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RESEARCH PAPER

Uncovering the business value of the internet of things in the energy domain – a review of smart energy business models

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Abstract

In the energy industry, Internet of Things technologies emerge in the form of smart energy products, like smart meters, which are expected to reveal new business potentials and offer value for customers. Through attractive business models, such technologies can generate economic value. However, until now, the existing research has not comprehensively identified, analyzed, and grouped together smart energy business models. Moreover, the literature has not placed smart energy business models under the concept of smart products and services. To address this gap, we review the literature through an information systems lens and assess the status quo of research on smart energy business models, identify relevant business model types, and propose a research agenda for future research on Internet of Things-based business models in the energy sector.

Keywords Smart energy · Smart grid · Smart energy business models · Smart grid business models · Internet of things business models

JEL classification Q40 · L94 · L86 · O32 · M10

Introduction

Since the Internet of Things (IoT) manifests in many forms, such as smart farming, smart retail, or smart homes, it has the ability to disrupt all areas of business and life (Porter and Heppelmann 2014). In the energy sector, the IoT is often discussed in the context of smart energy or smart grids (Georgakopoulos and Jayaraman 2016; Kranz et al. 2015). Smart energy includes technologies such as smart meters and intelligent battery storage, which we refer to as smart energy products. These products are equipped with information and communication technology (ICT), e.g., microprocessors, sensors, software, and network communication (Porter and Heppelmann 2014). They serve as the basis for innovative digital services, that is, smart services, which promise to offer new value for customers (Allmendinger and Lombreglia 2005). Smart meters, for instance, enable smart energy services—such as energy consumption visualizations and recommendations—to help customers to reduce their energy consumption (Geelen et al. 2013). Recent trends like 5G, cloud computing, blockchain technology, and artificial intelligence further empower smart connected energy systems. For instance, 5G technology enhances the connectivity by enabling real-time transactions, data analytics building on artificial intelligence is conducted in the cloud and blockchain technology secures (even small-scale) energy trading services (Kim et al. 2019).

Along with this digitalization leveraging intelligence in the energy system, the importance of decentralized energy production particularly as a result of governmental policies is increasing (Brunekreeft et al. 2015). Hence, the hierarchical structured power grid is shifting toward a decentralized grid with bidirectional information flows, the so-called smart grid (Farhangi 2010). This decentralization and digitalization threatens basically all

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traditional business operations of utilities and gives rise to new competitors, e.g., the blockchain startup, Powerpeers,[1] which operates a digital interactive peer-to-peer (p2p) marketplace for self-generated energy (Fritz et al. 2017). Consequently, these new technologies and services are enhancing or replacing existing conventional energy sector processes and technologies (Christensen and Bower 1996; Fritz et al. 2017), and smart products and services now have the ability to shift the role of technology away from process automation alone toward creating completely new business models (BMs) (Fichman et al. 2014; Teece 2010). They are particularly changing the way organizations communicate and interact with customers, exchange information, and conduct business (Kranz et al. 2015; Wünderlich et al. 2015). The BM concept is considered useful for finding ways to benefit from new technologies since BMs can leverage technological innovations to enter markets, satisfy undiscovered customer needs, and thus transform technological potential into economic value (Baden-Fuller and Haefliger 2013; Chesbrough and Rosenbloom 2002). Hence, BMs for smart energy technologies are a decisive factor when trying to gain a competitive advantage in changing energy sector market conditions. Set against this background, we focus our research on innovative smart energy BMs by studying the current literature on BM research in the smart energy environment. We aim to address the following research questions (RQs):

RQ 1: Which smart energy BMs are discussed in the literature?
RQ 2: How does the literature address smart energy BMs?
RQ 3: Where are future research opportunities regarding smart energy BMs?

By following established guidelines in information systems (IS) research for conducting a literature review (Vom Brocke et al. 2009), and by drawing on the BM concept, we identified different BM types for smart energy technologies discussed in the literature. In the past, the literature produced several reviews on energy-related BMs (Engelken et al. 2016; Richter 2012). Although some reviews include smart grid BMs (Bryant et al. 2018; Burger and Luke 2017) or focus on single aspects of smart grid BMs (Bhatti and Danilovic 2018; Bischoff et al. 2017; Niesten and Alkemade 2016), smart energy BMs as a whole have not been reviewed. Moreover, the BM literature has not been reviewed through an IS lens and by drawing on smart product and IoT research (Porter and Heppelmann 2014; Turber et al. 2014; Yoo et al. 2010).

