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Product–Service System applied to Distributed Renewable Energy: A classification system, 15 archetypal models and a strategic design tool

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ABSTRACT

Access to modern energy services represents a great challenge for about 1.4 billion people living in low and middle-income contexts. This paper discusses the combination of Distributed Renewable Energy (DRE) with Product-Service Systems (PSS) business models, an approach that is considered promising to deliver sustainable energy solutions in these contexts. This paper aims at filling the knowledge gap regarding the combination of these two models. In particular it puts forward a comprehensive classification able to encompass all the most important dimensions characterising PSS applied to DRE, and identifies 15 archetypal models of PSS applied to DRE. This new classification system and the related archetypal models have been tested and evaluated with companies and experts from Botswana and South Africa, showing their potential to be used as a strategic design tool to support innovation in this field.

Introduction

Access to energy services is one of the greatest challenges for many people living in low-income and developing contexts, as nowadays about 1.4 billion people—20% of the global population—lack access to electricity (OECD-IEA, 2010). A very high percentage of them (84%) live in rural areas (OECD-IEA, 2010). The lack of energy access is a serious hindrance to economic and social development and it must be overcome in order to achieve the UN Millennium Development Goals (MDGs) (OECD-IEA, 2010). Even if the MDGs do not directly refer to energy access, it is clear that in order to eradicate extreme poverty, energy access represents a fundamental step in the achievement of many of these goals.

In most rural areas in low-income and developing countries, centralised energy systems are not likely to respond to the energy demand in the short- to medium-term for financial, infrastructural and policy constraints (Myers, 2013; Zerriffi, 2011). Rural electrification is challenging because it involves delivering a service to populations who are remote and dispersed, and whose energy demand is usually relatively low. This means that the high costs of extending the grid would exceed the financial limits of the generally poorer customer base that is less able to pay the full cost of the service (Zerriffi, 2011).

Distributed Generation (DG), defined as “electric power generation within distribution networks or on the customer's side of the network” (Ackermann et al., 2001) appears as a promising approach to provide energy access to rural areas not connected to the grid (Friebe et al., 2013; Zerriffi, 2011; Terrado et al., 2008). In fact, the low population density and low consumption of rural customers can match with the flexibility and scalability of distributed power plants (Zerriffi, 2011). The combination of distributed generation with renewable energy sources (such as the sun, wind, water, biomass and geothermal energy) can be labeled Distributed Renewable Energy (DRE). Several authors agree that DRE can support decentralised markets and contribute to local economic development by creating employment, introducing new capital and innovation and developing new revenue sources for local communities (Chaurey et al., 2012; Colombo et al., 2014; Terrado et al., 2008).

Even if, as stated by the World Bank, a growing number of entrepreneurs, local small and medium-sized enterprises (SMEs) and multinational corporations are succeeding in providing off-grid electrification and grid extension services to low-income markets, DRE models do present some limitations. These are mainly related to technological constraints (capacity, voltage and transmission), economic barriers (cost competitiveness, high initial capital costs) and lack of appropriate regulation environment (Beck and Martinot, 2004; Terrado et al., 2008). To access those markets and to successfully meet low-income customers' needs, suitable products and technologies must be designed but, most importantly, additional services such as capacity building, installation, repair and disposal services and financing schemes must be provided (Terrado et al., 2008; Schäfer et al., 2011).

In this framework, the model of Product–Service Systems (PSS) appears to be appropriate to successfully meet rural energy needs and

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to create profitable businesses. PSS can be described as “a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs” (Tukker and Tischner, 2006). In these models, sometimes referred to as “functional economy” (Stahel, 1997), the business focus shifts from the traditional economic model (selling a product) to the delivery of a performance in order to provide users satisfaction (e.g. from selling heating systems to providing thermal comfort services) (Goedkoop et al., 1999; Mont, 2002). In practice, there are several successful examples of traditional manufacturing companies that changed their business model towards a PSS-oriented model such as Xerox, IBM (Gerstner, 2002) and Rolls-Royce (The Economist, 2009).

The PSS model can potentially offer a range of sustainability benefits. In fact, PSSs, if properly designed, can decouple economic value from material and energy consumption (White et al., 1999; Stahel, 1997; Heiskanen and Jalas, 2000; Wong, 2001; Zaring et al., 2001; UNEP, 2002; Vezzoli et al., 2015b). This is because in a PSS model, customers pay per unit of function or performance delivered and not per unit of product sold. Thus, providers are economically incentivised to reduce as much as possible the material and energy resources needed to provide that performance. In other words, the economic and competitive interests (of the stakeholders involved in the PSS offer) continuously foster improvements in resource productivity (e.g. if the manufacturer retains ownership of products then there is an economic incentive to produce long-lasting products and avoid the costs of maintenance, disposal and manufacturing of new products (Halme et al., 2004)). There are several other potential benefits associated with PSS business models. For companies, it means the possibility to find new strategic market opportunities (Wise and Baumgartner, 1999; Goedkoop et al., 1999; Manzini et al., 2001; Mont, 2002), increase their competitiveness (Gebauer and Friedli, 2005), establish a longer and stronger relationship with customers (UNEP, 2002; Mont, 2004; Correa et al., 2007) and build up barriers to entry for potential new competitors (Gebauer and Friedli, 2005; Oliva and Kallenberg, 2003). For customers/users, it means increased value through a more tailored offer (Mont, 2002; Cook et al., 2006) and a release from the responsibilities of ownership (Mont, 2002).

From what has been said above, it is promising to look at the application of PSS models to DRE as an approach to deliver sustainable energy solutions in low-income and developing countries (Vezzoli et al., 2015a; Da Costa and Diehl, 2013). There are in fact several potential advantages derived from the combination of the two models:

In terms of *economic advantages*, DRE systems are associated with lower transmission costs for remote regions and lower energy prices in the long-term (with benefits for both providers and consumers) (Lopes et al., 2007). Small-scale energy systems can also result in great flexibility and economic resilience (Johansson et al., 2004). There are also additional benefits if a PSS approach is applied to DRE. PSS offers do not require payment for the full value of the equipment, and thus can enable low-income consumers to get access to modern electricity services without buying expensive technologies with high initial costs. Also, PSS models can provide great benefits in product-related services such as maintenance, after-sale services and user training and can affect the economic and technical performance of the products involved (Tukker, 2004).

From an *environmental* point of view, the use of locally available and renewable energy sources, such as the sun, wind, water, biomass and geothermal energy, results in a reduced environmental impact compared to the various processes of extraction, transformation and distribution of fossil fuels (Schillebeeckx et al., 2012). Moreover, local electricity production and distribution increase reliability and reduce failures compared to bulk electricity transmission (Lopes et al., 2007). Again, a PSS approach can provide additional benefits because energy providers would be, as explained before, economically incentivised in optimising material and energy consumption.

Regarding the *socio-ethical dimension*, the main benefit of DRE systems is that they enable a democratisation of energy access, thus enhancing community self-sufficiency and self-governance (Chaurey et al., 2012). DRE systems are in fact relatively easy to install and manage by small economic entities such as single individuals and/or local communities, enabling them to be no longer only consumers but also producers of the energy. Combining a PSS approach offer additional advantages because a PSS offer can be tailored to the particular (cultural and ethical) needs of customers. Also, since PSSs are labour- and relationship-intensive solutions, they can lead to an increase in local employment and dissemination of competences and, eventually, to strengthening the role of local economy (UNEP, 2002; Tukker and Tischner, 2006).

An example of PSS applied to DRE: Sunlabob, Laos

Sunlabob provides energy service through a renting model: the company leases the charging station and energy-using products (lanterns) to a village committee who in turns rents the products to the individual households. The committee is in charge of setting prices, collecting rents and performing basic maintenance. Sunlabob retains ownership, maintenance responsibilities and offers training services. End-users can rent the recharged lantern for a small fee and it will last for 15 hours of light, while the committee pays monthly fees to lease the charging station.

Although extensive research has been carried out on PSS and DRE, researchers have explored these two models separately and therefore no single study addresses an adequate classification of models of PSS applied to DRE. The previous classifications are limited as they do not fully cover all the dimensions characterising PSS and DRE models, and thus have a narrow focus (these classifications will be discussed in the next section). The aim of this paper is to explore the existing models of PSS applied to DRE and to classify them. More specifically, the goal is to provide a unified classification that is able to capture all the most important dimensions characterising PSS applied to DRE. In particular, the research questions tackled in this paper are

- What are the models and applications of PSS and DRE in low-income and developing contexts?
- What are the characteristics of these models and how can we classify them?

The proposed classification system is presented as a tool that helps to understand and develop the DRE market and explore applications of PSS applied to DRE. It is intended to be used by companies and practitioners involved in the DRE market to analyse competitors, identify market opportunities and trigger ideas of new business propositions. This classification system considers the majority of characterising dimensions of PSS and DRE models. However, it is important to highlight that, despite the inclusion of the most important dimensions, the classification system cannot be considered a comprehensive assessment framework for policy-makers or investors as it does not inform about regulations, organisational forms and financing options.

This research is framed within the LeNSes project (Learning Network on Sustainable Energy Systems) funded by the European Commission (2013–2016, Edulink Programme). It involves four African and three European universities and aims to develop a shared knowledge on the development and diffusion of sustainable energy systems, with a specific focus on PSS applied to DRE.

The article is structured as follows. First, it presents a literature review that focuses on existing classifications of DRE and PSS. Then the methodology to develop the new classification system is illustrated. The following section presents the new classification system and 15 archetypal models of PSS applied to DRE. The discussion section illustrates the applications of the classification system and how it has been tested with companies, practitioners and experts. The paper concludes underlining the limitations and identifying further research developments.

Literature review

Classifications of distributed generation

Several solutions are available to provide distributed generation energy services. These can be grouped as

- Stand-alone energy systems: off-grid systems serving an independent user (Rolland, 2011). Under this category we can find
  - *Mini-kits*—small systems with energy generator, battery and appliances such as lights and phone charger (Bardouille, 2012).
  - *Individual energy systems*—independent systems for individual users (such as a household), productive activities, or larger users (e.g. schools).
  - *Charging stations*—stand-alone systems with a generator component and a storage system for providing energy services such as charging or Internet connection (Rolland, 2011).

- Grid-based systems: they are larger stand-alone systems which supply power at a local level, using local-wide distribution networks (Rolland, 2011). We can distinguish between
  - *Isolated mini-grids*—generator facilities that supply electricity to households, productive activities or other users.
  - *Connected mini-grids*—generator systems that are connected, and exchange electricity with, the main grid.

Apart from this broad differentiation, "no consensus has been reached […] for a classification of distributed generation" (Mandelli and Mereu, 2013). In fact, what emerges from the literature is a lack of a shared approach for an extensive categorisation of models that encompasses different dimensions (technology, ownership, organisational form, target user, etc.). Several classifications have been proposed and each of them takes into consideration a different set of dimensions.

One of the possible approaches is to classify DG models through a technology lens. In this respect, Ackermann et al. (2001) suggested a very broad categorisation of distributed generation according to the *power produced* (ratings of DG): micro distributed generation (~1 W–5 kW), small distributed generation (5 kW–5 MW), medium distributed generation (5 MW–50 MW) and large distributed generation (50 MW–300 MW). The technology choice also implies the *type of generation*, i.e. whether the technology is deployed through individual stand-alone systems or through mini-grids. Several authors (Lemaire, 2011; Terrado et al., 2008; Zerriffi, 2011; Mandelli and Mereu, 2013) provide a description of models by considering the connection type. In particular, Bardouille (2012) present an extensive classification by categorising the options in: household devices and systems, community-level mini-utilities, and grid-based electrification. The technology dimension also includes the type of source used for the energy production (solar, wind, biomass, hydro) and, in some cases, authors classify DG models including both renewable and non-renewable sources (Zerriffi, 2011).

The *value proposition* and *payment structure* are two additional dimensions used to classify DG models. The value proposition describes the offer provided to customers (i.e. the combination of the product and/or service), while the payment structure refers to the type of financial transaction (e.g. cash model, leasing model). In particular, some authors (Friebe et al., 2013; Schulte et al., 2003; Chaurey and Kandpal, 2009; Palit and Chaurey, 2011; Terrado et al., 2008), have classified DG models in sales models (cash or credit model, with end-user credit or dealer credit options) and service models (leasing, fee-for-service model). However, they only focused on a specific technology (i.e. PV stand-alone systems). On the other hand, ISES (2001) provides a very similar classification by taking into consideration all technology choices.

Another dimension considered by some authors is *capital financing*, which can come in the form of loans, subsidies, credit mechanisms or international donations. Capital financing represents an important factor as it determines how the capital costs are met but it also affects the recovery of operating expenses and tariff structure (Zerriffi, 2011). Hankins and Banks (2004), for instance, provide a description of consumer and company financing options when classifying DG models through PV systems models. Bardouille (2012), on the other hand, distinguishes between commercial/enterprise-based, quasi-commercial and non-commercial models according to the financial sustainability and the type of subsidies involved.

Another important dimension of DG and strictly related to the value proposition, is the *ownership of the system*. Authors identify different models of ownership: user, service provider or community ownership. When describing the ownership dimension of the DG model, some authors have only focused on one specific technology: for example, Anderson et al. (1999) classify mini-grids in community-led DG in village energy committee, regional user organisation and large-scale utility. Others (Rolland and Glania, 2011; Terrado et al., 2008) describe the possible models as micro-utility, private sector-based, community-based and hybrid models (often Private Public Partnerships). In this latest classification, another dimension taken into consideration is the *organisational form*. As defined by Zerriffi (2011), it indicates the nature of the organization providing the energy solution. The dimension refers to whether the main service provider is a public entity (utility, government), a private company (SMEs, local entrepreneurs), a cooperative or a Private Public Partnership (PPP) made up of different actors. This relates to the network of stakeholders involved and to their roles in the provision of energy services. Directly related to this dimension is in fact the *energy system operation*, describing who uses and maintains the energy systems (i.e. in a mini-grid system, either the community or a trained agent can be responsible for operating the system).

The last dimension considered in some classifications is the *target customer*, which refers to the nature of the end user: household and individual use, productive use (agriculture, commercial activities) and community use. Mandelli and Mereu (2013), for instance, focus on the user together with the technology choice to differentiate between distributed generation (home-based systems, community and SME-based systems, centralised microgrids) and decentralised generation (hybrid microgrid systems).

Drawing our conclusions from the literature review, we can state that the dimensions used to describe DG models are several: *energy system*, *value proposition/payment structure*, *capital financing*, *ownership*, *organisational form*, *energy system operation* and *target customer*. Nevertheless, there is no joint classification of models which takes all of them into consideration (see Table 1).

Classification of Product–Service Systems

Most of the PSS classifications presented in the past (Hockerts et al., 1993; Hockerts and Weaver, 2002; UNEP, 2002; Tukker and van Halen, 2003; Tukker, 2004; Vezzoli, 2007) agree on three main PSS categories: *product-oriented*, *use-oriented* and *result-oriented* PSSs. Tukker (2004) proposes a more detailed and widely adopted classification by identifying, within these three categories, eight archetypal models of PSSs[1]:

- *Product-oriented PSS*—defined as value propositions where a company (or a partnership of companies/stakeholders) sells a product and provides additional services to guarantee its life cycle performance (Tukker, 2004). Examples of such services are maintenance, repair, upgrading, substitution, product take-back, etc. (UNEP, 2002). Tukker (2004) refers to *product-related services*, when these services are needed during the use or end-of-life phases of the product, while *advice and consultancy services* are offered by the provider about the most efficient use of the product.
- *Use-oriented PSS*—defined as value offers where a company (or a partnership of companies/stakeholders) provides access to products that enable customers to achieve particular results (Tukker, 2004).

[1] The classification presented here is summarized by Ceschin (2014).

Table 1
Dimensions considered by authors in the classification of DG.

Authors	Classifications of DG models	Dimensions						
		Energy system: considers the type of generation (stand-alone, grid-based systems) and type of source involved (e.g. solar, wind, hydro, biomass)	*Value proposition/payment structure*: type of offered provided (combination of products and services) and payment type (e.g. credit, leasing model)	*Capital financing*: indicates presence of subsidies and affects cost recovery and tariff structure (government subsidies, donations, private loans, MFI etc.)	*Energy system ownership*: who owns the system (provider, user, shared)	*Organisational form*: nature of the organisation providing energy solution (private company, local entrepreneur, government, PPP, utility, community)	*Energy system operation*: who operates and manages the system (provider, user, entrepreneur)	*Target customer*: nature of end user (i.e. households, communities or productive activities)
Mandelli and Mereu (2013)	Distributed generation (home based systems, community and SME-based systems, centralised microgrids); decentralised generation (hybrid microgrid systems)	×						×
Friebe et al. (2013) Chaurey and Kandpal (2009)	*Stand-alone systems* (*PV*): Sales models (cash model, credit model), service models (leasing, fee-for-service)		×		×		×	
Bardouille (2012)	Household level devices and systems, community-level mini-utilities, grid based electrification. Divided into commercial/enterprise-based, quasi-commercial, non-commercial	×		×		×		
International Solar Energy Society (ISES) (2001)	Cash and carry, instalments credit, finance leasing (hire purchase) fee-for-service		×		×	×	×	
Lemaire (2011)	Grid extension, stand-alone systems, distributed mini-grid systems	×						
Zerriffi (2011)	Distributed Rural Identification Models (DREM) rated according to the impact and the outcomes of the projects.	×	×	×		×	×	×
Palit and Chaurey (2011)	*Stand-alone systems*: consumer financing, fee-for-service, leasing model *Mini-grid systems*: community-based model or utility model		×			×		
Rolland and Glania (2011)	*Mini-grid systems*: micro-utility, private-sector based, community based, hybrid model				×	×		
Terrado et al. (2008)	*Stand-alone systems*: dealer credit, fee-for-service, leasing model *Mini-grid systems*: enterprise, community-based or utility model	×	×		×	×	×	
Hankins and Banks (2004)	*Stand-alone systems* (*PV*): commercially led, multi-stakeholder programmatic model, utility model, grant-based model		×	×		×	×	
Schulte et al. (2003)	*Stand-alone systems* (*PV*): cash sales model, credit model (dealer credit, end user credit, lease/hire purchase), fee-for-service model		×		×	×		
Ackerman et al. (2001)	Distinguish between ratings of distributed generation (micro, small, medium, large DG)	×						
Anderson et al. (1999)	Village energy committee, regional user organisation, large-scale utility				×		×	

Table 2
Dimensions of DRE, PSS and PSS applied to DRE.

