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A TAXONOMY OF CONSUMER-ORIENTED SMART ENERGY BUSINESS MODELS

Ute Paukstadt
University of Münster, ute.paukstadt@ercis.uni-muenster.de

Torsten Gollhardt
University of Münster, torsten.gollhardt@ercis.uni-muenster.de

Maria Blarr
University of Münster, maria.blarr@ercis.uni-muenster.de

Friedrich Chasin
University of Münster, friedrich.chasin@ercis.uni-muenster.de

Jörg Becker
University of Münster, becker@ercis.uni-muenster.de

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Research paper

Paukstadt, Ute, University of Münster, European Research Center for Information Systems (ERCIS), Münster, Germany, ute.paukstadt@ercis.uni-muenster.de

Gollhardt, Torsten, University of Münster, European Research Center for Information Systems (ERCIS), Münster, Germany, torsten.gollhardt@ercis.uni-muenster.de

Blarr, Maria, University of Münster, European Research Center for Information Systems (ERCIS), Münster, Germany, maria.blarr@ercis.uni-muenster.de

Chasin, Friedrich, University of Münster, European Research Center for Information Systems (ERCIS), Münster, Germany, friedrich.chasin@ercis.uni-muenster.de

Becker, Jörg, University of Münster, European Research Center for Information Systems (ERCIS), Münster, Germany, becker@ercis.uni-muenster.de

Abstract

The significance of Internet of Things (IoT)-driven innovation grows in the energy sector. The use of smart energy products like smart meters promises new customer values and opens up potentials for business transformation. Against this background, traditional business models (BMs) along the energy value chain such as those of established energy utilities are challenged by a gradual shift in the energy production paradigm. Consumers can optimize their consumption and become prosumers by generating their own decentralized energy based on smart energy technologies. To capitalize on this development, businesses require an understanding of new business options and ways to exploit smart technologies. Based on both empirical and conceptual sources, we develop a taxonomy that provides a comprehensive overview of smart energy BMs. The taxonomy supports business leaders to describe and analyze important elements of smart energy BMs addressing residential customers. With new configurations of those elements, it serves as a stimulus to innovate traditional offerings along the energy value chain. Moreover, we add descriptive knowledge to the field of domain-specific IoT BMs and strengthen the conceptual fundament of smart energy BMs for future research.

Keywords: Smart Energy Business Models, Smart Grid Business Models, Business Model Taxonomy, Business Model Innovation

1 Introduction

The Internet of Things (IoT) has the ability to disrupt all areas of business and life and emerges in many forms such as smart farming, smart retail or smart home (Gartner, 2014; Porter and Heppelmann, 2014). In the energy sector, IoT is often referred to as smart energy or smart grid (Kranz et al., 2015; Georgakopoulos and Jayaraman, 2016). Smart energy includes technologies such as smart meters and intelligent battery storages which we refer to as smart energy products. These products are equipped with Information- and Communication Technology (ICT), e.g., sensors, actuators and connectivity (Porter and Heppelmann, 2014). They serve as a basis for innovative digital services, that is, smart services, which promise new values for customers (Allmendinger and Lombreglia, 2005; Porter and Heppelmann, 2014; Wünderlich et al., 2015). Smart services can enable monitoring, control, optimization and autonomous capabilities (Porter and Heppelmann, 2014; Beverungen et al., 2017).

Sophisticated smart services are capable of learning, dynamic adaptation, and improved decision making based on collected and processed data (Medina-Borja, 2015).

An illustrative case is Powerpeers (Fritz et al., 2017). The platform enables households to "select electricity from specific sources, and share self-generated electricity with others", using a complex algorithm[1]. The start-up promotes itself with connectivity, blockchain technology and a cloud-based "energy-company-in-a-box" solution. This single case characterizes several disruptive changes taking place in the energy industry: The diffusion of central power generation into thousands of small power plants, peer-to-peer energy transactions, radical innovations and alternative solutions for household customers. In sum, the digitalization is threatening all business operations of traditional energy utilities (Christensen and Bower, 1996; Allmendinger and Lombreglia, 2005; Fritz et al., 2017). Furthermore, legal regulations accelerate the dissemination of smart energy technologies. The compulsory roll-out of smart meters within the European Union forces utilities to equip at least 80% of consumers with smart meters by 2020 (EU, 2009). In contrast to that, traditional utilities experience difficulties with innovating their business models (BMs) (Chesbrough, 2007; Shomali and Pinkse, 2016). For instance, energy utilities are still mainly focusing on the provision of energy (Nillesen et al., 2014) and are challenged with assigning value to customer-focused, smart energy solutions. The shift from being a commodity provider towards being a (smart) energy service provider is necessary to stay competitive in the future (Fleisch et al., 2014; Wünderlich et al., 2015). The BM concept is considered useful for finding ways how to benefit from new technologies, since BMs can mediate between technological innovation and economic values (Chesbrough and Rosenbloom, 2002; Baden-Fuller and Haefliger, 2013). It helps companies to understand their market position and to innovate, as it describes and simplifies how a company creates and captures value (Osterwalder et al., 2005; Shafer et al., 2005; Teece, 2010).

Existing BM tools like the Business Model Canvas (Osterwalder and Pigneur, 2010) are suitable for analyzing an individual BM, but reach its limits when comparing several BMs (Peters et al., 2015). Furthermore, domain-specific frameworks and classifications allow for a fine-grained perspective on smart energy BMs with their particularities and provide a better understanding of smart energy technology-enabled BMs (Remane et al., 2016). To structure single elements of domain-specific BMs, information systems research commonly uses taxonomies (Peters et al., 2015; Remane et al., 2016).

