluated by a point system on the Quirky platform (Fig. 19).

Local Motors

Active *since: 2007*

Provider/s: Enthusiasts, hobbyist innovators, designers, engineers, fabricators and other professionals

Customers: Designers, inventors, individuals with specific skills

S.PSS Type: Hybrid of use-oriented and product-oriented S.PSS

DE configuration: Distributed D and Decentralized Manufactoring

Products: Motor Vehicles (rally cars, motorcycles, electric bicycles, tricycles, children's ride-on toy cars, radio-controlled model cars and skateboards)

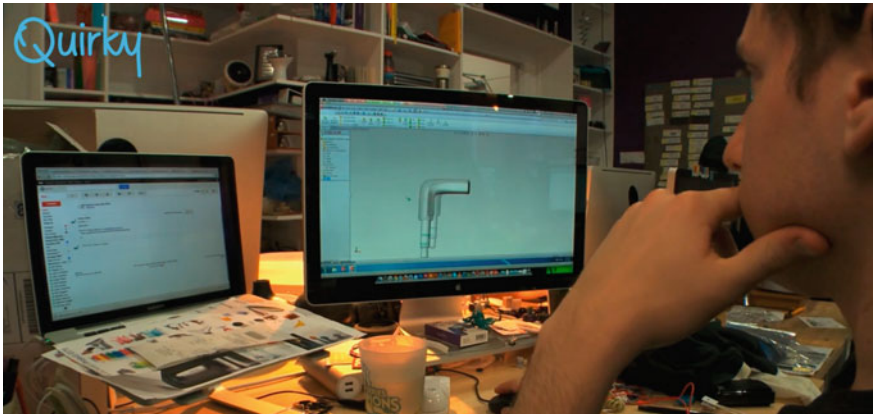

Fig. 19 Quirky invention platform, 2009

Fig. 20 Local Motors vehicle manufacturing company, 2007

Services: Management of the global network of microfactories and the co-creation community

Payments: Free (users get even paid in case of revenue for their contribution)

Location: USA

Local Motors (LM) is a motor vehicle manufacturing company focused on low-volume manufacturing of open-source motor vehicle designs using multiple micro-factories. Their products include the Rally Fighter automobile and Racer motorcycle, various electric bicycles, tricycles, children's ride-on toy cars, radio-controlled model cars and skateboards. They 3D print some components. Rally Fighters have used co-creation techniques, whereby products are designed cooperatively with end-users, as part of its designing phase. Their website is a community focusing on engine vehicle innovation. The content is co-created by the users of the community who discuss designing, engineering and building innovative engine vehicles (Fig. 20).

3 S.PSS Applied to DE: A Scenario

Envisioning the coupling of the two offer models, S.PSS and DE, some further considerations highlighting some of their evident characteristics could be given.

First of all, as far as we have diverse types of DE (Distributed energy Generation (DG), Distributed Manufacturing (DM), Distributed production of Food (DF), Distributed Water management (DW), Distributed production of Software (DS), Distributed production of Information/knowledge (DI), Distributed Design (DD) and the 3 main types of S.PSS (Product-oriented S.PSS, Result-oriented S.PSS; Use-oriented S.PSS), it is clear that a set of diverse combinations of these could emerge in principle.

Secondly, another possible main variable is the type of customer or user, i.e. whether a B2B offer, B2C offer, p2p non-market, and so on.

Furthermore, as far as the **hardware** of each DE and who is producing it is a key characteristic (because in an S.PSS offer model she/he is the one that has the economic interest to redesign it with a low environmental impact), it is of key interest to identify the hardware for each type of DE.

Finally, other characteristics worth highlighting are related to the DE structure types, i.e. they could be **Distributed** or **Decentralized** and each of those could be **stand-alone** or **network-structured**.

In relation to those variables and their possible sustainable combinations, a *Sustainable Design-Orienting Scenario* (SDOS) for *Sustainable Product-Service System (S.PSS)* applied to *Distributed Economies (DE)* in low and middle-income (all) contexts has been designed[1] to provide a new vision of sustainable production & consumption systems.

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[1]The scenario design process emerged from a case study analysis of S.PSS applied to DE (best practices), as well as an idea generation workshop focused on S.PSS applied to DE using the SDO toolkit (www.lens-international.org). The scenario presented here is an update of a scenario

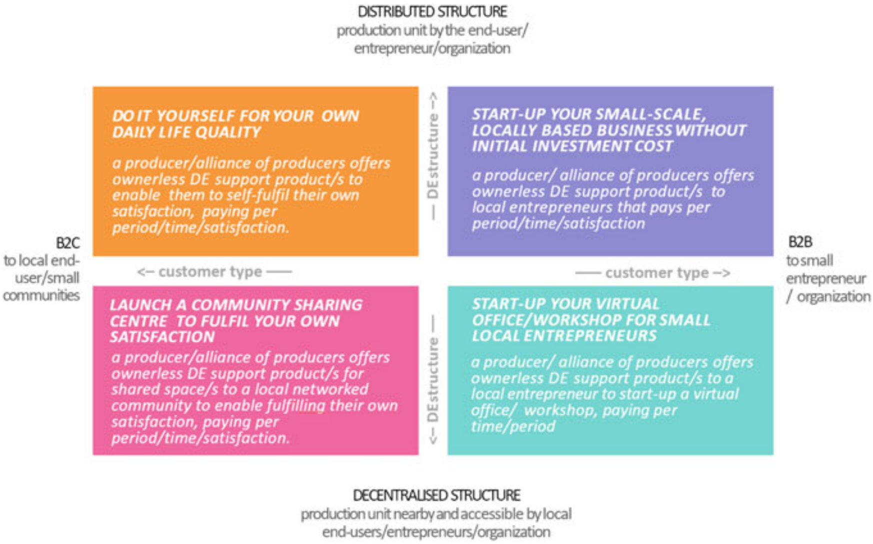

Fig. 21 The Sustainability Design-Orienting Scenario for S.PSS applied to DE

The Scenario is composed of a polarity diagram with 4 visions, for each of the 4 quadrants in the diagram matrix. Each vision represents a Sustainable win-win configuration, combining socio-cultural, organizational and technological factors, fostering solutions with a low environmental impact, a high socio-ethical quality and a high economic value.

The scenario matrix is polarized on the vertical axis by the type of DE structure, distributed or decentralized, and on the horizontal axis by the type of customer/user, B2C (final user or small communities) or B2B (small entrepreneur or small business). The crossing of those polarities produced the following 4 visions, relative to the four quadrants (see Fig. 21)[2]:

A. **[distributed-B2C] DO IT YOURSELF FOR YOUR OWN DAILY WELL-BEING**: a producer/alliance of producers offers ownerless DE support product/s to enable the end-user to self-fulfil their own satisfaction, paying per unit of period/time/satisfaction.
B. **[distributed-B2B] START-UP YOUR SMALL-SCALE, LOCALLY BASED BUSINESS WITHOUT INITIAL INVESTMENT COST**: a producer/alliance of producers offers ownerless DE support product/s to local entrepreneurs that pay for unit of period/time/satisfaction.
C. **[decentralized-B2C] LAUNCH A COMMUNITY SHARING CENTRE TO FULFIL DAILY LIFE SATISFACTION**: a producer/alliance of producers

developed by Cenk Basbolat for his degree thesis at the School of Design of Politecnico di Milano, tutored by Carlo Vezzoli.

[2]A set of videos presenting the visions of the scenario as well as their possible options are available at http://lens-europe.eu/tools/view/2

offers ownerless DE support product/s for shared space/s to a local networked community to enable fulfilling their own satisfaction, paying per period/time/satisfaction.

D. **[decentralized-B2B] START-UP AS SMALL, LOCAL ENTREPRENEURS WITH VIRTUAL OFFICE/WORKSHOP**: a producer/alliance of producers offers ownerless space for an office and/or workshop equipped with DE support product/s to a local entrepreneur to start-up its business, paying per unit of time/period.

To illustrate the scenario, we now describe one example (case study) per each of the visions.

A. **Do-it-yourself for your own daily life quality**: **example**

Qurrent: *The company teaches customers how to produce and manage renewable energy, allowing them to organize the exchange of energy in small local networks. Qurrent offers Solar Home Systems (SHS) composed of photovoltaic panels (and related components) and three core products: Qbox, Qmunity website, Qserver. Specifically, the Qbox measures all production and consumption of electricity and makes it possible to share capacities with the neighbourhood.*

B. **Start-up your small-scale, locally-based business without initial investment cost**: **example**

SELCO: *With the support of government funds and bank loans, SELCO facilitates and enables financing options for rural entrepreneurs to set up solar powered enterprises like photocopying and printing kiosks, tailoring units and mechanized cattle milking units in underserved areas. This generates sustainable livelihood options and offers access to services for the community.*

C. **Launch a community sharing centre to fulfil daily life satisfaction**: **example**

Helsinki Metropolitan Area Reuse Centre: *The Reuse Centre sells donated second-hand goods and building and hobby materials in their retail outlets, which are located in many locations in Helsinki, Finland. The organization makes it easier for customers to reuse and recycle by offering transportation services and leasing pull-trailers for a fee, and customers can borrow a cargo-bike for free if they purchase something from one of the shops. The Reuse Centre also provides educational workshops on recycling and the environment to children.*

D. Start-up a virtual office/workshop for small, local entrepreneurs: example

Maker Station: *Maker Station is a large makerspace, workshop and co-working space that provides access to industrial tools and equipment, studio space and storage space for artists, artisans, designers and small producers on a membership basis in Cape Town, South Africa. It also links artists, artisans and designers with projects and companies needing their skills and labour, and it provides technology workshops for hobbyists and marginalized children. The equipment and tools it provides include milling machines and lathes, laser cutters, CNC vinyl cutters, 3D printers, electronics stations, sheet metal equipment, welding equipment, woodworking equipment, hand tools and sewing machines.*

Exploring opportunities within the S.PSS applied to DE Scenario

Within the SPSS applied to DE Scenario, the following strategies (and guidelines) have been identified[3] as potential diversification of proposals within each of the visions:

- Complement DE hardware offer with Life Cycle services
- Offer ownerless DE systems as enabling platform
- Offer ownerless DE systems with full services
- Optimize stakeholders' configuration
- Delink payment from hardware purchases and resource consumption
- Optimize DE structure.

Complement DE hardware offer with Life Cycle services

- The **provider/s** complements the offer of the **DE** system with:
  - **financial services** to support **initial investment** and eventual maintenance and repairing costs, e.g. micro-credit, crowdfunding, donation to **maintain**, **repair** one or more **DE hardware/components**
  - support **services** for the **design** and/or **installation** of its components (e.g. in DG, the micro-generator, the storage, the inverter, the wiring, etc.)
  - support **services during use**, i.e. maintenance, repairing and upgrading of its components
  - support **services** for the **end-of life treatment** of its components
  - support **services** to enable the customer to either **design** and **produce with their DE hardware**, **share** their **DE** hardware, **sell/provide their** production, **provide services** through their DE hardware.

[3]Those presented here are an update of a set of criteria and guidelines developed by Cenk Basbolat for his degree thesis at the School of Design of Politecnico di Milano, tutored by Carlo Vezzoli.

Offer ownerless DE systems as enabling platform

- The **provider/s** complements an ownerless offer of the **DE** system with **training/information** services **to enable** the customer:
  - to **design** the DE **hardware/components**
  - to **maintain**, **repair** one or more **DE hardware/components**
  - to **install** one or more **DE hardware/components**
  - to **upgrade** one or more **DE hardware/components**
  - to **optimize use** of one or more **DE hardware/components**
  - to either **design**, **produce with their DE** hardware, **share** their **DE** hardware, sell/provide their products, provide services through their **DE** hardware.

Offer ownerless DE systems with full services

- The **provider**/s complements an ownerless offer of the **DE** system with **full** support **services**:
  - to **design** the **DE hardware/components**
  - to **maintain**, **repair** one or more **DE hardware/components**
  - to **install** one or more **DE hardware/components**
  - to **upgrade** one or more **DE hardware/components**
  - to **optimize use** of one or more **DE hardware/components**
  - to either **design**, **produce with their DE** hardware, **share** their **DE** hardware, **sell/provide** their production, **provide services** through their **DE** hardware.

Optimize stakeholders' configuration

- Offer the S.PSS to the final user, or a collective, to **improve the quality of life** or the environment
- Offer the S.PSS to an entrepreneur to **enable a business start-up** or empower business
- Optimize a stakeholder partnership with **vertical integration** by combining all complementary components of one single DE type (e.g. in DG, the micro-generator, the storage, the inverter, the wiring, etc.)
- Optimize a stakeholder partnership with **horizontal integration** (by combining different DE offers as a full package offer)
- Make the DE hardware manufacturer S.PSS offers either alone or in a joint venture with another stakeholder
- Make the DE service provider S.PSS offers either alone or in a joint venture with another stakeholder.

Delink payment from hardware purchases and resource consumption

- Offer **pay x period**, i.e. the cost is daily/weekly/monthly/yearly fixed
- Offer **pay x time,** i.e. the cost is fixed per minutes/seconds of access
- Offer **pay x use**/satisfaction unit, i.e. the cost is fixed per product performance (e.g. km for a vehicle, washing cycles for a washing machine)
- Offer payment based on **hybrid** pay x period, pay x time, pay x use modalities

- Offer other economic transactions not based on financial currencies, such as time exchange or direct exchange of goods
- Apply for additional financial support from public administrations/entities.

Optimize DE structure

- Offer **stand-alone DE** Product-Service Systems for homes or business sites (especially isolated sites)
- Offer local **mini-network** connecting **DE** systems, to enable local production surplus sharing or for enabling shared use of the **DE** hardware and sharing operations for DE service provision
- Offer **decentralized stations**, e.g. 3D printing service spot, charging spot, etc., for local communities or decentralized service providers, e.g. a local technician's shop
- Offer **decentralized** systems to locally supply DE production throughout a **mini-network** for homes and/or business sites or a mini-network of service providers
- Offer the DE system with a **connection** to a **worldwide network/main-grid**, enabling homes, small business and communities the selling/purchasing of production or for enabling shared use of the DE hardware and/or the shared provision of local services.

4 Barriers and Trade-Offs to Integrating S.PSS and DE

Distributed Economies evolve with context and situation to provide different opportunity spaces that can attract new stakeholder configurations. This requires a constant adjustment of the S.PSS model, which can be informed by these changing opportunities. This means that the organization needs to be flexible in allowing possibility for customization according to local needs and context of different network nodes in terms of providing a relevant S.PSS model.

As evidenced by many of the case studies in this chapter, setting up these systems needs long-term engagement with local communities and networks. It must include capacity building, community mobilization and awareness creation at multiple nodes. Bringing together these capabilities and developing networks for learning and sharing the know-how. However, we must have sustained and long-term investment in developing the knowledge and capacity in multiple regional and local centres, and this can be a challenging proposition.

Scaling up of distributed networks again can be challenging, as it requires strategic components to be centralized to optimize resources. Finding the balance between the distributed and centralized components of a product-service system in a distributed economy must include an intelligent business plan backed by policies that support the sustainability of the system.

Distributed Economies may not necessarily provide the most environmentally efficient solution. It is important to assess and balance all three components of sustainability—economic, environmental and socio-ethical—to arrive at the best possible model. This would be possible if we had increased access to assessment tools and frameworks as well as modelling technology, all of which today are not very easily available to planners and entrepreneurs at the grassroots level.

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Designing S.PSS and DE: New Horizons for Design

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1 General Considerations for Conceptual Integration into the Design Process

Assuming S.PSS applied to DE is an opportunity for a locally based sustainability for all, as introduced in this volume, we envision a new role for designers:

Designing Sustainable Product-Service Systems applied to Distributed Economies, or shortly **System Design for Sustainability for All (SD4SA)**.

To introduce this topic, the following preliminary definition could be given to articulate the new potential of such design:

> System Design for Sustainability for All (SD4SA):
>
> design of S.PSS applied to DE, i.e. the design of Systems of Products and Services that are together able to fulfil a particular customer demand (deliver a "unit of satisfaction"), within the Distributed Economies 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/costs remain with the provider/s, so that the provider/s continuously seek environmentally and/or socio-ethically beneficial new solutions accessible to all with economic benefits.

Within this framework a new knowledge-base and know-how emerge: competences in designing and implementing Sustainable Product-Service Systems applied to Distributed Economies, i.e. Distributed energy Generation, Distributed production

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C. Vezzoli et al. (eds.), *Designing Sustainability for All*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-3-030-66300-1_4

of Knowledge, Distributed Software development, Distributed Manufacturing and Distributed Design.

Based on the foundations of S.PSS design [10, 6], the following approaches and skills can be identified and refined for System Design for Sustainability for All (SD4SA):

(a) “Satisfaction-system” approach: This calls for skills to design the system of products and services that, within a DE paradigm, can satisfy a particular demand (“satisfaction unit”);
(b) “Stakeholder configuration” approach: This calls for skills to design the stakeholders’ interactions in a particular DE satisfaction-system;
(c) “System sustainability4all” approach: This calls for skills to design-for-all a DE system where the providers continuously seek environmental and/or socio-ethical beneficial new solutions, with economic benefits.

This new role in SDS4A calls for the design of “appropriate stakeholder configurations” and favouring the design of “appropriate technologies”, to address S.PSS applied to DE. In this framework, two key approaches have been merged, redefined and updated: Product-Service System Design for Sustainability and Distributed Economies (DE) design. Other disciplines that are not explicitly mentioned here could and should also be included, to contribute to a comprehensive and complete research base, e.g. Social Entrepreneurship for Sustainable Development and System Innovation for Sustainability.

2 A Reference Model of S.PSS and DE Design

2.1 Method and Tools for System Design for Sustainability for All

Criteria, method and tools

Before introducing and describing methods and tools, let us summarize the main issues discussed so far. It has been argued that a potential role exists for design for sustainability, in promoting and facilitating innovation resulting in environmentally beneficial, economically viable and socially equitable/cohesive enterprises/initiatives offering a mix of products and services, especially when applying the Sustainable Product-Service Systems (S.PSS) model to Distributed Economies (DE).