DRE dimensions	PSS dimensions	PSS + DRE dimensions
1. Energy system	–	1. Energy system
2. Value proposition/payment structure	2. Value proposition/payment structure	2. Value proposition/payment structure
3. Capital financing	–	3. Capital financing
4. Energy system ownership*	4. Products ownership*	4. Ownership (of the energy system and energy-using products)
5. Organisational form	–	5. Organisational form
6. Energy system operation	6. Product operation**	6. Energy system operation***
7. Target customer	–	7. Target customer
–	8. Provider/customer relationship	8. Provider/customer relationship
–	9. Environmental sustainability potential	9. Environmental sustainability potential

* Dimension #4: DRE ownership dimension refers to the owner of the energy system, while the PSS ownership takes into consideration all products involved in the PSS solution.
** Dimension #6: in DRE classification, it refers to who operates on the energy system, while in PSS, it refers to who operates on all the products involved in the PSS solution.
*** Dimension #6 of PSS + DRE refers only to the operation of the energy system. In fact, the end-user always operates on the energy-using products (appliances); thus, it cannot be considered as a characterising dimension of PSS + DRE.

Customers do not own the product (the ownership is kept by the provider), and pay only for the time the product is actually used. Three main subcategories can be found under this category (Tukker, 2004): *product lease*, for unlimited and individual access to the product by paying a regular fee; *product renting or sharing*, where the same product can be sequentially used by different customers; *product pooling*, where, differently from renting and sharing, there is a simultaneous use of the product by different customers.

- *Result-oriented PSS*—value propositions where a company (or a partnership of companies/stakeholders) offers a customized mix of services in order to provide a specific "final result" (Tukker, 2004). Customers pay the company to get an agreed final result; they do not own the products and do not operate them to achieve that result (ibid.). In this type of PSS, we can distinguish (ibid.): *activity management/outsourcing*, when part of an activity of a company is outsourced to a third party (e.g. outsourcing of chemical management activities); *pay per service unit* where the user pays for the output of the product (e.g. pay-per-print formula in relation to printing machines); *functional result* where the provider delivers a result agreed with the customer (e.g. thermal comfort), without directly referring to any predetermined product or technology involved.

Gaiardelli et al. (2014) have carried out an extensive analysis on the dimensions taken into consideration in PSS classifications. Five main dimensions can be identified:

- The *value proposition* (or PSS offering) describes the value offered to the customers, as the specific combination of products and services for which the customer is willing to pay (Gaiardelli et al., 2014).
- The *product ownership* indicates whether the products involved in the PSS solution are owned by the provider, by the end user or shared by a number of users (Tukker, 2004). This dimension is strictly related to the value proposition and considered a key dimension of PSS models by several authors (Manzini and Vezzoli, 2003; Tukker, 2004; Markeset and Kumar, 2005; Aurich et al., 2010; Windahl and Lakemond, 2010).
- The *product operation* refers to who operates the product/s involved in the PSS offer, i.e. the user or the provider. Also, this dimension is strictly depending on the value proposition.
- The *provider/customer relationship* dimension represents the nature of interaction between those actors and ranges from a transaction-based relationship (in product-oriented PSSs) to creating and maintaining a stronger relationship (in use and result-oriented PSSs) (Frambach et al., 1997).[2]
- Another important dimension is the *environmental sustainability potential*. In relation to this, several authors (e.g. Manzini and Vezzoli, 2003; Tukker, 2004; Tukker and Tischner, 2006; Tukker, 2015) agree that the environmental sustainability potential is higher for use-oriented PSSs, followed by result-oriented PSSs and product-oriented PSSs.[3] Thus, this dimension can be aligned with the value proposition dimension and to a certain extent to energy efficiency and demand side management strategies (EE/DSM).[4]

The need for a new classification system

The previously presented PSS classification is widely accepted by scholars. Its strength is to be very generic and, because of this reason, applicable to various domains. However, for the same reason, it is not appropriate to be used to provide an exhaustive overview of PSS models in a specific application. In particular, regarding the scope of this paper, this classification alone is not suitable to describe the variety of models of PSS applied to DRE. In fact, as shown in Table 3, this classification is not able to cover all the dimensions that characterise DG models.

In relation to DG, the literature review showed that there are several approaches to classify DG models. However, as shown by Table 1, these classifications focus on a few (or sometimes only a single) dimensions, and thus they are individually unable to cover all the dimensions characterising PSS applied to DRE.

For these reasons, we believe that a new classification system, capable of simultaneously taking into consideration all the main characterising dimensions (see Table 2 and Fig. 1) is needed. However, it must be highlighted that different types of classifications can be carried out depending on the specific classification purposes. In this research, the focus of our classification system is on the different offer models of PSS applied to DRE (i.e. the product–service combination

[2] In general, the nature of provider/customer relationship presents a continuum ranging from transactional to relational (Penttinen and Palmer, 2007). Usually, product-oriented PSSs present a transaction-based relationship while use-oriented and result-oriented present an increasingly more intense relational-based relationship. However, the intensity of the relationship can vary from case to case and some product-oriented PSS can present a more intense relationship between provider and customer than other cases (Gaiardelli et al., 2014).

[3] Tukker (2004) and Tukker and Tischner (2006) have analysed the environmental impact of several PSSs and argue that, on average, the highest environmental benefit can potentially come from result-oriented PSSs (up to 90% reduction, or factor 10, compared to traditional business models based on selling products), followed by use-oriented PSSs (up to 50% reduction, or factor 2, except for leasing which can provide a reduction of up to 20%) and product-oriented PSSs (up to 20% reduction). These data have been confirmed by a literature review done by Tukker (2015). However, it is important to highlight that the sustainability performance of PSSs should be considered case by case. PSSs in fact have to be specifically designed, developed and delivered, in order to generate a lower environmental impact than the competing product orienting models (UNEP, 2002).

[4] EE/DSM services are, to a certain extent, aligned with the PSS type dimension and the potential environmental sustainability dimension. In fact, moving from product-oriented to use-oriented and result-oriented PSSs, providers would be increasingly more interested (for economic reasons) to adopt EE/DSM techniques. For example, if a provider sells an energy system it is not much interested in increasing efficiency in energy use. On the other hand, if a provider is offering a final result it will be economically interested in making sure that energy consumption and efficiency are optimised (thus it will be interested in adopting EE/DSM techniques).

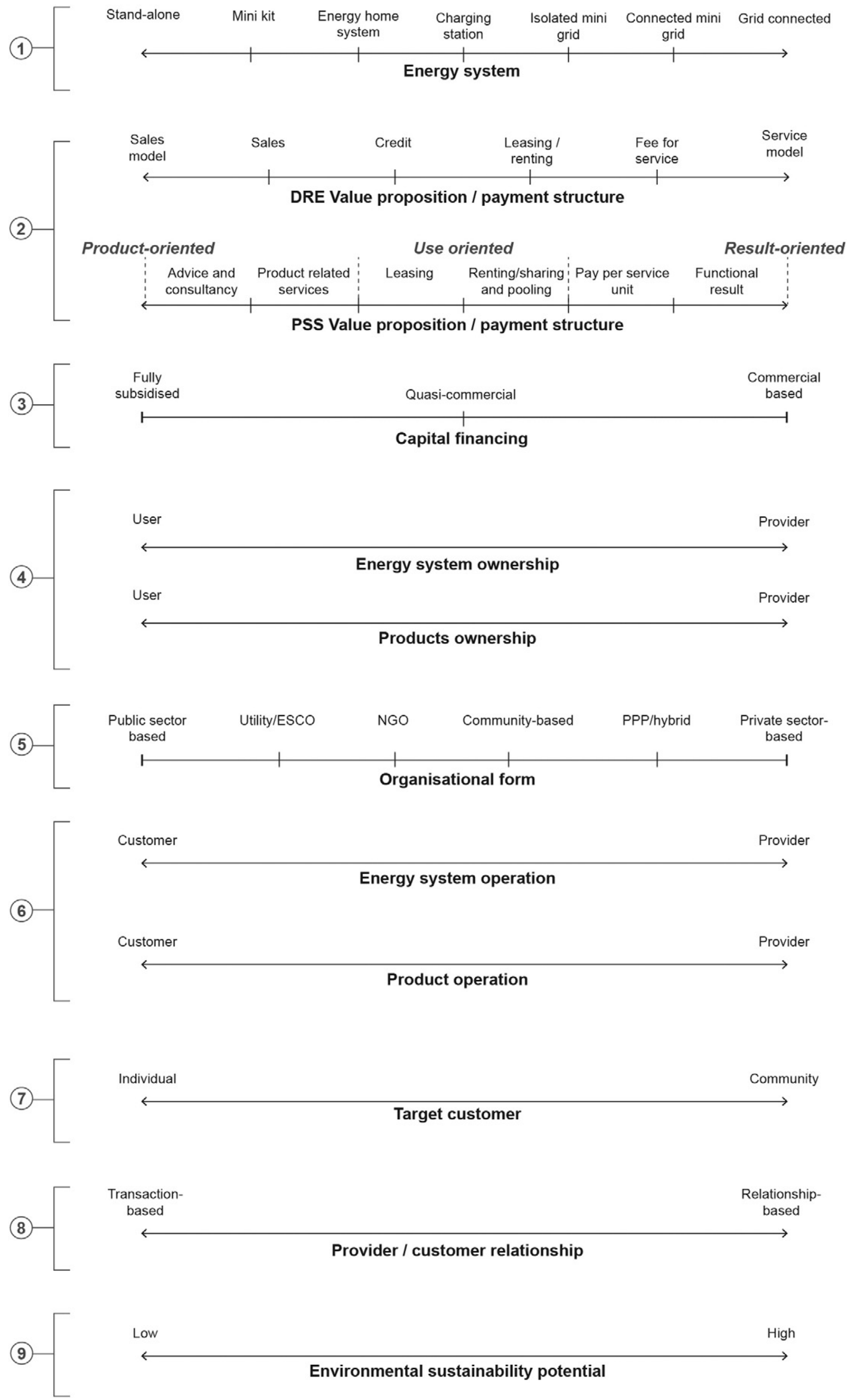

Fig. 1. Characterising dimensions of PSS and DRE.

offered to end-users). In relation to that, we must, however, recognise the complexity of these models: PSSs applied to DRE can in fact result in solutions that focus on offering access to energy systems (i.e. the generator, such as the mini-grid), energy-using products (i.e. appliances, such as lights), a combination of these, or the output from energy systems (i.e. energy).

Methodology

To address the research questions posed in this paper, we adopted a three-stage research approach. A theory-building approach,[5] combined with a case studies analysis, was used to develop a first version of the classification system and the related archetypal models. The new classification system and archetypal models were then tested in Botswana and South Africa with local companies involved in the renewable energy sector and academic experts on DRE and PSS. In the third stage, the feedback gained from experts and practitioners was used to refine the final version of the classification system, presented in this paper. The methodology was structured in the following steps (see Fig. 2):

1. *Development of the classification system:*
   1. Identification of characterising dimensions of PSS and DRE models: Building upon the results of the literature review, we identified the dimensions characterising PSS and DRE models (see Table 2 and Fig. 1). These dimensions were used to describe the case studies of PSS applied to DRE (step 2), and to build the new classification system (step 3).
   2. Case studies analysis on PSS applied to DRE: The goal of this step was to collect and analyse cases of PSS models applied to DRE, in order to gain an understanding of the range and characteristics of existing models. A case study approach is considered appropriate for studying new topic areas (Strauss and Corbin, 1990) and especially for understanding complex phenomenon (Merriam, 1998). For these reasons, this approach suits well the aims of our study. Since our aim was to describe the widest number of variations of models, the maximum variation strategy (Miles and Huberman, 1994) was adopted for the selection of cases. This means that the aim was to sample for heterogeneity and select cases that maximise diversity. In particular, cases were selected in order to cover, as much as possible, all the possible differences in the characterising dimensions (e.g. different types of technologies and energy sources, different types of target customers). The only common characteristic is the context of application: selected cases are implemented in rural areas in low- or middle-income contexts. In order to enhance the validation of the collected data, case studies relied on triangulation (Yin, 1994): multiple methods for collecting data were used to verify that all sources converged on the facts of a case. Within this research, the sources of information are constituted by secondary sources, including scientific papers, case studies made by other researchers, reports made by international organisations (such us the World Bank), companies' reports and websites. A final number of 56 cases were collected (see Appendix I). Each case was described detailing the dimensions identified in step 1 (see Appendix II for an example of an extract from a case description).
   3. Classification system development: The next step was the development of the classification system. This was based on a polarity diagram and was developed in order to encompass the majority of the characterising dimensions identified in step 1. In fact, as stated in a previous section (The need for a new classification system), the goal is to build a classification system capable of simultaneously taking into consideration the most important dimensions characterising the models of PSS applied to DRE. The development of the classification model is discussed in a following section (Classification system development).
   4. Classification system population: In this step, the collected cases were positioned in the polarity diagram.
   5. Clustering and identification of archetypal models: The final step consisted of identifying cases with similar characteristics. This led to grouping them in meaningful clusters and defining archetypal models of PSS applied to DRE. In total, 15 archetypal models were identified. These are described in a following section (Classification system development).
2. *Testing of the classification system:*
   After developing the new classification system, researchers presented it to DRE companies and academic experts during a research period spent by the research team in Botswana and South Africa, between March and May 2015. In total, 21 participants (12 from eight different companies, five experts on DRE and PSS, one from a national research centre on innovation and technology, and three from a strategic design consultancy) were engaged in the testing activities (see Appendix III for details). Regarding the sample size, the principle of theoretical saturation (Morse, 1995; Strauss and Corbin, 1990) was adopted. The principle refers to the continuation of data collection until no new insight is generated. In particular, an initial sample size of 15 participants was used. Six additional participants were then involved. Based on the data collected from the second group of participants and the lack of new information emerging (comments and suggestions provided by interviewees were similar to the ones provided by the first group of participants), sampling was completed with 21 participants. Testing activities aimed at evaluating different aspects of the classification system: the completeness and inclusion of all possible archetypal models (Step 6); the clarity and ease of use (Step 7); and its usefulness as a strategic design tool (Step 8). Testing activities were structured as follows. First, interviewees were introduced to the concept of PSS applied to DRE with a one-hour-long presentation. Then, the classification system, together with a set of cards describing the archetypal models, was shown to interviewees. Interviewees had about 30 min for positioning the case studies on the classification system. The final part of the testing activities involved a discussion regarding potential applications of the classification system. Feedback was collected through questionnaires and the results are discussed in the section Testing the completeness. The following steps describe the testing activities.
   6. Testing the completeness: Companies and experts have been asked to verify that the classification system can include all possible types of PSS applied to DRE and that the archetypal models can encompass all existing cases.
   7. Testing the ease of use: In this stage, the aim was to demonstrate that the classification system is clear and easy to use, i.e. the polarity diagram and its axis are understandable and cases can be easily and correctly positioned on the polarity diagram. Interviewees were asked to use the classification system in a practical exercise with the aim of exploring the different models of PSS applied to DRE. They were provided with a set of case studies (5–7 per interview) that describe existing offerings of PSS applied to DRE. The interviewees had then to map these cases on the classification system and discuss the ease of use.
   8. Testing the usefulness: In this step, interviewees were asked to use the classification system for mapping their offers and discuss potential applications. Similarly to the mapping exercise with case studies, companies described their offers and then positioned them on the classification system. Interviewees then discussed and rated (through a questionnaire) potential applications of the classification system as a strategic design tool.

[5] In particular an "*analytical conceptual research*" approach (Meredith, 1993; Wacker, 1998). This approach focuses on building new insights through logically developing relationships between defined concepts (in this particular case the PSS and the DRE concepts). Basically, it involves integrating research, often from a diverse background of literatures, and suggesting relationships between variables based on these existing findings.

