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Energy 4.0: A Taxonomy-based Maturity Model of Smart Energy Business Models

Master thesis

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(Thema)

Energy 4.0: A Taxonomy-based Maturity Model of Smart Energy Business Models

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1. Introduction

1.1 Motivation of the topic

- The energy sector is in a state of continuous transformation in line with the technological, political and socio-economic changes associated with wide-reaching implications for global energy industries and actors (Fattouh et al., 2019; Moe, 2010)
- Recently, the Covid-19 pandemic not only had a considerable impact on the global economy and people's daily lives, but it was also a triggering event for lasting transformations in several sectors, including the energy sector. Indeed, one of the major impacts of COVID-19 on the energy sector is the oil price shock exacerbated by around 60% drop in oil prices (Abu-Rayash, A., & Dincer, I., 2020). This sudden shift in prices has mostly resulted in economic implications for fragile oil-exporting developing countries, making the need for a transition to a more diversified and resilient energy future even more urgent (Engebretsen, R., & Anderson, C, 2020).
- Furthermore, the fall in oil prices due to the pandemic was accompanied by a decrease of 4% in the global energy demand in 2020, which is the largest decline since World War II and the largest ever absolute decline (IEA, 2021) .
- Indeed, large electricity consumers such as industrial and commercial buildings have been forced to shut down or switch to minimum operating levels due to the restrictive policies (Figure 1). On the other hand, residential load has increased as people have been forced to stay in their homes (H. Zhong et al., 2020; Jiang et al., 2021).
- Such changes in electricity demand could lead to a sudden influx of unplanned electricity flows, which unbalances the conventional power grid and threatens the electricity supply (Abrahamsen et al., 2021). To improve the grid's ability to cope with changes in electricity supply and demand, new management, control methods as well as a more efficient distribution of energy are required. Therefore, electricity networks must integrate new technologies that guarantee an efficient and secure supply of electricity (Abrahamsen et al., 2021). Such power grids are, as defined by the European Commission, capable of the smart integration of the behavior and activities of different consumers and/or producers to maintain an efficient, sustainable, economical and secure supply of electricity (European Union, 2013).

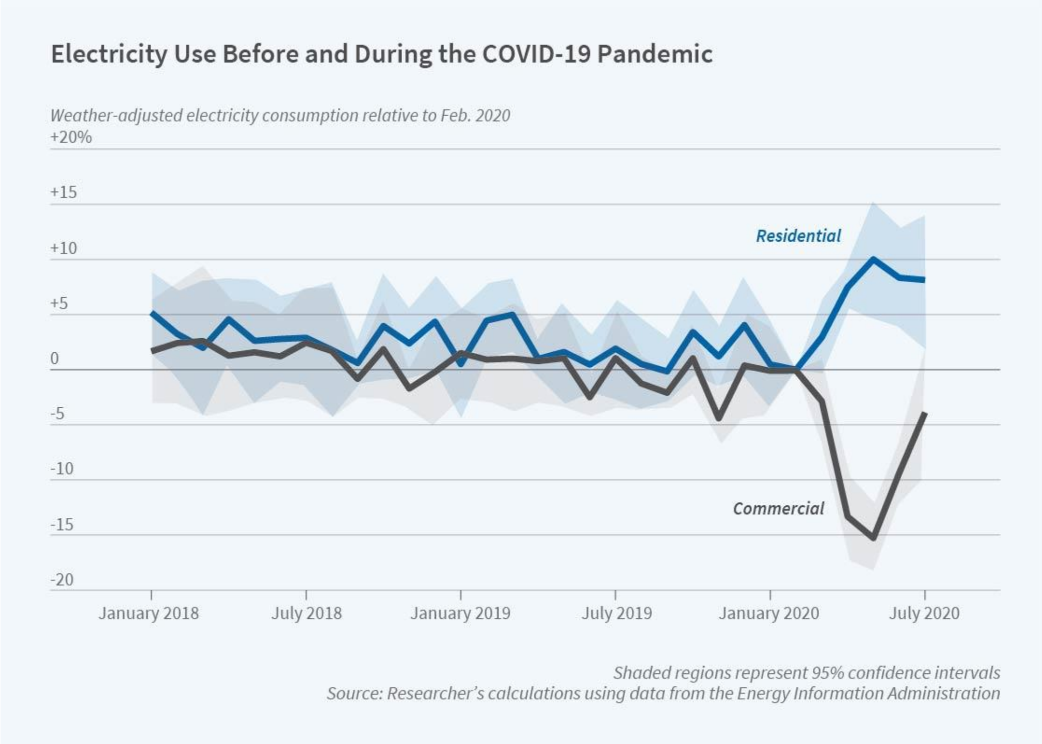

Figure 1: Electricity use before and after the COVID-19 Pandemic (NBER, 2022)

- However, it is important to highlight that the decrease in energy demand has mainly affected conventional energy resources (IEA, 2021). On the other hand, the demand for renewable energy has increased by 3% in 2020 according to the International Energy Agency statistics (IEA, 2021). Thus, renewable energies certainly remain the success story of the Covid-19 era.