The **first key point** is the approach to design a stakeholders’ configuration, which is committed to creating and promoting innovative types of interactions and partnerships between appropriate socio-economic stakeholders of a system responding to a particular social demand (unit of satisfaction). Consequently, new skills are required from the designer, directly or as a facilitator of a design process:

- A designer must be able to design both products and services, related to a given demand (needs and/or desires), i.e. a satisfaction unit;
- A designer must be able to identify, promote and facilitate innovative configurations (i.e. interactions/partnerships) between and among different stakeholders (entrepreneurs, users, NGOs, institutions, etc.), i.e. a satisfaction system related to a given demand (needs and/or desires) as a satisfaction unit

The **second key point** emphasizes S.PSSs applied to DE innovations that are environmentally, socio-ethically and economically sustainable, i.e. they have a low environmental impact and promote socially equitable and cohesive results, with economic benefits. This underlines that the design process should be oriented towards sustainable solutions, i.e. a designer must be capable to design S.PSSs applied to DE systems (and related stakeholder interactions) that couple economic benefits with environmental and socio-ethical, beneficial new solutions. Consequently, these new skills are required from the designer:

- The ability to orientate the system design process towards *eco-efficient* solutions, encompassing both environmental and economic sustainability;
- The ability to orientate the system design process towards *socio-efficient* solutions encompassing both socio-ethical and economic sustainability.

In this chapter, we describe a series of tools that can be applied during different phases of a design process. Besides their specific functions, more generally, they are meant to assist the designer in accomplishing three objectives:

1. Assessing existing system sustainability and defining sustainability system design priorities;
2. Generating a sustainability-focused system idea and concept (innovative S.PSS applied to DE);
3. Checking/visualizing the sustainability improvement/worsening of developed system concept/s (comparing the existing baseline with the new, innovative system).

Various research projects have been funded by the European Union and the United Nations Environment Programme (UNEP)[1] over the past decades to develop and test methods and tools for system design, the main ones being SusHouse,[2] ProSecCo,[3] HiCS,[4] MEPSS,[5] SusProNet,[6] LeNS[7] and LeNSes.[8]

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[1]Design for Sustainability (D4S): A Step-By-Step Approach (UNEP funded, 2005–2009) (see [6]).

[2]SusHouse: Strategies towards the Sustainable Household (EU funded, 1998–2000) (see [9]).

[3]ProSecCo: Product-Service Co-design (EU funded, 2002–2004).

[4]HiCS: Highly Customerised Solutions (EU funded, 2001–2004) (see Manzini et al. [3]).

[5]MEPSS: MEthodology for Product Service System development (EU funded, 2002–2005) (see [8]).

[6]SusProNet: Sustainable Product-Service co-design Network (EU funded, 2002–2005) (see [7]).

[7]LeNS: Learning Network on Sustainability (2008–2010).

[8]LeNSes: Focused on System Design for Sustainable Energy for all (EU-funded, Oct 2013–Oct 2016).

In this chapter, the Method for System Design for Sustainability (MSDS) is described, together with its tools for System Design for Sustainability for All, i.e. design of S.PSS applied to DE. It is important to note that experimentation, both in applied research projects and in teaching, has been fundamental and will continue to be so in future, in order to allow methods and tools to be assessed, adapted and improved.

2.2 MSDS: A Modular Method for System Design for Sustainability

The MSDS method aims to support and orient the entire process of system innovation development towards sustainability. It is conceived for designers and companies, but it is also appropriate for public institutions, NGOs and other types of organizations. It can be used by an individual designer or by a more extensive design team. In all cases, special attention has been paid to facilitate the co-designing processes both within the organization itself (between people from different disciplinary backgrounds) and outside, bringing different socio-economic actors and end-users into play. The method is organized in stages, processes and sub-processes. It is characterized by a flexible modular structure so that it can easily be adapted to the specific needs of designers/companies/organizations and to diverse design contexts and conditions. Its modular architecture is of particular interest in terms of the following considerations:

- Stages/processes: all stages and related processes can be undertaken, or only some depending on the particular requirements of the project;
- Tools: the method is accompanied by a series of tools that can be selected and deployed during the design process according to the project need;
- Dimensions of sustainability: the method takes into consideration the three dimensions of sustainability (environmental, socio-ethical and economic). It is possible to choose which dimension(s) to operate on;
- Integration of other tools and activities: the method is structured in such a way as to allow the inclusion of design tools that have not been specifically developed for it. It is also possible to modify existing activities or add new ones according to the particular aspects of the design project.

The basic structure of *MSDS* consists of four main stages:

1. Strategic analysis
2. Exploring opportunities
3. System concept design
4. System detailed design.

An additional stage can be added, across the others, for drawing up documents to report on the sustainability characteristics of the designed solution:

- Communication.

Table 1 shows the aim and processes for each stage.

Table 1 The stages of MSDS with their aims and processes. Sustainability-oriented processes are in bold

MSDS method		
Stage	Aim	Processes
1. Strategic analysis	To obtain the necessary information to facilitate the generation of sustainable system innovation ideas	• Analyse the project proposers and outline of the intervention context • Analyse the context of reference • **Analyse the carrying structure of the system** • **Analyse cases of sustainable best practice** • **Analyse the sustainability of the existing system and determine priorities for the design intervention in view of sustainability**
2. Exploring opportunities	To make a 'catalogue' of promising strategic possibilities available: a sustainability design-orienting scenario and/or a set of promising sustainable system ideas	• Benchmark against sustainable solutions for similar problems • **Generate sustainability-oriented system ideas** • **Outline a design-oriented sustainability scenario**
3. System concept design	To develop one or more system concepts oriented towards sustainability	• Select clusters and single ideas • Develop system concepts • **Conduct environmental, socio-ethical and economic assessment** • Visually represent the most promising concept
4. System detailed design (and engineering)	To develop the most promising system concept into the detailed version necessary for its implementation	• Detailed system design • **Review environmental, socio-ethical and economic issues and visualization**
5. Communication	To draw up reports to communicate the general and above all sustainable characteristics of the system designed	Draw up the documentation for communications of sustainability

3 Tools Developed by LeNS

This section describes several tools that may be used to support the various stages of the *Method for System Design for Sustainability* (MSDS) with an integration of Distributed Economies (DE).[9] In general, the tools are created to support designers to achieve four objectives:

- To assess existing systems and define sustainability design priorities;
- To explore opportunities by generating sustainability-oriented system ideas with a specific focus on S.PSS applied to DE;
- To visualize the proposed S.PSS and DE concept design;
- To detail and communicate the proposed S.PSS and DE concept design by highlighting environmental, social and economic benefits.

Seven S.PSS and DE design support tools, newly developed within the LeNSin project, are presented below:

- Sustainability Design-Orienting Scenarios (SDOS) on S.PSS and DE
- Innovation Diagram for S.PSS and DE
- Concept Description Form for S.PSS and DE
- System Map for S.PSS and DE
- S.PSS and DE Idea Borads (embedded into the SDO toolkit)
- Strategic Analysis Toolkit (SAT) for DE for Socio-Economic Ecosystems (SEE)
- Distributed Manufacturing (DM) applied to PSS design toolkit.

MSDS and other tools for system design for sustainability have been developed to support system design for sustainability for all, and a wide selection of these tools can be found and downloaded from the LeNS platform (www.lens-international.org). This particular section of the book aims to help potential users to apply the newly developed S.PSS and DE tools in practice. For this reason, each tool is described using the following structure:

1. The aim and the components of the tool;
2. The tool's integration into the MSDS design process;
3. How to use the tool;
4. Availability and resources required.

[9] This is the one of the outcomes of the LeNSin project, creating, integrating and updating tools produced by the project partners together with other existing tools and approaches linked to system design for sustainability. The tools described here are a selection of those that have been used and tested during a set of pilot courses as part of the LeNSin project and in several studies with companies and industry experts.

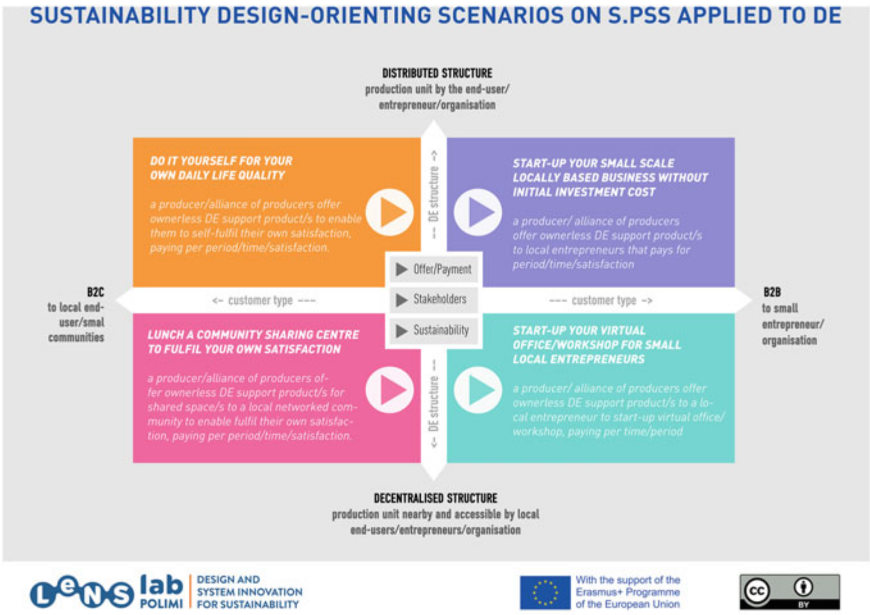


Fig. 1 SDOS on S.PSS and DE tool

3.1 Sustainability Design-Orienting Scenarios (SDOS) on S.PSS and DE

Aims

The objective of *Sustainability Design-Orienting Scenarios (SDOS) on S.PSS and DE* (Fig. 1) is to orient the design process towards sustainable system solutions by using immersive and inspiring scenario videos to stimulate the generation of *S.PSS-based DE* ideas for all.

Components

The *Sustainability Design-Orienting Scenarios on S.PSS and DE* consist of:

- Four main visions' videos
- Three sub-videos presenting options for all the visions in terms of:
  - Offer/payment
  - System configuration
  - Sustainability.

Integration into the MSDS design process

The *SDOS on S.PSS and DE* is used in **Ideas generation oriented to sustainability** to stimulate the generation of ideas (Fig. 2).

How to use the *SDOS on S.PSS and DE*

The tool is used in two simple steps:

First, open the *SDOS on S.PSS and DE* tool. Play the four videos of the four visions, to get initial design inputs through sample stories (Fig. 3).

Secondly, play the three sub-videos, to open up sample stories linked to all options related to:

- Offer/payment
- System configuration
- Sustainability (Fig. 4)

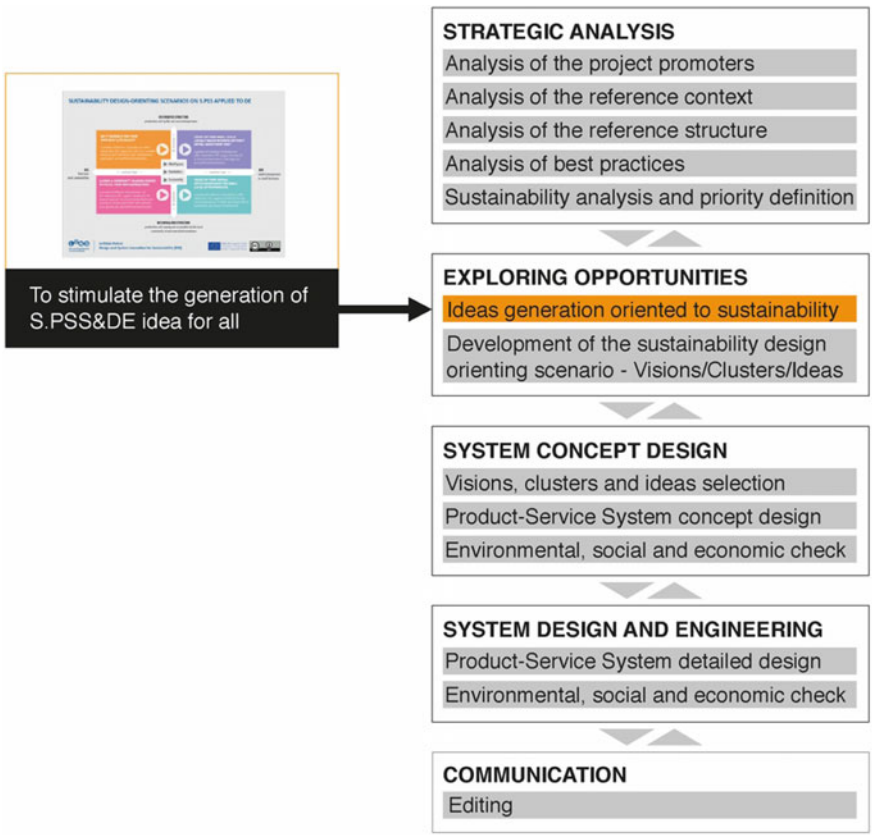


Fig. 2 Integrating SDOS Scenario on S.PSS and DE into the MSDS process

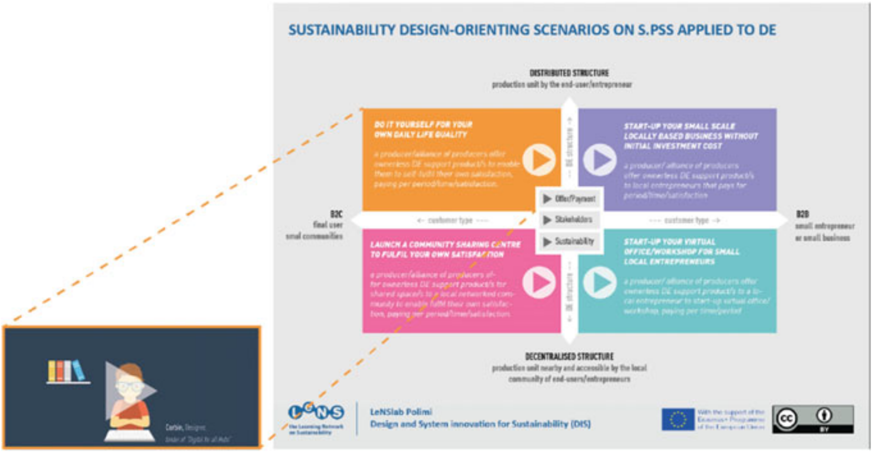


Fig. 3 The menu page of the SDOS on S.PSS and DE tool with the links to the four vision videos

Fig. 4 SDOS on S.PSS and DE tool links to the three sub-videos visualizing offer/payment, system configuration and sustainability

Availability and requested resources

The *SDOS on S.PSS and DE* tool is an open-access tool that can be downloaded for free from www.lens-international.org, ‘Tools’ section. A computer, a PDF reader and Internet connection are required to access the tool.

The tool may be used by a single designer, though the support of a multi-disciplinary team is preferable.

This tool requires 15 min to explore and get inspired by the proposed visions.

3.2 *Innovation Diagram for S.PSS and DE*

Aims

The objective of the *Innovation Diagram for S.PSS and DE* (Fig. 5) is to help designers to position and characterize existing offers and competitors and select promising ideas for new concept profiling.

Components

The diagram consists of:

- Polarity diagram concept profile
- Digital sticky notes
- Database of labels.

Integration into the MSDS design process

The Innovation Diagram for S.PSS and DE is used at various stages of the design process (Fig. 6).