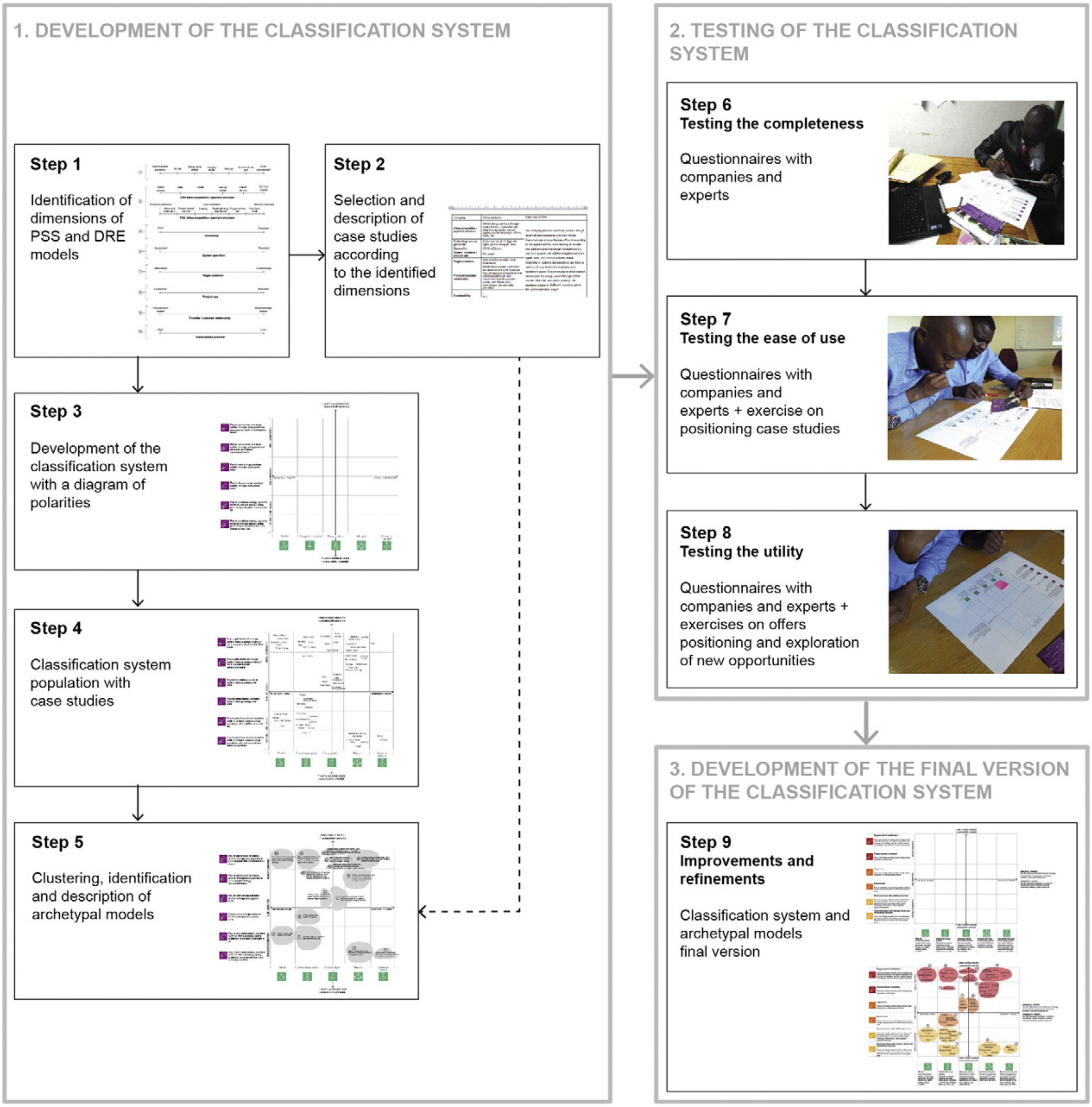

Fig. 2. Schematic of the methodology adopted for this research.

3. *Development of the final version of the classification system:*

9. After collecting feedback from companies, practitioners and experts, the last step consisted of refining and improving the classification system.

A new classification system and a set of archetypal models of PSS applied to DRE

Classification system development

As previously stated, the proposed classification system has been developed in order to simultaneously take into consideration the majority of the dimensions that characterise models of PSS applied to DRE. To this end, we first analysed the characterising dimensions in order to identify which of them could overlap and be grouped together. We found that eight dimensions can be clustered into two groups (see Fig. 3). The first group encompasses dimensions 2, 4, 6, 8 and 9. These dimensions can in fact overlap one another:

- The *value proposition* (dimension #2) ranges from product-oriented to use-oriented and result-oriented PSSs. This dimension is therefore strictly related to the *ownership* (*of energy system* and *energy-using products*) dimension (#4). In fact, in product-oriented PSSs the final user is the owner of the product/s, while moving towards result-oriented services the ownership is retained by the provider.
- The value proposition can also be aligned with the *energy system operation* dimension (#6), which refers to the management and operation of energy systems. In product-oriented and use-oriented PSSs, customers operate the energy systems to achieve the results they aim to. In result-oriented PSSs, the provider is responsible for operating

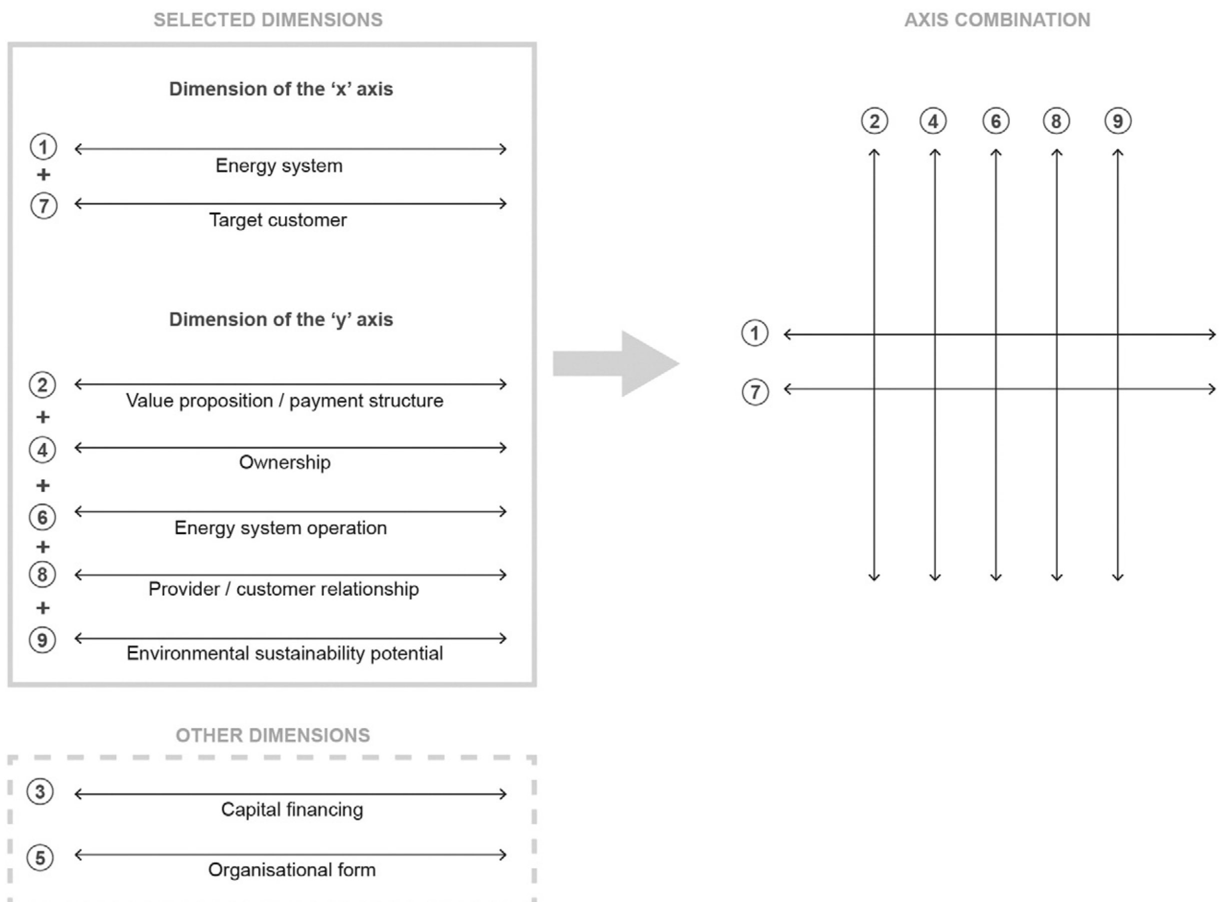

Fig. 3. Selection of dimensions' polarities and combination of axis used to build the classification system.

the system in order to deliver the agreed final result to the customer. When energy-using products are included in the offer, their operation is always performed by end-users (e.g. using lamps and other appliances), hence the polarity only refers to energy system operation.

- The *provider/customer relationship* dimension (#8) ranges from being transaction-based in product-oriented PSSs, to relationship-based in result-oriented PSSs where a more intense relationship between provider and customers is created. For this reason, it can be aligned with the value proposition.
- Lastly, the *environmental sustainability potential* dimension (#9) can be encompassed in this group and it ranges from high (for result-oriented PSSs and use-oriented) to low (for product-oriented PSSs).

The second group encompasses dimensions 1 and 7. The *technology choice* dimension (#1) is strictly related to the *target customer* dimension (#7). In fact: stand-alone systems, such as mini-kits and home systems, are targeted to individual users; PSSs offered through charging stations are targeted to groups of users (e.g. lanterns sharing systems); finally, PSSs linked to mini-grids are offered to communities.

After clustering the dimensions, we used the two groups to build a polarity diagram (Fig. 3). The *x*-axis is the one that includes technology choice and target customer. The *y*-axis encompasses the value proposition, ownership, provider/customer relationship and product use/system operation dimensions.

The *y*-axis describes the different PSS types. In product-oriented PSS, we distinguish:

- *Pay to purchase with training, advice and consultancy services.* In this model, energy systems (with or without energy-using products) are sold to the customer together with some advice related to the product/s sold, such as how to efficiently use the system, how to dispose of it, management training, etc. This advice can be delivered in many ways (e.g. after the purchase, during the use of the product, through training courses).
- *Pay to purchase with additional services.* Here, the provider sells the energy system but also offers services related to the installation, use and or end-of-life phases. These services can include a financing scheme, a maintenance contract, an upgrading contract, an end-of-life take-back agreement, etc.

In use-oriented PSS, we differentiate in:

- *Pay to lease.* In leasing models, the provider keeps the ownership of the system (and is often responsible for maintenance, repair and disposal), while the customer pays a regular fee for an unlimited and individual access to the leased product.
- *Pay to rent.* In this case, the provider keeps the ownership of the energy system and energy-using products and is often responsible for maintenance, repair and disposal. Customers pay for the use of the energy-using products (e.g. pay per hour) without having unlimited and individual access. Other clients in fact can use the product in other moments (different users can sequentially use the product).

In result-oriented PSS, we divide in:

- *Pay-per-energy consumed*: In this type of PSS, the provider offers a "result" to customers and has the freedom of choosing the most appropriate technology to provide energy services. The energy solution provider keeps the ownership of the products (energy system and energy-using products) and is responsible for maintenance, repair and disposal. Customers pay for the output of the system (energy) according to what they consume (pay-per-kWh).

- *Pay-per-unit of satisfaction*: Here, the provider offers access to energy (and/or energy-using products) and customers pay according to the agreed satisfaction unit e.g. pay to recharge products, pay for a certain amount of energy per day, pay for the output of products for a limited amount of time. The provider chooses the best technology to provide the "satisfaction" and keeps ownership and responsibility for the products (energy system and energy-using products) involved.

The final diagram is illustrated in Fig. 4. Differently from existing classification systems, the one we propose encompasses the majority of the dimensions characterising PSS and DRE, and thus provides an overview of the possible different models of PSSs applied to DRE. In other terms, it is a unified classification system capable of mapping and illustrating the different characteristics of these models.

It is important to highlight that the developed polarity diagram excludes some of the characterising dimensions: in particular the *capital financing* (#3) and the *organisational form* (#5) dimensions. Since the main focus of our classification is on the types of offer models of PSS applied to DRE, those dimensions can be considered secondary. This does not mean that these secondary dimensions are not important but simply that they are cross-cutting to different types of offer models: in fact the same type of offer model of PSS applied to DRE can be provided by different types of organisational forms and through different capital financing solutions. In other terms, these dimensions are not crucial for the purpose of characterising offer models of PSS applied to DRE.

Identification of archetypal models of PSS applied to DRE

After building the classification system, this was populated with 56 case studies. The next step was to group them into clusters of similar cases. This led us to identify 15 archetypal models of PSS applied to DRE. Cases included within each archetypal model are of course not identical. Their key traits, such as type of value proposition and target customer, are essentially similar, but their secondary characteristics (e.g. the organisational form, the capital financing) are sometimes different. Fig. 5 provides an overview of the 15 archetypal models.

The following text describes each archetypal model according to its main dimensions. Each model is coupled with a stakeholder system map, a visualisation showing the actors involved in the PSS offer and their relationships (see Appendix IV for a legend of the icons used in the maps). An overview of the archetypal models and their main characteristics is presented in Appendix IV. In the next paragraph, archetypal models are described starting from the bottom of the diagram: first

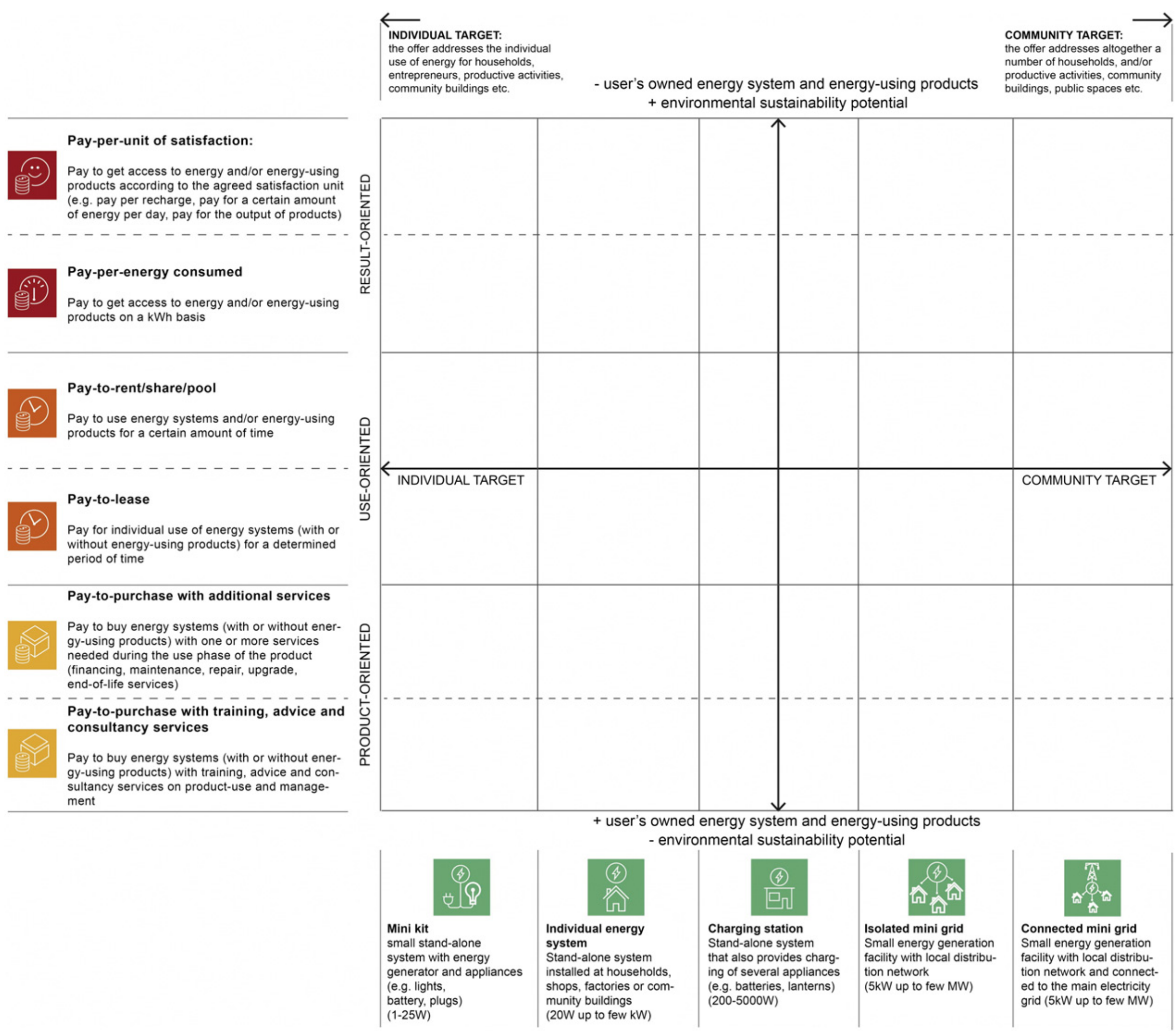

Fig. 4. Classification system.