The purpose of our research is to support practice and research with a better understanding of the emerging phenomenon of smart energy BMs in the consumer market by developing a taxonomy, which systematically considers relevant concepts from extant BM research, IoT literature and the energy domain. As smart energy infrastructures have just recently begun to enter the end consumer market (Brunekreeft, 2015; Alexander von Humboldt Institut and co2online, 2018), the taxonomy concentrates on the consumer-oriented smart energy market.

The taxonomy should serve energy companies, particularly incumbents challenged by the digitalization, to analyze and describe existing smart energy BMs as well as to identify options for configuring new BMs in the end customer segment. Specifically, it can support the generation of new ideas for innovations related to smart energy products and services based on the dimensions provided in the taxonomy. Additionally, we enhance the theoretical understanding of smart energy BMs from an IS perspective and complement descriptive knowledge in the field of domain-specific IoT BMs.

2 Research Background

2.1 The Energy Value Chain

The predominant, traditional BM in the energy industry consists of the bulk production of energy (i.e., electricity) and delivery for a specific price per kilowatt-hour. *Figure 1* illustrates the basic processes of the corresponding energy value chain (Richter, 2012; NIST, 2014).

[1] https://www.powerpeers.nl/about

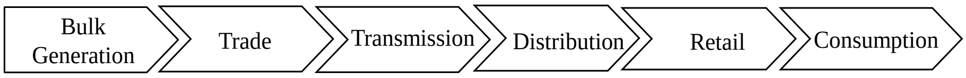

Figure 1. Traditional energy value chain. Adapted from Richter (2012) and NIST (2014).

After energy is *generated* in central bulk power plants, it is fed into the grid, eventually *traded* in electricity markets and led over *transmission* networks with high voltage towards *distribution* networks that supply the end customer with low voltage electricity. The *retail* part mainly consists of administrative tasks such as the purchase of energy from producers and traders and selling it to end customers as well as metering and billing. The last step of the energy value chain is *consumption*. With the upcoming smart grid and energy technologies, the traditional value chain undergoes several changes. Energy storages play an increasingly important role as volatile renewables constitute a higher amount of energy generation. The fluctuation in generation also leads to higher significance of the consumption process through demand side management. Moreover, new markets for trading emerge, where consumers and aggregators buy and sell energy (NIST, 2014). Private households not only consume but also generate, manage and store their own energy (and thus become “prosumers”), which opens up new opportunities to provide services for residential customers along generation, supply and consumption processes, for instance, with consultation, installation, financing, operation, maintenance, and warranties (Richter, 2012). In the future, the smart energy value chain is expected to transform into a smart energy value network due to the increase of bidirectional information flows between decentralized energy resources and actors (International Energy Agency, 2015).

2.2 Business Model Research

BMs are simplified models representing how a company creates and captures value, and thus are a template of a company’s business logic (Osterwalder, 2004; Shafer et al., 2005). They are used as a tool to describe the way a company makes profit out of its business activities (Teece, 2010) and help to make these activities and components visible, analyzable and manageable (Osterwalder, 2004).

To design and describe a BM and its components, research has proposed several conceptualizations (Zott et al., 2011). When comparing different BM frameworks (Shafer et al., 2005; Zott et al., 2011; Peters et al., 2015), it becomes clear that the components vary widely among the frameworks. However, some of the most established frameworks among them Chesbrough and Rosenbloom (2002), Johnson et al. (2008), Morris et al. (2005), Osterwalder et al. (2005) and Teece (2010) also share some common elements, particularly, value proposition, value creation, value network/delivery and cost/revenue model (Shafer et al., 2005; Zott et al., 2011; Peters et al., 2015; Remane et al., 2017). Although the single components of the frameworks differ in detail, these common dimensions are often regarded as overarching and constituting building blocks of a BM (Osterwalder et al., 2005; Peters et al., 2015).

With respect to our goal to develop a BM taxonomy, we include the following overarching dimensions and definitions: The *value proposition* refers to the bundles of products and services that are offered to a specific customer segment and the corresponding value (Osterwalder, 2004; Osterwalder and Pigneur, 2010). The *creation of valu*e is achieved through the combination of activities and resources (Morris et al., 2005; Shafer et al., 2005; Johnson et al., 2008). In recent years, the *value network* has received more attention by research of IoT BMs, since the complexity of smart products increases the necessity to collaborate with different partners, stakeholders and customers. In this regard, we refer to *value network* instead of value delivery which supports the *value creation* by integration of external resources and capabilities (Chesbrough and Rosenbloom, 2002; Shafer et al., 2005). The *value capture* component finally determines how a company generates profit by defining revenue streams and considering the cost structure (Johnson et al., 2008; Teece, 2010). In this paper, we apply the BM concept to analyze smart energy BMs and to derive the core dimensions for our taxonomy.

2.3 Smart Energy and Smart Energy Business Models

Kranz et al. (2015) define smart energy “as the use of ICTs in energy generation, storage, transmission, and consumption, aiming at increasing efficiency, encouraging eco-friendly behavior, and decreasing the emission of GHG [Greenhouse Gas]" (p.8). A smart energy system represents a cyber-physical system consisting of various sensor and actuator networks, which are integrated with the physical electricity grid infrastructure (Kranz et al., 2015). Lund et al. (2012) regard smart energy systems as the broader concept in contrast to smart grid. A smart grid is an ICT-enhanced intelligent electricity grid, that is able to integrate renewables by automatically coordinating unsteady energy production and demand (Goebel et al., 2014). Thus, a smart grid is part of an overall smart energy system that refers to several kinds of energy, not only electricity (Lund et al., 2012; Goldbach et al., 2018)

A smart energy system can also exist within a single household (Van Dam et al., 2010; Weiller and Neely, 2014). In this regard, a smart energy system can be viewed on different levels of abstraction. The intelligent utilization of home appliances is an example of a micro-level application, whereas the development of national smart grids for a more efficient and intelligent supply and distribution of energy takes place on a macro-level (Gubbi et al., 2013). The main properties of smart energy systems whether on a micro- or macro-level are bidirectional data and the intelligent utilization of information for energy management in private and public environments (Gubbi et al., 2013; Shrouf et al., 2014). Hence, smart energy can be subsumed as a topic of the IoT which assumes that every physical object becomes part of the internet, facilitating data and information flows between the environment and other objects (Fleisch et al., 2014).