Our literature review delivers an up-to-date overview of research on smart energy BMs and identifies several gaps for future IS research. Moreover, our conceptualization of smart energy (BMs) extends the understanding of the domain and contributes to the body of knowledge of IoT in the energy sector from an IS perspective (Kranz et al. 2015).

The next section provides relevant background information on the underlying concept of BMs, the energy value chain, and smart energy by referring to literature on smart products and the IoT. In the research methodology section, we explain our research approach to the literature review before synthesizing and presenting our findings. Building on this, we identify and discuss research gaps. Finally, the last section sums up our findings.

Theoretical background

As we seek to identify the current state of smart energy BM research, an understanding of the general BM concept and the changing energy value chain serve as a prerequisite to explain smart energy and corresponding BMs in a following step. This section introduces relevant background knowledge on smart energy BMs, the main concepts of which have already been included in a published conference paper (Paukstadt et al. 2019).

Business model research

BMs are simplified models representing how a company creates, delivers, and captures value, and thus they are the template of a company's business logic (Osterwalder 2004; Teece 2010). They are used as a tool to describe how a company makes a profit out of its business activities (Teece 2010) and help to make these activities and the corresponding components visible, analyzable, and manageable (Osterwalder 2004). Further, studying BMs can help to ease change, assess new BMs, and improve the current way of doing business (De Reuver and Haaker 2007; Osterwalder and Pigneur 2002).

To design and describe a BM and its components, researchers have proposed several conceptualizations (Zott et al. 2011), such as Osterwalder and Pigneur's (2010) and Teece's (2010) BM frameworks. Building on Teece's (2010) framework, BMs are structured according to three components: *value creation*, *value delivery*, and *value capture*. *Value creation* is achieved through the combination of activities and resources (Johnson et al. 2008; Morris et al. 2005; Shafer et al. 2005) and includes the value proposition, which addresses customer needs and defines the customer relationship (Osterwalder 2004). *Value delivery* describes how a company delivers the value to its customers (Johnson et al. 2008). The *value capture* component finally determines how the company earns money and makes a 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 the current state of smart energy BM research in the extant literature, i.e., how it is applied to the smart energy domain. Particularly, we are interested in literature presenting smart energy BMs in form of important components, representations and classifications.

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

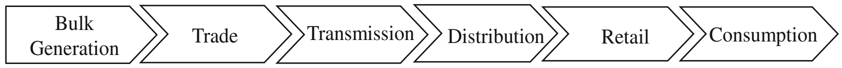


Fig. 1 Traditional energy value chain. (Adapted from NIST (2014) and Richter (2012))

The energy value chain

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

After energy is *generated* in central bulk power plants, it is fed into the grid, eventually *traded* in electricity markets, and led over high-voltage *transmission* networks toward *distribution* networks that supply the end customer with low-voltage electricity. So-called transmission system operators operate the transmission networks and distribution system operators operate the distribution system. 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*.

In the future, the energy value chain is expected to transform into a smart energy value network due the growing importance of consumer resources and decentralized production (Shomali and Pinkse 2016). Although this development requires smart technologies and there has been a progress in specific fields of the smart energy domain, e.g., the smart meter roll-out in many countries, the complete transformation towards a smart grid or even a smart energy value network takes more effort and time (IEA 2019).

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 gases]" (p. 8). Lund et al. (2012) consider 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 and coordinates the unsteady energy production with 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 (Goldbach et al. 2018; Lund et al. 2012). A smart energy system can exist on a business or household level, and therefore it does not necessarily need to be connected to the overall power grid (Van Dam et al. 2010; Weiller and Neely 2014). Consequently, a smart energy system can be viewed on different levels of abstraction. The intelligent utilization of home appliances to support a household's energy efficiency is an example of a micro-level application, whereas the development of smart grids for a more efficient and intelligent supply and distribution of energy by suppliers may lead to fewer resources required on a macro level (Gubbi et al. 2013). The main properties of smart energy systems are bidirectional flows of data and the intelligent utilization of information for energy management (Gubbi et al. 2013; Shrouf et al. 2014). To intelligently manage energy flows, various smart energy products can be used as shown in Fig. 2. Some of the smart energy products are rather consumption-oriented, for instance, smart home systems help to reduce the own energy use, whereas intelligent energy generation plants focus on the production part of the value chain and enable customers to produce their own energy.