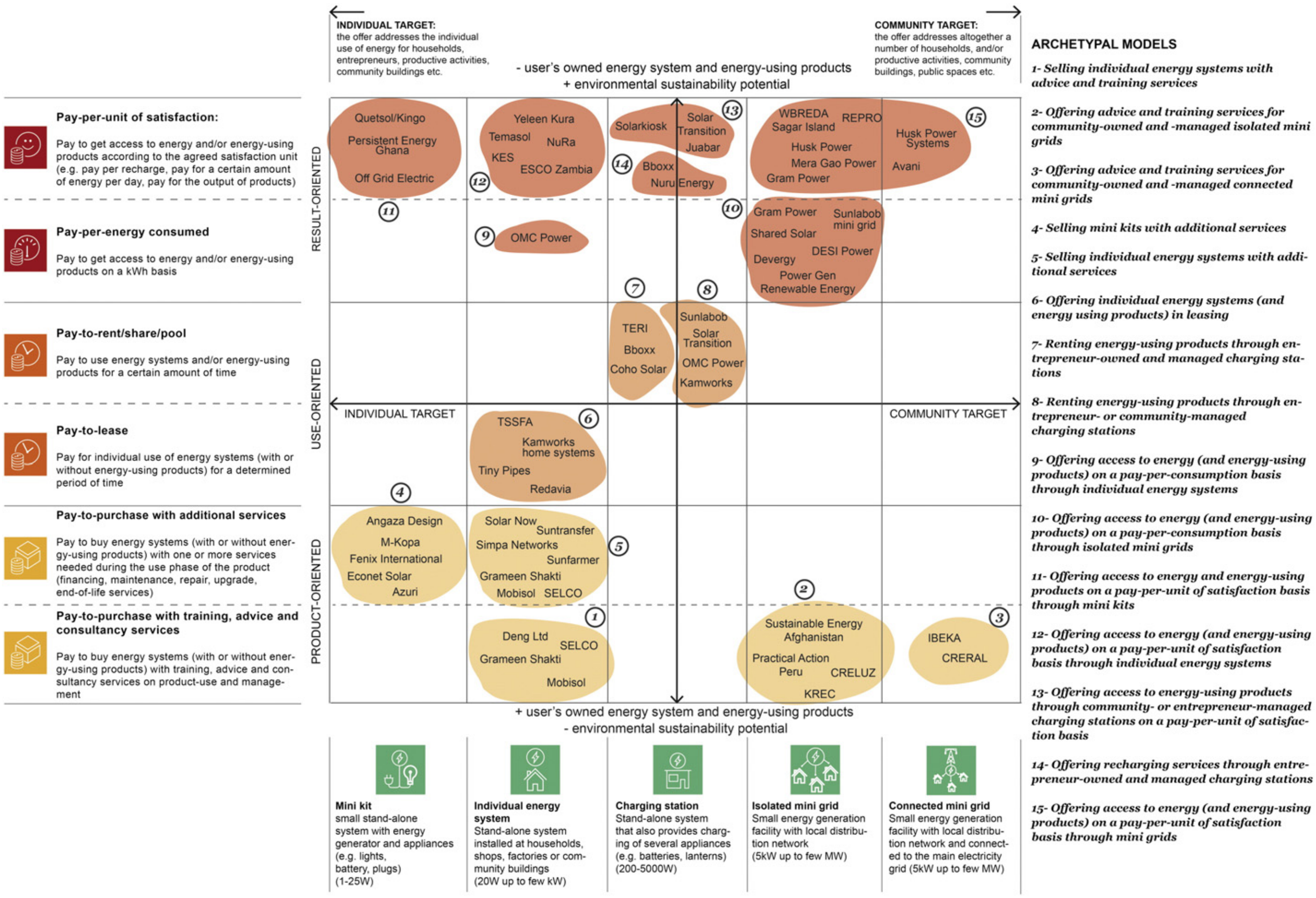

Fig. 5. Classification system with archetypal models.

product-oriented and then use-oriented and result-oriented PSSs. (See Figs. 6–20.)

In product-oriented PSSs, the first group of archetypal models (1, 2 and 3) is related to pay-to-purchase with training, advice and consultancy services.

1. Selling individual energy systems with advice and training services. In this model, the sale of individual energy systems (in most cases, solar home systems), is coupled with training and education. Depending on the target user, these services can focus on design, installation, repair and skills to develop a business on energy systems, or on basic maintenance and environmental awareness. Customers become owners of the systems at the moment of purchase and they are responsible for operation and maintenance.

2. Offering advice and training services for community-owned and -managed isolated mini-grids. The energy solution provider sells mini-grids to communities. Communities are responsible for operating and managing the system. They can also be in charge of designing a payment structure and fee collection. In addition to selling mini-grids, the provider offers a training service to a village committee on the operation, maintenance and management of the energy system. In some cases, communities may repay the installation with in-kind contributions such as labour.

3. Offering advice and training services for community-owned and -managed connected mini-grids. This model is very similar to the previous one but, in this case, the mini-grid is connected to the main electricity grid. In this case, the system allows the community to not only produce

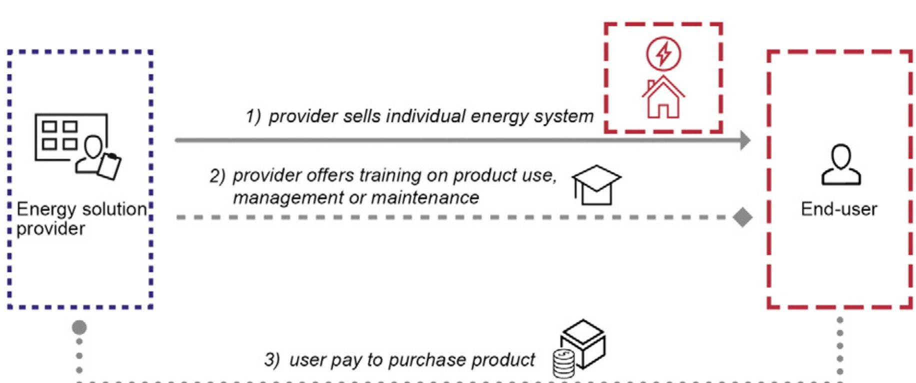

Fig. 6. Archetypal model 1: Selling individual energy systems with advice and training services.

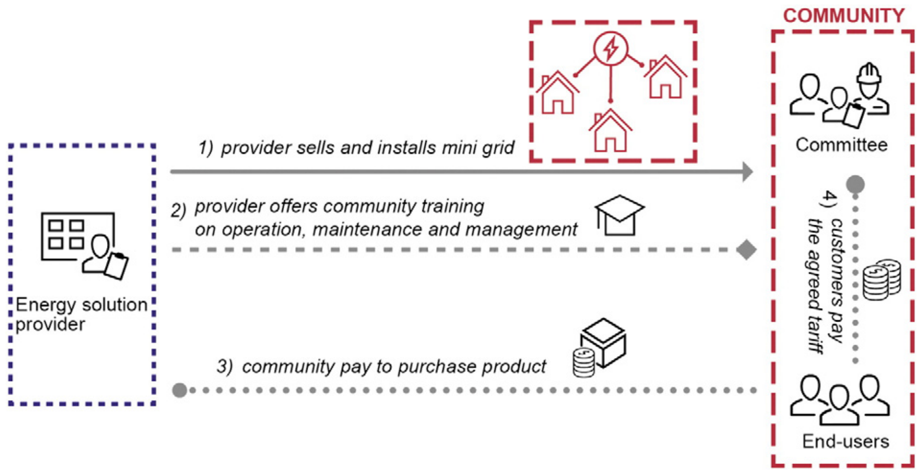

Fig. 7. Archetypal model 2: Offering advice and training services for community-owned and -managed isolated mini-grids.

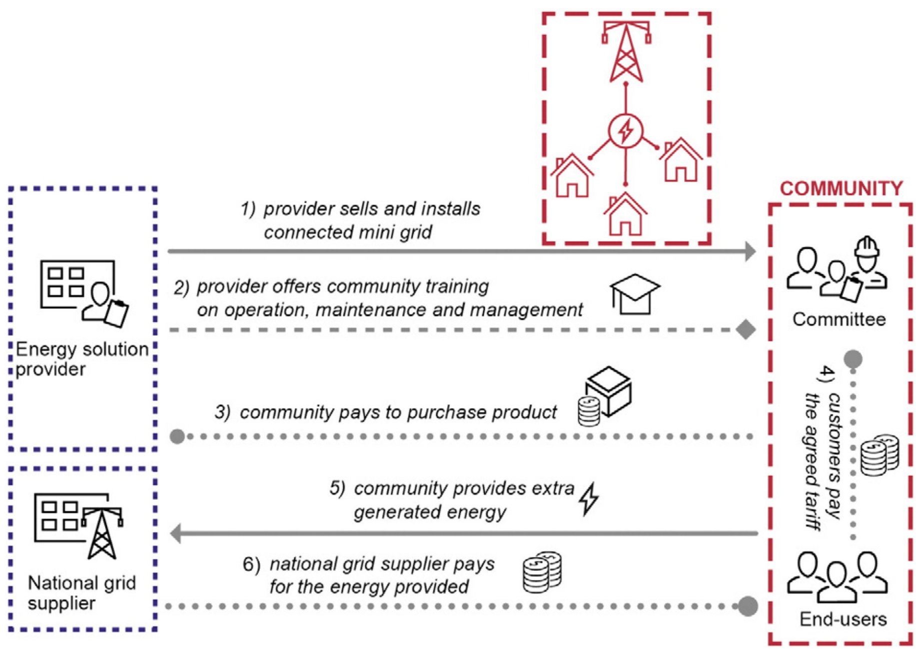

Fig. 8. Archetypal model 3: Offering advice and training services for community-owned and managed connected mini-grids.

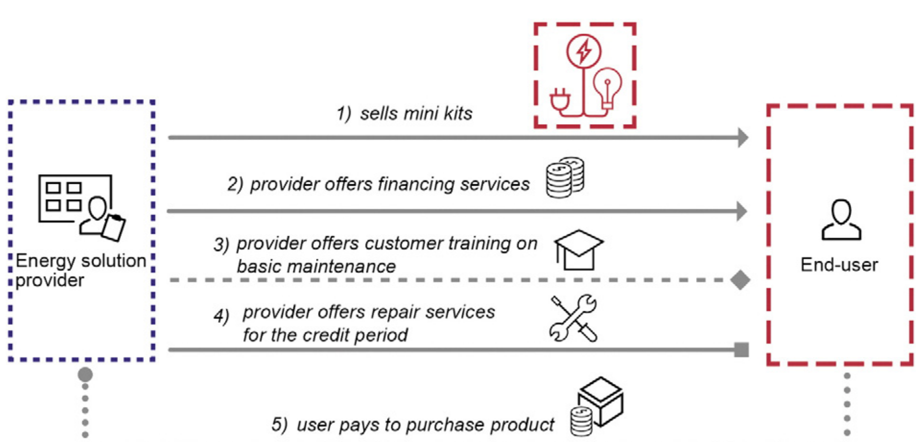

Fig. 9. Archetypal model 4: Selling mini-kits with additional services.

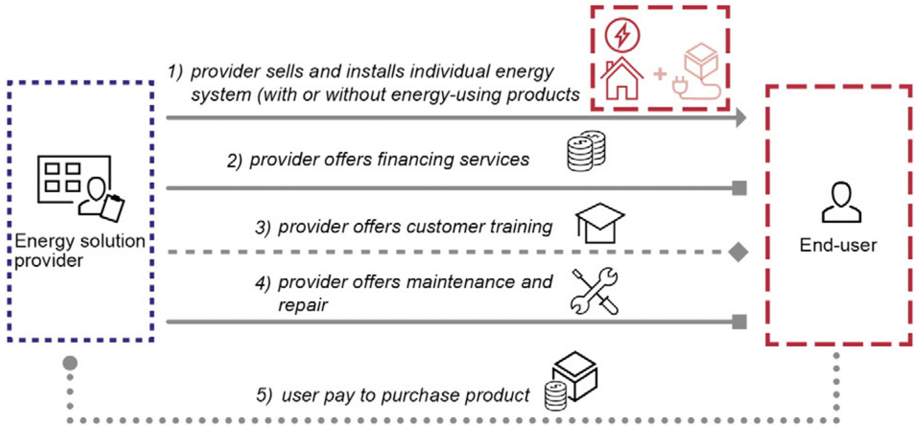

Fig. 10. Archetypal model 5: Selling individual energy systems with additional services.

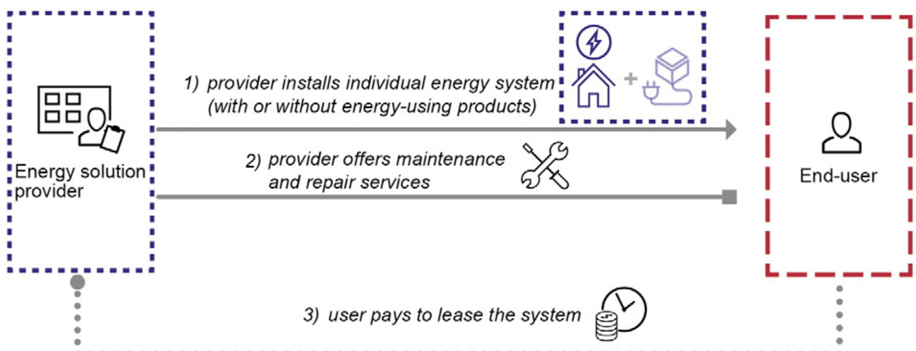

Fig. 11. Archetypal model 6: Offering individual energy systems (and energy-using products) in leasing.

and distribute energy to the local network but also to sell electricity to the national electricity supplier.

The second group of product-oriented PSSs (models 4 and 5) is defined as *pay-to-purchase with additional services*.

4. Selling mini-kits with additional services. The provider sells mini-kits with additional services, such as financing, so that customers can pay through small, flexible instalments over time. After the credit period, usually 1 or 2 years, the ownership is transferred to the customer. Operation and maintenance are the customer's responsibilities and end-users receive training on system care. During the credit period, the provider offers repair services and sometimes includes extended warranties after the credit repayment.

5. Selling individual energy systems with additional services. The provider sells individual energy systems with or without energy-using products, and includes in their offer a range of services like financial credit, customer training, installation and after-sales services such as maintenance and repair. End-users pay to purchase the energy system (with or without energy-using products) and the ownership is transferred to them, sometimes after the credit period.

Within the use-oriented PSSs group, we can distinguish between *pay-to-lease* (archetype 6) and *pay-to-rent/share/pool* models (archetypes 7 and 8).

6. Offering individual energy systems (and energy-using products) in leasing. The provider offers energy home systems in leasing, with or without energy-using products, for an agreed period of time. The offer may or not include energy-using products. Customers do not become owners of the system but have unlimited access to it (and to the energy-using products) during the leasing contract. Additional services, such as repairs and maintenance, are included in the product–service package.

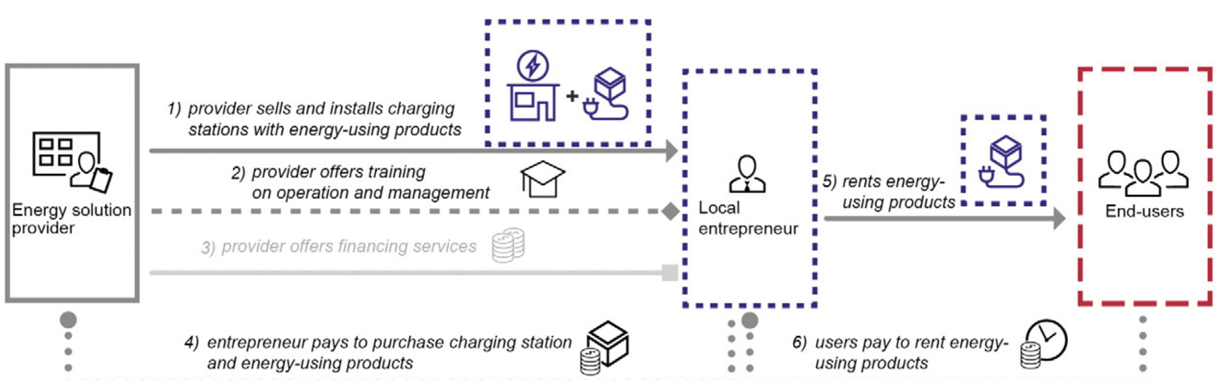

Fig. 12. Archetypal model 7: Renting energy-using products through entrepreneur-owned and -managed charging stations.

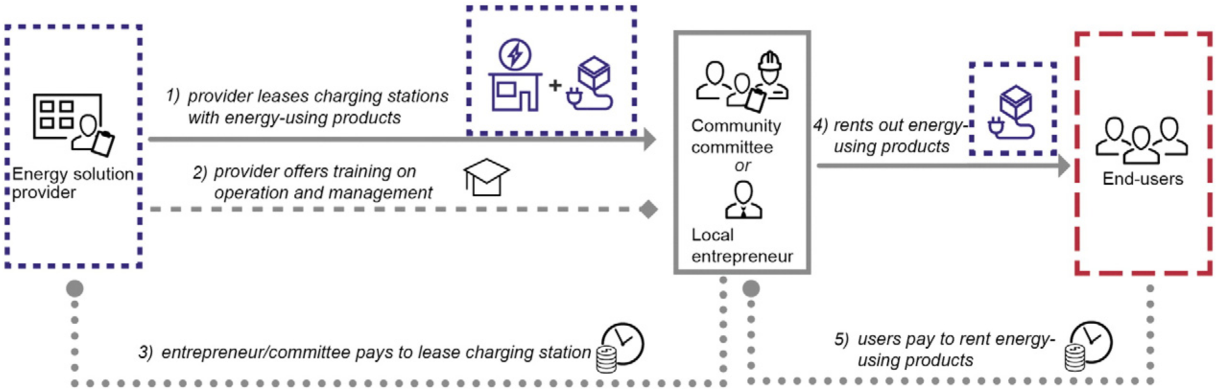

Fig. 13. Archetypal model 8: Renting energy-using products through entrepreneur- or community-managed charging stations.

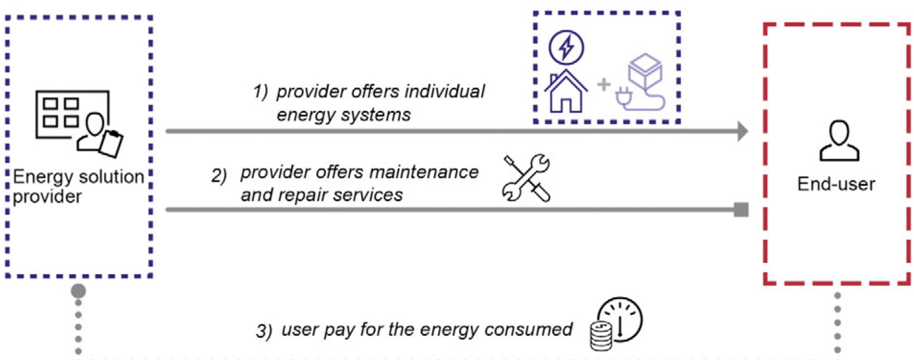

Fig. 14. Archetypal model 9: Offering access to energy (and energy-using products) on a pay-per-consumption basis through individual energy systems.