To manage energy flows intelligently on a micro (household or community)-level, different smart energy products can be used. Some are consumption-oriented, whereas others focus on the production side. Furthermore, there are intelligent components to ensure the connection and integration of energy flows. *Figure 2* shows smart energy technologies relevant for the residential sector.

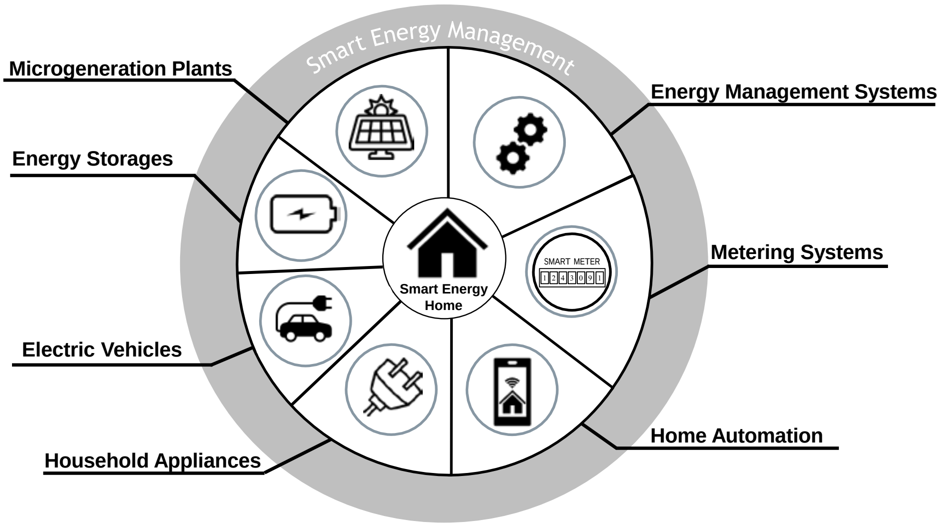

Figure 2. Smart energy management in the residential sector (smart energy home).

To assess the potential of smart energy technologies for new BMs, it is necessary to understand their underlying structure. Generic IoT architectures such as proposed by Khan et al. (2012) or Fleisch et al. (2014) are useful for this assessment. Following the proposed logic, a smart energy system can be structured in distinctive layers representing the respective components deployed and functionalities provided by the system. The layers build upon each other, and the lower layers enable the higher layer functionalities (Fleisch et al., 2014). Fleisch et al. (2014) propose a product-centric architecture which we adopted in *Figure 3* for smart energy products and services.

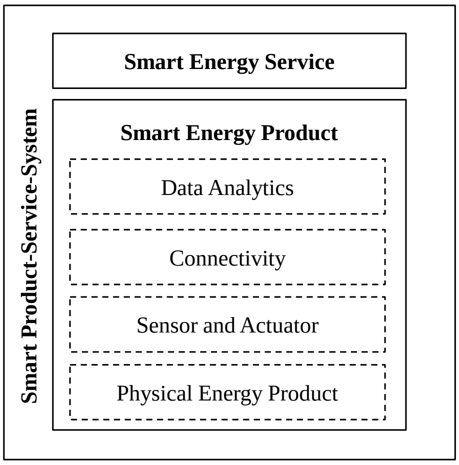

Figure 3. Smart energy product and service. Adapted from Fleisch et al. (2014).

On the bottom layer, physical objects such as thermostats are rooted. Equipped with sensors, they gather data and send information to the higher layers. Through a connectivity layer the object can communicate with the internet as well as other objects and can use cloud services for data analytics. Based on the underlying layers, which constitute a smart energy product, smart energy services can be provided to the end user, e.g., in form of smart home or demand response (DR) applications (apps). The architecture of Khan et al. (2012) also includes the business and environmental context on the highest level, e.g., BMs, which allows a holistic understanding of smart energy systems.

By combining smart energy with the BM concept, we understand smart energy BMs as *IoT-based BMs in the energy industry, that rely on smart energy products (e.g., smart meters, smart thermostats, smart lights) and make extensive use of this data-based digital technologies to create and capture value, and therefore provide customers with enhanced or new tailored energy-related values.* For instance, regarding electric vehicles (EV) we only consider energy-related BMs such as charging stations and flexibility services provided by the EV storage. Moreover, smart energy BMs can be created on different layers of the smart product architecture, e.g., by offering sensors, actuators and network assets as well as software for end-users to interact with smart products or data analytics services. In the residential consumer market, we see a reduced layer being provided to the customer: In most cases, either smart products covering the full-stack (i.e., smart energy products including smart energy services) or only higher layers such as smart energy services in form of apps for energy monitoring are offered. However, products and services for end-consumers are often co-created by underlying value networks consisting of manufacturers of physical products, sensor providers, cloud service providers, IoT platform operators and data analytics providers (Yoo et al., 2010; Turber et al., 2014; Valocchi et al., 2014). Since we concentrate on BMs directly addressing the residential customer, we focus on the end-consumer products and services and consider the ecosystem perspective only for value-creation in networks.