- In **Analysis of the project promoters and the reference context,** it can be used to:

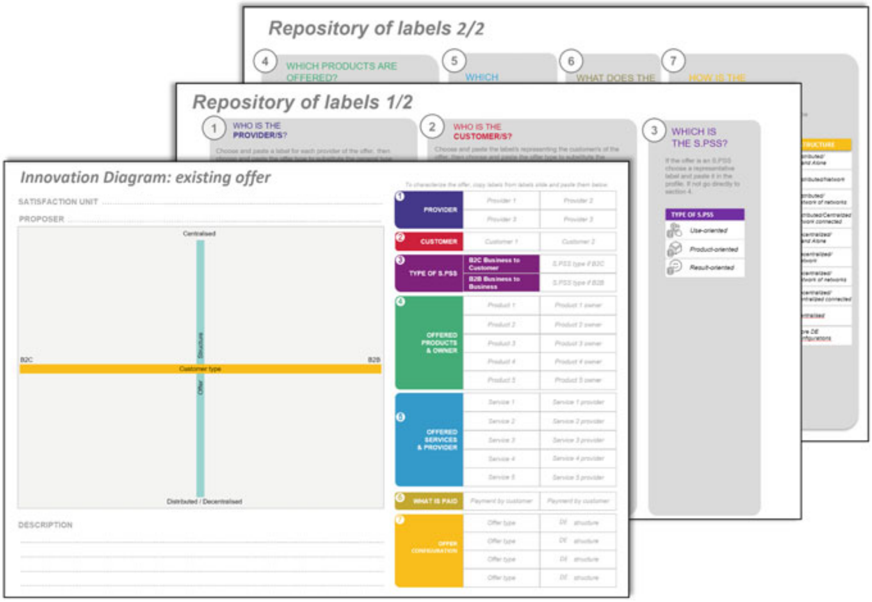


Fig. 5 Innovation Diagram for S.PSS and DE

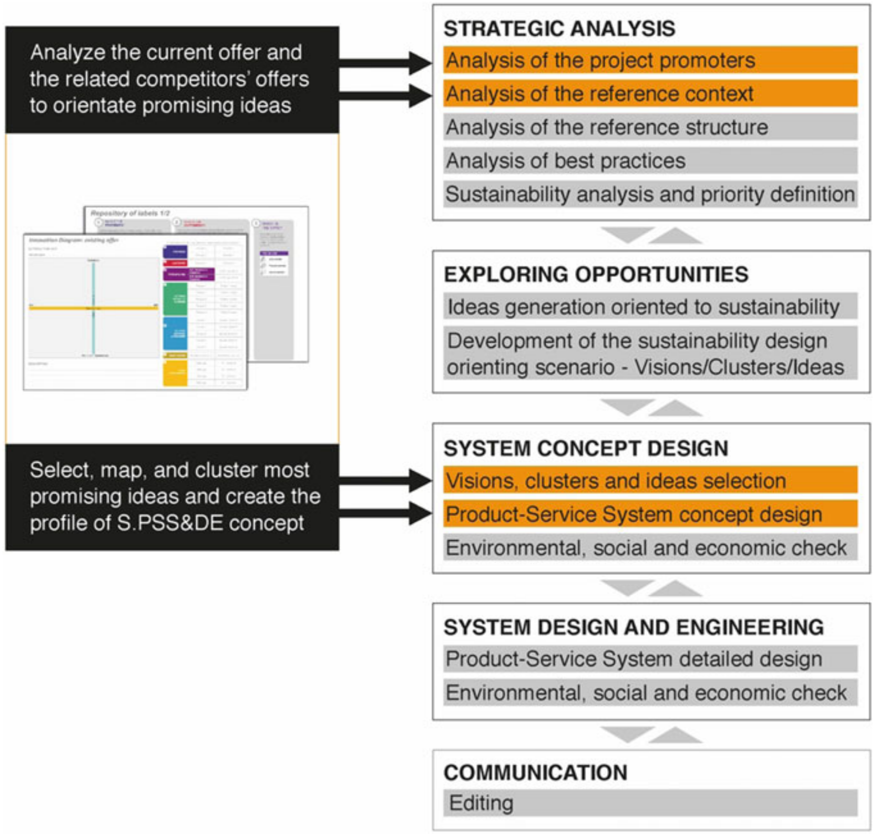


Fig. 6 Integrating Innovation Diagram for S.PSS and DE integrated into MSDS design process

  - Analyse the current offer and the related competitors' offers to orientate promising ideas.

- In **Visions, clusters and ideas selection and System concept development** it can be used to:

  - Select, map and cluster the most promising ideas and create the profile and S.PSS and DE concept.

How to use the *Innovation Diagram for S.PSS and DE*

First, open the tool and move to the "…_existing offer" slide. Work in the "existing offer" slide to position an existing offer (Fig. 7). Select the company/organization icon (1) and choose one of the DE types to substitute the general one. Paste the label in the diagram and write the company/organization name in the free space on the label.

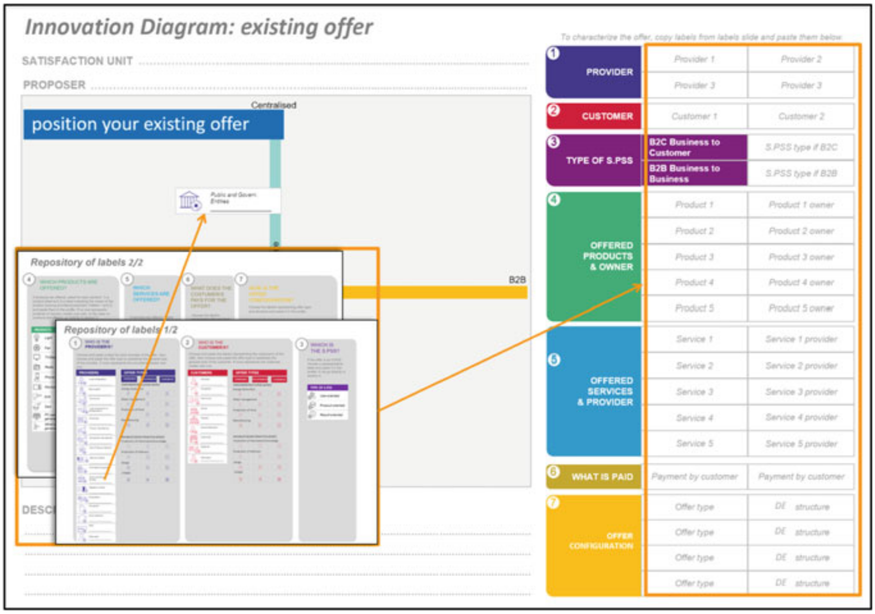


Fig. 7 The existing offer slide of the Innovation Diagram for S.PSS and DE

The second step is to characterize the existing offer by specifying all of the following (Fig. 8):

- **Provider (1)**. Select the company/organization structure label, and choose one of the Offer type characterization icons (Distributed, Decentralized or Centralized and its sector, i.e. energy Generation, Food production, Water management, Manufacturing, Software development or Knowledge) to substitute the general one. Place in the provided section and write the company/organization name in the free space on the label.
- **Customer (2)**. Select customer/s (B2B–B2C) structure label icon/s and choose one of the characterization icons to substitute the general one. Place in the customer section and write customer/s name in the free space on the label.
- **Type of PSS (3)**. Select the S.PSS type of the offer (if any): PRODUCT-ORIENTED, USE-ORIENTED, RESULT-ORIENTED and place it in the S.PSS type section. Remember, that in most cases existing offers are not S.PSS.
- **Offered Products & owners (4)**. Select the product icon representing what the company offers and paste in the products section. Select who retains the product OWNERSHIP (provider or customer) and place the label in the provider/customer label.
- **Offered Services & providers (5)**. Select the service icon representing what the company offers and paste in the service section. Select who PROVIDES the service and place the label in the provider label.

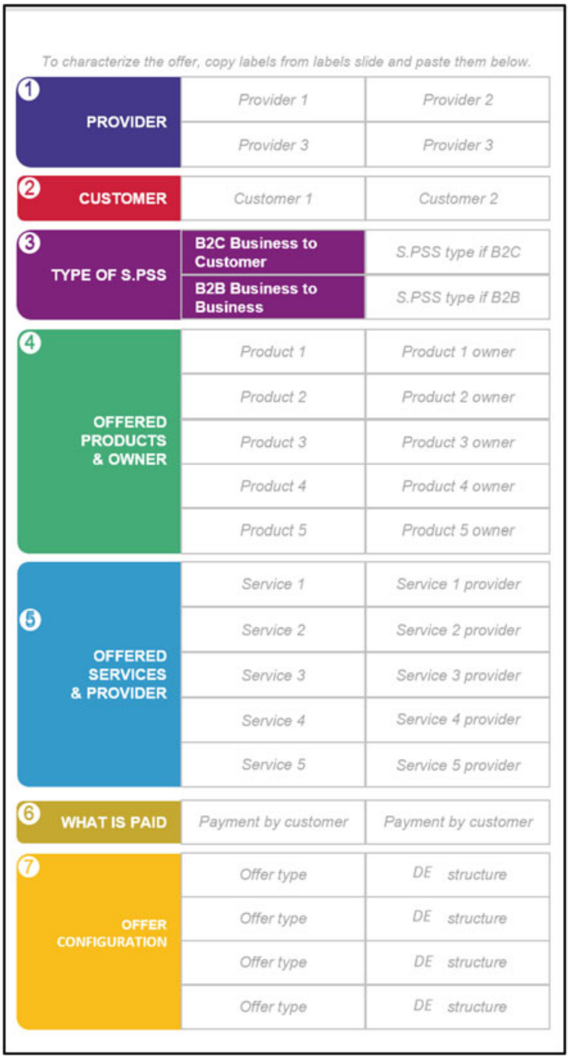


Fig. 8 Elements to characterize in the existing offer

- **What is paid (6)**. Select the icon describing what is paid by the customer/s and place the label in the payment section.
- **Offer configuration (7)**. Select the DE type icon of the offer and paste it in the DE type space. Select its structure icon and place it in the nearby space.

The same process to characterize the existing offer could be done in relation to competitors, by moving to the "…_Competitors" slide. Finally, the Innovation Diagram could be used to insert and position promising ideas designed with the idea boards (SDO toolkit), within the "…_Concept" slide (Fig. 9).

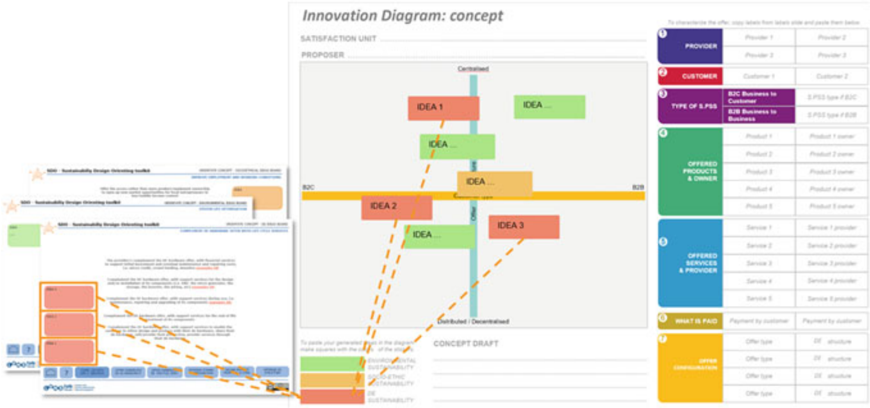


Fig. 9 The concept slide of the Innovation Diagram for S.PSS and DE with the SDO idea boards

Now it is time to generate new ideas spotting the areas that are left empty (Fig. 10). Identify and cluster those ideas that can be combined to draft the system concept. Write a text (max 200 characters) outlining the preliminary system concept.

Finally, profile an S.PSS and DE draft concept by copying and pasting characterizing icons of the emerging S.PSS and DE concept (Fig. 11).

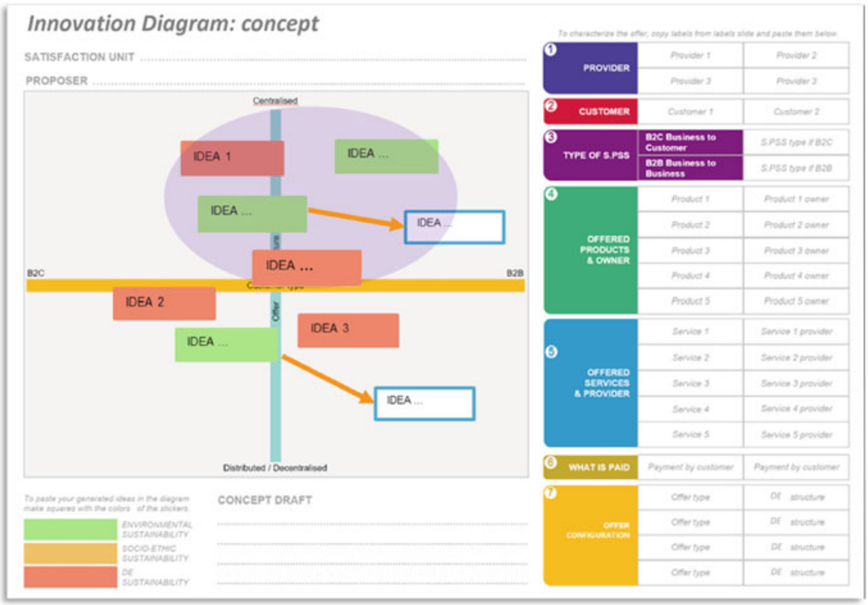


Fig. 10 The concept slide of the Innovation Diagram: new idea generation, idea clustering and system concept drafting

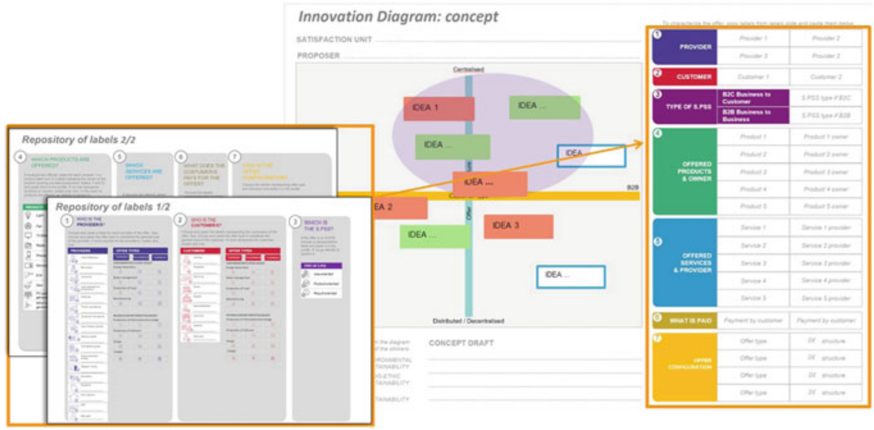


Fig. 11 Innovation Diagram: profiling an S.PSS and DE draft concept

Availability and requested resources

The Innovation Diagram for S.PSS and DE is an open access tool that can be downloaded for free from www.lens-international.org, 'Tools' section. A computer and a PowerPoint reader are needed to access the tool. This tool requires at least:

- 20 min to position and characterize the existing offer, 15 min to position and characterize the competitors,
- 45 min to select promising ideas, generate new ones, cluster them and identify/describe/profile a draft concept.

3.3 Concept Description Form for S.PSS and DE

Aims

The objective of the *Concepts Description Form for S.PSS and DE* (Fig. 12) is to finalize the description and characterization of a new S.PSS and DE concept.

Components

It consists of a sum-up of the concept with:

- Concept title
- Satisfaction unit
- Concept description
- Concept profiling, i.e. Provider, Customer, Type of S.PSS, offered Products & owner, Offered services & provider, What is paid, Offer configuration.

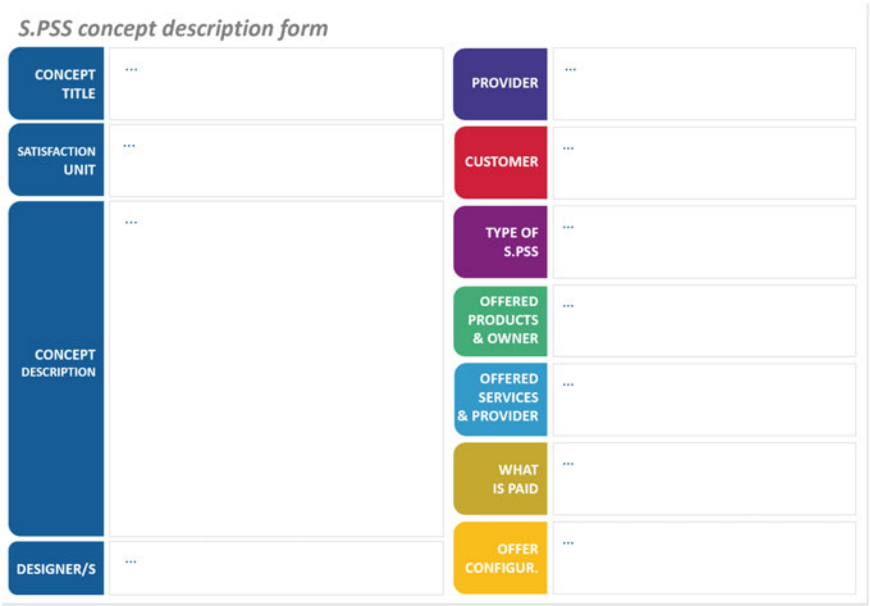


Fig. 12 Concept Description Form for S.PSS and DE

Integrating the tool into the MSDS design process

The Concept Description Form for S.PSS and DE is used in System Concept Design to describe and profile the designed S.PSS and DE concept (Fig. 13).

How to use the S.PSS and DE concept description form

The Concept Description Form can be used in three simple steps (Fig. 12). First, write the title and the description of the S.PSS and DE concept. Secondly, indicate the UNIT OF SATISFACTION of the concept. Finally, characterize the concept with the information in all the fields.

Availability and requested resources

Like the previously described tools, the *Concept Description Form for S.PSS and DE* is an open access tool that can be downloaded for free from www.lens-international.org, 'Tools' section. A computer, a PowerPoint reader, and Internet connection are required to access this tool. The tool may be used by a single designer, though the support of a multi-disciplinary team is preferable. This tool requires at least 15 min to complete.

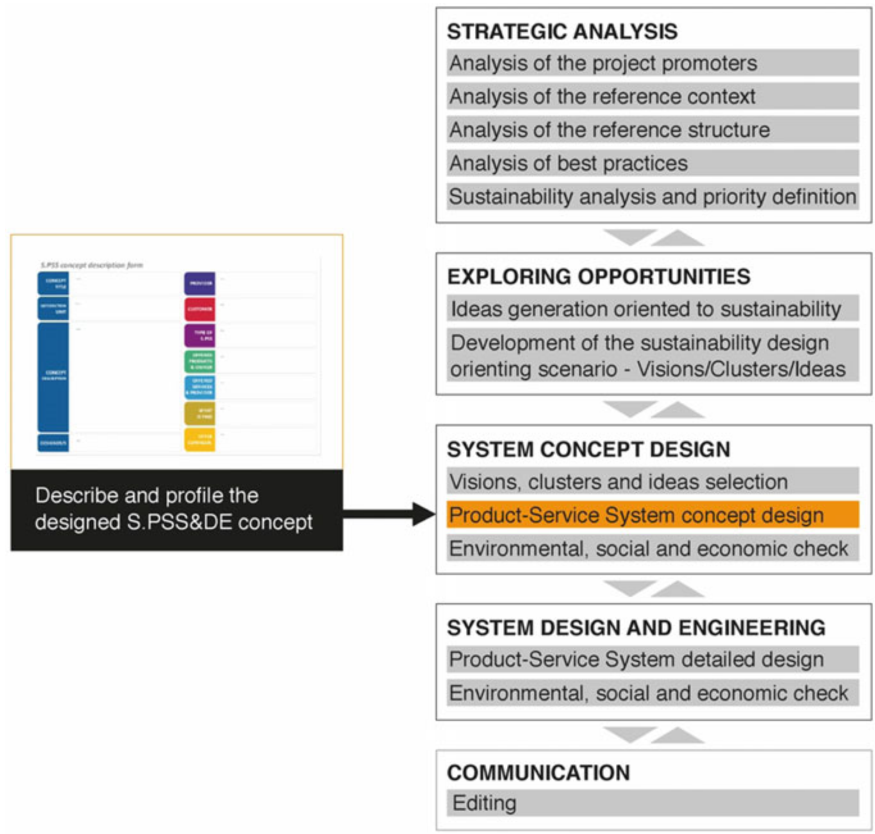


Fig. 13 Concept Description Form for S.PSS and DE integrated into the MSDS design process

3.4 System Map for S.PSS and DE

Aims

The purpose of the System Map for S.PSS and DE (Fig. 14) is to support (co-)designing, visualization and configuration of the system structure, indicating the actors involved and their interactions in distributed systems providing additional support to its users defining DE configuration.[10]

Components

The System Map for S.PSS and DE contains graphical representations of:

- Stakeholders involved;
- Flows/interactions: physical, financial, informational and labour performance;

[10]The original System Map tool is presented in detail in the first LeNS book, Sect. 3.6 [10].