7. Renting energy-using products through entrepreneur-owned and -managed charging stations. The charging station is sold to a local entrepreneur and ownership of both the charging station and the energy-using products is transferred to him/her. Training on operation and management of the charging station is provided and financing services can sometimes be included. The local entrepreneur rents out the energy-using products to end users, who pay a fee when they want to use the products involved. The entrepreneur is responsible for operation and maintenance of the system and the energy-using products.

8. Renting energy-using products through entrepreneur- or community-managed charging stations. The energy solution provider installs a charging station for renting out energy-using products to individual users. The provider keeps ownership of the charging system and the energy-using products but the management and operation is undertaken by local entrepreneurs or by the community itself, who pays a leasing fee to use the charging station. End-users pay to rent energy-using products when they need.

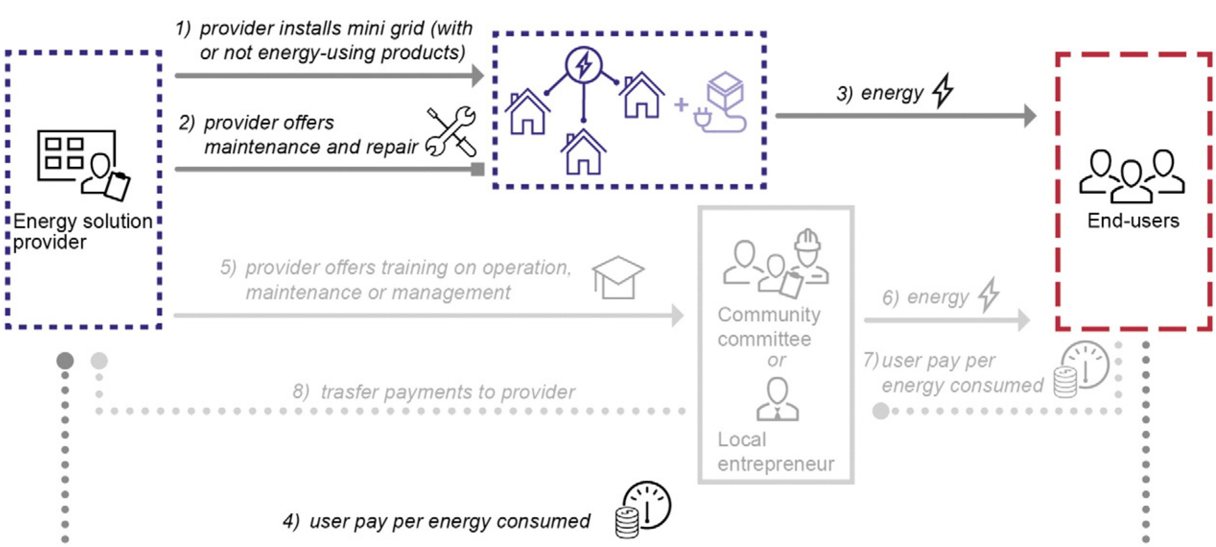

Fig. 15. Archetypal model 10: Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids.

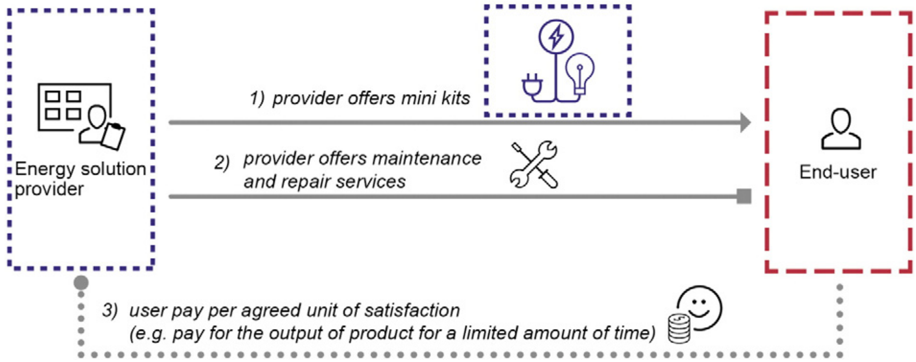

Fig. 16. Archetypal model 11: Offering access to energy and energy-using products on a pay-per-unit of satisfaction basis through mini-kits.

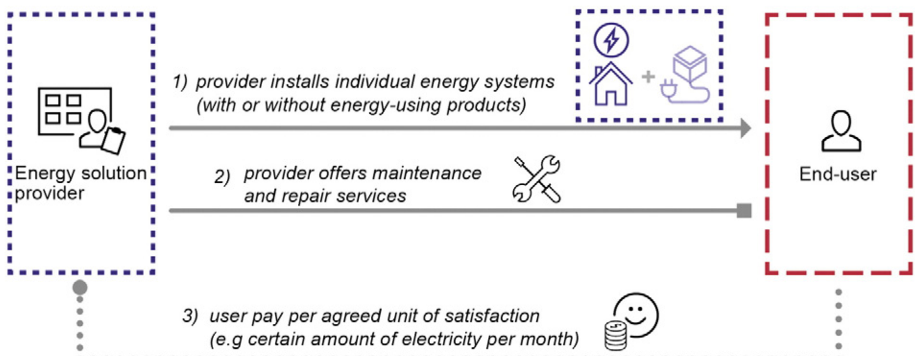

Fig. 17. Archetypal model 12: Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through individual energy systems.

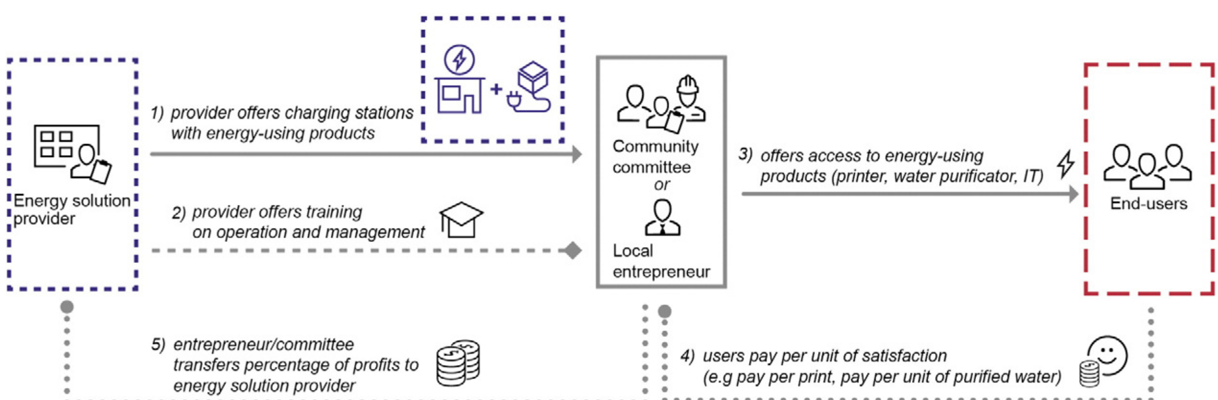

Fig. 18. Archetypal model 13: Offering access to energy-using products through community- or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis.

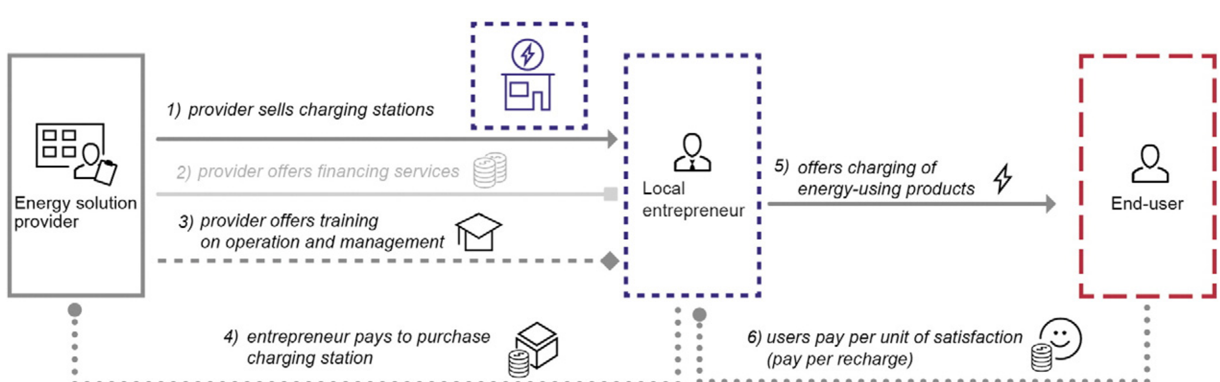

Fig. 19. Archetypal model 14: Offering recharging services through entrepreneur-owned and managed charging stations.

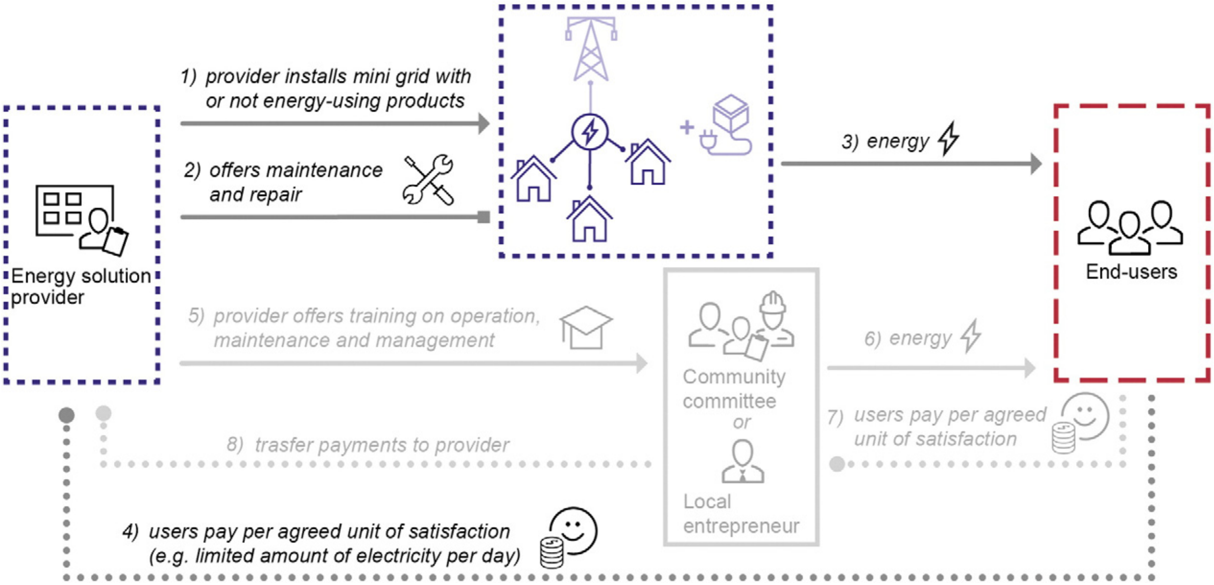

Fig. 20. Archetypal model 15: Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini-grids.

In result-oriented models, the first group of archetypal models (9 and 10) can be defined as *pay-per-energy consumed*.

9. Offering access to energy (and energy-using products) on a pay-per-consumption basis through individual energy systems. The provider installs individual energy systems at customers' site to satisfy the electricity need. Customers pay according to the energy they consume. The provider retains the ownerships of systems and takes care of operation, maintenance and repairs.

10. Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids. The provider offers energy services by installing mini-grids (with or without energy-using products) at a community level. End-users pay according to the energy they consume. The provider always retains the ownership of the energy system and products involved. This model can present some variations (flows 5–8): in some cases, the local community or an entrepreneur receives training and can be involved in the management, operation and maintenance of the mini-grid or fee collection. In this case, end-users pay their fees to the committee or entrepreneur, who is responsible for transferring them to the energy solution provider (in this case, flow 4 would then disappear).

The second group can be named *pay-per-unit of satisfaction* and encompasses archetypes 11–15.

11. Offering access to energy and energy-using products on a pay-per-unit of satisfaction basis through mini-kits. The energy solution provider offers energy services through mini-kits equipped with energy-using products. Users pay according to the service package they choose and the appliances they want to use (for example, they can pay to use two lights and a mobile charger for a maximum of 8 h a day). The provider, who retains ownership and responsibilities of the mini-kits, includes in the offer maintenance and repair services.

Table 3
Questionnaire results.

Testing the completeness						
1. Can you think of other types of offers or other examples/cases that are not included in the archetypal models? If yes, which ones?	100% of interviewees (21/21) agreed that there are no other cases that fall outside the classification system and that cannot be included in the archetypal models					
Testing the ease of use						
Questions	1: very poor	2: poor	3: sufficient	4: good	5: very good	Average
2. To what extent is the classification system easy to understand (i.e. the meaning of each axis is clear)	0 (0%)	0 (0%)	2 (10%)	7 (33%)	12(57%)	4.5
3. To what extent is the positioning of case studies in the classification system easy for you?	0 (0%)	0 (0%)	2 (10%)	6 (28%)	13 (62%)	4.5
Testing the usefulness						
Questions	1: very poor	2: poor	3: sufficient	4: good	5: very good	Average
4. The classification system is intended to be used for positioning a company's offer(s). To what extent is the classification system contributing to the achievement of this objective?	0 (0%)	0 (0%)	2 (10%)	8 (38%)	11 (52%)	4.4
4.1. Would you use the classification system for this purpose in the future?	Yes: 21 (100%) No 0 (0%)					
5. The classification system is intended to be used for mapping the existing offers of PSS applied to DRE (competitors in the same business sector, other companies operating in the selected context etc.). To what extent is the classification system contributing to the achievement of this objective?	0 (0%)	0 (0%)	1 (5%)	9 (43%)	11 (52%)	4.5
5.1. Would you use the classification system for this purpose in the future?	Yes: 20 (94%) No 1 (6%)					
6. The classification system is intended to be used for exploring new business opportunities (repositioning of offer, combination of different offers). To what extent is the classification system contributing to the achievement of this objective?	0 (0%)	0 (0%)	0 (0%)	12 (57%)	9 (43%)	4.4
6.1. Would you use the classification system for this purpose in the future?	Yes: 21 (100%) No: 0 (0%)					
7. The classification system and archetypal models can be used for generating ideas. To what extent is the classification system contributing to the achievement of this objective?	0 (0%)	0 (0%)	1 (5%)	7 (33%)	13 (62%)	4.6
7.1 Would you use the classification system for this purpose in the future?	Yes: 21 (100%) No: 0 (0%)					

12. Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through individual energy systems. The provider installs energy home systems at the customers' site to provide electricity on a pay-per-unit of satisfaction basis. End-users in fact pay a fixed monthly fee to get access to electricity or to use the included energy-using products, usually for an agreed number of hours a day. The provider always retains the ownerships of the energy system (and energy-using products) and takes care of maintenance and repairs.

13. Offering access to energy-using products through community- or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis. The provider offers, together with training services, the charging station with energy-using products to a local entrepreneur or a community committee. They in turn provide a range of energy-related services to end-users, such as printing, purifying water and IT services to the local community. End-users pay to get access to the energy-using products (e.g. printer, photocopy or computer) on a pay-per-unit of satisfaction basis (e.g. pay per print or pay per unit of purified water). The entrepreneur/committee transfers part of the profits to the energy solution provider and is responsible for operation and maintenance of the charging station and energy-using products.

14. Offering recharging services through entrepreneur-owned and -managed charging stations. The technology provider sells, with training and sometimes with financing services, the charging station to a local entrepreneur who offers recharging services to customers. End users pay to recharge their products when they need (pay-per-unit of satisfaction), for example, they pay to charge mobile phones. The entrepreneur is owner of the system and responsible for operation and maintenance.

15. Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini-grids. The provider offers energy services by installing mini-grids (and energy-using products) at a community level. Mini-grids can be connected or not connected to the main grid. End users pay to get access to a limited amount of electricity for few hours a day. The provider always retains the ownership of the system and products involved in the offer. This model can present some variations (flows 5–9): in some cases, the local community or an entrepreneur is involved in the operation, management of the mini-grid, or in the fee collection as well. In this case, end-users pay the agreed tariff to the community committee or entrepreneur and payments are then transferred to the energy solution provider (in this case, flow 4 would then disappear).

Testing the new classification system

The combination of new classification system with the archetypes has been tested in practice by companies, DRE and PSS experts and designers. As described in the Methodology section, the objective was to test the completeness, the ease of use and the usefulness of the classification system. Results are reported in Table 3 and discussed below.

Testing the completeness

The first objective of the testing activities was to validate the completeness of the classification system (i.e. to what extent it can encompass all possible models of PSS applied to DRE), and the completeness of the archetypal models (i.e. to what extent they are able to represent all existing models). For this purpose, we involved companies and experts and asked them to point out cases or offers that fall out of the defined archetypal models. After the introductory presentation and description of archetypal models (see Methodology), interviewees had about 20 min to again observe the classification system and the archetypal models. Among all the interviewees, none of them could identify cases that were not included in the identified archetypal models (21 out of 21 responses). This implies that participants consider the classification system to be complete: if all possible cases can be encompassed by the archetypal models, hence no case can fall outside of the classification system meaning that it covers all possible models of PSS applied to DRE.

Although participants have confirmed that the archetypes cover all existing models and that the classification system encompasses all possible models of PSS applied to DRE, the involvement of a broader set of companies and experts, in particular from other geographical contexts, would be beneficial to provide a more robust validation (see Research limitations and further research activities).