3 Research Method

We apply the taxonomy development procedure by Nickerson et al. (2013). It is a systematic and rigorous method and has already been proven as a useful tool to build domain-specific (BM) taxonomies (e.g., Remane et al., 2016). Within several iterations, it allows not only academic literature (conceptual-to-empirical) as a source for creating dimensions and their characteristics, but also to derive those from observations of empirical objects (empirical-to-conceptual). The method requires defining a central purpose for the taxonomy and a set of objective and subjective ending conditions, which specify when to terminate the iterative development process (Nickerson et al., 2013).

The aim is to provide companies with guidance for describing, analyzing and innovating BMs facilitated by smart energy products and services. Thus, the taxonomy is derived from all overarching BM elements, in which smart energy technologies play an essential role for the value proposition, value creation, value network and value capture for residential customers. All dimensions and characteristics have to be derived from this purpose to manifest the structural differences of smart energy BMs.

We adopt three ending conditions of Nickerson et al. (2013): Each characteristic within a dimension should be unique; each dimension is unique and not repeated; and at least one empirical object must be classified to each characteristic and dimension. The five subjective ending conditions revealed by Nickerson et al. (2013) are also respected.

For the first conceptual-to-empirical iteration we conduct a literature review. Particularly the literature mentioned in Section 4 "Characteristics of Smart Energy Business Models in the Literature" enables us to conceive initial dimensions and corresponding characteristics of smart energy BMs. For the empirical-to-conceptual approach, we set up a database of smart energy companies[2] with a focus on residential customers which we collect from common databases like Crunchbase[3], rankings of energy utilities, accelerator programs of large energy companies such as eon agile[4] as well as newspaper and blog articles identified via google search. We primarily search for start-ups, since start-ups are often more innovative than incumbents and are commonly used as empirical objects for BM taxonomies (Remane et al., 2016; Labes et al., 2017; Gimpel et al., 2018). We extract the BMs according to the offerings which means that one company can implement more than one BM. The iterations are described in *Table 1*.

As quality criteria for this research, we consider intersubjective traceability as highly important and given by the six-eyes principle. Besides, we aim at external validity by choosing an extensive number of smart energy companies and guarantee internal validity by providing the list of analyzed cases.

#	Iteration
1	**Conceptual-to-empirical:** The first iteration uses the conceptual-to-empirical approach, since the domain is an emerging field (Nickerson et al., 2013). In this iteration, we build on our literature review on smart energy BMs (Section 4).
2	**Conceptual-to-empirical:** Since the BM taxonomy is a domain-specific IoT BM taxonomy, we review IoT and corresponding BM literature (e.g., Yoo et al., 2010; Fleisch et al., 2014; Porter and Heppelmann, 2014; Dijkman et al., 2015; Püschel et al., 2016; Mittag et al., 2018). Not all objects can be classified properly in the taxonomy as some characteristics are not concise or explanatory enough.
3	**Empirical-to-conceptual:** After two literature-based iterations, an empirical-to-conceptual iteration helps to achieve a robust empirical grounding. Subsequently, three researchers independently classify 60 smart energy BMs with the majority being BMs from start-ups. Not all ending conditions can be met, further refinements to the dimensions are made.
4	**Empirical-to-conceptual:** In this iteration, 30 smart energy BMs are selected. Again, three researchers independently analyze these BMs, which leads to the successful classification of all objects in the data sample. Within this iteration, we meet the objective and subjective ending conditions.

Table 1. Taxonomy development iterations.

4 Characteristics of Smart Energy Business Models in the Literature

Within the conceptual-to-empirical approach in the taxonomy development (Nickerson et al., 2013), we conducted a comprehensive literature search on smart energy-related BMs and corresponding classifications. In the following, we group the identified literature according to specific archetypes of smart energy BMs and describe their corresponding characteristics.

Energy Efficiency with Smart Home and Smart Meters*:* A major part of the literature describes BMs offering smart homes and meters, which often include energy efficiency and saving services (e.g.,

[2] We define smart energy companies as companies which offer smart energy products and services.

[3] https://www.crunchbase.com/

[4] https://eon-agile.com/startups

Hamwi and Lizarralde, 2017). Specifically, they promise to reduce the amount of energy consumed (Behrangrad, 2015). Energy savings in smart energy BMs often rely on monitoring and control capabilities of smart meters and connected household appliances (Hall and Roelich, 2016; Bischoff et al., 2017; Hamwi and Lizarralde, 2017). A product-focused BM is the basic sale of smart devices that helps the customer to save energy, e.g., smart thermostats (Hamwi and Lizarralde, 2017).

Flexibility: Apart from energy efficiency BMs, DR-related BMs also belong to the category of demand side management. However, in contrast to energy efficiency, DR programs shift the energy load and do not necessarily lower it (Behrangrad, 2015). Particularly, DR tries to change energy usage either through energy price changes over time or through financial incentives to achieve lower energy usage at high wholesale market prices or when grid stability is at risk (US. Department of Energy, 2006). To be financially attractive, such flexibility BMs often consider the role of an aggregator. An aggregator is a company that has many contracts with customers, aggregates their loads and markets the flexibility. Customers receive a financial bonus for the provision of resources and the aggregator profits from trading those. Apart from demand side aggregation, companies can also aggregate resources on the supply side (Martin-Martínez et al., 2016). Possible ways to aggregate resources are microgrids, virtual power plants (VPPs), storage of EV fleets, or aggregation of customers. A microgrid is usually regarded as a local cluster of microgeneration, storage and loads operating as a single system (Lasseter, 2002; Martin-Martínez et al., 2016). Microgrids can be interconnected or isolated from the main grid (Dimeas and Hatziargyriou, 2005; Martin-Martínez et al., 2016). In contrast to microgrids, VPPs are virtually aggregated, and thus are not bound to a local region. EV BMs can provide flexibility through the aggregation of EV battery storages (vehicle-to-grid) or participation in DR programs where the charging process is shifted to times with low demand (Niesten and Alkemade, 2016).