To assess the full potential of smart energy technologies for new BMs, it is useful to have a better understanding of their underlying structure by applying generic IoT architectures, as proposed by Yoo et al. (2010) and Fleisch et al. (2014). Following this logic, Fig. 3 structures smart energy products in distinctive layers representing the respective components deployed and the functionalities provided by the system. The layers build up on each other with the lower layers enabling the higher layers' functionalities (Fleisch et al. 2014).

Physical objects, such as thermostats, are rooted on the bottom layer. 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 it 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 the form of smart meter applications.

Smart energy products serve as boundary objects for smart energy services by integrating resources and activities of the company and the customer for mutual value. For the case of a smart meter, the benefit can consist of energy consumption data for the company and energy savings for the customer (Beverungen et al. 2019). Moreover, smart energy products enable different levels of service capabilities that can reach from simple monitoring to controlling, optimization towards autonomous actions (Porter and Heppelmann 2014). Since smart energy services require smart products, which in turn frequently include supporting services, e.g., the financing and installation of photovoltaic systems, we would also group these services together with smart products as smart service offerings (Niesten and Alkemade 2016; Richter and Pollitt 2018; Wunderlich et al. 2012).

Smart energy products do not only serve as a basis for new BMs that can be created along the energy value chain processes, but BMs also emerge on different levels of the smart product architecture, for instance, by offering sensors, actuators, and network assets as well as software for end users. Therefore, smart energy products and services are often co-created by underlying

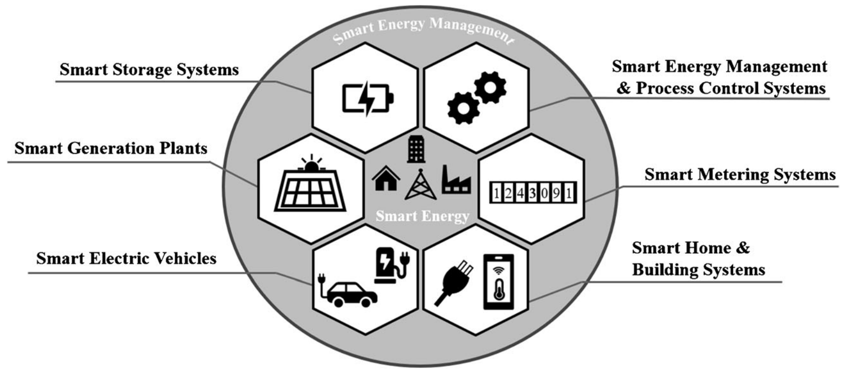


Fig. 2 Smart energy technologies. (Adapted from Paukstadt et al. (2019) and Hilger et al. (2018))

value networks consisting of manufacturers of physical products, sensor providers, platform operators, and data analytics providers (Beverungen et al. 2019; Turber et al. 2014; Valocchi et al. 2014; Yoo et al. 2010).

By combining smart energy with the BM concept, we understand smart energy BMs as *IoT BMs in the energy domain that rely on smart energy products (*e.g.*, smart meters, smart thermostats, and smart lights) and make extensive use of corresponding data-based digital technologies to create and capture value and therefore provide customers with enhanced or new tailored energy-related value.* For instance, regarding electric vehicles (EV), we only consider energy-related BMs like intelligent charging stations and flexibility services provided by EV storage. The supply of energy is also a smart energy BM if it is enriched by smart energy technologies (e.g., tailored energy plans based on smart meter data).

Research method

To answer our research questions, we conducted a comprehensive review of the literature on smart energy-related BMs. To ensure methodological rigor, IS literature reviews often follow

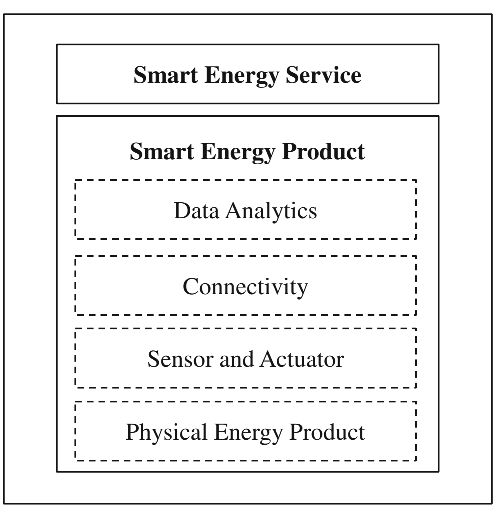


Fig. 3 Smart energy products and services. (Adapted from Paukstadt et al. (2019))