Testing the ease of use

A second point that required validation with companies and experts was the usability aspect, i.e. that the classification system can be clearly understood and that the case studies could be positioned without difficulty.

The first step consisted of testing the clearness of the tool, i.e. the meaning of the axis of the classification system is clear and it can be easily understood. Most interviewees judged this aspect with high ratings (33% rated 4 = good and 57% rated 5 = very good), adding that "the visual nature of the mapping tool makes it extremely user-friendly" (O8) and "[the map] clearly separates cases [offers], making it easy to use" (C6). Four interviewees reported initial doubts in differentiating between leasing and renting models and between mini-kits and individual energy systems (in the case of solar home system), but a short reflection led to clarified initial hesitations ("It's straightforward but one would need a bit of time to understand" (C5), "took some time to understand" (C6)). Interviewees also provided suggestions to improve the clearness of the classification system, in terms of adding a color-coded distinction of PSS types and short texts to better explain PSS types and energy systems.

The second aspect to be tested was the ease of use in positioning PSS applied to DRE offers. Interviewees were asked to position case studies (between 5 and 7 per interview, 3–5 min for each case) on the map. The positioning exercise helped to clarify whether the map and case studies were easy to understand and, among a total of 81 cases positioned by interviewees, 87% of them (70 cases) were placed properly. After we explained where the mistakes were, those who misplaced the cases were able to reposition them correctly, showing that the positioning is easy but it just takes a bit of time to understand it ("brilliant matrix, just takes time to become familiar with [it]" (O2)). We then asked them to review the ease of use by rating it in the questionnaire. Overall, most of the interviewees found the map easy to use (28% rated 4 = good, 62% rated 5 = very good).

Testing the usefulness

Testing activities showed that the new classification system can be useful for those businesses which are already operating on the market of energy services, and for those start-ups or new ventures that are willing to enter this market. In particular, we identified the following applications:

1. **Positioning of a company's offer(s):** Our hypothesis was that the classification system allows managers to identify where their company lies by positioning its existing offerings on the map. This means that a single company can position more than one offering (Fig. 21) and can simultaneously cover different areas of the map (e.g. selling energy home systems with additional services—Existing offer A—and also renting energy-using products through charging stations—Existing offer B). In order to validate our assumptions, companies involved in the study were asked to place their offerings similarly to the exercise with positioning of case studies. Experts were asked to evaluate the potential usefulness for positioning companies' offers by rating this application of the classification system. A major percentage of participants (38% rated 4 = good, 52% rated 5 = very good) considered the classification system very useful as tool to position companies' offerings and all of them affirmed that they would use it for this purpose in the future. Some interviewees appreciated that the map can provide support in understanding where a company's offering is positioned in relation to the other potential alternatives ("a company can easily locate where it fits in" (E1), "companies can see where they are and plan where they want to be" (C4)).
2. **Analysis of offers in a specific context:** Another identified application lies in supporting the strategic analysis of energy solution providers in a specific geographic area. For instance, companies that are

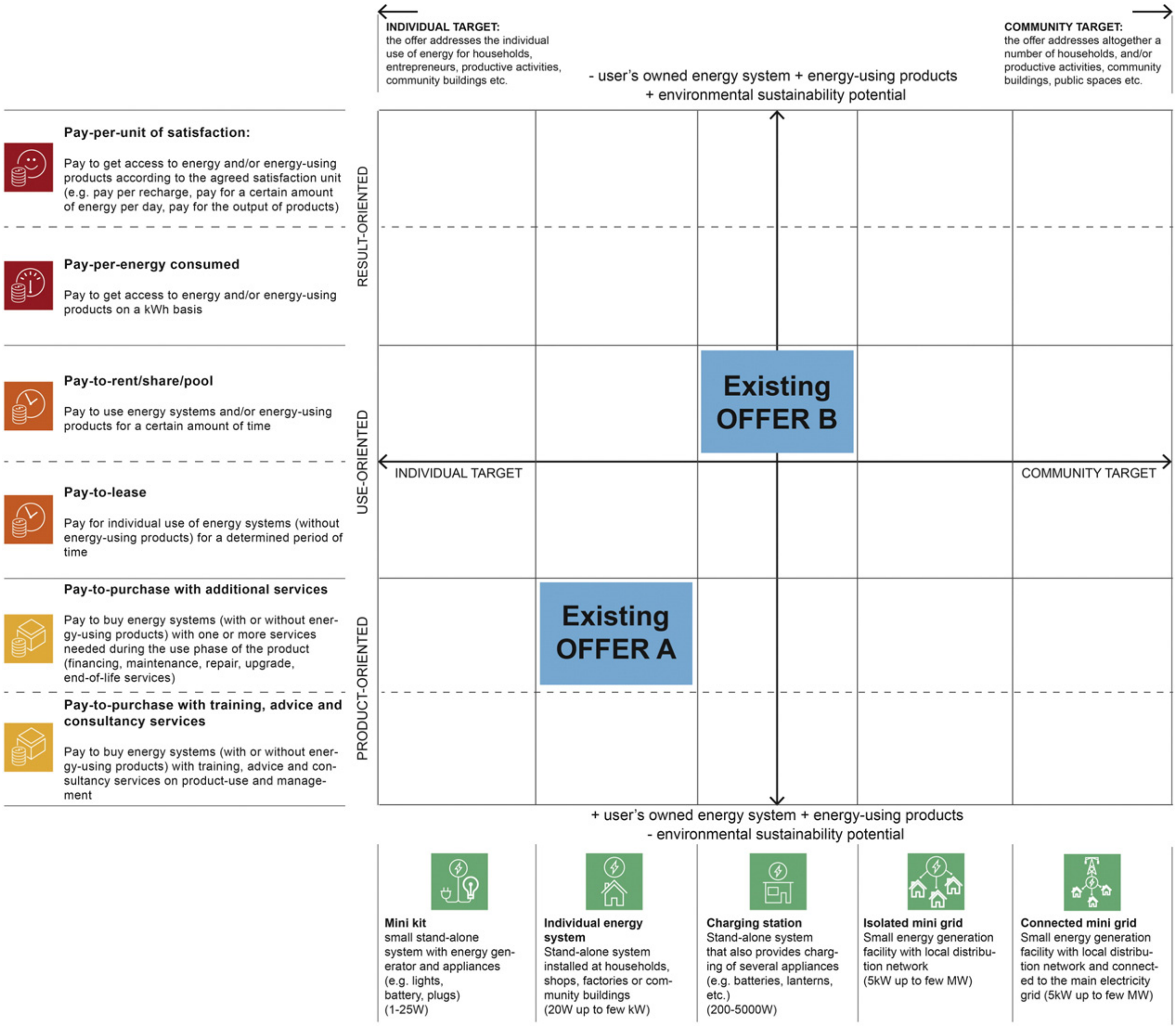

Fig. 21. The classification system can be used to position a company's offers.

willing to enter a certain market can use the classification system to map what types of offerings local companies are providing and which energy systems are most diffused (e.g. stand-alone or grid systems) (see Fig. 22). Another option is to map only the companies dealing with a specific technology (e.g. individual energy systems) and explore the types of offerings in the specific context. This can help to identify those offerings (and related archetypal models) which are not delivered in that area and that might be potentially interesting to be explored (Fig. 22). Our assumption was that the classification system could be useful for mapping the existing situation of a specific context or country, and companies could use it to have an overview of competitors and envision new business opportunities. We tested our hypothesis by asking interviewees to rate the use of the classification system for mapping existing offers of PSS applied to DRE and most of them commend this application (43% rated 4 = good and 52% rated 5 = very good). Some stated that "by using the tool, one can immediately understand where gaps exists (E1)", that "you can clearly see gaps in the market (C1)", and leads to a "better understanding of competition (C10)". Although some have highlighted that competitors' analysis and strategic positioning may be more complex and depends on several factors, the classification system is intended to be used for mapping offerings and painting a general overview of possible competitors.

3. **Exploring new business opportunities:** Linked with the two previous applications, the system could help managers and practitioners in identifying new business opportunities for expanding their offers. For example, a company that sells solar home systems with additional services (offer A) can explore new ways of providing energy solutions by offering its products on leasing (existing offer A1) and therefore repositioning its offering in a new area of the map (Fig. 23). Another option, for example, is to combine different offerings with the aim of reaching new target customers. A company that provides energy services through big individual energy systems on a pay-per-consumption basis (existing offer B) could decide to target lower-income communities by offering renting of products charged through the same energy system (e.g. lanterns, batteries). In this case, the company will combine two offerings (offers B and B1), two types of target customers (individual and community) and two technologies (individual energy systems and charging station) (Fig. 23). The classification system could support the exploration of new opportunities by visualising companies' offerings repositioning and combination. With the aim of validating our assumptions, we asked participants to discuss this application of the classification system. With an average rating of 4.4, interviewees particularly appreciated the possibility of envisioning possible opportunities in a visual way, "painting a picture of opportunities that lie outside of what [the company] does (C10)". Most companies reported that they were not aware of some types of offerings or other options to provide energy solutions and that the classification system

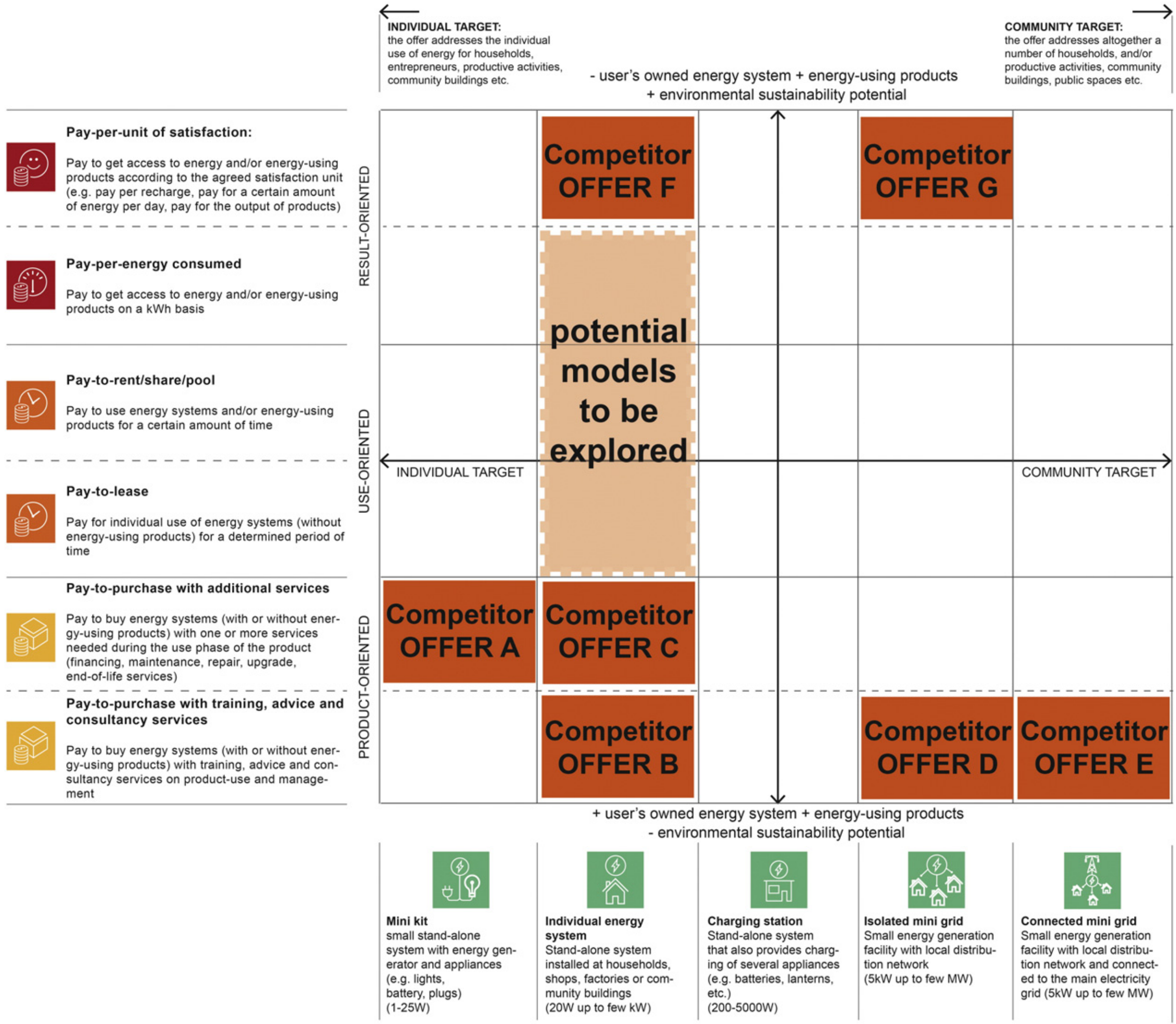

Fig. 22. The classification system can be used for mapping offers in a specific context and highlight possible models to explore for a selected technology (i.e. individual energy systems).

helped in "broadening minds (C2)" and thinking outside of the box for "other ways by providing solutions instead of the traditional way of selling products (C6)".

Research limitations and future research activities

This research presents some limitations. The approach used to identify the archetypes is based on collecting, analysing and grouping existing cases of PSS applied to DRE. Even if companies and experts agree that the archetypal models encompass all the possible cases, we might have not been able to collect all the relevant cases. In other terms, some cases, with different characteristics compared to the ones we collected, might not have been considered in the development of the archetypes. The empty areas in the map (Fig. 5) could be empty because there is no existing case with those specific characteristics, or because there are some cases that we were not able to find. However, it is reassuring that companies and experts involved in the interviews were not able to identify cases not included in the archetypal model, showing the completeness of the classification system and its archetypes. Also, in the hypothesis, we missed some cases, our classification system can be easily updated adding new archetypal models. For this purpose, it is important to constantly integrate the latest state-of-practice in the classification system (i.e. collect new cases, position them in the map and identify new archetypes).

Some limitations are also related to the testing activities. In fact, companies engaged so far are located in a similar socio-economic context (i.e. Botswana and South Africa) and thus they might not have a broad picture of the energy sector. However, in order to reduce this risk, experts (i.e. academics, researchers) who have such a broad picture of the energy sector were involved in the study. Nevertheless, further research activities will aim at involving a greater and broader number of companies and practitioners operating in different geographical contexts.

Another limitation of the classification system is that it does not include factors related to market regulations, organisational forms and capital financing options. The classification system is in fact meant to be used as a generic tool to understand, compare and ideate models of PSS applied to DRE (with the primary focus on the product–service combination offered to customers and the related payment structure). However, the importance of the excluded dimensions must be acknowledged. For example, when developing a particular product–service solution, the market regulations factors play a crucial role. For this reason, further research should be conducted to understand how to integrate the excluded dimensions in the developed framework. This could lead to a classification system structured in different layers: a *basic layer* (which is constituted by the current classification system), a *market regulation layer* (which can provide indications on the feasible offer models in a particular geographical context), an *organisational form layer* (which can provide indications on different organisational forms that can be applied to a specific product–service offer), and so on with other dimensions such as the

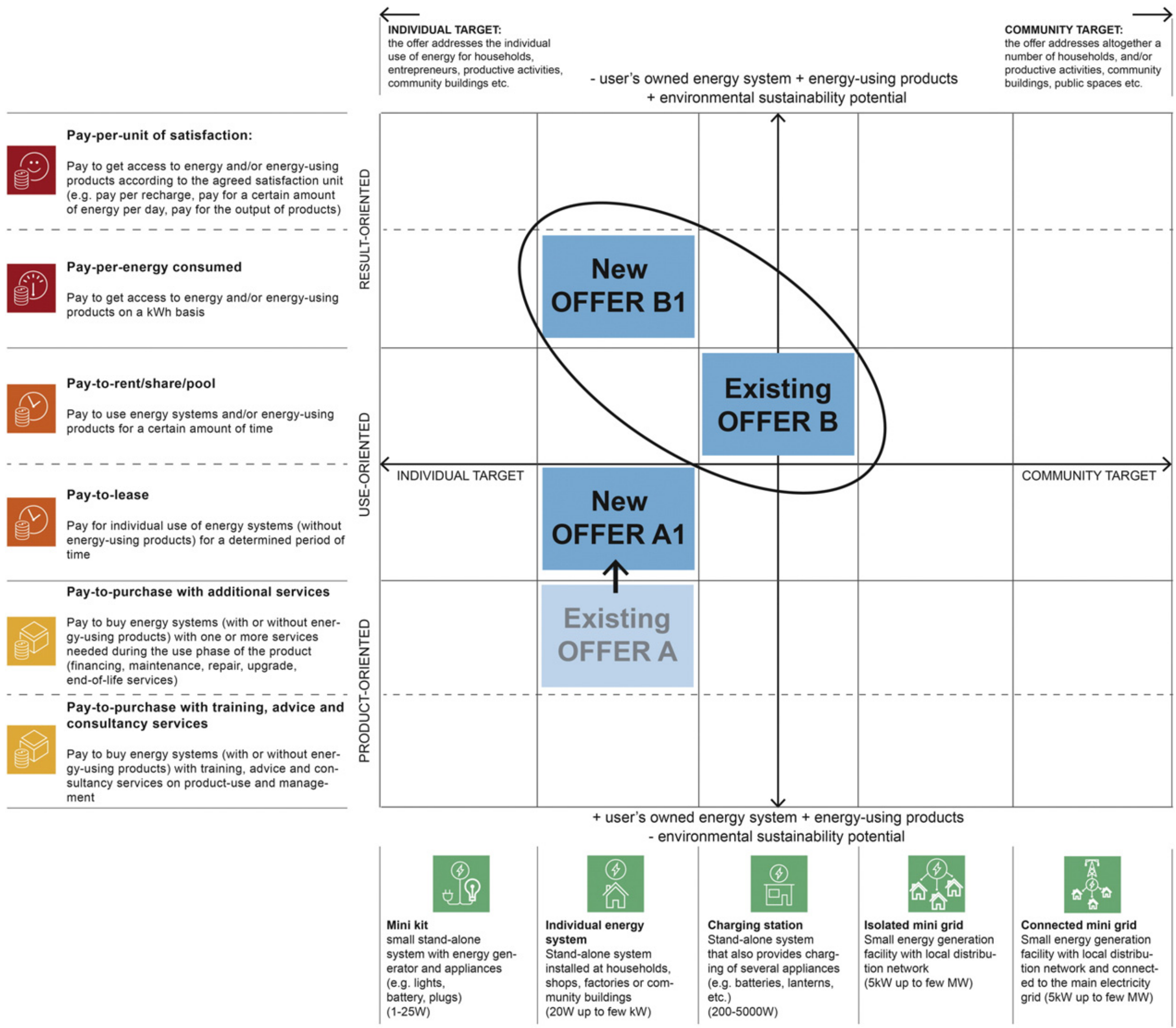

Fig. 23. The classification system can be used for repositioning an existing offer (New offer A1) or for combining different offers (existing offer B and new offer B1).

capital financing one. In other terms the current classification system might become a "platform" onto which various information layers can be added on depending on the specific interests (e.g. policy-makers could use the framework in combination with the market regulation layer).