Energy Trading: Brokerage BMs are similar to flexibility models and enable customers to sell energy to other parties through a broker (Rodríguez-Molina et al., 2016). There are also BMs where consumers can buy and sell resources on their own, e.g., on peer-to-peer marketplaces (Hall and Roelich, 2016).

Decentralized Energy Resources: The sale and installation of decentralized energy resources (e.g., Photovoltaics (PV)-systems and battery storages) (Hamwi and Lizarralde, 2016) is another rather product-oriented and commonly studied BM (Niesten and Alkemade, 2016). The BMs can include different contract depths such as installation, remote monitoring, predictive maintenance and optimization of PV-systems and battery storages (Knab and Rohrbeck, 2014; Helms, 2016). Another BM consists of cloud storages which are offered to residential and small commercial customers. With a cloud storage, a consumer does not need to buy a physical storage but can participate from a virtual storage for a usage fee (Liu et al., 2017).

Energy Communities: Beyond the sale of energy among peers, energy community BMs are discussed, which are groups of (mostly) prosumers who share energy resources, such as microgeneration units and storage. Energy communities exist in manifold forms: Resources can consist of a decentralized energy resources farm in a central place (i.e., microgrid) but could also be distributed, e.g., on the rooftops of private households (i.e., VPP) (Hamwi and Lizarralde, 2017). Customers can register financially or with their capacities such as energy storage or generation plants. In contrast to Hamwi and Lizarralde (2017), we do not regard grassroot or civil-society based communities as a BM unless it leads to a revenue stream for a profit-oriented company.

EV Storage and Charging: With a sole focus on electric mobility, Kley et al. (2011) present a morphological box describing options for comprehensive EV BMs including battery storage and charging infrastructure. Especially the battery and charging-related BMs are relevant for smart energy.

Beyond literature focusing on a specific energy product or service, our literature review revealed more comprehensive classifications of different smart energy BMs. For instance, Bischoff et al. (2017) present seven clusters of smart meter-based BM archetypes: DR, data hubs, VPPs, dynamic tariffs, optimized sales of electricity, smart efficiency services and smart home. In general, previous research on smart energy-related BMs does not provide classifications in terms of a taxonomy, but rather BM archetypes. Often the archetypes do not provide enough information to cover the whole BM concept which is, however, a necessary step to describe archetypes properly (Fielt, 2013). Most of the reviewed articles have used, if using a BM framework at all, the Business Model Canvas by Osterwalder et al. (2010). Moreover, it is partly difficult to identify if the authors refer to “smart” grid respectively energy BMs. The conceptualizations in literature regarding the characteristics of the BMs guided our initial taxonomy development, and thus served as the basis for the empirical iterations: By extracting the essential components described in the archetypes we derived initial elements of smart energy BMs for the taxonomy, e.g., flexibility as a central component, the differentiation between consumers, prosumers and communities and the characteristic of the offerings, which can be rather product- or service-oriented with the ownership changing among the actors.

5 Taxonomy of Smart Energy Business Models

The taxonomy of smart energy BMs consists of nine key dimensions with related characteristics (*Table 2*). They can be classified along four higher-level building blocks: *value proposition, value creation, value network* and *value capture*.

	Dimension	Characteristics				
Value Proposition	*Offering*	Only Digital Service	Digital and Physical Service	Smart Product-Service-System		
	Monetary Value	Cost Saving	Additional Revenue	None		
	Customer Segment	Consumer	Prosumer	Community		
Value Creation	*Customer Contribution to Grid*	Flexibility	None			
	Technology Purpose	Production-/ Supply-oriented	Consumption-oriented	Integration-oriented		
	Product Ownership	Customer	Focal Company	Third Party	Fractional	Not Relevant
Value Network	*Digital Platform*	Operation	Participation	Operation and Participation	None	
	Business Partnership	Cooperation	Stand-alone			
Val. Cap.	*Revenue Stream*	Transaction	Subscription	Hybrid	Unknown	

Table 2. Taxonomy for smart energy BMs (val. cap. = value capture).

The taxonomy covers the most important dimensions, along which smart energy BMs differ. Components that are identical for all BMs are not part of the taxonomy. One of those is the value proposition of sustainability, since it is part of every smart energy BM’s value proposition by definition (Kranz et al., 2015).

Since a plethora of non-monetary value propositions can be identified (e.g., comfort, convenience, lifestyle, self-sufficiency and security of supply), including non-monetary characteristics would have weakened the taxonomy’s clarity. Thus, we decided to concentrate on monetary values, which are easier to identify objectively based on website reviews, compared to non-monetary factors. Furthermore, we regard *monetary value* and *customer segment* not to be mutually exclusive. A mutual exclusive characteristic for these dimensions does not reflect the complexity of all identified BMs and the subsequent information loss would have threatened the taxonomy's purpose (Nickerson et al., 2013). The rationale for each dimension and its characteristics is explained in detail below.

Value Proposition:

Offering: The offering can comprise *only digital services*, e.g., an energy manager app. A digital service would also be a flexible tariff or DR programs, since we regard energy flows as inherent parts of all kind of offerings. It can further be a combination of *digital and physical services* which could be a predictive maintenance service for a smart PV-system sending a signal to a technician for repair tasks. The digital service would be predictive maintenance, whereas the physical (i.e., human-based) service consists of the repair service conducted by a technician. The third option is to offer a whole *smart product-service-system* consisting of a smart product, a digital service and an optional physical service (Mittag et al., 2018), e.g., a PV-system bundle with an app and a physical installation.