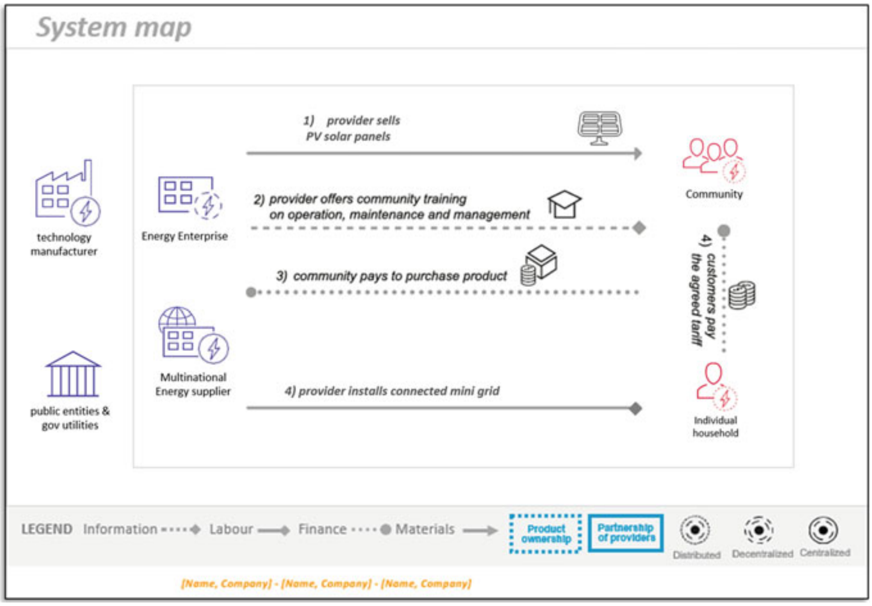


Fig. 14 System Map for S.PSS and DE

- System configurator: Distributed, Decentralized, Centralized.

Integration into the MSDS design process

The System Map for S.PSS and DE is used at various stages of the design process (Fig. 15).

- In Product-Service System Concept Design it can be used to:
  - Visualize stakeholders' interaction within the concept
- In Product-Service System detailed design it can be used to:
  - Further detail and visualize stakeholders' interactions within the concept.

How to use the System Map for S.PSS and DE

The System Map for S.PSS and DE enables comprehensive visualization of the system structure (Fig. 16). To start with, identify boundaries, including offer boundary and system boundary.

Later, identify the actors involved: select a structure icon, then choose a characterization icon to substitute the general one, and finally drag and drop into the system map (Fig. 17).

Now it is time to define interaction flows using arrows and descriptions. Interaction flows can be material flow, information flow, financial flow and labour flow (see the

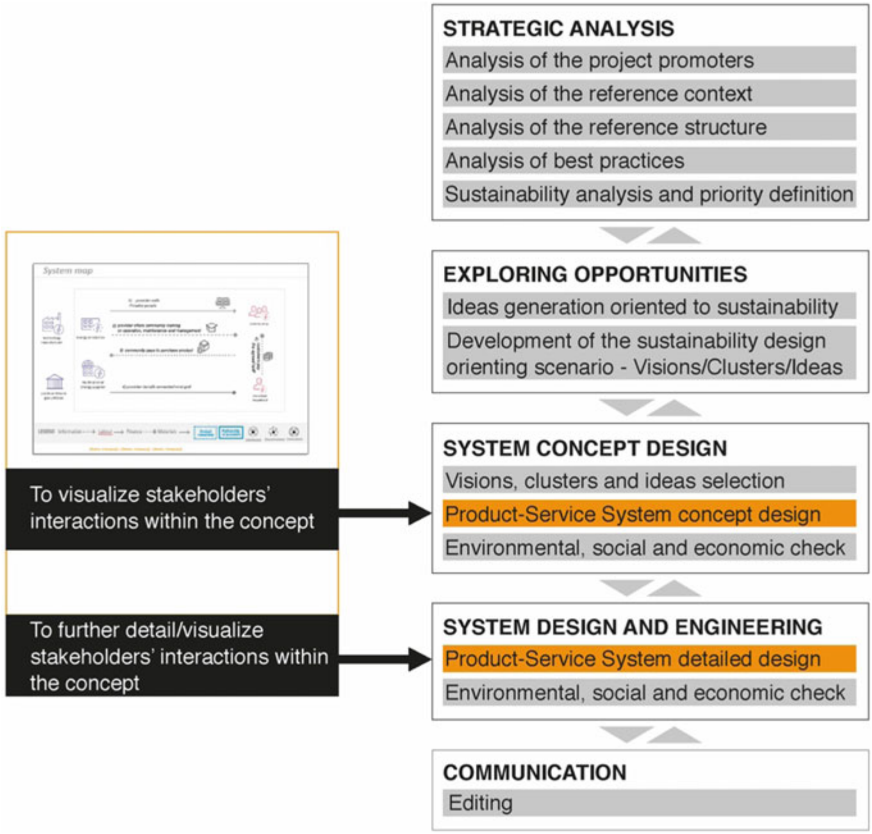


Fig. 15 System Map for S.PSS and DE integration into the MSDS design process

Legend in Fig. 18). Remember that the reading order is essential, thus note the numbering of interaction flows.

Finally, use dashed squares to indicate ownership (owner and product inside) and squares around actors to indicate partnership (Fig. 19).

Availability and requested resources

The System Map for S.PSS and DE can be drawn on paper with no need for software. It is, however, advisable to use slideshow software, in order to facilitate management and modifications. The System Map for S.PSS and DE with labels and icon repositories is open access, available for free download at www.lens-international.org, "Tools" section. The tool is based on a layout and a set of standardized icons, usable with PowerPoint readers. From this base it is possible to modify the various icons and add new ones.

The tool was developed for use by any design team member, and no particular graphic skills are required. The time required to set up a System Map for S.PSS and

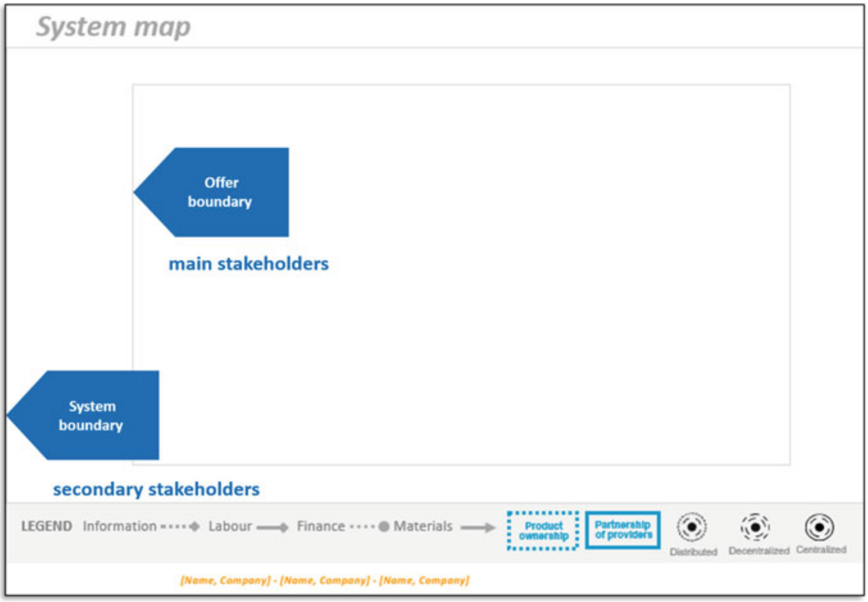


Fig. 16 System Map for S.PSS and DE: design offer boundary and system boundary

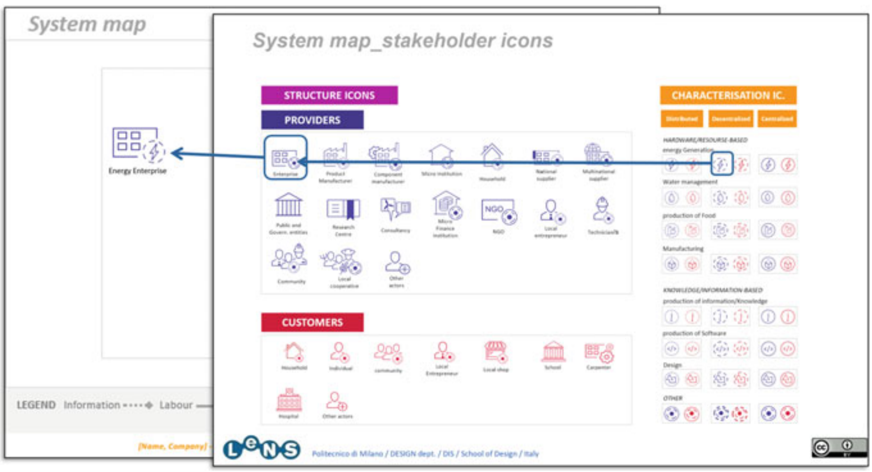


Fig. 17 System Map for S.PSS and DE: design and position actors

DE depends on the level of details along the design process; nevertheless, it could range from approximately 60–90 min.

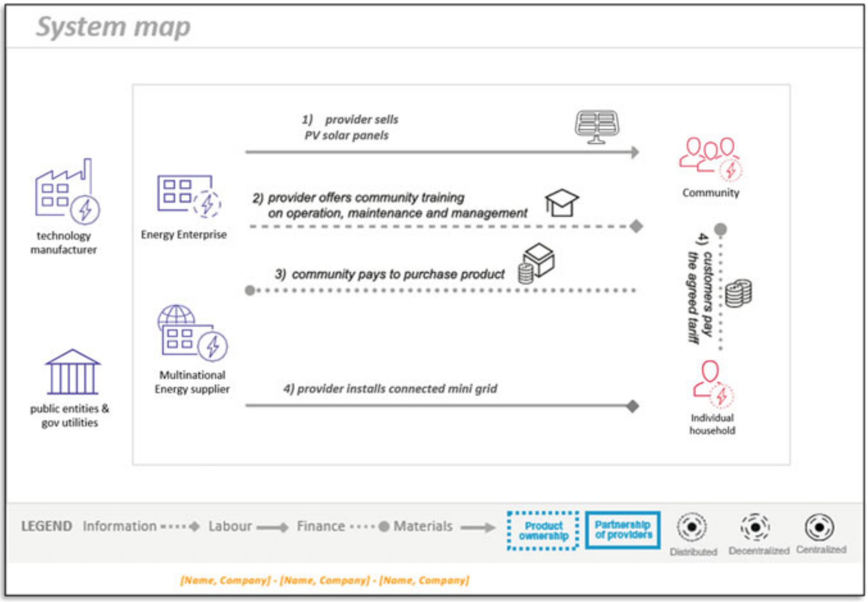


Fig. 18 System Map for S.PSS and DE: design interaction flows

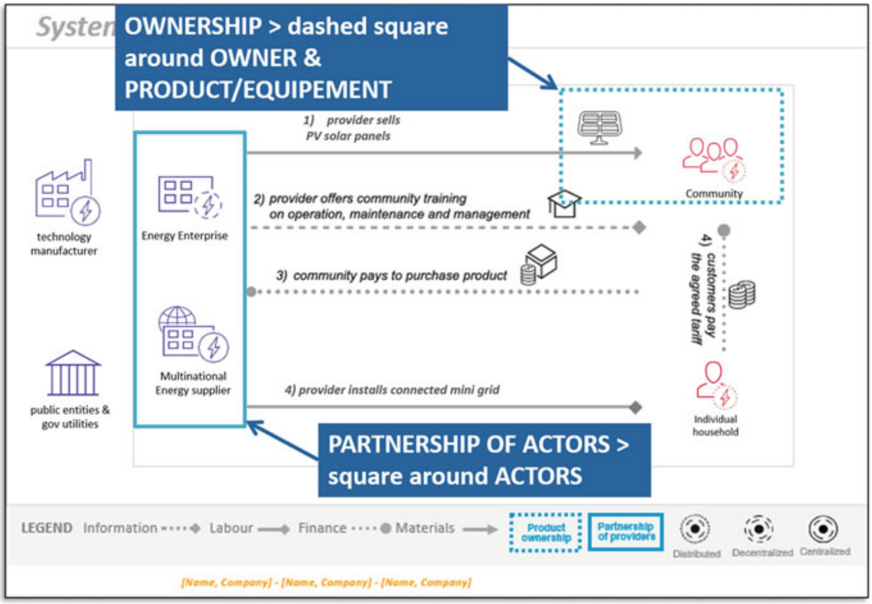


Fig. 19 System Map for S.PSS and DE: design ownership and partnership

3.5 S.PSS and DE Idea Boards (embedded into the SDO toolkit)

Aims

The objective of S.PSS and DE Idea Boards (embedded into the SDO toolkit) (Fig. 20) is to support designers in orientating the system idea generation design process towards sustainable DE for all S.PSS-based solutions.

Components

The tool consists of 6 Idea Boards, one per criteria as listed below, and a corresponding set of guidelines suggesting S.PSS-based DE ideas through innovative stakeholder interactions:

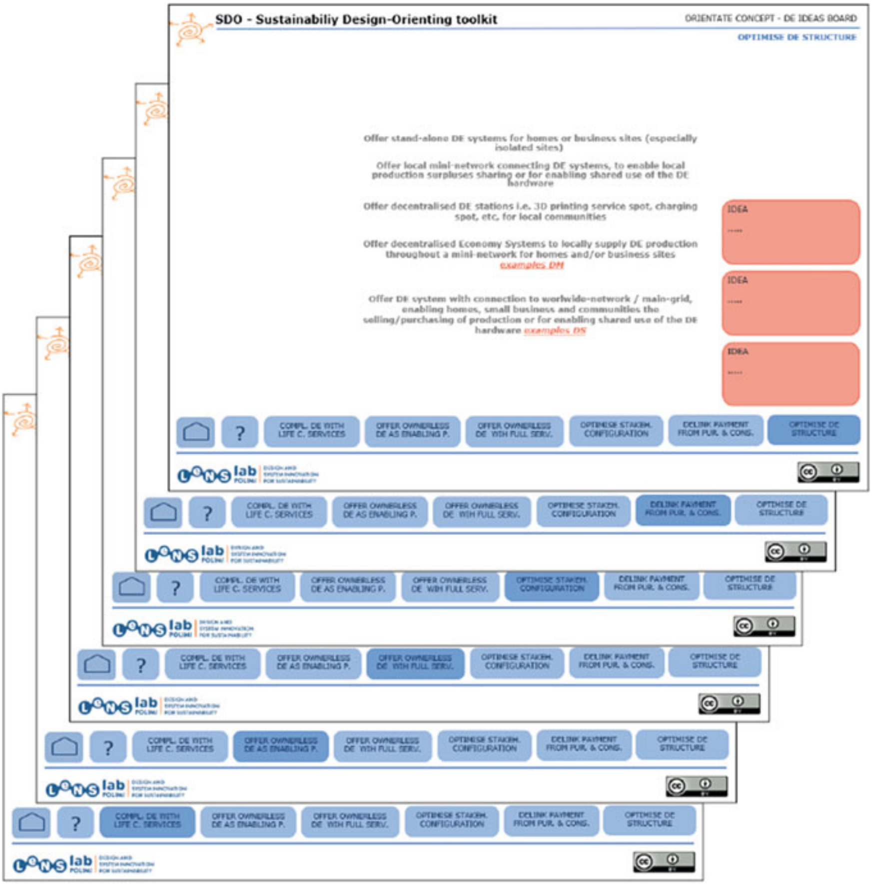


Fig. 20 S.PSS and DE Idea Boards (SDO toolkit)

- Complement the DE hardware offer with Life Cycle services
- Offer ownerless DE systems as enabling platform
- Offer ownerless DE systems with full services
- Optimize stakeholders' configuration
- Delink payment from hardware/resource purchases
- Optimize DE systems structure.

Integration into the MSDS design process

The S.PSS and DE Idea Boards (SDO) are used in idea generation oriented to sustainability to orientate the system idea generation design process towards sustainable S.PSS-based solutions for all (Fig. 21).

