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Which digital energy services improve energy efficiency? A multi-criteria investigation with European experts

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ABSTRACT

Energy providers still struggle to decide on which digital energy services can help them stay competitive and aligned with energy efficiency policy targets. This research aims to assist organisations in choosing a service by modelling the selection process along decision criteria via the Analytic Hierarchy Process. This analysis includes evaluations by surveying experts for their opinions and an assessment of objective decision factors such as technical feasibility, business potential, behavioural change and innovativeness. It was found that behavioural and business factors are most important for organisations choosing new services, indicating that there should be a stronger focus on highlighting and assessing these aspects in future research. Additionally, all ICT-based services still ranked closely to each other, demonstrating that it is neither imperative nor easy to identify a single service. It can be concluded that energy providers should adopt a wider approach by offering a digital platform of energy services. Likewise, political adjustments should be enacted in parallel which enable approaches more conducive to organisations for gaining relevant experience. Examples are establishing innovation zones and altering restrictive regulations to facilitate markets to transfer monetary incentives to customers as means to enable new ways how such services can be offered.

1. Introduction

The current market environment for energy providers has been changing dramatically. On the one hand, companies are under pressure to take on environmental responsibility given the European Union's policy emphasising climate mitigation. As such, EU member states are obliged to reduce primary energy consumption by 20% by 2020 (EEA, 2013) and additionally to achieve an energy efficiency target of 27% or more by 2030 (EC, 2016). While decentralised energy resources increase, energy providers are required to tackle the inherent complexities of distributing energy. This includes collaborating with those end-customers which will become empowered stakeholders in the market, by providing, storing and consuming energy in their houses (Giordano et al., 2013; Roelich et al., 2011; Valocchi et al., 2010).

The smart meter roll-out in the EU has offered an initial step to measuring and communicating energy related information remotely and bilaterally between consumers and energy providers as a way to improve energy efficiency. Based on these new capabilities, information and communication technologies (ICT) based services have been created and tested. Much of the research has demonstrated that ICT-based services, or digital energy services, offer energy-saving potentials (EC, 2014), an opportunity to change energy-consumption behaviours of customers through motivational and informational functionalities (see EEA, 2013; Harter et al., 2010; Krishnamurti et al., 2012; Martiskainen and Coburn, 2011; McHenry, 2013) and to provide economic potentials by managing demand (Faruqui and Sergici, 2010; Haney et al., 2009; Haustrup Christensen et al., 2013). Its application has been supported by the policy of the European Union with the Energy Services Directive (2006/32/EC), the Third Energy Package Directive (2009/72/EC) and the Energy Efficiency Directive (2012/27/EU) with regards to the political aim of climate change mitigation. As such, these services are being promoted as promising business models for energy providers in

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the market.

However, many stakeholders, including energy companies, are still struggling with the still-evolving complexities of adopting the service-oriented operation of digitalised energy systems (Giordano et al., 2013). This may be due to the organisational inertia of how companies and organisations wait until other organisations initiate the implementation of new services to better judge the consequences of such activities (Azevedo et al., 2013). Another reason may be that existing solutions have mainly been offered either as electricity or as heating services. Partly due to the fact that heating can be provided through renewable resources (for example heat pumps), recent research has emphasised an integrated energy perspective, where the sectors for electricity and heating can no longer be viewed in separation, but are instead understood to merge together (Connolly, 2017; Mathiesen et al., 2015). One synergy relates to the customers, giving them a complete solution to tackle their energy consumption (and production), not only for one sector, but for their entire energy system at home or work. However, this approach poses a new challenge in the way such services are offered to customers. Since energy providers usually are composed of separate departments that have been treating heating and electricity largely in a disjointed manner, the offering of new services for energy may pose a drastic change to their internal management and structure.

We argue that despite the growing availability of case studies, which have tested different functionalities and proved energy-saving potentials, especially in the electricity sector, their market-wide diffusion is still rare and lagging behind expectations. As many stakeholders such as utilities, service providers, agencies and local governments are still new to deciding on which digital energy services for customers may help them to stay competitive and in line with policy targets, this research aims to assist these organisations in choosing a potential ICT-based service. According to Saaty (1990), organisations relate such a decision to several criteria by evaluating and ranking several options (Chapter 2). As such, this paper provides a model describing an organisation's approach to evaluations when not all necessary information can be easily compared (Chapter 3). Therefore, this article aims to model a decision-process of organisations choosing ICT-based services upon several decision criteria. We therefore dismantle the decision-process that we assume organisations go through. The innovative features of the assessment include the confluence of subjective evaluations from surveying experts' opinions with the consideration of objective factors in assessing ICT-based energy services' potential on energy efficiency (Chapter 4). It will provide a ranking of services targeting both residential and public users, and includes heating and electricity for a more general assessment level, thereby expanding the scope of previous research (Chapter 5). Subsequently, this paper will discuss these findings within the context of necessary requirements for the energy market and policy development (Chapters 6 and 7).