the five steps proposed by Vom Brocke et al. (2009), which we applied as well: (I) definition of the review scope (section "Introduction"), (II) conceptualization of the topic (section "Theoretical Background"), (III) literature review (section "Research Methodology"), (IV) literature analysis and synthesis (section "Literature Analysis and Synthesis"), and (V) research agenda (section "Discussion"). Since we have already defined the scope in the introduction and conceptualized the topic in the theoretical background, we describe step three—including details on the research approach—in the following. Since smart energy as a topic emerged rather recently, we restricted our search to the years 2009 to 2019 (until 27 August 2019). In our search strategy, we employed different keyword combinations by joining "smart grid," "smart grids" or "smart energy" with "business model" and "business models" in the abstract, title, and keywords fields (or if not available full text) of common databases (EBSCOhost, Web of Science, Scopus, and ScienceDirect). Thus, we used a rather small selection of keywords which, however, are the key terms of our research interest. In general, the significant literature uses the terms smart grid or smart energy. Moreover, a wider selection of research terms (e.g., local energy systems, decentral energy systems) would have led to too many (irrelevant) results and would not have considered smart technologies specifically. In addition, based on the identified key literature further important work can be found by searching forward and backward which we applied to ensure that had not overlooked relevant work (Webster and Watson 2002). Due to our IS lens and the importance of digital and IoT BMs in the IS domain, we also searched major IS journals and conference proceedings (International Conference on Information Systems (ICIS), European Conference on Information Systems (ECIS), basket of eight*)*. In total, we found 634 articles.

To filter the literature, we decided on some exclusion criteria: We restricted our scope to articles from peer-reviewed journals and conference proceedings to ensure a proper quality of the literature. As we also included conference proceedings, we evaluated each paper due to its quality and its contribution for (novel) insights on smart energy BMs. Since our research objective was to identify a comprehensive picture of different smart energy BMs, we evaluated the literature by drawing on the BM concept (i.e., how value is created and captured) and our IS perspective (i.e., smart product concept). Consequently, our research only considered papers that presented (at least implicitly) the most important BM elements, such as the value proposition and revenue stream (Osterwalder and Pigneur 2010). Furthermore, we excluded papers that did not refer to any smart technologies (e.g., presentation of pure renewable energy BMs).

An initial analysis of titles and abstracts reduced the number of articles to 159 since some articles were considered non-relevant to our research objectives or were duplicates. Articles that appeared appropriate for answering our research questions were verified by reading the full texts. In total, we identified 66 papers as relevant to our research (Table 2).

To analyze the literature and to identify relevant categories, we employed content analysis (Mayring 2010). Since our interest is in gaining an overview of smart energy BMs, e.g., in the form of classifications, archetypes, or descriptions of BMs, by using BM frameworks, we looked for structured BM presentations (e.g., by applying Business Model Canvas [Osterwalder and Pigneur 2010]). However, most of the BM research within the (smart) energy domain has not proposed structured presentations, but rather short BM descriptions with a focus on their core products and services. Therefore, we analyzed the BMs mentioned in the literature according to their value creation and assigned the BMs to categories according to their core offering: *flexibility & trade, smart home/building, smart decentralized energy resources* (SDER) (i.e., generation plants and/or storage*), p2p marketplaces & energy community, smart energy data, smart grid infrastructure, smart energy supply*, and *smart EV*.

Further, we differenced the targeted customer base according to either private households, business customers or the papers indicated no specific customer segment. To better understand how BM research has been assessed in the literature so far, we further noted the research approach applied (qualitative, quantitative, conceptual, literature review, and mathematical modelling). Empirical research can be of quantitative or qualitative nature, whereas conceptual work is based on literature and conducts analysis with theoretical (BM) frameworks. We also interpreted the presentation of concepts for research prototypes as conceptual work. Mathematical modeling applies mathematical models and algorithms (e.g., for computational simulation or optimization models) which are often used in studies for evaluation of BMs. Literature reviews use a structured approach to analyze the literature of a field (Engelken et al. 2016).

Moreover, we were interested in how the research on smart energy BMs presents the BMs, for example, by applying an established BM framework. Since most research did not use theories, we only employed a simple category and analyzed whether the paper referred to a BM concept/theory (i.e., well-known BM literature).