How to use S.PSS and DE Idea Boards (SDO)

The following steps must be performed to access the tool:

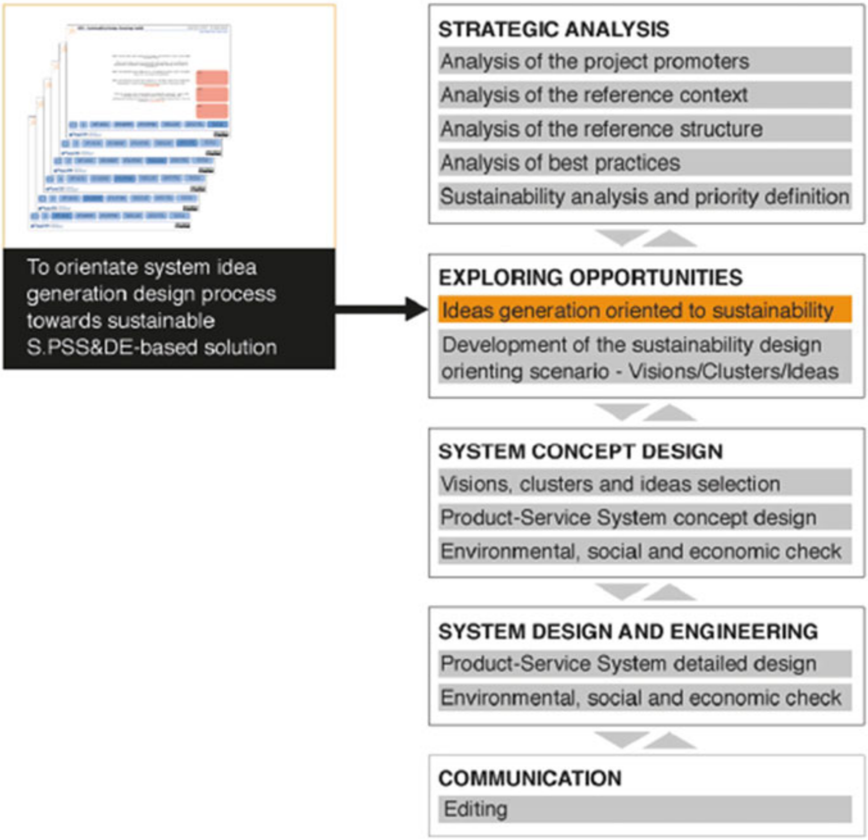


Fig. 21 S.PSS and DE Idea Boards (SDO) integration into the MSDS design process

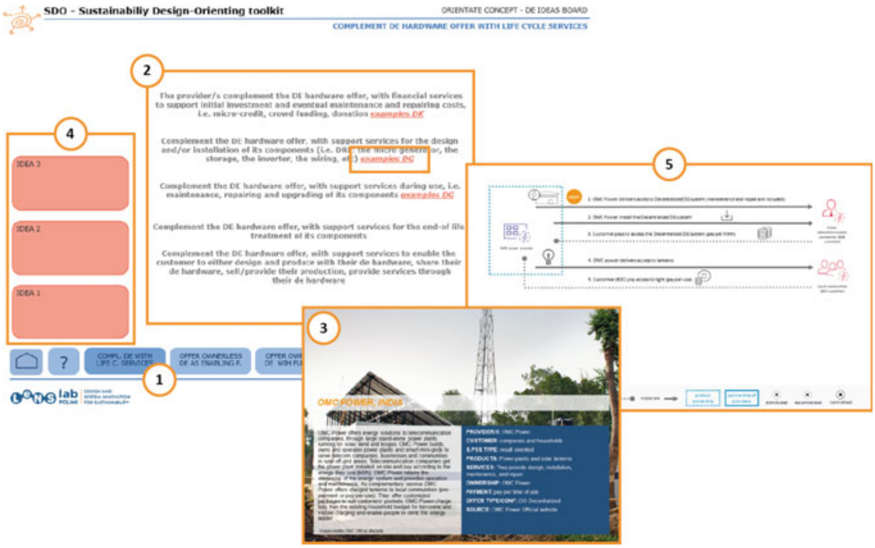


Fig. 22 S.PSS Idea Boards (embedded into SDO toolkit)

- Download the SDO toolkit from www.lens-international.org
- Type project name, etc.
- Click on S.PSS and DE sustainability dimension
- Click on orientate concept.

To orientate the system idea using the S.PSS and DE Idea Boards (Fig. 22), select the idea tables one by one (one for each criterion) (1). Then, read the guidelines (a set for each criterion) (2) and check the guideline's example for further inspiration (3). Drag and drop the "digital post-it" and describe the emerged system ideas (for each criterion) (4). You can see and read more information on the case related to the specific guideline (5).

Availability and requested resources

S.PSS and DE Idea Boards are embedded into the SDO toolkit. The tool is also available for free download at www.lens-international.org, "Tool" page. A computer, a PowerPoint reader and Internet connection are needed to use the tool. Idea Boards require at least 75 min to complete.

3.6 Strategic Analysis Toolkit (SAT) for DE for Socio-Economic Ecosystems (SEE)

The Strategic Analysis Toolkit, SAT, consists of tools which first identify the actors and their activities in the ecosystem; then the infrastructure and needs of the actors; clarifies the goal, problem statement definition, design brief and unit of satisfaction using participatory design tools; and, finally a tool for competitor analysis. This section introduces tools related to processes and sub-processes within the Strategic analysis stage in the MSDS methodology (Fig. 23).

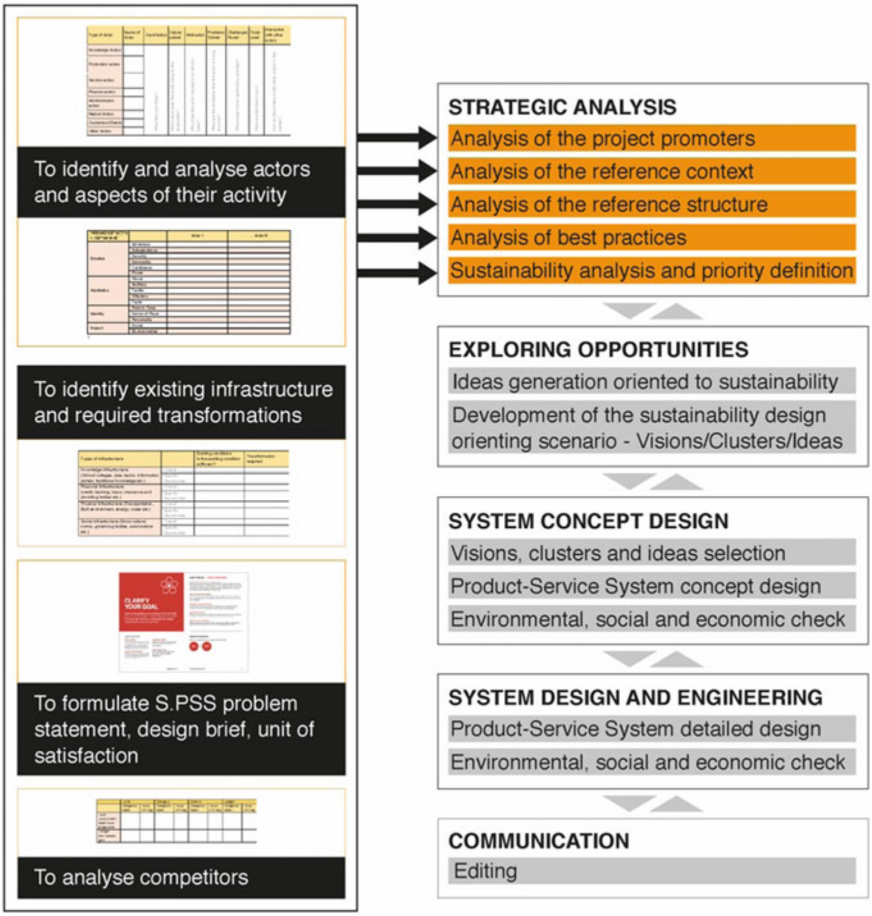


Fig. 23 Strategic analysis toolkit (SAT) integration into the MSDS design process

Aims

The strategic analysis toolkit aims to help a designer in Sustainable Product-Service System Design with an intervention focus on Socio-Economic Ecosystems (SEE) of multi-cultural and diverse communities engaged in distributed economic activities.

Process 1: Project Socio-Economic Ecosystem Analysis

1. *Awesome Actors Tool*. The first step of strategic analysis is to identify all the actors and their aspects of activity, best accomplished by interviewing local administrators and visionaries (e.g. local elders, thought leaders, NGOs, etc.). The Awesome Actors Tool helps its users to identify the main value proposition of the local ecosystem, its problems, all actors and their activities (Table 2).
2. *KFPS Knowledge Mining Tool*. This tool helps to identify existing infrastructure and required transformations. Interviewing local administrators/visionaries helps in acquiring information on service, product-service, and infrastructure transformations planned and required in the local ecosystem (Table 3).
3. *Empathy Mapping*, AEIOU Mapping, Value Opportunity Analysis, SWOT, PESTLE, System Map. A set of tools supports their users in meeting the actual actors and understanding their needs, e.g. Value Opportunity Analysis tool (Table 4).

Process 2: Defining intervention context

4. Co-design using "Clarify Your Goal". The tool adopted from Frog Design [2] helps to define design goals, identify the problem statement, design brief and unit of satisfaction (Fig. 24).
5. Competitor analysis on form, category, generic, budget level (using Porter's five forces analysis if applicable [5]). The tool helps to collect the competition space knowledge (Table 5). Competitors of the system are found based on the clarified goal of the design intervention and the main value proposition of the local context.

Currently, the toolkit has been designed and tested on two SEE contexts, both located in Assam, India.

Availability and resources required

Downloadable files of each tool can be found in Banerjee et al. [1] with the following information on resources and time needed to carry out design processes using each tool.

Table 2 Awesome actors tool

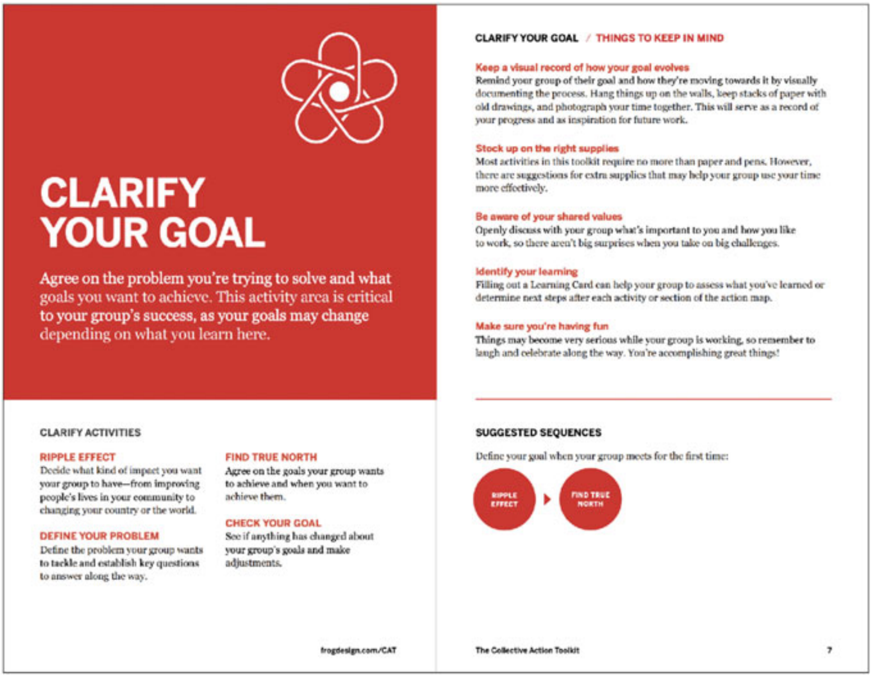
Type of actor	Name of Actor	Contribution	Values added	Motivation	Problems Solved	Challenges faced	Tools used
Knowledge actors		What they are doing?	What value does the actor bring to the ecosystem?	What value does the actor choose to do what it does?	What are the problems that the actor is trying to solve?	What stops it from performing activities?	How do they interact with other actors in the system?
Production actors							
Service actors							
Finance actors							
Administration actors							
Market actors							
Customers/clients							
Other actors							

Table 3 KFPS knowledge mining tool

Types of Infrastructure		Existing conditions: Is the existing condition sufficient?	Transformation required
Knowledge Infrastructure: (School colleges, data banks, information portals, traditional knowledge etc.)	Overall		
	Specific Stakeholder		
Financial Infrastructure (credit, banking, loans, insurance and providing bodies etc.)	Overall		
	Specific Stakeholder		
Physical Infrastructure (Transportation, built environment, energy, water etc.)	Overall		
	Specific Stakeholder		
Social infrastructure (Socio-cultural norms, governing bodies, associations etc.)	Overall		
	Specific Stakeholder		

Table 4 Value opportunity analysis

What are the needs of the actors?		Actor 1	Actor N
Emotion	Adventure		
	Independence		
	Security		
	Sensuality		
	Confidence		
	Power		
Aesthetics	Visual		
	Auditory		
	Tactile		
	Olfactory		
	Taste		
Identity	Point in Time		
	Sense of Place		
	Personality		
Impact	Social		
	Environmental		


CLARIFY YOUR GOAL

Agree on the problem you're trying to solve and what goals you want to achieve. This activity area is critical to your group's success, as your goals may change depending on what you learn here.

CLARIFY ACTIVITIES

RIPPLE EFFECT
Decide what kind of impact you want your group to have—from improving people's lives in your community to changing your country or the world.

DEFINE YOUR PROBLEM
Define the problem your group wants to tackle and establish key questions to answer along the way.

FIND TRUE NORTH
Agree on the goals your group wants to achieve and when you want to achieve them.

CHECK YOUR GOAL
See if anything has changed about your group's goals and make adjustments.

frogdesign.com/CAT

CLARIFY YOUR GOAL / THINGS TO KEEP IN MIND

Keep a visual record of how your goal evolves
Remind your group of their goal and how they're moving towards it by visually documenting the process. Hang things up on the walls, keep stacks of paper with old drawings, and photograph your time together. This will serve as a record of your progress and as inspiration for future work.

Stock up on the right supplies
Most activities in this toolkit require no more than paper and pens. However, there are suggestions for extra supplies that may help your group use your time more effectively.

Be aware of your shared values
Openly discuss with your group what's important to you and how you like to work, so there aren't big surprises when you take on big challenges.

Identify your learning
Filling out a Learning Card can help your group to assess what you've learned or determine next steps after each activity or section of the action map.

Make sure you're having fun
Things may become very serious while your group is working, so remember to laugh and celebrate along the way. You're accomplishing great things!

SUGGESTED SEQUENCES

Define your goal when your group meets for the first time:

RIPPLE EFFECT ▸ FIND TRUE NORTH

The Collective Action Toolkit 7

Fig. 24 "Clarify Your Goal" section of Frog Collective Action Toolkit

3.7 Distributed Manufacturing (DM) Applied to PSS Design Toolkit

The DM applied to PSS design toolkit (Fig. 25) has been tested with students, experts, manufacturing industry professionals and design practitioners through three rounds of empirical application, to ensure its effectiveness and usability [4].

Aims

The DM applied to PSS design toolkit serves two purposes: (1) it provides its users with knowledge about potential DM opportunities and (2) supports idea generation for PSS solutions improved with DM features.

Components

The toolkit consists of four elements, each of which is described below in detail:

- 40 near-future scenario cards
- 3 scenario cards' selection diagrams
- 1 introductory card
- 1 idea generation diagram.

Table 5 Competitor analysis on form, category, generic and budget levels

	Form		Category		Generic		Budget	
	Competitor name	Value offering	Competitor name	Value offering	Competitor name	Value offering	Competitor name	Value offering
Local-Ecosystem's main value proposition								
Design intervention goal								

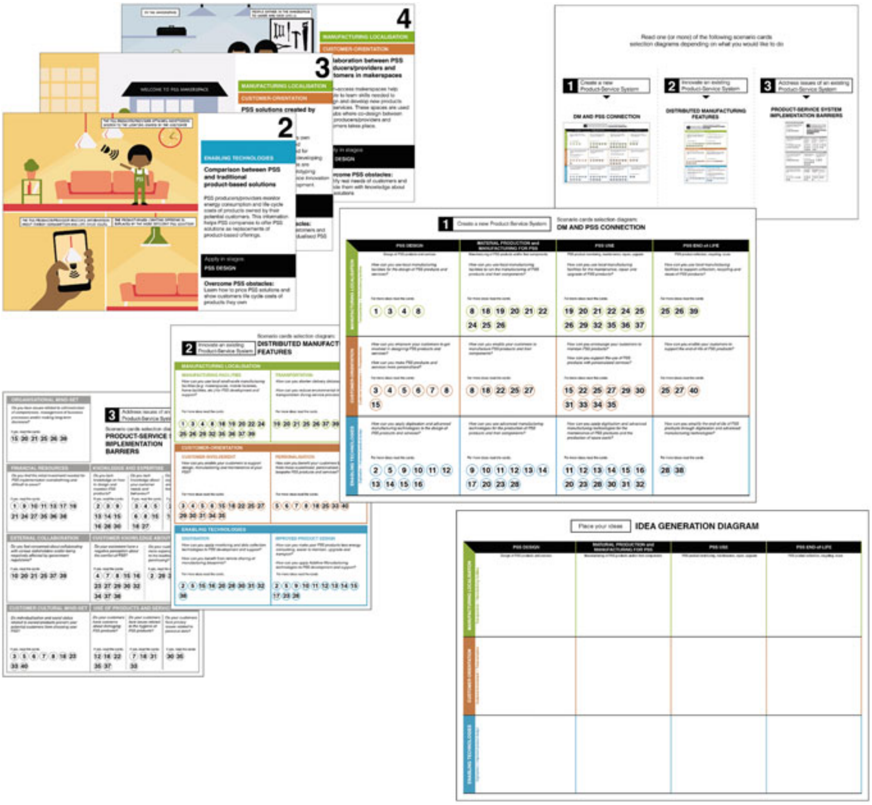


Fig. 25 The DM applied to PSS design toolkit

Near-future scenario cards

Double-sided near-future scenario cards are brief snapshots illustrating how specific features of Distributed Manufacturing can be applied to Product-Service Systems throughout their life cycle (Fig. 26). Scenario cards are made to inspire and to encourage future-oriented thinking. Furthermore, they serve an educational purpose and contain a sufficient amount of information to support a learning process about DM and PSS.