2. How to make decisions: the Analytic Hierarchy Process (AHP)

When an organisation wants to implement an ICT-based service this can be defined as a type of product innovation process. A product innovation includes all new outputs from an organisation, such as services or new products (Totterdell et al., 2002). In a process of dealing with such an implementation or adoption, organisations usually face several sequential phases (1) idea generation, (2) idea evaluation, (3) planning, (4) project implementation and (5) market launch. This research concentrates on the second phase where several ideas are evaluated. The ideas identified in phase one stem from existing research on ICT-based services that have already been tested for heating and electricity previously. They will be introduced in the literature review in Chapter 3.

Since we assume that many stakeholders are still unfamiliar with digital services, they could have some concerns about which service to include and which one to exclude, making an evaluation difficult. Arranging the decision-making into a model or hierarchy can therefore prove helpful. First, it can provide an overall view of the complex relationships inherent in the decision-making process and secondly, it can portray whether the factors that are evaluated differ in their magnitude of impact (Saaty, 1990). We have chosen the analytic hierarchy process (AHP) to facilitate an originally qualitative problem into a quantitative assessment, thereby streamlining comparison and evaluation. Its aim is to find a general assessment that can be used by several stakeholders confronted with such a decision, to easily depict the most valuable service or to identify to which extent the parameters influence the decision. The model has been proven as being clear and accessible in evaluating choices (Ahmad and Tahar, 2014; Saaty, 1980). Its reliability has been substantiated by its application into many fields, including manufacturing (Ho and Ma, 2017), healthcare (Calantone et al., 1999) and sustainable energy-planning (Seyhan and Mehpare, 2010; Pohekar and Ramachandran, 2004), to name a few. To the knowledge of the authors, this is the first attempt to use the AHP to assess the potentials of ICT-based energy services.

AHP offers several advantages. Given the diversity of application fields (Ho and Ma, 2017), it is flexible to adopt as a research method being confronted with a selection problem for several energy services. Also, it has been shown that it is effective with small sample sizes of even less than 50 respondents (Whitmarsh and Palmieri, 2009) and that the pairwise comparisons reduce the cognitive burden of prioritising decision-making. In contrast, there is currently a discussion to which extent multi-criteria decision tools are actually helpful. It has been identified that such methods are still less used in managerial settings than the financial methods of cost-benefit or SWOT analyses (Ishizaka and Siraj, 2018). Based on this observation there has been a study to identify the usefulness of such approaches. In a test with software applications to carry out multi criteria decision-making, it was shown that decision-makers followed the recommendations or rankings made (Ishizaka and Siraj, 2018). Even though we could not identify how such recommendations were used by the organisations, its flexibility and tested replicability were the reasons for using the AHP to model a decision of selecting energy services.

3. The integrative model

In principle, the AHP orders the decision-making process into a hierarchy with three levels (Fig. 1).

3.1. Improving energy efficiency

The first level is the goal, which provides direction to the overall evaluation. It should answer the question: What should be the outcome of implementing the services? While there could be several possible targets in a company, for this research we decided to focus on the policy aim of improving energy efficiency. As a political focus, it stands for a strategic direction which an organisation wants to choose to sustain as a market actor. Thus, the decision aims to identify which energy services can improve energy efficiency.

While it is true that organisations decide on the services, these services can only be effective if they are valuable to the customers themselves, making them a crucial variable within the model. Being the receivers of the services, customers act as target users. When thinking of which target users are useful to evaluate, we found that most research has concentrated on changing energy consumption via ICT-based solutions for residential users (Abrahamse et al., 2005; Darby, 2006; EEA, 2013; Schleich et al., 2013). There are also some scholars who have tested ICT-based services in the commercial sector. Different results have arisen when such services were delivered at the organisational or sub-organisational levels (e.g. by facility managers) to improve the energy consumption regime, as compared to services targeting the actual users of the buildings (Kastner and Matthies, 2014; Orland et al., 2014). The inclusion of diverse kinds of users has already stimulated recent initiatives to apply sophisticated ICT services, such as the monitoring/simulation tools of energy consumption and generation which

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