- Nevertheless, an unexpected and sharp increase in the renewables demand could lead to significant challenges for the energy sector. In fact, the intermittent renewable energy production leads to variability in the electricity production, which leads to technical problems impairing the grid stability and supply reliability (Piel et al., 2017).

- Indeed, even though the focus is often directed towards optimized power grids, they are only one aspect of an integrated smart energy system (Mathiesen et al., 2015). For all the actors of the energy sector to have control over the current energy systems and to better manage the possible changes that might occur in the future, it is crucial to take into consideration all the parameters and applications of energy systems and develop innovative energy business models on their basis (Mathiesen et al., 2015). This assumption gives, therefore, rise to the question of integrating new technologies to adopt a smart energy system (Mathiesen et al., 2015).

- As illustrated in Figure 2, which indicates the different parts of an integrated smart energy system, technologies such as the Internet of Things (IoT) can be integrated into many applications along the energy supply chain, such as optimized energy grids, smart buildings and smart mobility (Motlagh et al., 2020).

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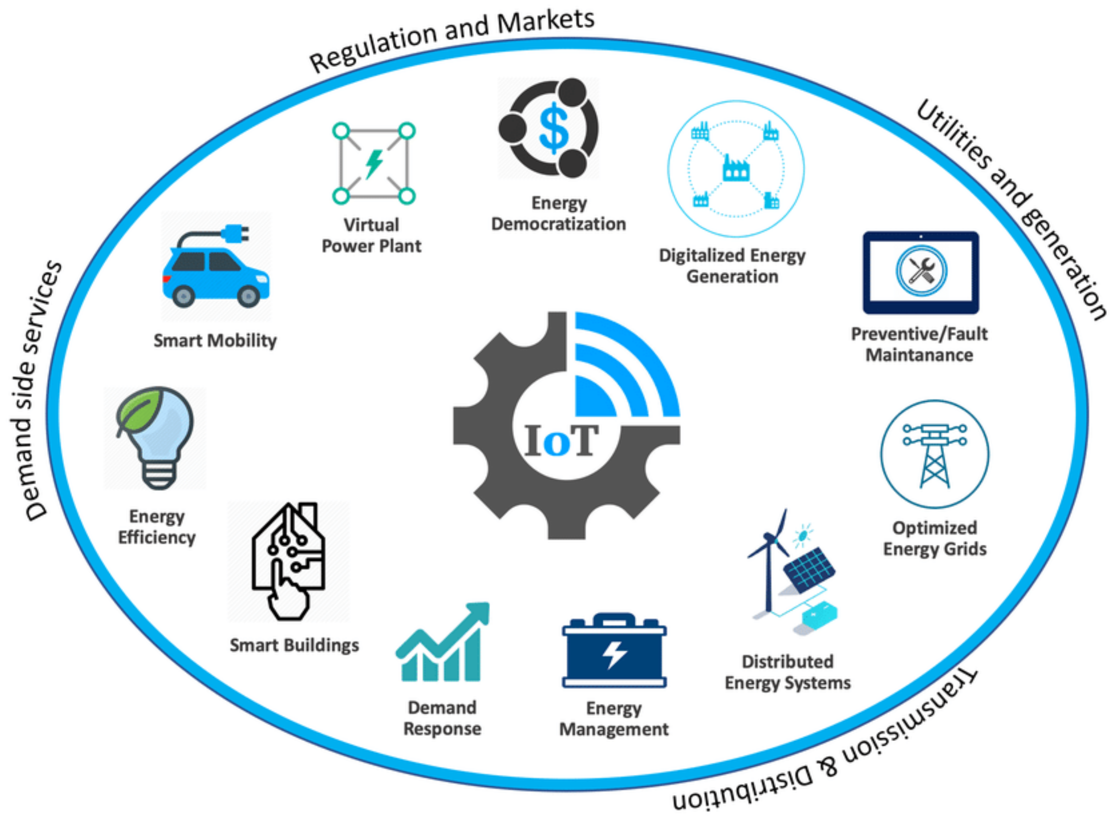

Figure 2: Applications of IoT in an integrated smart energy system (Motlagh et al., 2020)

- In this context, innovative technological solutions are changing the energy sector and opening new pathways to energy monitoring, optimization, and autonomous capabilities (Gielen et al., 2021; Paukstadt et al., 2019). These technologies, also known as information and communication technologies (ICT), are the basis for innovative or intelligent digital services, which promise new values to customers in several sectors, including the energy sector (Paukstadt et al., 2019). As a result, these emerging transformations in the energy sector l have a major impact on energy business models (Rodríguez-Molina et al., 2014).

- To leverage new technologies, it is essential to understand the implications of these developments on both existing and new energy business models, especially since the latter can increase economic value. These new models help organizations to gain insight into their market position and to innovate because they outline and simplify the way a company creates and captures value (Paukstadt, Strobel, Eicker, 2019).

- The following section highlights the research gap and formulates the central research questions of this work.

1.2 Relevance and Derivation of the research gap

Studies on smart energy business models are of great importance to understand their different structures and components as well as to discern their mutual influence. However, little research has been conducted on this topic as we have noticed in our extensive literature research (outlined in the second and fourth chapters).