Scenario cards' selection diagrams

Scenario cards' selection diagrams on which scenario cards are mapped illustrate areas tackled by the near-future scenarios. The toolkit contains three scenario cards' selection diagrams (Fig. 27): [1] the stage-by-stage DM and PSS connection diagram (1); [2] the DM features diagram (2); and [3] the PSS implementation barriers diagram (3). These diagrams are made to facilitate relevant scenario cards' selection. Each diagram classifies scenario cards according to PSS life cycle stages and/or DM features, or PSS implementation barriers and contains questions helping to select relevant cards.

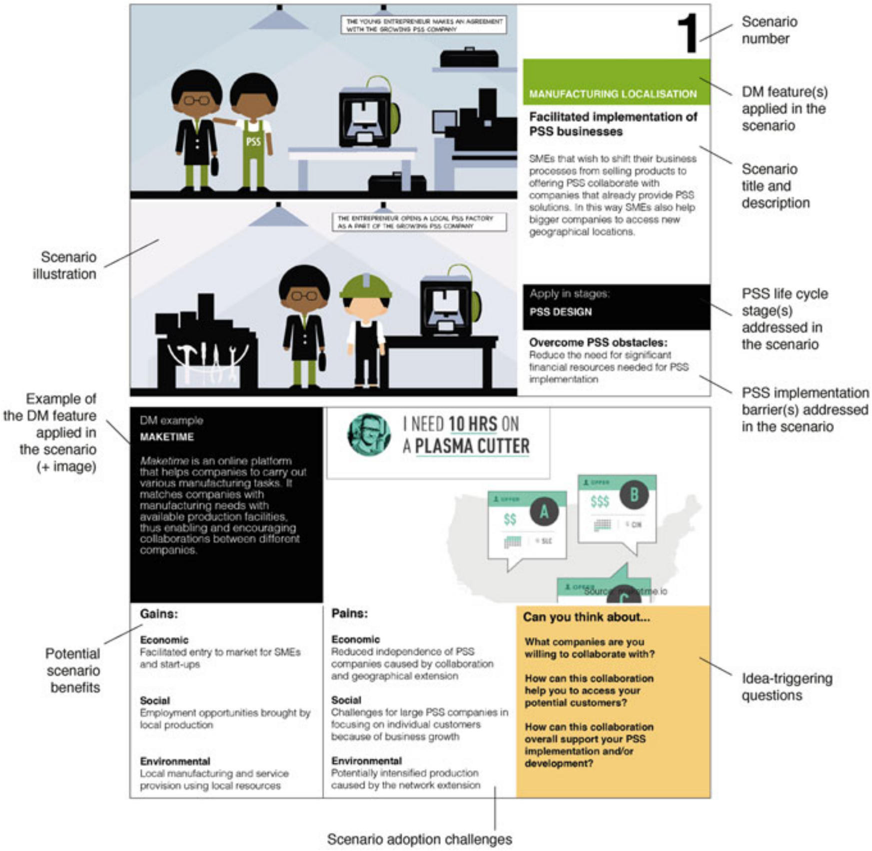


Fig. 26 Front and back sides of the near-future scenario card

Introductory card

This toolkit is made to facilitate new PSS development as well as to improve existing PSS solutions. The introductory card allows the toolkit's users to decide whether they would like to create a new PSS or to improve an existing one (Fig. 28). Depending on their choice, one of the three scenario cards' selection diagrams must be selected.

Idea Generation Diagram

The Idea generation diagram (Fig. 29) is used for positioning ideas developed using near-future scenario cards.

Integration into the MSDS design process

The DM applied to PSS design toolkit can be best used to facilitate idea generation for S.PSS solutions enabled by DM. In addition, near-future scenario cards can be used to explore and analyse existing examples of DM and learn about the DM

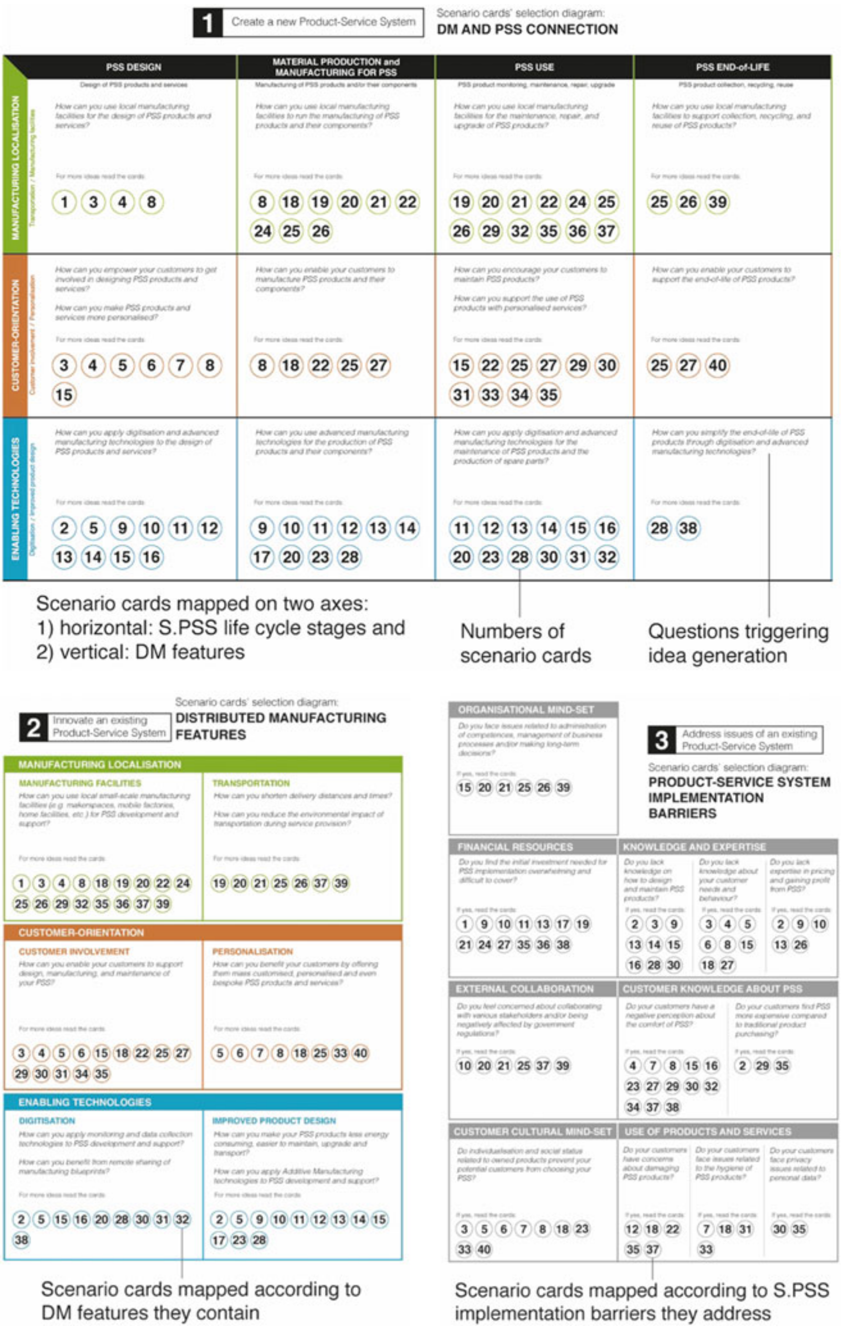


Fig. 27 Scenario cards' selection diagrams

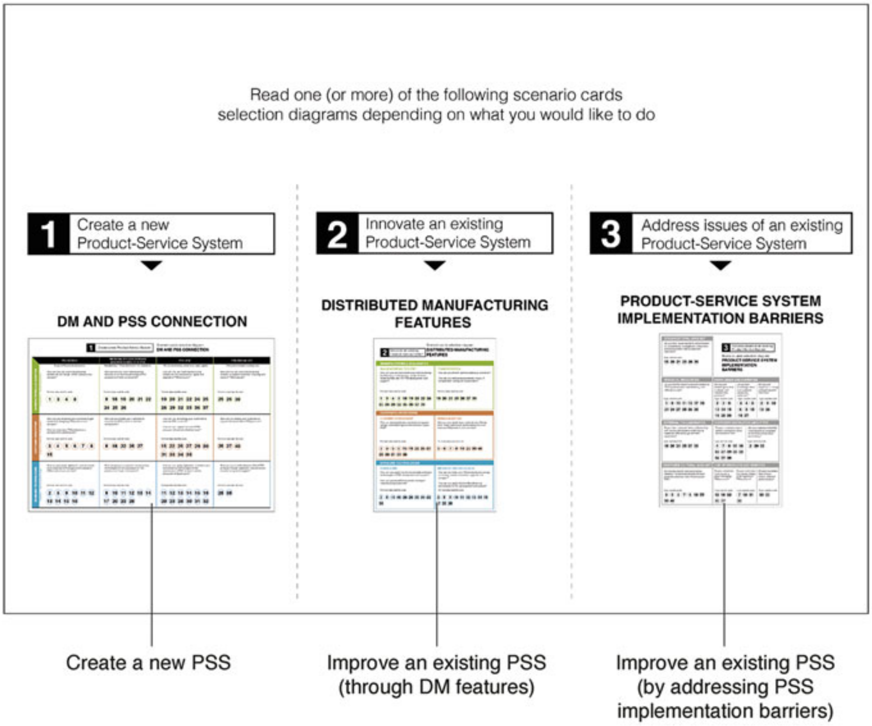


Fig. 28 The introductory card

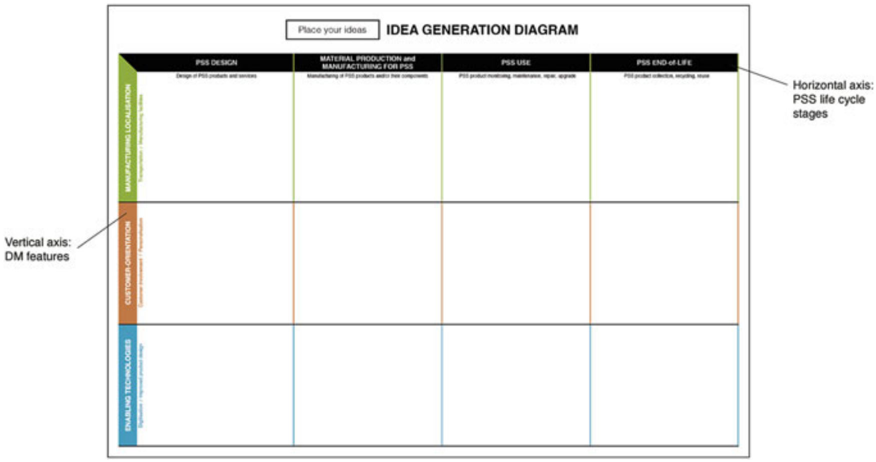


Fig. 29 Idea generation diagram

potential. Finally, the idea generation diagram can be used to position, cluster and select promising developed ideas for further detailing (Fig. 30).

How to use the DM applied to PSS design toolkit

Each element of the DM applied to PSS design toolkit is created to be used in a purposeful order (Fig. 31): first, the identification of the goal using the introductory card (1); second, the selection of relevant scenario cards using the scenario cards' selection diagrams (2); third, DM applied to PSS idea generation using near-future scenario cards (3); and, finally, positioning of developed ideas on the idea generation diagram (4).

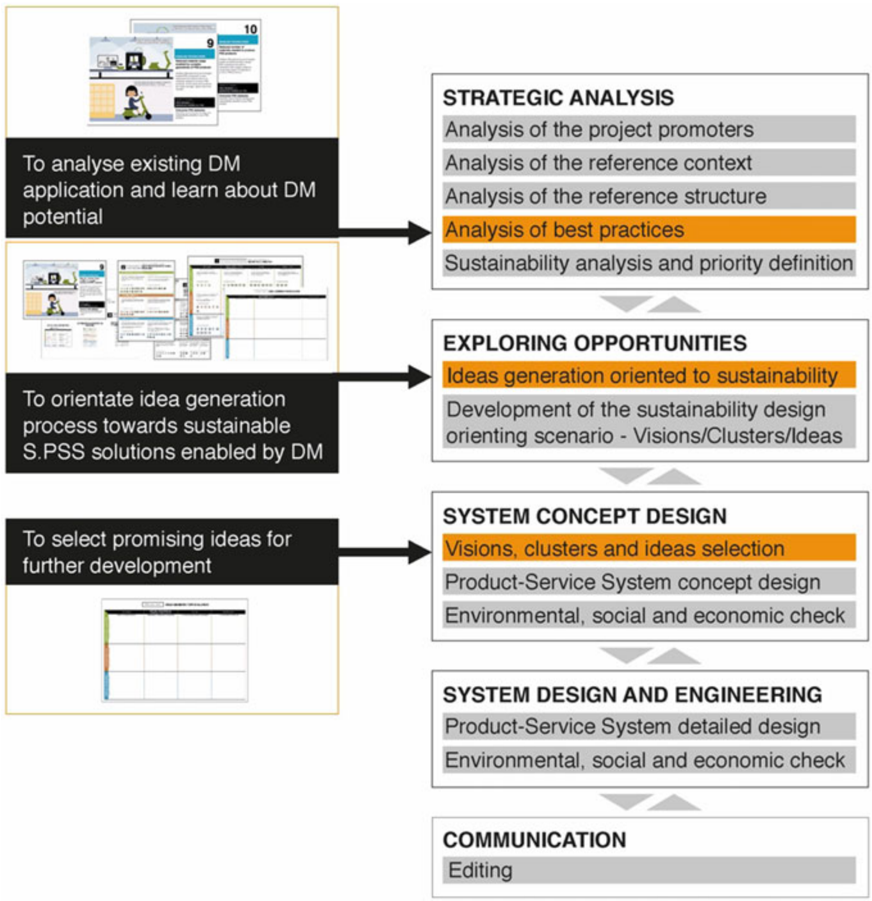


Fig. 30 DM applied to PSS design toolkit's integration into the MSDS design process

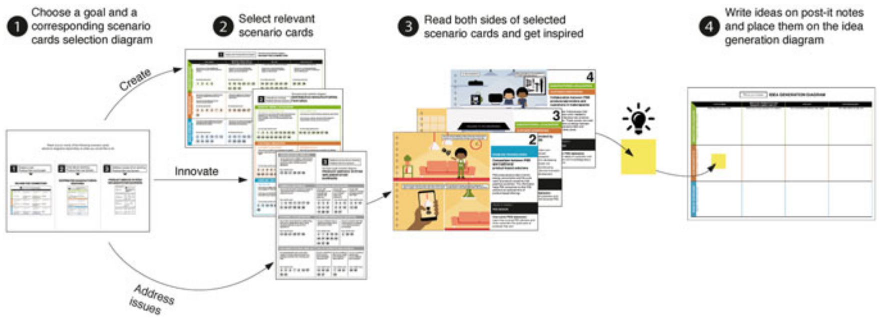


Fig. 31 A proposed design process of the DM applied to PSS design toolkit

Availability and resources required

The DM applied to PSS design toolkit is available for free download (from www.lens-international.org, "Tools" section). The toolkit needs to be printed; other required resources are post-it notes and pens.

The toolkit may be used by a team of designers, design students, or multidisciplinary team. It is advisable to involve various system actors. The toolkit requires at least 120 min to conduct a complete ideation process.

3.8 Summary

This chapter has presented several tools supporting the design of S.PSS applied to DE that have been developed or updated during the LeNSin project. Many other tools have been developed to support system design for sustainability for all and a wide selection of those can be found and downloaded from the LeNS platform (www.lens-international.org).

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S.PSS and DE in Practice

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1 Introduction: Teaching and Learning Contemporary Design for Sustainability

Contemporary challenges related to sustainability are shared across the globe. Their materializations, prioritizations and emphases, however, vary from one region and context to another. As we have seen in the previous chapters, Sustainable Product-Service Systems (S.PSS) and Distributed Economies (DE) as concepts are still in the making, and tools to assess and implement them in design are still developing. Their interpretations can also take various forms when they become introduced into different contexts. Alongside these shared challenges, there are also specific regional or historical tensions, which connect not only with education, design and the histories and trajectories of industrialization, but also arise in international projects and collaboration. Such tensions become even more evident if new concepts and contents come into play. It can also lead to differing interpretations on how to approach them.

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C. Vezzoli et al. (eds.), *Designing Sustainability for All*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-3-030-66300-1_5

The international LeNS network was created in an EU-funded project between 2007-2010, and it has continued to expand and interact in the LeNSes project (2011-2015, with a focus on renewable energy for all) and in the LeNSin project (2015-2019). With its 'ethos' on 'multi-polar' collaboration and several strong regional networks, the international LeNS network has accommodated an atmosphere that has been sufficiently open and sensitive to elaborate these concepts further, and to critically assess their potential in developing new, more sustainable solutions.

This chapter shares the experiences from the LeNSin seminars and pilot courses from various perspectives. In this chapter, we also briefly discuss the potential of design education as a transdisciplinary matchmaker between various actors and networks.

2 Introducing S.PSS and DE into Higher Education in Design

Despite its recent origins in the mid- to late twentieth century, discourses around professional design, its identity and expectations, are relatively consistent across the globe, particularly with regard to industrial design. Various methods for sustainable design, including product-service system design, have also evolved, increasingly acknowledged in public discourse, such as in EU and UNEP publications. However, the very concept of PSS still allows for various interpretations depending on the socio-economic context. For example, in some pedagogical contexts, the concept of a 'sharing economy' may be seen as more engaging or understandable for design students than 'user-oriented PSS'. Moreover, when relatively broad concepts such as Distributed Economies are introduced into sustainable design teaching, interpretations can vary significantly with regard to focus and expectations.