Literature analysis and synthesis

While the next chapter presents the different smart energy BMs derived from the literature, this chapter describes the quantitative findings according to studied smart energy BM types, customer segments and the research approach.

Quantitative analysis of the findings

Among the relevant papers, most of the literature was published in energy and sustainability journals and conference proceedings, particularly *Energy Policy, Applied Energy* and *Renewable and Sustainable Energy Reviews*. We identified only five papers from the IS domain which are published in the proceedings of major conferences (Table 1).

Moreover, in our study, we experienced an increase in the amount of publications in the last years (Table 2).

Smart energy BM types

Of the 66 papers included in this study, 47 deal with flexibility & trade BMs (Fig. 4). Among the flexibility BMs seven papers specifically study demand response BMs with consumer load and 16 papers study Vehicle-to-Grid/Grid-to-Vehicle BMs solely or in combination with other BMs. Particularly in recent years, the research presented in the literature has frequently studied p2p marketplace and energy community BMs. Less-studied BMs are smart energy supply BMs, smart energy data BMs, and smart grid infrastructure BMs.

Customer segment

In 30 of the papers included in this study, the research concentrates on the residential sector. Additionally, research aiming to provide an overview of BMs often focuses on specific customer groups, such as prosumers (i.e., consumers who produce their own energy) (Rodríguez-Molina et al. 2016), districts (Sepponen and Heimonen 2016), or private households (Hamwi and Lizarralde 2017). 18 paper address business customers, however, with a large variety in detail, for instance, industrial customers (Khripko et al. 2017), fleet operator, parking garage operator (Brandt et al. 2012), building sector (Sisinni et al. 2017), municipalities (Burger and Luke 2017), grid operator (Bischoff et al. 2017) or small businesses

Table 1 Publication domains

Journal/Conference Domain	Number of Articles
Energy & Sustainability	43
IS	5
ICT/Computer Science	10
Miscellaneous	8

Table 2 Number of research papers published per year in the sample

Year	No. of Studies	Studies
2009	2	Andersen et al. (2009); Fox-Penner (2009)
2010	1	Bache et al. (2010)
2011	4	Kley et al. (2011); He et al. (2011); Strüker et al. (2011); San Román et al. (2011)
2012	4	Giordano and Fulli (2012); Budde Christensen et al. (2012); Brandt et al. (2012); Curtius et al. (2012)
2013	6	Dave et al. (2013); Goebel (2013); Oren (2013); Vasirani and Ossowski (2013); Wagner et al. (2013); Roscher et al. (2013)
2014	5	Bae et al. (2014); Kahlen et al. (2014); Rodríguez-Molina et al. (2014); Sánchez-Miralles et al. (2014); Weiller and Neely (2014)
2015	3	Alvarez et al. (2015); Behrangrad (2015); Matusiak et al. (2015)
2016	10	Hall and Roelich (2016); Helms et al. (2016); Jiao and Evans (2016); Koirala et al. (2016); Laurischkat et al. (2016); Martin-Martínez et al. (2016); Niesten and Alkemade (2016); Rodríguez-Molina et al. (2016); Sepponen and Heimonen (2016); Shomali and Pinkse (2016)
2017	9	Bischoff et al. (2017); Burger and Luke (2017); Fang et al. (2017); Hamwi and Lizarralde (2017); Khripko et al. (2017); Liu et al. (2017); Lynch et al. (2017); Pouttu et al. (2017); Sisinni et al. (2017)
2018	12	Bhatti and Danilovic (2018); Bryant et al. (2018); Khan et al. (2018); Koirala et al. (2018); Makris et al. (2018); Massey et al. (2018); Pereira et al. (2018); Steriotis et al. (2018); Xu et al. (2018a), b); Zaidi et al. (2018); Zhou et al. (2018)
2019	10	Alshahrani et al. (2019); Grosse et al. (2019); Hamelink and Opdenakker (2019); Kalathil et al. (2019); Kim et al. (2019); Lezama et al. (2019); Paukstadt et al. (2019); Ropuszyńska-Surma and Węglarz (2019); Valtanen et al. (2019); Xu et al. (2019)

(Liu et al. 2017). From 18 papers addressing business customers five address small businesses which are often collected with private households (Liu et al. 2017). Moreover, 30 paper do not refer to any specific customer group.