Monetary Value: The typical value proposition for end customers in the energy domain are *cost savings*, *additional revenues* (e.g., through DR participation), security of supply, sustainability and non-energy related values such as comfort or security surveillance in smart homes (Curtius et al., 2012; Niesten and Alkemade, 2016; Shomali and Pinkse, 2016; Tayal and Rauland, 2017). As we only consider distinct characteristics which are not common in all BMs, the taxonomy focus lies on the monetary values *cost savings* and *additional revenues*. *Cost savings* can be a result of energy savings, e.g., "Hour of Power" by Electric Kiwi. *Additional revenues* can be part of new BMs in terms of financial compensation for offering flexibility to the grid, or prosumers selling their energy on marketplaces such as "powerpeers". Similar to Turber et al. (2014) we differentiated between monetary and non-monetary values. If the value proposition is motivated only by personal values and attitude (e.g., home security) we consider the monetary value proposition as *none*.

Customer Segment: In terms of residential customers, an interesting and growing market are local energy *communities*, e.g., integrated energy systems consisting of several households to whole districts (Koirala et al., 2016). For instance, the BM of "prosumergy" addresses multi-family houses, where the owner(s) buy a PV-system and use the energy themselves and/or supply tenants. For this manuscript, *consumers* are defined as a *community* if they affiliate themselves with a *community*. At some platforms like Buzzn GmbH, *communities* either already exist or form their own groups on the platform. If producing their own energy, a *consumer* can be called as a *prosumer* (Rodríguez-Molina et al., 2014). In this taxonomy, a *consumer* willing to buy a PV-system is declared as a *prosumer* (i.e., in the BM of a company selling smart PV-systems).

Value Creation:

Customer Contribution to Grid: *Flexibility* is a valuable resource in the energy industry, since demand and supply have to be coordinated continuously. With smart energy technologies such as smart metering and controlling devices, consumers can participate in demand side management. In this regard, the active involvement of the consumer does not only increase due to his or her data like in other IoT BMs but particularly due to his or her "co-creation of value" through customer energy resources (Zwass, 2010; Turber et al., 2014). For instance, they can provide battery storage to reduce peak loads. Other options are DR programs where consumers are asked to shift their load to times with lower energy demands. In this regard, the co-creation of value refers to the customer's participation along with companies in the creation of value (Zwass, 2010). If the BM does not have any contribution in means of *flexibility* to the grid the characteristic will be *none*. In this case, a yes/no characteristic would threaten the taxonomy's extensibility, since we cannot foreclose further ways of contribution to the grid in the future (e.g., consumers could contribute with their data).

Technology Purpose: Smart energy BMs are based on smart energy technologies, which can be differentiated between *production-/supply- oriented*, *consumption-oriented* and technologies for *integration* of production, supply and consumption. Some smart PV-systems only monitor and visualize production. This would be considered as rather *production-oriented*. However, a gateway for energy management would be an *integration-oriented* technology, if it enables to actively manage the energy flows by optimizing demand and supply. A platform for an energy community, which matches consumption and production, makes use of an *integration-oriented* technology. *Consumption-oriented* technologies often refer to smart home appliances and smart meters for visualizing and influencing energy consumption.

Product Ownership: Smart products always comprise digital services (Yoo et al., 2010; Fleisch et al., 2014; Mittag et al., 2018), and therefore are product-service-systems. Accordingly, beyond the classic paradigm of *customer* ownership of products, BMs are shifting to be more usage- and performance-based models (e.g., heating or PV-system contracting) with the *focal company* or a *third party* as product owner. For instance, products like smart meters often remain the property of the *focal company*. In some BMs a smart energy product is not directly part of the BM. Thus, the product ownership is *not relevant*.

Value Network:

Digital Platform: A digital platform can be defined as a "set of digital resources including services and content that enable value-creating interactions between external products and consumers" (Parker et al., 2016; Constantinides et al., 2018). Regarding our taxonomy, a company often *operates* a digital platform, e.g., an energy community platform like Buzzn. On such multi-sided platforms, prosumers can optimize their energy portfolio and sell their own produced energy (Giordano and Fulli, 2012). A gateway with an app to integrate and connect smart home appliances is a digital platform as well. For instance, the energy manager by SOLARWATT is an open system to integrate PV-systems and large household appliances from different vendors. Companies can also *participate* in a digital platform such as an open app store for smart energy apps. A smart thermostat like "tado" *participates* through integration with smart home platforms such as google home or the apple home kit. To better understand digital platforms, it is characterized with at least two interacting parties, among them service providers and service consumers. Regularly, there is a third party *operating* the platform.

Business Partnership: In smart energy BMs there is an increasing necessity to collaborate in business networks (Turber et al., 2014). Innovative BMs discussed in literature often position energy companies such as utilities into a wider ecosystem of actors, e.g., in the electric mobility domain or smart home and city environment (Kley et al., 2011; Giordano and Fulli, 2012). In such *cooperations*, companies can offer bundles of smart energy products and contribute on different smart product layers such as a provider of physical products, sensors, gateways, platforms and/or apps for energy visualizations (Turber et al., 2014; Valocchi et al., 2014). We only considered rather closed business networks between companies as *cooperation*. For instance, Innogy GmbH works together with different companies to offer a full bundle of PV-system (Heckert Solar GmbH), battery storage (VARTA AG), power inverter (KOSTAL Solar Electric GmbH) and energy manager (Innogy GmbH)[5], which is a close business *cooperation*. In contrast to that, SOLARWATT is regarded as *stand-alone*, since they do not communicate fixed *cooperations* with specific companies.