Design activities have gradually extended further from the studio and the factory line. Currently, design connects with various domains of interest, with products and services, but also systems innovation; with organizations and business, but also societal change-making. Designers work with diverse professionals and experts, as well as laypeople and public media. This diversity extends the area where such interpretations can be trialled.

In this section, we reflect on how S.PSS and DE as concepts can be introduced into different geographical, socio-cultural and educational contexts, and we examine some of the choices and emphases in developing two rounds of pilot courses during the project. We also address the variety in which the DE focus can be adjusted and look into the role of the university in contemporary knowledge building for transdisciplinary sustainability.

One integral aspect in the LeNSin project has been in sharing experiences on teaching and in developing new educational content. The main strength has been the strong network, which has helped to overcome practical difficulties, and to balance course expectations and institutional constraints in developing new teaching contents.

2.1 Experiences from Regional Pilot Courses: An Overview

Sustainable design has gradually become a highly promoted strategy linking industrial developments, consumer domain actions and policymaking. In sustainable design, as often in complex problem-solving processes, several actors from different fields need to work towards a shared goal, and a more detailed discussion on the driving values and goals pursued is needed. The challenge of sustainability lies in connecting not only scientific research and politics, but also the perceptions and actions of professionals and laypeople. In this sense, design for sustainability can be understood by its very nature also as transdisciplinary, drawing together considerations from ecological, societal and economic domains into a shared process of mediation and making.

Contemporary design activities in various regions are in many ways still based on the educational programme of the Bauhaus school, where architects, painters, and sculptors combined multiple perspectives with an emphasis on workshop or studio work [4]. In the last few decades, however, the role of design has gradually shifted towards higher levels of focus, from the crafts studio and factory line towards society at large and towards broader socio-technical systems [6]. Today, design has been noted as a possible catalyst for social innovation [10] and sustainability transitions [9]. Consequently, the potential of design has been increasingly noted also in relation to transdisciplinary activities in education and in sustainability at large ([5, 8, 14]).

Design schools around the world share similarities in both the challenges they face, as well as the potential that the discipline itself allows. As a discipline in higher education, design often connects with engineering and business, but also media and art. Earlier, it has acted as a bridge between the producer and consumer world. Particularly now, with new phenomena heralding new agency and competencies for users and consumers—as seen in the spread and promotion of social innovation, the influence of the internet and peer networks, and the DIY, amateur design ‘maker movement’—these roles have also become increasingly mixed [11].

2.1.1 Developing Teaching in Two LeNSin Pilot Rounds

The LeNSin project focused on developing new teaching contents on S.PSS and DE, but also on expanding the network of partners, to gather an understanding of various DE related actors in different contexts and countries. This was taken forward in the form of case studies, new tools and methods, local seminars to gather insight, and in consecutive pilot courses in which various DE topics were taken under study with students (DE topics are discussed in Chap. 2). The seminars gathered local actors that shared an interest in the topics, but also linked to already existing networks and projects. The consecutive pilot collaborations took place with design students from various fields, ranging from media and graphic design to industrial and service design, and to engineering and architecture.

To understand what impact the project has had, we look into the interactions in developing these collaborations and reflect on the preparation process, the emphases taken in the actual pilot courses, as well as their outcomes. Our reflections are grounded on the course materials (syllabuses, teachers' course reports), our own experiences and insights from interviews with the teachers involved.

Overall, five seminars and ten pilot courses were organized in five countries, with two main partners from each country and additional associate partners around the region. This interaction also constituted one main part of the whole project, where theoretical contents, design methods practice and real case studies came together. Initially, in each country the two partners came together to host a seminar, in which the main topics of S.PSS and DE were discussed from the regional perspective. Later the pilot courses were conducted, which aimed at examining and designing for DE in the various contexts in student case work. Teachers refined their understanding of the connection between S.PSS and DE during the courses, as well as tested and refined design tools. In China, the focus in the first pilot course was on lighting and 3D printing, in both commercial contexts and marginalized communities, and in the second pilot on regional food culture. In India, the focus of the first pilot was to help a local NGO actor boosting regional health, well-being and resilience and the second was on developing the local silk weaving industry. In South Africa, the focus was first on developing distributed health solutions and information and then on developing a supporting app for deaf people. In Brazil, the case work in the first pilot focused on the local fashion cluster and the second one on local mobility. And lastly, in Mexico, the first pilot focused on a local book club programme and then the second pilot on the university payment service system for students. Finally, besides access to a gradually extending case study library and improved revisions of toolsets, student teams also had an opportunity to submit their solution to the LeNSin student competition, and eventually six national winners were selected (including Europe), and four honourable mentions were given [12].

Overall, the themes in the regional educational activities progressed in different directions. However, the predefined structure of interaction and thematic content helped to keep a relatively coherent whole. Regional seminars and the following pilot courses called for a cumulative amount of preparation, but also ensured that the network of actors was gradually formalizing and roles became clear. In the end, the teaching activities involved an extended number of educators, both from the local region as well as internationally, and they attracted local attention.

During the teaching collaborations, in many locations, there were also unexpected local events—natural or societal—that led to additional challenges in preparations (for example, employee union strikes, student strikes, political instability and natural disasters such as earthquakes). The strong network allowed the necessary reflexivity that helped to overcome these obstacles.

Although each pilot comprised introduction to S.PSS theory and tools and an introduction to DE topics, the structure of the pilots varied. As the participating teachers visited several locations, and experiences were shared across, the teaching as a whole nevertheless remained rather coherent in relation to its main topics. Additionally, various experiences with tools and methods for teaching were exchanged during the pilots, but also informally across the network via email conversations or face-to-face meetings.

The structure of the seminars and two consecutive pilot courses held in each region provided the possibility to have ‘rounds of iteration’. Each pilot also had visiting teaching partners from another university, as well as observers from a third one. Experiences were then gathered in reports and exchanged in project meetings. This material also allows for subsequent academic communications and reflections in various forms.

Although it was challenging to insert an intensive, short course within most of the institutions involved (see Sect. 6), many of the teachers later reported that the very intensity was beneficial to the students’ learning. Many things about the pilot course were ‘new’ for both students and teachers: the diversity of didactic approaches (from theoretical lectures to active teamwork and fieldwork); the diversity of the student body (e.g. coming from all over the country, see Sect. 5, or from different departments, see Sects. 3 and 4); and the diversity of perspectives represented (teachers from other countries, stakeholders from companies or NGOs, and so on). Teachers quickly learned to improvise and take advantage of each other’s expertise, while needing to create a learning structure that did not lose students through the gaps. Teachers later appreciated how these opportunities and challenges helped create courses that managed to avoid “superficial sustainability” or “sustainability-as-usual”, as a kind of green paint splashed onto design education. Students were rather pushed to improve their abilities in systems thinking and to imagine and aim for new paradigms beyond business-as-usual: the territory of Distributed Economies where locally relevant solutions with greater sustainability potential are identified and fostered or designed anew and gradually embedded within the existing culture. S.PSS and DE were unquestionably often problematic concepts, but both teachers and students worked on translating the terms literally and culturally: reframing, re-coding and re-interpreting them. In some cases, the internationality of the work helped to raise the profile of sustainable design education in the institution and lend it further legitimacy, in a global context of tight budgets and instrumentalist learning objectives.

2.2 Reflections: Teaching S.PSS and DE Design

The concept of S.PSS is rather established in both design teaching and industry in many regions, and as a concept, it also acts as a suitable basis to develop a new understanding on DE. DE as a thematic area of focus, however, introduces very different interpretations in different contexts, regarding expectations, mode of work and developed outcomes. One important outcome is, in this sense, also in being able to discuss these views and to spread it forward to new actors. Getting to grips with what Distributed Economies actually means and why it is a beneficial umbrella concept requires much discussion among teachers and students on what kind of industrialized or post-industrial context they exist within and how it compares to others. It is pedagogically useful to make the concept familiar, to bring it ‘home’, by identifying local case studies that can be classified as various DE cases, whether distributed manufacturing or distributed renewable energy. This, in turn, helps identify the case's sustainability benefits and threats, as a locally relevant system with cultural, social, technical and economic aspects. Teaching and learning DE is therefore not a case of importing a European concept into a non-European socio-technical environment, nor is the intent to design a solution that imitates solutions from the global North. Instead, what is important is to define 'sustainability' in dialogue and according to what is locally appropriate.

Adams et al. [1] promote developing education based on a "sustainability culture conceptual framework", which connects people, teachers to other staff to students to external stakeholders, and that entails organizational transformation: building systems that support dialogues on both visible artefacts and activities and invisible values. Consequently, when we introduce design collaboration into the context of sustainability, its driving values are challenged, and responsibility and ethics come into play. To overcome these obstacles, collaboration is needed across continents and disciplinary sectors. In this process, projects as arenas to facilitate these discussions have high impact—and an open and supportive network helps.

Sustainability and 'sustainable development', in the end, are wedded to (global) equality, equity and justice, roles, access to participation and transparency. To this end, if design practitioners have a role in promoting collaborative mediation for sustainability or even further—to promote democratic assessment of heterogeneous perspectives for sustainable innovation [13]—this also calls for fundamental changes in how to approach design education and its processes of teaching and learning.

And yet, design activities around the world are fundamentally grounded on iterative development. Design thinking acts in bridging problem and solution spaces [7], and its activities proceed by default through trial and error. Design as a discipline remains a developing field, continually producing new methods and collaborations in various contexts, in between and in connection to multiple domains and discourses. And finally, at best, teaching design involves an open and expansive process. Contemporary design activities involve several emphases on inducing and promoting collaboration and shared mediation. Collaborative, participatory design processes can support shared knowledge building and development of practice. Such interaction can also connect with local and tacit understanding, to be adapted and better applied in new contexts.

2.2.1 Discussion: The Changing Role of (Design) Academia

When design educators are networking globally and bringing local actors into dialogues to promote sustainability in various contexts, conventional industrial collaborations can expand further into new networks (see Sect. 3). S.PSS and DE as concepts allow such expansion and extend these networks further.

In developing new international collaboration on teaching and making, interaction needs to be embedded in a shared and reflexive process. In support of this, design remains an open field for education and action, linking various local and global inquiries across several professional domains. And as a result, design for sustainability as an aim and agenda can support a transformation in contemporary practices of making and learning; design acts as one key focus for developing policies and action, attracting interest in developing new ideas for societal sense-making.

Today, universities are adopting a new role, to establish their position in the political and economic structures of an increasingly knowledge-driven society. This new role emphasizes knowledge production for society and societal benefit, calling for stronger connections between research, education and everyday practices to expand participation to the outside world. For contemporary universities, this call moves the emphasis on how students and other stakeholders in the processes of learning are taken into account when joining up the fundamental orientations for any action.

As a mode of interaction and collaboration—and shared development of learning content—the LeNSin pilot course interactions provided a valuable opportunity to develop new tools and methods to implement sustainable design, and to share and connect the topics further. In parallel with the pilot courses, other curricular courses and collaborations with stakeholders (NGOs, municipal authorities, companies and so on) furthered the lessons learned. In the following sections, we will describe further how collaboration particularly with external stakeholders in the courses is carried out, from fieldwork involving regional industry clusters to small NGO partners in a long-term partnership in education.

3 Working with a Regional Industry Cluster in Education in Brazil

In the north-eastern part of Brazilian territory, nearly 23.5 million people have faced harsh living conditions due to severe weather for decades. This so-called Semi-Arid region is characterized by high temperatures and low rainfall, generating water shortages. Poverty and social injustice have emerged as problems associated with the scarcity of water, but policy and top-down solutions have failed to democratize access to the water supply, hindering local development and putting individuals under economic, political and cultural domination. However, in recent years, with the implementation of social innovation initiatives, local communities of the Semi-Arid region have begun to change their dependence on centralized public policies and to develop bottom-up alternatives to mitigate the conditions associated with water scarcity.

Based on innovative interactions between stakeholders, the Agreste's fashion cluster was created. The cluster specializes in the manufacturing of jeans, cotton and polyester clothing. A total of 18 000 SMEs employ 8% of the workforce in the state of Pernambuco and generate 5% of the state's GDP. Despite all the economic benefits brought to the Semi-Arid area by the fashion cluster, the region's environmental and social degradation has worsened. It was impacted by the intense use of already scarce resources, such as wood and water, which are used in the manufacturing process, mainly for the washing and finishing of jeans. From 60 to 100 litres of water are necessary to wash one pair of jeans. Toritama, the city where jeans are produced, manufactures 800 000 pairs of jeans per month. The waste from this process is not correctly processed. It is disposed of in the river that crosses the city, changing the colour of water from pink to blue to a coloured mix.

3.1 The LeNSin Pilot Course Brazil

In June 2017, the first LeNSin Pilot Course Brazil took place in the city of Recife, at the Federal University of Pernambuco. Thirty-five students from the business administration and design courses from UFPE were challenged to develop S.PSS proposals for the fashion cluster of Pernambuco. The students were expected to develop an understanding of current environmental issues; demonstrate understanding of the tools used to develop S.PSS concepts; discover design strategies and to design an S.PSS for Distributed Design and Distributed Manufacturing with a particular focus on the Brazilian context; and to explore and test out-of-the-box concepts and ideas for S.PSS concepts. A field trip was organized to the fashion district to collect data and to give participants the opportunity to 'experience' some of the issues described in the challenge. Students also presented and validated initial ideas with representatives of the fashion cluster. Their final design concepts ranged from ways to transform waste from manufacturing processes to solutions to promote the empowerment of women in the region.

From the point of view of learning objectives, the mixture of students from different disciplines was beneficial: it proved to be quite effective for the learning process to have business and design students together in mixed groups. Having the participation of lecturers from other universities and presenting local and international case studies brought together the local and the global perspectives on S.PSS, fostering a better understanding of the concepts and enriching the discussions. That said, sustainability is complex and much information was presented, needing systematic and constant reviews throughout the course.

The collaboration with the regional industry cluster was important for several reasons. First, there is an urgent need to put our students in contact with the context in which they live. For instance, many of the students did not know the possible negative environmental impacts of the clothing they were wearing. Coming into direct contact with the problem through a site visit enhanced the creative process and resulted in a more empathic process, even if such visits are time-consuming within short courses. Furthermore, the field study sped up the bonding among team members, resulting in a pleasant atmosphere for the practical part of the course. The second reason the collaboration with industry was essential is because it shows potential partners outside the university, the role academia can play in practice, with concrete tools and innovative ways for understanding their problems.

3.2 Reflecting on Industry-Academic Collaborations in Brazil

There are at least three key challenges for setting up a direct collaboration with industry, based on the Brazilian experience. The first relates to information scarcity. Achieving a robust (meta) concept on PSS and DE requires a wide set of data, information and intelligence that is not usually ready to be used by students. The inherent nature of Distributed Economies often implies the consideration of stakeholders that conventional companies have not integrated into their business process and, therefore, have little knowledge as to how to support the creative process. In other cases, the business partner cannot disclose information as it often deals with strategic and sensitive issues, such as the long-term vision and objectives regarding the service and product portfolio. In order to enable a meaningful experience, the approach adopted in the pilot courses in Brazil was to present a compact set of information about the problem, leaving some room for the students to collect additional information as needed. Although students can opt to adopt more empathic approaches with the stakeholders (such as focus groups) or more quantitative approaches (such as Business Analytics), short courses have shown that it is more viable to dedicate time to the analytical process than the data collection. Awareness of the scope and depth of the information required by S.PSS applied to DE Design is, therefore, one of the expected learning outcomes of these courses.

The second challenge relates to expectations regarding innovation insights. Expectation management is quite important when developing courses on S.PSS applied to DE. When the business partner is not fully aware of the meaning of PSS and DE, the expectations may be overoptimistic regarding what would be delivered at the end of the course. While on a regular product design course a student may be able to produce a usable prototype, tested in a real-world setting, the complexity of an S.PSS applied to DE problem usually allows the students to only get to the (meta) concept stage. When the business partner is knowledgeable about S.PSS and DE the expectations are naturally more realistic. In such situations, the (meta) concept produced by the students results in insights for the business partner, which is the most relevant benefit of the cooperation. No ethical issues have been raised in any of the pilot courses in Brazil in this academia-industry collaboration, since none of the student groups have reached a stage where an idea could effectively result in e.g. a patent. Indeed, most of the projects developed by the students have achieved more innovation at the system and service level than at the product level, making it difficult to reach a stage where copyrights would be an issue to be raised.

The third key challenge in industry-academia collaboration is being part of the learning process and not just a client. Comparing the experiences in Brazil, it is quite clear that a full involvement of the business partner contributes to a better result with regard to the learning process. Such involvement might require a wide set of contributions: giving technical and managerial feedback on the evolving concepts; reassuring the students regarding the attractiveness (or not) of their concepts; pointing out barriers and strategic advantages of their ideas in topics that have been overlooked by the students; bringing onto the table insights from past experiences; information about the dynamics of the stakeholders in the industry, and so on.

When the industry is already involved and interested in PSS projects, the motivation to take part in the learning process of the students is two-fold: to have direct contact with methods and tools developed in academia, and to contribute to the training of possible future employees. In Brazil, there is a growing demand for design professionals with competencies in PSS and Service Design. Actively developing new young professionals, observing them in action, offers the partner companies the opportunity to identify new talents that might be recruited to join their staff.