Research approach

It is not surprising that 29 of the papers are conceptual papers (Fig. 5) since due to regulations and the lack of smart grid infrastructure several BMs only exist theoretically (Wolsink 2012). Some models also do not appear to be financially attractive, for example, some smart EV BMs (Weiller and Neely 2014). Therefore, 15 papers use mathematical modelling and simulations to demonstrate and evaluate the viability of a specific BM proposed. Qualitative research is often of explorative nature in form of case studies of companies or interviews with managers and experts. The research approach matches with the research focus since the conceptual and literature review papers often try to present an overview of specific BMs, while the simulation studies focus on the economic feasibility of the BM.

BM framework and BM concept

Although the research identified in the literature claims to present BMs, only 32 refer to the well-known BM literature and only 23 use a BM framework to present the BM. If using a BM framework, the literature uses the BM framework developed by Osterwalder and Pigneur (Osterwalder and Pigneur 2010). Accordingly, the vast majority of the research does not systematically describe BMs or provide information on the single elements of BMs in a structured fashion.

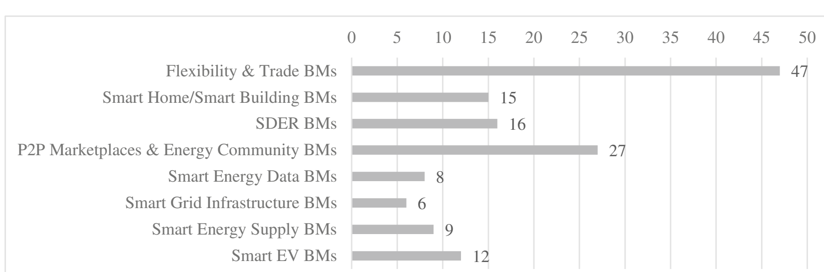


Fig. 4 Distribution of studied smart energy BM types

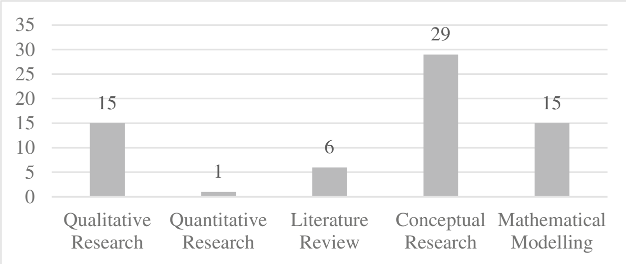


Fig. 5 Research methodologies

Smart energy business model types

In the following, we present our identified smart energy BM types that we derived from the literature. The types are arranged according to the structure of the modular smart product architecture (Fig. 6). Hence, the product-oriented BM types are explained first before the higher layers (i.e., infrastructure and service layer) are described. After the description of each BM type, we discuss the mapping of the smart energy BM types along the layered architecture.

Smart decentralized energy resources BMs

A rather product-oriented BM is the selling (or other financing types) and installing of SDER (Bryant et al. 2018; Burger and Luke 2017; Hamwi and Lizarralde 2017). The smart components implemented in the generation and storage systems enable operation and management services like predictive maintenance and remote monitoring or the optimization of energy flows in the home, commercial or industrial buildings. The efficiency and value of SDER can be further enhanced by integration to the smart grid (e.g., in terms of offering flexibility resources or taking part in energy markets) (Bhatti and Danilovic 2018; Kim et al. 2019; Matusiak et al. 2015; Niesten and Alkemade 2016; Sisinni et al. 2017). Beyond SDER being installed on the end customer side, there are also smart energy BMs dealing with SDER setup and operation of utilities and grid operators. For instance, offshore wind parks that are enhanced by smart energy technologies offer predictive maintenance and enhance the efficiency of the plants (Burger and Luke 2017; Khripko et al. 2017).

A further BM consists of cloud storage that is particularly addressed to private households and small commercial customers. Similar to other cloud BMs with cloud storage, a consumer does not need to buy and own physical storage but can participate in virtual storage for a usage fee (Liu et al. 2017).