Building upon the results presented in this paper, the next step will be to explore, for each archetypal model and in relation to the 9 characterising dimensions, the critical factors influencing a successful implementation of PSS models applied to DRE. The final goal is to translate these insights into a set of tools/strategies/guidelines for companies, PSS designers and practitioners in general to support the ideation and design process.

Conclusions

This research aims at addressing the lack of a comprehensive classification of PSS and DRE models and develops a unified classification able to capture all the most important dimensions characterising these models. The new classification system encompasses the 7 major dimensions that describe both PSS and DRE models. Through the empirical population of the classification system with 56 case studies, we have been able to identify 15 archetypal models that describe the existing applications of PSS and DRE. By testing and evaluating the classification system with a number of companies, experts and practitioners, we have demonstrated its several applications: to understand the landscape of PSS applied to DRE and visualise all possible models; to strategically analyse a geographic area and the range of competitors; to map companies' offerings and explore new business opportunities. In sum, the classification system can be considered not only as a tool to classify models of PSS applied to DRE but also as a tool to support strategic conversations to provide assistance and facilitate discussion about competitors, current portfolio of offerings and new potential market opportunities.

Acknowledgments

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Appendix I. Case studies

Name	Country	Archetypal model	Sources
The Sun Shines For All (TSSFA)	Brazil	Offering individual energy systems (and energy-using products) in leasing	C. Vezzoli. System design for sustainability: a promising approach for emerging and low-income contexts Y. Mugica (undated) Distributed Solar Energy in Brazil: Fabio Rosa's Approach to Social Entrepreneurship. UNC Kenan-Flager Business School Cases, University of North Carolina, p. 27 C. Sutton(2007) The Role of the Utilities Sector in Expanding Economic Opportunity. Harvard University. http://energymap-scu.org/ideaas/
Sunlabob	Laos	Renting energy-using products through entrepreneur- or community-managed charging stations	Flotow, P., Friebe, C. (2013). Scaling up Successful Micro-Utilities for Rural Electrification. SBI, Burgstrasse http://www.ashden.org/winners/sunlabob http://energymap-scu.org/sunlabob/ http://www.youtube.com/watch?v=wXCdreDNDC0
Grameen Shakti	Bangladesh	Selling of individual energy systems with additional services	Wimmer, N. (2013).The art of rural business. Journal of Management for Global Sustainability 2 107–119 Biswas, W.K., Bryce, P., Diesendorf, M. (2001). Model for empowering rural poor through renewable energy technologies in Bangladesh. Environmental Science and Policy 4, 333–344 Gunaratne, L. (2002). Rural Energy Services Best Practices. USAIS/SARI http://energymap-scu.org/grameen-shakti/
SELCO	Sri Lanka	Selling of individual energy home systems with training, advice and consultancy services. Selling of individual energy home systems with additional services	Gunaratne, L. (2002). Rural Energy Services Best Practices. USAIS/SARI http://energymap-scu.org/selco/ http://www.selco-india.com/ http://www.ashden.org/winners/selco07
M-Kopa	Kenya	Selling of mini-kits with additional services	Nique, M., Arab, F. (2012). Sustainable Energy and Water Access through M2M Connectivity. GSMA http://gigaom.com/2014/04/10/how-m-kopa-unlocked-pay-as-you-go-solar-in-rural-kenya/ http://acumen.org/investment/m-kopa/ http://www.m-kopa.com/
Fenix International—Ready Set	Uganda, Rwanda	Selling of mini-kits with additional services	Collings, S. (2011). Phone charging micro businesses in Tanzania and Uganda. GVEP International, London http://www.fenixintl.com/uganda/ http://singularityhub.com/2012/08/20/readyset-solar-charger-successful-in-africa-now-headed-to-us/ http://greenfrog.typepad.com/weblog/2013/08/social-enterprises-choosing-for-profit-business-model-to-light-the-world.html
Shared Solar	Uganda, Mali, India, Myanmar, Bolivia	Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids	Roach, M., Ward, C. (2011). Harnessing The Full Potential of Mobile for Off-Grid Energy. IFC, London http://sharedsolar.org/ http://blogs.ei.columbia.edu/2012/02/09/solar-power-lights-up-new-business/ http://www.greentechmedia.com/articles/read/can-microgrids-electrify-one-billion-people
Practical Action Peru	Peru	Offering advice and training services for community-owned and managed isolated mini-grids	Albi, E., Liebermarn, A. E. (2013). Bringing clean energy to the base of the pyramid. The interplay of business models, technology and local context. Journal of Management for Global Sustainability 2, 141–156 http://energymap-scu.org/practical-action-peru/ http://practicalaction.org/peru-1 http://www.ashden.org/winners/practicalaction
Husk Power Systems	India, Bihar	Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini-grids	Palit, D., Chaurey, A. (2011). Off-grid rural electrification experiences from South Asia: Status and best practices. Energy for Sustainable Development 15, 266–276 http://www.ashden.org/files/Husk%20winner.pdf http://www.huskpowersystems.com/index.php?pageT=Home&page_id=1 http://acumen.org/investment/husk-power-systems/ http://energymap-scu.org/husk-power-systems/
NuRa	South Africa	Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through individual energy systems	Winrock International for World Bank (2008). Final Report Policy and Governance Framework for Off-grid Rural Electrification with Renewable Energy Sources Lemaire, X. (2011). Off-grid electrification with solar home systems: The experience of a fee-for-service concession in South Africa. Energy for Sustainable Development 15, 277–283
Nuru Energy	Rwanda	Offering pay per unit energy services through charging stations	Dish, D., Bronkaers, J. (2012). An analysis of the off-grid lighting market in Rwanda: sales , distribution and marketing. GVEP International, London http://www.kiva.org/partners/271 http://www.se4all.org/commitment/expanding-rural-energy-entrepreneurship-and-access-to-clean-lighting-in-east-africa/ http://nuruenergy.com/nuru-africa/the-solution/powercycle/ http://www.forbes.com/sites/csr/2011/10/10/how-sameer-hajee-has-shed-real-light-in-africa/
Angaza Design	Tanzania, Kenya, Zambia	Selling of mini-kits with additional services	Albi, E., Liebermarn, A. E. (2013). Bringing clean energy to the base of the pyramid. The interplay of business models, technology and local context. Journal of Management for Global Sustainability 2, 141–156 https://energypedia.info/wiki/Fee-For-Service_or_Pay-As-You-Go_Concepts_for_Photovoltaic_Systems#Rent-To-Own_vs._Service_Concepts

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Appendix I. (*continued*)

Name	Country	Archetypal model	Sources
			http://energymap-scu.org/angaza-design/ https://wbi.worldbank.org/wbdm/ready-to-scale/angaza-design?destination=&page=6&viewall=all& http://www.angazadesign.com/wp-content/uploads/2013/09/Angaza_DIV_Release.pdf
BBOXX	Africa	Offering recharging services through entrepreneur-owned and managed charging stations	http://www.bboxx.co.uk/energy-kiosk-2/ http://www.ft.com/cms/s/0/e49fc980-68a2-11e3-996a-00144feabdc0.html#axzz2yy3DniJ9 http://bennu-solar.com/wp-content/uploads/2013/05/Social-Impact-Assessment-of-Bboxx-in-Uganda.pdf
IBEKA	Indonesia	Offering advice and training services for community-owned and managed connected mini-grids	Mumpuni, T. (2012) Ashden case study | IBEKA, Indonesia, Report http://www.ashden.org/winners/ibeka12 http://www.unescap.org/sites/default/files/23.%20Indonesia-Micro-Hydropower-Projects.pdf http://www.planetedentrepreneurs.com/planete/?p=2611&lang=en http://www.youtube.com/watch?v=Xm-PaJNlRp8
CRERAL	Brazil	Offering advice and training services for community-owned and managed connected mini-grids	Prado, J. (2008). Cooperative uses mini-hydro to increase electricity supply on local grid. Ashden Awards report. 2008 http://www.creral.com.br/index.php?id_menu=consumidor http://www.ashden.org/winners/creral08 http://vimeo.com/groups/hedon/videos/8597278
Azuri	Sub-Saharan Africa	Selling mini-kits with additional services	IFC (2013). Lighting Africa Market Trends Report http://eight19.com/overview/indigo-pay-you-go-solar https://energypedia.info/wiki/Fee-For-Service_or_Pay-As-You-Go_Concepts_for_Photovoltaic_Systems#cite_note-35 http://www.youtube.com/watch?v=TNRZa9fGp3E
Simpa Networks	India	Selling individual energy systems with additional services	IFC (2013). Lighting Africa Market Trends Report https://energypedia.info/wiki/Fee-For-Service_or_Pay-As-You-Go_Concepts_for_Photovoltaic_Systems#Rent-To-Own_vs._Service_Concepts http://simpanetworks.com/
Deng Ltd.	Ghana	Selling individual energy systems with advice and training services	Bosteen, F., Buabeng, H. (2009). Deng Ltd. Ashden Case Study Report http://www.ashden.org/winners/deng http://www.deng-ghana.com/index.php?option=com_content&view=article&id=7:dstc-offers-pv. http://www.dstcafrica.com/
ESCO Zambia	Zambia	Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through individual energy systems	Gustavsson, M., Ellegard, A. (2004). The impact of solar home systems on rural livelihoods. Experiences from the Nyimba Energy Service Company in Zambia. Renewable Energy 29, 1059–1072 Lemaire, X. (2009). Fee-for-service companies for rural electrification with photovoltaic systems: the case of Zambia. Energy for Sustainable Development 13, 18–23
Khimti Rural Electrification Cooperative (KREC)	Nepal	Offering advice and training services for community-owned and managed isolated mini-grids	http://www.ied.ethz.ch/news/publect/publect_old/Maskey_PL2011.pdf http://www.gorkhapatra.org.np/rising.detail.php?article_id=32509&cat_id=27 https://www.ekantipur.com/the-kathmandu-post/2010/04/19/Business/HPL-rural-electrification-improves-lives-in-Khimti/207397/ http://www.hpl.com.np/social_jhankre.php
Sustainable Energy Services Afghanistan	Afghanistan	Offering advice and training services for community-owned and managed isolated mini-grids	http://sesa.af/projects/sayed-karam-solar-pv-project/ http://www.sesinter.com/our-projects/afghanistan/bamyan-solar-project/ http://www.infrastructurenews.co.nz/node/728
TERI	India	Renting energy-using products through entrepreneur owned and managed charging stations	http://www.sv.uio.no/iss/english/research/projects/solar-transitions/announcements/TERI-Lighting_a_BillionLives_Palit.pdf http://cdkn.org/2013/05/feature-lighting-a-billion-lives-in-india/ http://www.theguardian.com/global-development/poverty-matters/2013/mar/06/-india-solar-electricity http://india.blogs.nytimes.com/2012/08/06/alternate-energy-practices-at-the-grassroots/?_php=true&_type=blogs&_r=0 http://www.hedon.info/LightingBillionLives+TERI
DESI Power	India	Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini–grids	Palit, D., Chaurey, A. (2011)Off-grid rural electrification experiences from South Asia: Status and best practices. Energy for Sustainable Development 15 266–276 http://energymap-scu.org/desi-power/ http://www.desipower.com/Activities.aspx http://www.entrepreneurstoolkit.org/index.php?title=DESI_Power,India-_A_case_study http://www.desipower.com/downloads/DP_Presentation_Short.pdf
REPRO	Rwanda	Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini-grids	http://www.riexrwanda.com/repro/index.html http://www.newtimes.co.rw/news/views/article_print.php?i=14966&a=52583&icon=Print
Avani	India, Uttarakhand	Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids	http://energymap-scu.org/avani/ http://businesstoday.intoday.in/story/uttarakhand-company-producing-power-with-pine-needles/1/190360.html http://acumen.org/investment/avani-bio-energy/ http://thealternative.in/social-business/rural-innovation-series-turning-thorns-opportunity/ http://www.energynext.in/powering-progress/ http://www.vrac.iastate.edu/ethos/files/ethos2013/Room%202/Sunday%20PM/Village-level%20Pine%20Needle%20Gasification%20to%20Meet%20Rural%20Electrical%20and%20Cooking%20Energy%20Needs%20in%20the%20Indian%20Central%20Himalayas.pdf
Coho Solar	Guatemala, Philippines	Renting energy-using products through entrepreneur owned and managed charging stations	http://energymap-scu.org/coho-solar/ http://www.synergysocialventures.org/featured-ventures/coho-solar/ http://prezi.com/nm5uaysmt55e/coho-solar-bottling-the-sun-the-blue-economy/
Quetsol/Kingo	Guatemala, South Africa	Offering access to energy and energy using-products on a pay-per-unit of satisfaction basis through mini-kits	http://www.quetsol.com/ http://kingoenergy.com/about/ http://latincorrespondent.com/tag/quetsol/

Appendix I. (*continued*)

Name	Country	Archetypal model	Sources
			http://agorapartnerships.org/accelerator-2/for-entrepreneurs/by-class/quetsol https://www.bcorporation.net/community/quetsol http://magazine.good.is/articles/how-pay-as-you-go-solar-is-bringing-light-to-rural-guatemala http://www.fastcoexist.com/3016109/change-generation/bringing-solar-to-impoverished-towns-with-a-model-straight-from-the-corpor#1fckLR
Kamworks	Cambodia	Renting energy-using products through entrepreneur- or community-managed charging stations	http://www.kamworks.com/uploads/tx_news/Solar_Lantern_development_and_implementation_LQ__final__november_2010_01.pdf http://contourmagazine.com/2011/09/12/cambodia-by-moonlight-solar-powered-lantern-by-kamworks/ http://nexus-scu.org/energymap/kamworks/ http://www.ease-web.org/wp-content/uploads/2011/07/20110630-Final-report-EASE-Pico-Sol-Cambodia.2.pdf http://www.picosol.org/en/countries/cambodia/181-business-in-a-box http://www.renewableenergyworld.com/rea/news/article/2011/04/off-grid-solar-solutions-shine-in-low-income-rural-cambodia
Off Grid Electric	Tanzania	Offering access to energy and energy using-products on a pay-per-unit of satisfaction basis through mini-kits	http://offgrid-electric.com/ http://venturebeat.com/2014/03/21/off-grid-electric-gets-7m-to-light-africa-in-a-decade-exclusive/ http://www.jasmine.org.nz/ventures/off-grid-electric/ http://www.fastcoexist.com/1681724/how-to-power-10-million-off-grid-african-homes-in-10-years
Devergy	Tanzania	Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids	http://www.devergy.com/ https://cleanenergysolutions.org/webfm_send/1196
Persistent Energy Ghana	Ghana	Offering access to energy and energy using-products on a pay-per-unit of satisfaction basis through mini-kits	http://www.persistentenergyghana.com/ http://www.enn.com/pollution/article/46836 http://www.triplepundit.com/2013/12/persistent-energy-ghana-brings-solar-need-light/
KES	South Africa	Offering access to energy (and energy using-products) on a pay-per-unit of satisfaction basis through individual energy systems	Prasad, G. (2007). Electricity from solar home systems in South Africa. Energy Research Centre UCT, South Africa http://total.com/en/energies-expertise/renewable-energies/solar/photovoltaic-solar-energy/projects-achievements/kes-1 http://www.engineeringnews.co.za/article/kwazulu-energy-services-expands-rural-electrification-programme-to-e-cape-2009-05-06 http://about-us.edf.com/fichiers/fckeditor/Commun/Developpement_Durable/2011/Acces_energie/2011/EDF_AccesEnergie__AfriqueduSud_va.pdf
Yeleen Kura	Mali	Offering access to energy (and energy using-products) on a pay-per-unit of satisfaction basis through individual energy systems	Sutton, C. (2007). The Role of the Utilities Sector in Expanding Economic Opportunity. Harvard University. http://www.naruc.org/international/Documents/15%20MALI-%20Toure%20and%20Kassambara%20Presentation%20March%202011.pdf http://ec.europa.eu/energy/idae_site/deploy/prj058/prj058_1.html
Temasol, (EDF)	Morocco	Offering access to energy (and energy using-products) on a pay-per-unit of satisfaction basis through individual energy systems	http://www.growinginclusivemarkets.org/media/cases/Morocco_Temasol_2011.pdf http://www.oecd.org/mena/investment/46769870.pdf http://www.ffem.fr/jahia/webdav/site/ffem/shared/ELEMENTS_COMMUNS/U_ADMINISTRATEUR/5-PUBLICATIONS/Changement_climatique/Plaquette_Electrification_rurale_marocang-oct2005.pdf http://www.pickar.caltech.edu/me105/materials/case-studies/temasol_full_case_final_web.pdf http://www.adbi.org/files/2009.11.20.cpp.pascual.sess10.solar.power.ppp.morocco.pdf http://www.esc-pau.fr/ppp/documents/featured_projects/morocco.pdf
Mobisol	Tanzania, Kenya, Ghana	Selling of individual energy systems with additional services	Nique, M., Arab, F. (2012). Sustainable Energy and Water Access through M2M Connectivity. GSMA http://microenergy-project.de/index.php?id=637 http://www.plugintheworld.com/mobisol/impact/ http://www.aecfafrica.org/windows/react/projects/mobisol-gmbh http://vimeo.com/56383921 http://prezi.com/cyrhpc3tmi10/mobisol-a-green-inclusive-business/ http://www.arushatimes.co.tz/Local%20News_5.html
Solar Transitions	Kenya	Renting energy-using products through entrepreneur-community-managed charging stations	Ulsrud, K., Winther, T., Palit, D., Rohracher, H., Sandgren, J. (2011).The Solar Transitions research on solar mini-grids in India: learning from local cases of innovative socio-technical systems. Energy for Sustainable Development 15 293–303 http://www.sv.uio.no/iss/english/research/projects/solar-transitions/energy-centre/index.pdf http://south-south.connect.teriin.org/files/Ikisaya-brochure.pdf http://www.sv.uio.no/iss/english/research/projects/solar-transitions/ http://www.ifz.tugraz.at/eng/Research/Energy-and-Climate/Current-projects/Solar-Transitions
CRELUZ	Brazil	Offering advice and training services for community-owned and managed isolated mini-grids	Pedo, M., Battisti, E. (2010). Cooperativa de Energia e Desenvolvimento Rural do Médio Uruguai Ltda (CRELUZ), Brazil Case study. Ashden Awards http://www.creluz.com.br/ http://www.youtube.com/watch?v=BSWaqN0IoXk
PowerGen Renewable Energy	Mageta Island, Kenya	Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids	http://powergen-renewable-energy.com/micro-grids/ http://accessenergy.org/ http://www.youtube.com/watch?v=rvSAX8Uwn4k http://www.kiva.org/partners/340 http://www.wired.co.uk/news/archive/2013-08/29/remba-micro-grid http://inhabitat.com/accessenergy-aims-to-bring-life-changing-clean-energy-to-kenyas-slum-island/