Value Capture:

Revenue Stream: Pay-per-function and other usage- and performance-based pricing models are realized beyond the basic sale of smart products leveraging more recurrent payments (Hui, 2014; Chan, 2015; Anke, 2018). These payments depend on the actual usage, and thus are *transactional*-based payments, whereas *subscription*-based payments are regular time-based payments regardless of usage (Gimpel et al., 2018). Sometimes both *transactions* and *subscriptions* are offered in combination (*hybrid*), e.g., in the case of energy communities, which may have a monthly subscription fee and require paying a transaction fee for surplus energy needed from an external energy provider. Moreover, we added the characteristic *unknown* to the revenue stream, since in some cases evidence was not available in the data.

[5] https://www.innogy.com/web/cms/de/3894880/fuer-zuhause/energie-selbst-erzeugen/photovoltaik-aus-sonne-wird-strom/photovoltaikloesungen-von-innogy/

6 Empirical Illustration and Discussion of the Smart Energy Business Model Taxonomy

The results of the classification lead to the assumption that, even with smart energy BMs, the structure of the energy domain remains conventional in many aspects. About two thirds of BMs are *stand-alone* solutions, give product ownership in *customers*' hands and almost as many have a standard *transaction* as their revenue stream. Although many offer *smart product-service-systems*, the underlying BM structure has not changed yet to "Smart Energy-as-a-Service". A typical offer is likely to address a *consumer*, offering *cost savings* with a *consumption*-oriented technology (such as smart home solutions), not contributing any *flexibility* to the energy grid. From a business perspective, only about one third is involved in any type of value network. All smart energy companies that were studied are listed in *Table 4* (Appendix).

In the following, three cases that were part of our analysis are shortly described (*Table* 3): First, an energy manager by Watty, which illustrates a *smart product-service-system* in a traditional setting. Then we have chosen the energy community by Buzzn and an intelligent energy storage by Caterva, which both belong to the outstanding one third of innovative BMs.

Dimension	**Case 1: Watty**	**Case 2: Buzzn**	**Case 2: Caterva**
Short BM Description	Energy Manager	Energy Community	Intelligent Energy Storage
Offering	Smart Product-Service-System	Digital Service	Smart Product-Service-System
Monetary Value	Cost Savings	Additional Revenue	Cost Savings; Additional Revenue
Customer Segment	Consumer	Community	Prosumer
Customer Contribution to Grid	None	None	Flexibility
Technology Purpose	Consumption-oriented	Integration-oriented	Integration-oriented
Product Ownership	Customer	Not Relevant	Customer
Digital Platform	None	Operation	Operation and Participation
Business Partnership	Stand-alone	Stand-alone	Stand-alone
Revenue Stream	Hybrid	Subscription	Hybrid

Table 3. Empirical illustration.

Watty (Energy Manager): The Watty box (physical product) and the corresponding app (digital service) is a *smart product-service-system* for controlling and optimizing the energy consumption. In addition to the Watty box, the customer needs to *own* a smart meter, which is not part of the BM per se. By optimizing energy consumption, the *consumer* can save energy, which can lead to *cost savings*. The customer needs to pay a monthly fee (subscription) and a one-time setup fee (transactional). Thus, the revenue stream is *hybrid*.

Buzzn (Energy Community): Buzzn provides an alternative for households producing energy and feeding-in surplus energy. By joining an energy (local or virtual) *community*, a prosumer can supply other *community* members with electricity. This BM offers a *digital service* without a physical product, although the BM relies heavily on physical products (e.g., a PV-system), which the prosumer has to own in the first place. Furthermore, Buzzn *operates* several *communities*. We consider these communities as platforms, in which prosumer and consumer participate. In case the prosumer owns a smart meter, it is free, otherwise a *subscription* fee has to be paid. The revenue stream on consumer-side is hybrid, which is common for electricity tariffs in Germany.

Caterva (Intelligent Energy Storage): Caterva Suns are smart energy storages for PV-systems. In addition to the energy storage system (*owned by the customer*), all storages are connected to a virtual energy storage system, which we understand as a *platform*. *Prosumers* can save energy respectively *save costs* by using the smart energy storage. Moreover, it is possible to generate *(additional) revenue* by participating in a partner program, where prosumers can offer *flexibility* in exchange for monetary benefits. Caterva *operates* a virtual energy storage system and *participates* by generating profit with the provided *flexibility*. The revenue stream is *hybrid*, since the customer needs to purchase smart energy storage (transaction) and to pay an annual fee as grid support (subscription).

7 Conclusion and Further Research Steps

The emergence of the IoT in the energy sector fosters new BMs. To support the analysis, description and innovation of BMs, this taxonomy for smart energy BMs was developed in accordance with a systematic development approach (Nickerson et al., 2013). To the best of our knowledge, this is the first taxonomy on smart energy BMs, since other research has primarily presented archetypes. The BM taxonomy considers domain-specific particularities and provides more elementary components for BM analysis than general frameworks such as the Business Model Canvas (Osterwalder and Pigneur, 2010). This facilitates analysis and description of a company's own BM, its competitors and finally to identify new options for innovation. By combining different characteristics in the taxonomy, companies can generate new ideas for BMs. Moreover, it allows the identification of white spots which have not been occupied by other companies (Peters et al., 2015). Furthermore, the paper contributes to the emerging research on how the digitalization in form of the IoT affects traditional industries; in this case, the energy industry (Porter and Heppelmann, 2014). To attain more relevance and test the usefulness of the taxonomy (Nickerson et al., 2013), we plan to evaluate and revise it with industry experts (e.g., in workshops) and apply the quality criteria proposed by Nickerson et al. (2013).