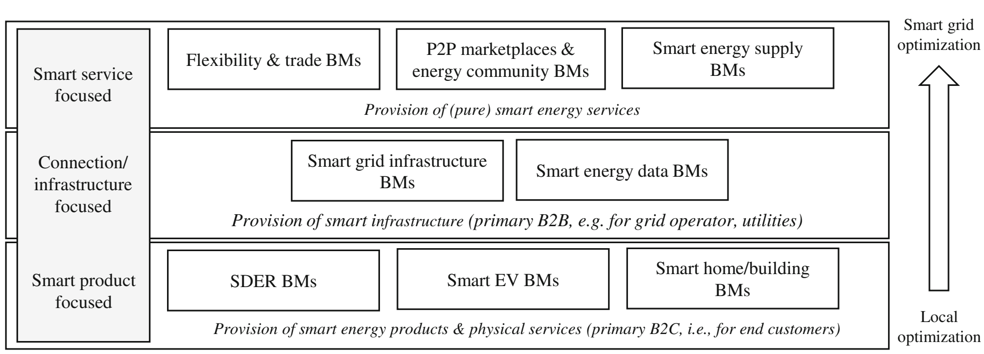
Smart home/building BMs

Another major segment of the literature describes BMs offering smart home/building and metering devices, e.g., the sale of smart thermostats and corresponding energy manager (Hamwi and Lizarralde 2017; Burger and Luke 2017). We grouped the BMs providing energy efficiency and savings services together with BMs for smart homes/buildings and metering since energy savings in smart energy BMs rely on the monitoring and control capabilities of smart meters and connected appliances (Hamwi and Lizarralde 2017). These BMs aim to optimize local energy usage in business and private environments (Burger and Luke 2017). For example, a company can provide information on energy consumption, signals regarding costs, and energy saving tips through mobile applications connected to the smart meter (Bischoff et al. 2017; Hall and Roelich 2016; Hamwi and Lizarralde 2017). Revenues are either generated based on equipment sales, software subscription fees, or (particularly for larger customers) through shared savings (a type of brokerage fee).

Smart electric vehicle BMs

With a focus on electric mobility, Kley et al. (2011) present a morphological box describing options for comprehensive (Smart) EV BMs, including battery storage and charging infrastructure. An EV battery can also be leased rather than bought (Andersen et al. 2009; Budde Christensen et al. 2012), or reused for second-life applications (Jiao and Evans 2016; Weiller and Neely 2014). As an alternative to public charging stations, intelligent battery swapping stations are suggested (Andersen et al. 2009; Budde Christensen et al. 2012; Kley et al. 2011). Energy companies also offer to install charging stations for customers (Kley et al. 2011). With an

Fig. 6 Mapping the smart energy BM types along the layered architecture



intelligent charging station, customer can monitor the optimal charging time as it informs the customer about current energy prices (Andersen et al. 2009; San Román et al. 2011). Smart EVs can be further used as storage through integration with the energy management system. This BM is referred to as Vehicle-to-Home/Vehicle as Storage (San Román et al. 2011; Weiller and Neely 2014). The charging can be integrated with renewable microgeneration units to optimize the energy flows at the customer side and/or at the grid level (Andersen et al. 2009; San Román et al. 2011). Charging facilities can be further improved by a BM for a multi-sided platform operator connecting different charging station providers (Laurischkat et al. 2016).

Smart energy data BMs

Data-related BMs include, for example, the collection of customer data and its sale to third parties (Giordano and Fulli 2012; Pereira et al. 2018; Shomali and Pinkse 2016). Further, we see BMs here that specialize in data management and analytics capabilities. Smart meter data management services can also be a BM for specific players (Strüker et al. 2011). Bischoff et al. (2017) perceive a data provider that operates a multi-sided platform bringing together utilities, power grid operators, and meter operators, and thus enables bidirectional communication and data exchange, as a BM. Revenue would be generated through a usage fee (Bischoff et al. 2017). A multi-sided platform could also allow other third parties to access the customer base and customer data in order to offer specialized energy services, software, and bundles (Shomali and Pinkse 2016; Bae et al. 2014; Valocchi et al. 2014).

Smart grid infrastructure BMs

Smart grid infrastructure BMs are primarily BMs focusing on the operation of the grid infrastructure and therefore address grid operators. These connection-oriented BMs install and manage the infrastructure for large network operations with the overall aim of power reliability (Xu et al. 2018a). Grid operation includes, for instance, infrastructure maintenance or load forecasts to ensure grid stability and bill for the costs of grid usage (Khripko et al. 2017).