4 Working with a Regional Industry Cluster in Education in India

This section presents the experience of the team at IIT Guwahati in teaching Design undergraduate, postgraduate and Ph.D. students the principles of Design for Sustainability (DfS) for Socio-Economic Ecosystems (SEE) of India [2, 3]. According to Banerjee et al. [2], “A SEE is a context where the economic activities of the community are deeply ingrained in the socio-cultural ways of living.” In these contexts, the major challenge for DfS is how, through design, one can bring about:

- *first, the sustainability orientation to the socio-ethical dimension in a manner that it is in the economic interest of the system stakeholders to be so, and;*
- *then, the sustainability orientation to the environmental dimension in a manner that it is in the economic interest of the system stakeholders.*

Another characteristic is that it is difficult to identify one company or stakeholder who is the promoter or provider of the offerings of the SEE. Instead, these are multi-stakeholder ecosystems. The inherent nature of the economic activities in these contexts is distributed (Distributed Economies) in nature. SEE might be distributed in terms of design, manufacturing and knowledge generation. These ecosystems might also have a long history of existence and, as a result, have evolved their system to be sustainable on many accounts. In order to initiate any design intervention, a designer must therefore deeply study these traditional ecological and social knowledge systems and their integration with the local cultures.

4.1 Case Study Location: Sualkuchi Silk Handloom Industry as a SEE

Sualkuchi in the Kamrup district of Assam, India is a census town and is made up of a cluster of 16 villages. It is on the banks of the river Brahmaputra, 35 km from Guwahati, the largest city in the northeast of India. The population is more than 100 000. It is also famously referred to as the 'Manchester of Assam' due to its large silk handloom weaving industry which now also has a trademark—Sualkuchi's. The handloom industry here is even mentioned in the works of Kautilya, an Indian royal advisor and economist who lived during 371–283 BC. The current form of the industry is a result of the encouragement it received during the Ahom Dynasty from 1228–1828 AD [15].

A typical household in Sualkuchi owns at least one loom and contributes to the silk weaving industry here. Post-independence of India, the industry began to flourish and reached its peak during 1981–2001 when looms per household increased from 2 to 6, on average [17]. During this time, many households shifted their operations towards entrepreneurship, owning 50 or more looms, employing weavers rather than using the family members as weavers. There are four major categories of actors in the ecosystem: owners, weavers, reelers and helpers. The owners might be small (<5 looms) or large (>50 looms) and own the instrument of production, the Jacquard loom. The small owners mostly weave and reel themselves with their family while others hire weavers, reelers and helpers. The contracted weavers are paid based on the length of garment woven and the number of design elements. They learn to weave on the job and come from all over Assam. Some of them stay back in Sualkuchi while others go back to their native place to start their handloom setup. The reelers are also contractual and perform pre-loom activities like reeling and spinning of yarn while the helpers are paid monthly for helping the other three actors. Other standalone actors support the ecosystem: designers, loom makers, and servicers, intermediaries, distributors, shopkeepers (selling raw materials, selling finished products), government support units for low-cost raw material for small owners, silk testing lab, and Sualkuchi Tat Silpa Unnayan Samity. The biggest strength of the existing system is its distributed nature in terms of design and manufacturing (it has very few large units). Attention to technology, design and business model upgrading has lacked due to unorganized production systems, leading to stagnation. There are also rising costs of raw materials and lack of a financial support system, meaning the small owners are slowly disappearing leading to possible centralized economic models kicking in.

The primary learning objectives for the course were "Developing competencies", "Creating and changing values, attitudes, and awareness", "Transferring knowledge and understanding", "Promoting sustainable behaviour and responsible action" and "More just and sustainable society". Students were introduced to the history, development, approaches and various tools for DfS in a global context, as well as how to tackle DfS for SEE in the Indian context. Through field study methods, they were encouraged to identify how indigenous systems have evolved to live in harmony and a mutually symbiotic relationship. This also entailed identifying what new challenges were entering the system and how they are challenging the sustainability (social, environmental and economic) of the system. Given this background, the students would then design for the emerging context using the fundamentals of DfS, SEE and Distributed Economies. Lectures were organized by local stakeholders, visionaries and administrators, along with faculty and researchers from Design, Engineering and Social Sciences. The students also came from diverse backgrounds, design, architecture and fashion.

In the first process, the ‘Project Socio-Economic Ecosystem Analysis’, the group of actors from the ecosystem were identified who will together own the new S.PSS and their critical activities, by interviewing the local administrators and visionaries. They can quickly provide the designer with the main value proposition of the local ecosystem, its problems and an understanding of all the actors and their activities. The interviews also provided valuable information to help identify the challenges, potential barriers and support for the S.PSS to be designed in terms of infrastructure (knowledge, economic, physical or social) and changes required. Using mapping tools, the students could then identify the needs of the actual actors.

In the second process, ‘Defining Intervention Context’, the context for intervention was identified using a participatory approach, involving as many actors of the SEE as possible. This resulted in the identification of an S.PSS problem statement, design brief and unit of satisfaction. In the light of the selected problem statement, the students could then conduct a competitive analysis on two ecosystem parameters: the local ecosystem’s main value proposition and the design intervention goal.

4.2 The Outcomes of the Course

The main outcome of the course was a shared Living Lab in the SEE for constant design upgrading and archiving in collaboration with the local NGOs, Government, entrepreneurs, educational institutes, designers, machinery and software manufacturers. This configuration thus reduces the cost of design and keeps design up-to-date with current fashion trends. A design concept for a co-working space was also developed, as well as a central online platform for global customers’ orders and customization offers.

The collaboration with local stakeholders was fruitful, as it emphasized to the students that we should not teach and learn sustainability as a criterion in the process of design, but design in the context of sustainability. Validation of ideas with stakeholders is vital to keep students grounded in the context and for the solutions to be useful. However, students find systems thinking complex and intimidating in the context of sustainability when the cascading impact of one decision can lie in multiple aspects of the system. Repeated one-to-one discussions with the instructors were needed to ensure final design solutions were oriented to the context the students had analysed. Moreover, having a range of faculty members to support was beneficial, as we need integration of multiple knowledge domains. This range can help with the constant tension in teaching between breadth versus depth of analysis and ideation in courses of limited duration.

5 Country-Wide Teaching Networks on Sustainability: LeNS China

In China, two pilot courses (Tsinghua University and Hunan University) were organized involving about 30 teachers from home and abroad, and around 150 students from more than 20 universities across the country (including almost all LeNS China member institutions and other universities offering sustainable design-related courses), as well as practitioners in the field of sustainable design.

5.1 Pilot Courses in China

The courses provided an international communication platform for people to promote and spread sustainable design in China. The teachers systematically combined the relevant knowledge of sustainable design for the students—history, basic concepts, methods and tools—as it is important for all students to discuss and think according to a common understanding and a unified paradigm. In the courses, the teacher teams not only encouraged students to think comprehensively about sustainable design from the environmental, social and economic levels, but also guided students to integrate 'culture' as an element into the design. In addition, students were encouraged to build their own understanding of sustainability and explore innovative and sustainable solutions. To address the concepts of S.PSS applied to DE (Distributed Manufacturing and Distributed Renewable Energy, see Chap. 3) the students were taken on field visits to relevant cooperating companies, on the one hand, to understand the most cutting-edge technology development and applications, and on the other hand to encourage students to consider sustainable solutions in the future from a commercial perspective. Sustainable solutions should not only exist at the concept stage, as they require effective technical support and reasonable commercial promotion to realize fully.

Organizing such a large pilot course was both compelling and challenging. It was compelling that students showed a strong interest in the background: the international cooperation of the teaching team and the subject. With different cultural backgrounds, academic backgrounds, novel ideas and a vision for a sustainable future, these future designers were coming together to communicate sustainable design ideas and share sustainable design practices, experiences and insights, which was not only beneficial to students, it was also for teachers and all participants. The difficulty was due to a large number of students: the degree of sustainable design knowledge and understanding was uneven, and it was, therefore, challenging to conduct more in-depth discussions during the course and for students to come up with more reflective opinions and ideas. The time pressure of the short, intensive courses nevertheless stimulated students and pushed them to their full potential. Behind each final presentation was the discussion, debate, disagreement and compromise of the students, which represents the meaning of teamwork. Despite this, it was an extraordinary experience and learning opportunity for the teachers and students who participated.

Tsinghua University Academy of Arts & Design and Hunan University School of Design & Art are among China's top design schools. As the organizer of the LeNSin pilot courses, both have great appeal and influence on other design schools in China. On the one hand, teachers in colleges and universities want to learn about the resources, teaching methods and curriculum materials of sustainable design teaching, and have more exchanges with domestic and foreign counterparts. On the other hand, students hope to master the cutting-edge knowledge of the design field and learn design thinking through the curriculum training.

5.2 *Having Impact Nation-Wide*

In China, teachers and students are increasingly interested in and becoming more involved in sustainable design, research and discussion. With the push of government policies in the field of sustainable development, many institutions are gradually opening courses related to sustainable design, and students are increasingly willing to reflect sustainable thinking through their projects. Therefore, there is a great need for the study of theories, methods and tools for sustainable design.

Sustainable design is empowered by its cross-disciplinary nature, by inviting not only international teachers, but also provide a global vision, broaden the horizons of students and promote cultural exchanges. Sustainable design is an area of continuous development and evolution, and it is also a process in which teachers and students learn and explore together. Designers must be conscious and responsible for their decisions to ensure that the design is positive for people, as the products and services we create will influence and change people's lives to a large extent. Sustainable design means that we must go beyond traditional design thinking to look at design innovation in a more systematic and integrated perspective. The ultimate goal of sustainable design is to achieve a win-win situation for social benefits, environmental protection and economic development. This course is part of this effort.

LeNS China is China's most active sustainable design teaching alliance. The two pilot courses organized by this project not only effectively promote the communication of sustainable design concepts and the exchange of teaching experience in design institutes, but also have impact more widely. The related course information has been widely disseminated on the WeChat platform and the courseware and lecture materials have been downloaded nearly a thousand times on the LeNS-China network platform.

Sustainable Product-Service Systems (S.PSS) as a design strategy, aimed at exploring how to understand and intervene in these new, emerging economic and social forms, generates opportunities for sustainable business model innovation and industrial value creation. In this process, new tools and design methodologies need to be included to continuously meet the requirements of economic, environmental and social sustainable development. Through curricula, teaching and learning of

S.PSS ideas, and the participants' use of methods and tools, more applications will be generated and new practices conceptualized to adapt to China's conditions.

6 Integrating Experimental Pilots into Long Curricular Courses

This section highlights the importance, challenges and opportunities of executing a pilot course during the complete term of an existing curricular course, which has previously established course objectives, credits and enrolled students in a full-time programme, and sometimes pre-assigned teachers who may (or may not) be familiarized with a Sustainable Design paradigm.

Incorporating a pilot course within a curricular course according to its full-time scheme sets a significant challenge, but also offers the opportunity to have a wider perspective regarding the trajectory of an enrolled student at an undergraduate design programme. It allows teachers to be able to identify what kinds of preliminary knowledge would be needed and when, to recognize what specific topics should be previously introduced or reinforced in strategic courses along the complete undergraduate programme, to promote interrelations with other curricular courses, and to understand how S.PSS and DE knowledge contributes to shaping the overall graduate profile of the students.

6.1 LeNSin Pilot Courses at UAM Universities

The Autonomous Metropolitan University (UAM) participated in the LeNSin Project involving two campuses, Azcapotzalco Campus and Cuajimalpa Campus, both in Mexico City. Though both precincts have different undergraduate programmes (Industrial Design and Design, respectively) they both share a general structure, in which courses are scheduled by Trimesters and envision a Three-Trimester-long course at the end of the undergraduate programme called "Final Project", in which students are to immerse in a complex problem, propose, evaluate and communicate a design solution through a thesis. The Final Project is thereby part of the UAM design programme's strategy to provide students with the time and academic space to have all previously acquired knowledge during the Bachelor's programme put into practice. It also denotes the ideal course in which to undertake the whole design process in a project, in which a real-life implementation and contribution to society are encouraged. In order to plan and realize the LeNSin Pilot Course as a Final Project course, there were thus three levels of objectives to be considered: the LeNSin Pilot Course particular objectives of designing for S.PSS applied to DE; the particular Final Project course objectives, and the objectives of the Undergraduate Design Programme.

Once the Pilot Course was defined to be integrated and planned as a one-year-long course, with a two-week "observation window", specific problems or thematic cases were established, as well as specific scheduling to accommodate the two campuses. calendar stages and topics related with the LeNSin Project. The thematic cases are briefly described in the following section.

6.2 Book Club and Desierto de Los Leones Park Projects

Libro Club (Book Club) is a government programme initially launched by the Cultural Ministry of Mexico City in 1998, whose main objective was to promote reading habits through the creation of open libraries (book clubs) managed by citizens throughout Mexico City. At the beginning of the programme, more than 1,019 book clubs were installed inside cultural and communitarian centres, hospitals, among others, having each one a basic bibliographic collection of around 500 books. The overall intention of book clubs was to offer a reading space, run by autonomous citizens, who could give unlimited access to their book collection through 'spoken agreement', based on trust. Due to an administrative change in the political agenda of Mexico City, much of the budget related to the Cultural Ministry was reduced and thereafter the Book Club programme became fragile and unstructured and more than 1200 clubs folded. The Book Club project on the UAM Cuajimalpa campus was thus an implementation opportunity for the Final Project and LeNSin Pilot Course, as a design intervention would provide an integrated strategy to strengthen and re-formulate book club structures from a systemic view, in a way that the resulting network would be authentically autonomous and resilient to all political changes through the redefinition of all its components as a socially relevant network.

The course structure consisted of three principal stages: contextual research and immersion through field study methods, development of design proposals, and proposal refinement and evaluation, in collaboration with the stakeholders, i.e. Book Club owners and users and representatives from the Cultural Ministry [16]. Synchronized with the general curricular course objectives, additional objectives were interwoven in order to incorporate a methodological base that would allow students to:

- acquire an awareness related to the promotion of sustainable principles in emerging contexts;
- identify the social, economic and environmental spheres of a complex problem/system;
- understand the importance of the configuration process of stakeholders, interactions and scenarios throughout an interdisciplinary design process; and
- identify the theoretical and methodological basis of S.PSS and Distributed Economies.

Starting from the identification of the overall Book Club macro-system and its principal problems, stakeholders and sustainability challenges, students defined and structured their intervention through the articulation of sub-systems. This way, each team of students proposed specific S.PSS design strategies through autonomous, yet articulated, proposals. According to the specific identified problems, the overall proposed system included products and services that would allow Book Club owners and users to start, continue and self-manage an autonomous reading space.

On the UAM Azcapotzalco campus, the pilot course aimed to implement concepts and tools of social innovation to design, as well as a research process where the academic work of students was tied with those of research. Social innovation has been shown to be an important focus in sustainable design projects because it allows addressing the social variable from a novel perspective in the discipline: the user as a generator of their own solutions, where the designer reconsiders disciplinarity as a key part of the process. However, this poses new challenges for design education, since it implies a multidisciplinary practice that is not always affordable in the classroom. The objective of this project was to propose a product-service system that generates a significant change in social relations to improve the quality of life and employment of the community of vendors of the Desert of the Lions Park in the State of Mexico. The stakeholders involved in teaching and tutoring the students came from other disciplines, also from outside academia.

6.3 Summary

The LeNS pilot course, implemented for one year on both UAM campuses, provided a series of advantages at different levels. At one level, it was possible to bring students closer to the theories involved, related to both sustainability and the particular problems of each project, at a higher level of depth than what is possible in a two-week course. Students could be completely immersed in the problems, reaching important levels of empathy with the users and actors involved in the projects. Secondly, even though a general introduction was given to the different tools and principles of S.PSS Design and Distributed Economies during the two-week workshop [18], during the entire project they were introduced again during the appropriate phases of research, development and/or evaluation. These reviews of tools and principles were done in such a way that students had the time and opportunity to understand, analyse, test and execute them, not only at a conceptual level, but also in a real way once the prototypes and final proposals were developed.

Moreover, having the pilot course directly integrated into the curricula of the design programmes allowed the identification of the knowledge and skills necessary to cover in previous courses related to a deep reflection of sustainability, S.PSS design and economic paradigms (in the case of UAM Cuajimalpa), as well as the place and moment in which this knowledge could be distributed throughout the design programme, suitable teachers, contents, and so on. The implementation of a pilot course through the development of a real design project, in which the different stages of analysis, development and evaluation were transparent as evidence to the stakeholders, not only allowed a total commitment on the part of the students, but also reached a deep level of empathy and conviction of the methodological scope used.

7 Lessons Learned, Challenges and Opportunities

Besides the development of S.PSS design methods, the main success in the LeNSin project has been in the development of the network of educators that share an interest in developing teaching for sustainable design. During the project, several educators and students have collaborated in seminars and pilot courses, but also in thesis guiding, organizing seminars and events and faculty exchange. This development continues strongly from a shared history in design teaching and is well oriented to the shared challenges of today.

The project has allowed partners to study DE as a concept in various settings. Through the project, several design schools have connected to share experiences on the concept, and various actors and networks have been invited into collaboration. Within each pilot course, having lecturers from other universities acted as an alternative training process for future replications of the learning content. Since each professor has to deal with different local contexts, the result was a prolific field of discussions on how to implement S.PSS and DE methods and tools into design curricula. Another valuable outcome from the seminar and pilot interactions was the collection of several case studies from around the world on various DE interpretations. This work has continued through collaboration with selected local actors in pilot courses and in developing ideas for local DE solutions in various contexts of action in student case work.

During the project, it also became evident that S.PSS and DE as concepts are portrayed differently in different historical, geographical and political contexts. Discussing the emerging tensions can be of help in developing new content, forging collaboration and ensuring funding for future action. Understanding these dynamics is also of assistance in developing new interaction across the globe.

Sustainability is the grand challenge for the century and answers to its call are needed across professional fields. The design profession, as a potential matchmaker between different disciplines that are involved in the processes of planning and development, also calls for new methods and tools to create new interpretations of more sustainable solutions. S.PSS and DE as approaches to design can also provide new perspectives on social sustainability, extending the considerations in conventional eco-design.

In solving the challenges of the twenty-first century, future designers need to become change agents and help to expand sustainability considerations further. In this process, projects such as LeNSin—and the networks that can be developed through them—are crucial mechanisms to take work further, to legitimize action across various settings and actors.

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