The research is constrained by some limitations. For the empirical iteration, BMs of smart energy companies were analyzed primarily based on their websites. In this regard, the classification of objects relies on secondary data available on websites. Thus, some aspects of BMs such as revenue streams or a detailed analysis of cooperations are difficult to identify. In this regard, future research could deepen the understanding of ecosystems and cooperation types in a smart energy environment. As the field of smart energy is an evolving domain, the taxonomy needs regular updates to be useful in the future (Nickerson et al., 2013). Another limitation is due to the practical domain maturity. In several areas (e.g., vehicle-to-grid, DR, data-based products, data- and advertising-related monetization), research on smart energy-related concepts is far more advanced than real-life conditions, especially in countries, such as Germany, where the compulsory smart meter rollout has not started yet. For instance, many existing smart energy BMs are rather product- than service-oriented. Moreover, we could not find smart energy BMs which rely only on non-monetary payments through advertisement or data. Neither performance-based financing options for smart energy technologies are common in the residential sector. In this regard, future research could enhance analysis of innovative data-driven smart energy BMs as well as more innovative ways of monetization like ad-funded product recommendations. Furthermore, not every new configuration in the taxonomy necessarily would be prosperous, and a BM configuration that may be successful for one company may be unsuccessful for another. Therefore, future research could develop success indicators for specific BMs and BM configurations.

In conclusion, the taxonomy adds descriptive knowledge to the field of domain-specific IoT BMs by illustrating the smart energy BM concept. It further strengthens the conceptual fundament for future research on smart energy BMs by assessing the single important BM elements. We thus hope that our research will foster and encourage more work on the important topic of smart energy BMs.

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Appendix

ID	Name	Website	ID	Name	Website
1	ambihome	https://www.ambihome.com/	40	Lo3	https://lo3energy.com/
2	Anyware	https://www.anyware.ag/	41	Merten	https://www.merten.de
3	Brighte	https://brighte.com.au/	42	Mixergy	https://mixergy.co.uk/
4	Buzzn	https://www.buzzn.net/	43	neeo	https://www.neeo-energy.com/
5	Caterva	https://www.caterva.de/	44	NEST	https://nest.com/
6	COMEXIO	https://www.comexio.com/	45	Netatmo	https://www.netatmo.com/
7	Comfylight	http://www.comfylight.de/	46	ohmconnect	https://www.ohmconnect.com/
8	Dajie	https://www.dajie.eu/	47	Orison	http://orison.energy/
9	DC Power Co	https://www.dcpowerco.com.au/	48	Pfalzwerke	https://www.pfalzwerke.de/
10	deematrix Energiesysteme	http://www.deematrix-energiesysteme.de/	49	Plugsurfing	https://www.plugsurfing.com/
11	Discovergy	https://discovergy.com/	50	Polarstern	https://www.polarstern-energie.de/
12	digitalStrom	https://www.digitalstrom.com/	51	Power Ledger	https://www.powerledger.io/
13	DZ-4	https://www.dz-4.de/produkte	52	power24	https://www.northdata.de
14	Easy Smart Grid	https://www.easysg.de/de/	53	Powershop	https://www.powershop.co.uk
15	Easycharge.me	http://easycharge.me/	54	prosumergy	https://prosumergy.de/
16	easyOptimize	https://www.shine.eco/	55	Redback Energy	https://redbacktech.com/
17	eCarup	https://web.ecarup.com/	56	Rocket Home	http://www.rockethome.de/de
18	ecobee	https://www.ecobee.com/	57	SENEC	https://www.senec-ies.com/
19	Ecoisme	https://ecoisme.com/	58	sens'it Discovery	https://www.sensit.io/
20	Electric Kiwi	https://www.electrickiwi.co.nz/	59	SIGFOX Smartrail SDL	http://www.smartprocess.co.uk/
21	Eltako	https://www.eltako.com	60	Smappee	https://www.smappee.com/
22	eMotorWerks	https://emotorwerks.com/	61	Smart-Red	https://www.smartred.de/
23	Energycurb	https://energycurb.com/	62	SMUD	https://www.smud.org/
24	EnergyHub	https://www.energyhub.com/	63	solaredge	https://www.solaredge.com/de
25	Enviam	https://www.enviam.de/	64	Solarfox	https://www.solar-fox.de/
26	Envuco	https://envuco.com/	65	SOLARWATT	https://www.solarwatt.de/
27	enyway	https://www.enyway.com/de	66	SOLshare	https://www.me-solshare.com/
28	EWE	https://www.ewe.de/	67	Somfy	https://www.somfy.de/
29	Free Energy	http://www.free-energy.com/	68	Sonnen	https://sonnen.de/
30	Fresh Energy	https://www.getfresh.energy/	69	Tado	https://www.tado.com/de/
31	Greenely	http://www.greenely.se/	70	TEQ Charging	https://www.teqcharging.com/
32	GreenSynergy	https://www.greensynergy.de/	71	TESCOL ONE	http://www.tecsol-one.com/fr
33	gridBox	https://gridx.de/	72	Ubritricity	https://www.ubitricity.com/
34	homeNow	http://homenow.at/	73	Varta	https://www.varta-storage.com/
35	Honeywell	https://www.honeywell.com/	74	Voltstorage	https://voltstorage.com/
36	Innogy	https://www.innogy.com	75	Wattcost	https://www.wattcost.com/
37	Innogy	https://www.innogy.com/	76	Wattio	https://wattio.com/en/
38	KUGU Home	https://www.kugu-home.com/	77	Watty	https://watty.io/
39	Lichtblick	https://www.lichtblick.de/			

Table 4. Smart energy companies that were analysed.

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