ARTICLE IN PRESS

Energy Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

# Morphological analysis of energy services: Paving the way to quality differentiation in the power sector

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ARTICLE INFO

*Keywords:*
Product differentiation
Energy service
Morphological analysis
Service design
Decision support

ABSTRACT

The activation of the still predominantly passive demand side is necessary to further guarantee a stable power system in the short term and ensure capacity adequacy in the long run. A system with a high share of generators with nearly no marginal costs requires new services that facilitate transmitting the right economic signals to the system stakeholders. To this end we refine the notion of energy services and propose a framework to systematically design quality differentiated energy services for consumers. This approach facilitates a value-based economic assessment of energy services that deviates from the marginal-cost-paradigm. We further illustrate pricing options for these new energy service products and outline infrastructural needs and additional use case-specific product properties. Moreover, we discuss how the morphological approach can be formalised using a mathematical programming formulation and introduce a complexity measure that facilitates assessing potential adoption obstacles for end consumers. Additionally, we illustrate the practical applicability of these findings by using a prototypical implementation of a decision support system. To foster differentiated energy services, we recommend a more lenient regulatory regime lowering the barriers for new market entrants.

## 1. Introduction

Currently, system stability is primarily ensured by supply side operations, in particular load balancing through conventional generators and system reserves. This traditional control approach may become increasingly unreliable due to uncertainty of intermittent renewable energy sources and decommissioning of conventional power plants. The increase of intermittent renewable energy sources on the supply side effectively decreases the share of controllable elements in the power system. The arising imbalance can be compensated through activation of the so far mainly passive demand side. To this end, appropriate economic incentives need to be designed.

However, these economic incentives need to be embedded in attractive service offerings corresponding to the individual application scenarios for different customer groups. This in turn requires the development of new products and services and considerations about the appropriate market environment. Fundamentally, these service offerings need to pave the way towards a value-oriented pricing paradigm instead of relying on the current marginal-cost-based assessment for the value of electricity. Marginal-cost-pricing will fail in the long-run if power systems are increasingly governed by zero-marginal-cost generation with high output volatility.

Our research objective is to characterise the corresponding energy service concept and to provide a structured approach to design energy service products for end customers under consideration of the key product characteristics. To this end we follow Zwicky (1967) and adapt the morphological approach to explore design dimensions for energy services encompassing the four categories of risk, pricing options, infrastructural requirements, and product properties.

First, we further specify what an energy service is in the context of this work and build on and adapt existing definitions of this term in Section 2. Additionally, we consider previous work regarding product differentiation in the electricity sector and more general in the service sector. From these foundations we derive the methodology built on Zwicky's framework in Section 3. Section 4 presents the morphological box for energy services while Section 5 elaborates on interdependencies between design options and the complexity related to energy service features. Furthermore, we illustrate the method by characterising real-world service configurations and a prototypical decision support system for service designers. Section 6 concludes and discusses policy implications for regulators to support the process of advancing energy services.

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http://dx.doi.org/10.1016/j.enpol.2017.03.024
Received 15 August 2016; Received in revised form 24 January 2017; Accepted 9 March 2017

## 2. Related work

This section revisits existing definitions of energy services and looks into general service design properties to guide our morphological approach for service innovation in the energy domain.

### 2.1. Energy services

The term energy service has different meanings in literature. These meanings can be classified into three main streams: Understanding the classic business of utilities as a service, planning, installation and financing of small power plants (e.g., photovoltaic power plants) and services enabled by the use of energy.

Hill (1977, p. 317) defines a good as "a physical object which is appropriable and, therefore, transferable between economic units". In contrast, "one economic unit performing some activity for the benefit of another" and thereby changing the condition of a person or a good is the idea of a service (Hill, 1977, p. 318). In line with this reasoning, Kloubert (2000) identifies two components in the classic core offering of utilities: The energy carrier (e.g., coal, gas) itself is a typical good. Transmitting this good in a possibly modified form to customers adds the characteristics of a service. Utility companies extend the so-called dual core offering by auxiliary services such as metering, consumption optimisation, and emergency services.

