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

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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.

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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.