(continued on next page)

Appendix I. (*continued*)

Name	Country	Archetypal model	Sources
Gram Power	India	Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids	http://www.grampower.com/about-us/ http://www.climatesolver.org/innovations/energy-access/gram-power-india http://articles.economictimes.indiatimes.com/2012-07-06/news/32566187_1_renewable-energy-innovation-pilferage http://www.theguardian.com/world/2012/sep/10/india-hamlet-where-power-stayed-on
OMC Power	India	1. Offering access to energy (and energy-using products) on a pay-per-consumption basis through individual energy systems 2. Renting energy-using products through entrepreneur- or community-managed charging stations	www.omcpower.com http://articles.economictimes.indiatimes.com/2012-11-01/news/34857689_1_uninterrupted-power-solar-power-conventional-power-lines http://www.gsma.com/mobilefordevelopment/one-mobile-tower-and-lantern-at-a-time https://mobiledevelopmentintelligence.com/insight/MDI_Case_Study_-_OMC_Power
Mera Grao Power	India	Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini-grids	http://meragaopower.com/gallery/ http://www.ashden.org/awards/2014/international http://www.theguardian.com/sustainable-business/selling-energy-service-meeting-needs-of-poor
Redavia	Tanzania	Offering individual energy systems (and energy-using products) in leasing	http://unfccc.int/secretariat/momentum_for_change/items/7850.php http://www.redaviasolar.com/ http://www.ruralelec.org/newsletter_022014.0.html?&L=%5C%5C%5C%5C%5C%5C%5C%5C#c7716
WBREDA Sagar Island	Sagar Island, India	Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini-grids	Chakrabarti, S., Chakrabarti, S (2000). Rural electrification programme with solar energy in remote region—a case study in an island. Energy Policy 30 33–42 Ulsrud, K., Winther, T., Palit, D., Rohracher, H., Sandgren, J. (2011).The Solar Transitions research on solar mini-grids in India: learning from local cases of innovative socio-technical systems. Energy for Sustainable Development 15 293–303 http://www.ashden.org/winners/wbreda http://www.wbreda.org/
Sunlabob mini-grid	Laos	Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids	http://www.sunlabob.com/news-2013/solar-power-mini-grid-opens-energy-access-to-rural-laos.html Rolland, S., Glania, G. (2011) Hybrid mini-grids for rural electrification: lesson learned. USAID/ARE, Brussels, Belgium http://www.sunlabob.com/news-2013/solar-power-mini-grid-opens-energy-access-to-rural-laos.html http://www.renewableenergyfocus.com/view/20376/case-study-lao-pdr-runs-hybrid-mini-grid/
Econet Solar	Zimbabwe, South Africa	Selling mini-kits with additional services	http://www.econetrenewable.com/ http://www.businesswire.com/news/home/20111202005054/en/Econet-Solar-Launches-Home-Power-Station#.Va3obipVhBc http://www.developingtelecoms.com/tech/green-energy/4964-econet-solar-lighting-up-african-homes-in-2014.html http://www.econetrenewable.com/
Tiny Pipes	Philippines	Offering individual energy systems (and energy-using products) on leasing	http://www.fastcompany.com/3020376/to-bring-power-to-15-billion-living-off-the-grid-a-cellphone-enabled-mini-solar-panel http://e27.co/tiny-pipes-project-to-power-off-the-grid-households-in-the-philippines/ http://www.tinypipes.net/
Solarkiosk	Africa	Offering access to energy-using products through community or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis	http://www.area-net.org/fileadmin/user_upload/AREA/AREA_downloads/AREA_Conference_12/presentatios/Session_1/SOLARKIOSK.pdf http://solarkiosk.eu/ http://www.gvepinternational.org/en/business/news/versatile-solarkiosks-providing-much-needed-energy-services-grid-communities http://www.sustainablebusinesstoolkit.com/solarkiosk/
Sunfarmer	Nepal	Selling individual energy systems with additional services	http://www.theguardian.com/sustainable-business/2014/aug/18/solar-systems-blackout-nepal-hospital-energy http://www.sunfarmer.org/ http://www.fastcoexist.com/3035841/bringing-solar-power-to-remote-hospitals-is-saving-lives
Suntransfer	Ethiopia	Selling individual energy systems with additional services	http://suntransfer.com/ https://www.lightingafrica.org/niwa-partners-with-sun-transfer-to-assemble-solar-products-in-ethiopia/ Kassahun Y. Kebede, Toshio Mitsufuji, Eugene K. Choi (2014). After-sales Service and Local Presence: Key Factors for Solar Energy Innovations Diffusion in Developing Countries. PICMET Conference on 28th July, 2014 at Kanzawa, Japan
Juabar	Tanzania	Offering access to energy-using products through community or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis	http://juabar.com/ http://www.cp-africa.com/2015/05/06/juabar-tanzanias-solar-powered-phone-charging-kiosk/ http://www.thenewafrica.info/bringing-power-people/ http://www.bbc.co.uk/news/business-30805419
Solar Now	Uganda	Selling individual energy systems with additional services	http://acumen.org/investment/solarnow/ http://www.solarnow.eu/ http://challengesworldwide.com/case-studies/improving-energy-access-in-uganda/

Appendix II. Extract from a case study description

Company	Off Grid Electric	Case short description
PSS type	Result-oriented: pay-per-unit of satisfaction	The company provides electricity services through solar mini-kits installed at customer's home. Customers can choose the size of the kit according to the appliances they need (starting kit includes two lights and a phone charger for eight hours a day) and upgrade with additional appliances (more lights, radio, TV). Off Grid Electric retains ownership of systems and appliances and trains a network of local dealers for installation and customer support. Customers pay an initial deposit and pre-pay the energy service through mobile money. When the payment is received, the customer receives an SMS with a code to unlock the system and start using it.
Value proposition/payment structure	Offering access to energy and energy using products through solar mini-kits. Customers pay daily fees to use the mini-kit and appliances for a certain amount of maximum time per day (e.g. 8 h)	
Target customer	Individual households, small businesses	
Energy system	Solar mini-kit (5–10 Wp)	
Energy-using products	Lights (2–6), phone chargers, radio	
Services	Installation, maintenance and repair, product upgrade	
Ownership (of energy system and energy-using products)	Off Grid Electric	
Energy system operation	Off Grid Electric	
Provider/customer relationship	Relationship based: customers are assisted with an 18-h-per-day call centre and agents ensure communication with new customers regarding correct system use	
Environmental sustainability potential	High	

Appendix III. List of companies, practitioners and experts involved in the testing activities

	Firm type and main business	Number of interviewees, job title/department	Date
Companies			
C1	Small-sized company: sale of solar systems/mini-kits with additional services	1: Technical director	2/04/2015
C2	Small-sized company: sale of solar systems with additional services	1: CEO/owner	9/04/2015
C3	Medium-sized company: sale of large solar systems with additional services	3: Managing Director, operations	10/04/2015
C4	Medium-sized company: sale of solar systems, solar water heaters with training and additional services	3: Finance director, Head of Mechanical Department, Head of Solar	13/04/2015
C5	Small-sized company: sale of solar systems and consultancy services	1: CEO/owner	17/04/2015
C6	Small-sized company: sale of solar systems, mini-kits and solar water heaters with additional services	1: Operations	5/05/2015
C7	Medium-sized company: sale of solar systems with additional services; energy provision through mini-grids	1: CEO	6/05/2015
C8	Big-sized company: offering energy provision through charging stations	1: Operations manager	13/05/2015
Experts			
E1	University of Botswana	1: Clean Energy Resource Centre director, lecturer	15/04/2015
E2	Department of Energy, Ministry of Minerals, Energy and Water Resources	1: Energy engineer	16/04/2015
E3	University of Botswana	1: Business model, accounting and finance lecturer	7/05/2015
E4	University of Botswana	1: Electrical engineering and power distribution lecturer	7/05/2015
E5	University of Botswana	1: PSS lecturer	13/05/2015
Others			
O1	Botswana Institute of Technology Research and Innovation	1: DRE researcher	23/04/2015
O2	Product and strategic design consultancy	3: CEO, product designer, strategic designer	28/04/2014

Appendix IV. Characterising dimensions of each archetypal model

Archetypal model	Dimensions						
	Energy system	Target customer	Value proposition/payment structure	Ownership (of the energy system and energy-using products)	Energy system operation	Provider/customer relationship	Sustainability potential
1. Selling individual energy systems with advice and training services	Individual energy system	Individual	Pay-to-purchase with training, advice and consultancy services	End user	End user	Transaction-based	Low
2. Offering advice and training services for community-owned and managed isolated mini-grids	Isolated mini-grid	Community	Pay-to-purchase with training, advice and consultancy services	End user	End user	Transaction-based	Low
3. Offering advice and training services for community-owned and managed connected mini-grids	Connected mini-grid	Community	Pay-to-purchase with training, advice and consultancy services	End user	End user	Transaction-based	Low
4. Selling mini-kits with additional services	Mini-kit	Individual	Pay-to-purchase with additional services	End user	End user	Transaction-based	Low
5. Selling individual energy systems with additional services	Individual energy system	Individual	Pay-to-purchase with additional services	End user	End user	Transaction-based	Low

(continued on next page)

Appendix IV. (*continued*)

Archetypal model	Dimensions						
	Energy system	Target customer	Value proposition/payment structure	Ownership (of the energy system and energy-using products)	Energy system operation	Provider/customer relationship	Sustainability potential
6. Offering individual energy systems (and energy-using products) in leasing	Individual energy system	Individual	Pay-to-lease	Energy solution provider	End user	Relationship-based	Low
7. Renting energy-using products through entrepreneur-owned and managed charging stations	Charging station	Individual and community	Pay-to-rent/share/pool	Energy solution provider	Energy solution provider	Relationship-based	Medium
8. Renting energy-using products through entrepreneur- or community-managed charging stations	Charging station	Individual and community	Pay-to-rent/share/pool	Energy solution provider	Energy solution provider	Relationship-based	Medium
9. Offering access to energy (and energy-using products) on a pay-per-consumption basis through individual energy systems	Individual energy system	Individual	Pay-per-energy consumed	Energy solution provider	Energy solution provider	Relationship-based	High
10. Offering access to energy (and energy-using products) on a pay-per-consumption basis through isolated mini-grids	Isolated mini-grid	Community	Pay-per-energy consumed	Energy solution provider	Energy solution provider	Relationship-based	High
11. Offering access to energy and energy-using products on a pay-per-unit of satisfaction basis through mini-kits	Mini-kit	Individual	Pay-per-unit of satisfaction	Energy solution provider	Energy solution provider	Relationship-based	High
12. Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through individual energy systems	Individual energy system	Individual	Pay-per-unit of satisfaction	Energy solution provider	Energy solution provider	Relationship-based	High
13. Offering access to energy-using products through community- or entrepreneur-managed charging stations on a pay-per-unit of satisfaction basis	Charging station	Individual and community	Pay-per-unit of satisfaction	Energy solution provider	Energy solution provider	Relationship-based	High
14. Offering recharging services through entrepreneur-owned and managed charging stations	Charging station	Individual and community	Pay-per-unit of satisfaction	Energy solution provider	Energy solution provider	Relationship-based	High
15. Offering access to energy (and energy-using products) on a pay-per-unit of satisfaction basis through mini-grids	Isolated or connected mini-grid	Community	Pay-per-unit of satisfaction	Energy solution provider	Energy solution provider	Relationship-based	High

Appendix V. Stakeholders system map legend

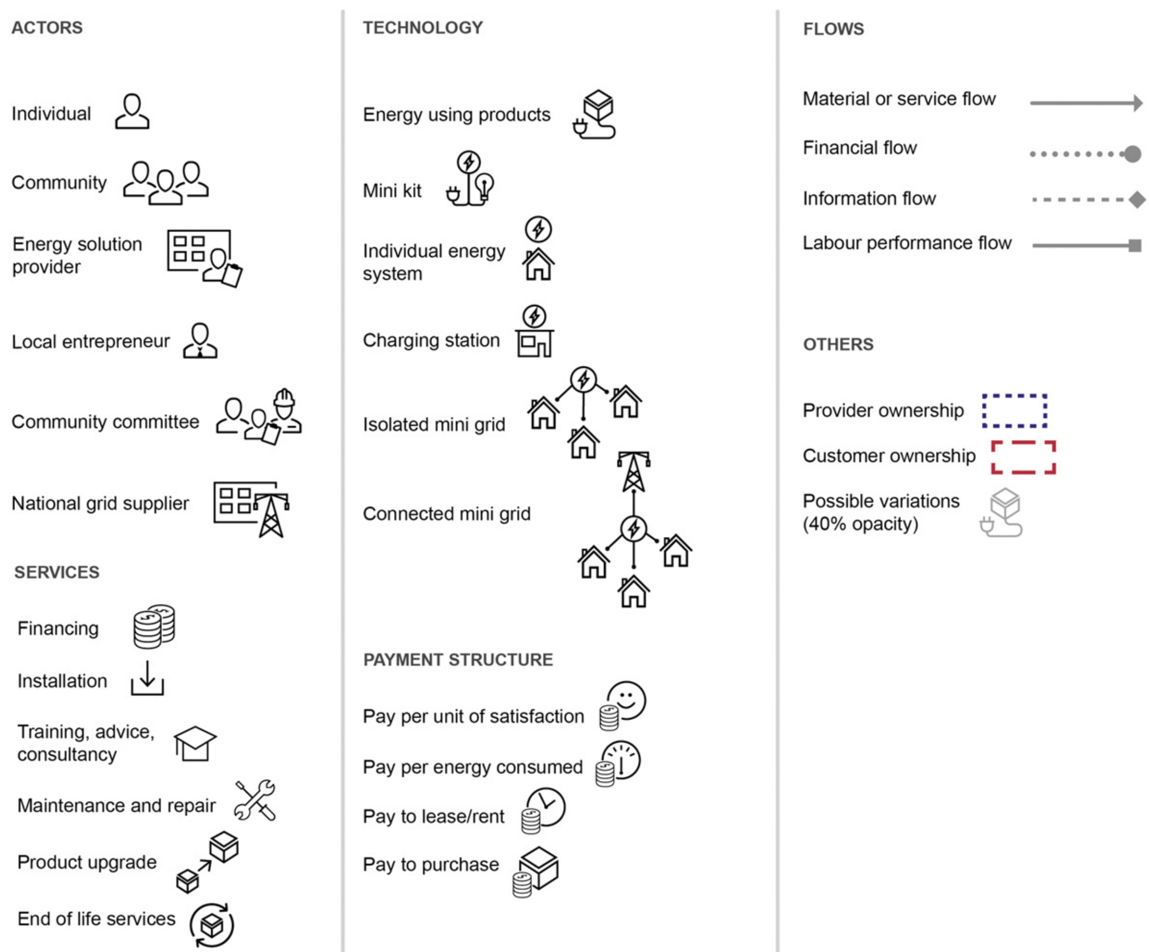

Fig. 24. Stakeholder system map legend.

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