In fact, the role and importance of technologies in the energy sector has been the subject of several scientific papers. However, their impact on economic models, the resulting applicable maturity model, as well as the interdependence and mutual influence between the different applications have remained mostly overlooked. In addition, most of the scientific studies that have addressed this topic are focused on a specific application, such as "smart home" (Andraschko et al., 2021; Balakrishnan et al., 2018; Kim et al., 2021), or „smart grid" (Rodríguez-Molina et al., 2014). Based on a search of academic literature, we realized that only two studies (Chasin et al., 2020; Paukstadt et al., 2019) treated the different smart energy business models as a whole. But then again, (Paukstadt et al., 2019) mainly targeted the residential sector and ignored the industrial or commercial sectors for example. Furthermore, the question of sustainable development was not clearly addressed in (Paukstadt et al., 2019). However, (Chasin et al., 2020) addressed the missing aspects in (Paukstadt et al., 2019) from a practitioner's point of view, it has also analyzed the building blocks of smart energy business models as well as the potential of smart energy technologies. While this study certainly provides a more comprehensive overview of smart energy business models, it does not offer a practical approach to classifying real-world objects into different categories to better understand the practical similarities and differences among the different business models.

These observations underscore the importance of conducting a detailed and clear study that aims to gain a first and deeper insight into the adoption of smart systems in the energy sector, hence the creation of smart energy business models. More comprehensively, this research has the particularity of providing a more in-depth overview of the status of smart business models in the energy sector, an emerging question that is treated as a single entity in our study, i.e. by combining several aspects of the topic from different perspectives: an economic perspective dealing with the economic aspects of smart energy Business Models (BMs), a technical perspective dealing with the different enabling technologies and a societal perspective dealing with their sustainability. In this sense, it participates in the achievement of one of the objectives that we have set for the research: providing a maturity model for analyzing and evaluating the success of companies in integrating technologies into their business models to help them later determine what capabilities they need to acquire, to improve their performance (Becker et al., 2009).

Thus, this research serves as a preliminary exploratory study and attempts to answer the following questions:

RQ1: How can smart energy business models be classified within a taxonomy?

RQ2: Which implications and recommendation can be deduced from this taxonomy to help smart energy companies identify and optimize their current situation?

1.3 Structure

The thesis is articulated in four chapters: first a theoretical background literature review Chapter 3 presents the methodology used to conduct the research. First, we present the research design, the research strategy, i.e. qualitative content analysis complemented by a strong processual approach, according to an abductive reasoning; and finally the research method, that of the multi-case study.

and, finally, the results and contributions of our research (chapter 4).

Chapter 4 explains the development process of the taxonomy by describing the first and second iterations, which are conceptual to empirical, and then the third, fourth and fifth, which are empirical to conceptual

Chapter 5 presents the development of the maturity model. Frist, we will analyse the clustering process. Second, we will present the resulting archetypes, and finally we will deduct the maturity model.

8. Conclusions and Outlook

The rise of information and communication technologies in the energy sector has led to the creation of new BMs. This taxonomy for smart energy BMs was created using an iterative manner to aid in the description, analysis, and innovation of BMs. Based on systematic and keyword-based literature review, we derive domain-specific dimensions and characteristics for our preliminary taxonomy. Then, we evaluate the taxonomy by applying it on a sample of objects. The observations are used to further develop the dimensions and characteristics. Where some dimensions/characteristics were considered useless or redundant and were completely removed, others only needed to be modified. We noticed improved, but we did not fulfill the ending conditions. These conditions were achieved at the fifth iteration and we obtained a complete and concise taxonomy.

It can be used as a platform for academics and practitioners to discuss the current state of the smart energy domain. Furthermore, because our taxonomy is extendable, academics and practitioners can edit, merge, add, and delete features and dimensions to meet their specific needs. It can encourage companies to capture the potential of integrating their business models in other fields of the energy sector which they do not yet cover. The survey taken by various specialist from concerned fields confirmed the usefulness and relevance of our taxonomy, even though we were face with various limitations that required further research steps

The first limitation to the research was that BMs of smart energy firms were examined mostly based on their websites for the empirical iteration. The classification of objects in this case is based on secondary data found on websites. As a result, some characteristics of BMs, such as revenue sources or a deep study of partnerships, can be difficult to spot. Future research in this area could help us better understand ecosystems and cooperation kinds in the context of smart energy. As brought to our intention by the participants in the evaluation survey, there are no dimensions that describe the savings potential of the smart energy BMs as well as their return on investment. We therefore recommend that these aspects be considered in future research. While we present the archetypal patterns in the smart energy field, we do not mention the reasons behind the establishment of such archetypes, which can another focus point for future research. Furthermore, the maturity model developed in our research is not general and requires every organization to define a corresponding methodology and identify its own levels.

By presenting the smart energy BM concept, the taxonomy offers descriptive knowledge to the field of domain-specific IoT BMs. By identifying the single most significant BM aspects, it also builds the conceptual foundation for future research on smart energy BMs.