Following Vine (2005), energy services consist of developing, installing and funding multi-year projects that enhance the energy efficiency or load reduction of customer facilities. Especially in the US, the literature employs the term "ESCO" (energy service company) to refer to this definition (Dayton et al., 1998; Goldman et al., 2005; Satchwell, 2010; Vine et al., 1999). This is in line with the notion of energy services as defined by Rosmanith et al. (2007) and the EU directive 2006/32/EC: An energy service is "the physical benefit, utility or good derived from a combination of energy with energy efficient technology and/or with action, which may include the operations, maintenance and control necessary to deliver the service, which is delivered on the basis of a contract and in normal circumstances has proven to lead to verifiable and measurable or estimable energy efficiency improvement and/or primary energy savings."[1]

In contrast to Vine's and Hill's understanding, Sorrell (2007) focuses on the service itself: "Energy service contracting involves the outsourcing of one or more energy-related services to a third party". This includes e.g., basic services like hot water supply or more sophisticated service offerings, such as illumination levels, room temperatures etc. Seizing the three-stage-framework of offering a service due to Kloubert (2000), Sorrell adds the result stage — transforming energy to something valuable for the customer — to the first two stages. These consist of (1) setting up infrastructures and procuring primary energy carriers and (2) producing and transmitting the energy, which is the base for the following considerations.

Building on Sorrell's definition we understand energy services as services that are facilitated by energy, in particular for energy-intensive applications, offered on the mass market. This notion introduces a new facet that facilitates to provide a value-based assessment of the utilisation of energy that is differentiated by the end-use application. In turn this enables new options to harness demand side flexibility potentials which are of great importance in future energy systems with large shares of intermittent generation sources (IEA, 2014).

### 2.2. Product differentiation in the electricity sector

Electricity is typically considered a homogeneous good. Therefore, product differentiation has mainly concentrated on dynamic pricing so far (Tan and Varaiya, 1993). Real-time pricing (RTP) and other variable pricing schemes are well-known and studied examples (Albadi and El-Saadany, 2008; Woo et al., 2014; Borenstein, 2005). Direct load control (DLC) is another way to manage the balance of demand and supply. In DLC programs utilities offer incentives to customers in exchange for accepting pre-specified curtailment options (Albadi and El-Saadany, 2008). Further work concentrates on differentiation of electricity with regard to conventional attributes like the generation source (Kaenzig et al., 2013). Recently, the willingness to pay for green generation options has been extensively studied (Roe et al., 2001; Borchers et al., 2007; Yoo and Kwak, 2009; Hansla et al., 2008). Depending on the scenario, most studies find a higher willingness to pay for electricity from renewable sources.

Other network-based industries, e.g., telecommunication, evolved in a comparable way (Rinaldi, 2004). Deregulation of the telecommunication market induced competition which forced the development of innovative and heterogeneous products to account for individual customer needs (Kenyon and Cheliotis, 2001). In analogy to that, product differentiation in the electricity sector should not only concentrate on pricing but also consider different customer usage scenarios. The ongoing implementation of smart grids forms the technical basis for this development (Woo et al., 2014). This way, the (physically) homogeneous good electricity becomes a differentiable transaction object in economic terms (Weinhardt et al., 2003).

### 2.3. Product differentiation in the service sector

Since the notion of energy services builds on the service concept, differentiation can in particular be attained by a variation of service quality attributes. Service quality has been subject to extensive research mainly building on top of quality indicators established in the SERVQUAL framework (Parasuraman et al., 1988). This framework focuses on "traditional" services performed by humans e.g., in stores, banks, or other businesses. The relevant service quality dimensions include the perception of *tangibles*, *reliability*, *responsiveness*, *assurance*, and *empathy*. Some of these concepts are also applicable to energy services, but have a different facet in their implementation. Tangibles for example are not as relevant or cannot be influenced, as well as empathy, and to some extent assurance, since the service is delivered through a device or appliance according to clearly defined technical specifications.

Parasuraman et al. (2005) have also put forward an important modification of the SERVQUAL concept to reflect the rise of electronic or e-services. The E-S-QUAL framework incorporates insights from numerous studies employing the Theory of Planned Behavior (TPB) and the Technology Acceptance Model (TAM). Its objective is to measure the "extent to which a website facilitates efficient and effective shopping, purchasing, and delivery." The general attitude towards the technological means that deliver a service can also be of importance for the energy services depicted later, since they too rely on technical interfaces. However, the focus of our work is to first define and characterise differentiation concepts, rather than assessing a particular implementation of one. The following main indicators employed in E-S-QUAL measure the quality of a service: reliability (correct technical function of a site), responsiveness (low latency and fast customer support), access (easy and timely), flexibility (choice of payment, shipping etc; rather referred to the delivery process), ease of navigation, efficiency (simple and effective usage design), assurance/trust (reputation of the site), security/privacy (data security level of the provider), price knowledge (price determination transparency during the purchasing process), site aesthetics, customisation/personalisation (user profiles).

Several of these indicators are directly applicable to energy service evaluation, in particular *assurance/trust* and *security/privacy*. Others like reliability and responsiveness can be adapted in a straightforward manner: The *reliability* of an energy service is intrinsically connected to the appliance that provides the service. Its reliability will typically be

[1] Article 3(e), Directive 2006/32/EC of the European Parliament and of the council.