To transform the overall grid into a smart grid, companies can offer installation and integration services. For example, sensors, control devices, advanced outage management, and distribution and automation systems can improve the reliability of the grid and enable it to self-heal. This service could be supplied to utilities and grid operators (Alvarez et al. 2015). Technology and data management companies could also help to integrate smart metering information into the utility infrastructure (Shomali and Pinkse 2016). In contrast to smart energy data BM types, which focus on data management and analytics as a service for external parties, we see the focus of smart grid service BMs on the setup and integration of smart grid assets in order to provide grid optimizations. As one subtype BM we consider here "utility-in-a-box" (Bryant et al. 2018) (e.g., as offered by the company Lumenaza) which are comprehensive software platforms regularly offered to utilities (known as business-to-business-to-consumer) for the provision of different flexibility services, energy efficiency support (e.g., by selling devices) trading and community sharing options for end customers (Bryant et al. 2018; Makris et al. 2018; Matusiak et al. 2015; Sisinni et al. 2017).

Flexibility & trade BMs

Flexibility is a valuable resource in the energy domain since it can be used to balance energy supply and demand, to stabilize the grid, and finally, to lower costs for the energy companies (Goebel et al. 2014; He et al. 2011). Flexibility in terms of load is often referred to as demand response. Demand response tries to change energy usage, either through energy price changes over time or financial incentives to achieve lower energy usage at high wholesale market prices or when the grid stability is at risk (US Department of Energy 2006). Demand response services can comprise incentives that are given to customers for enabling the utility to shut off their electric appliances. Other demand response services send signals to customers who respond on their own to shift their loads in exchange for financial compensation. Furthermore, some programs use flexible pricing (real-time pricing, critical/peak pricing, time-of-use pricing, etc.) to load shift (Goldbach et al. 2018; Niesten and Alkemade 2016; Salah et al. 2017). Like all smart energy BMs, demand response services rely on smart energy products, which in this case are smart meters with a visualization component and software to receive price information and can be included in the offering (Behrangrad 2015).

To be financially attractive, flexibility BMs often consider the role of an aggregator, which is a company that has many contracts with customers, aggregates their loads, and offers flexibility to the markets or to the grid operator (Burger and Luke 2017). Customers get a financial bonus for the provision of resources and the aggregator profits from selling and trading the resources. Apart from demand side aggregation, companies can also aggregate the resources on the supply side. Thus, possible forms of aggregation are micro grids, virtual power plants, storage (of EV fleets), or aggregation of customers (Burger and Luke 2017; Martin-Martínez et al. 2016). Although micro grid is a concept not clearly defined, a micro grid is normally a cluster of micro generation, storage, and loads operating as a single system (Lasseter 2002; Martin-Martínez et al. 2016). Micro grids can also be operated in isolation from the main grid (Koirala et al. 2016). In contrast to a micro grid, which is locally bound, the constituent parts of virtual power plants can be distributed and are virtually coupled (Koirala et al. 2016; Martin-Martínez et al. 2016).

Additionally, the storage of smart EVs can be used as a flexibility resource by aggregating fleets of smart EV battery storage (Vehicle-to-Grid) and selling the resources to the market or grid operators. Another option to use smart EV batteries for flexibility is to participate in demand response programs where the charging process is shifted to times when demand is lower. The intelligent charging of an smart EV is also referred to as Grid-to-Vehicle (Niesten and Alkemade 2016). An until now theoretical BM for Grid-to-Vehicle is a smart EV aggregator that exploits price differences by charging large smart EV fleets during off-peak hours and selling the charged energy at high retail prices (Bhatti and Danilovic 2018; Goebel 2013). These smart EV services require that the charging station is connected to the smart grid with an integrated smart meter and control device (Budde Christensen et al. 2012).

We included trade BMs in this category because aggregators normally trade flexibility resources to the energy market or grid operators. However, customers are also able to trade their energy resources. For example, brokerage BMs enable customers to sell their energy to other parties through a broker (Rodríguez-Molina et al. 2016). In this regard, Rodríguez-Molina et al. (2016) present different storage-based trading BMs which provide a trading software on a contract basis (either installed locally or cloud-based) to automatically purchase energy at lower rates or to sale energy at higher rates.

Since nowadays prosumers can trade and share their own produced energy with other prosumers and therefore are (almost) independent from the overall grid and utilities, we summarized these BMs in the category p2p marketplaces and community BMs.

Peer-to-peer marketplaces & energy community BMs

Digital p2p marketplaces allow customers to buy and sell their energy resources on their own (Hall and Roelich 2016). Peer-to-peer platforms for residential customers particularly profit from blockchain technology as the technology reduces the need for an intermediary and thus makes even small energy transactions viable (Pereira et al. 2018; Valtanen et al. 2019; Xu et al. 2018a). Revenues are gained by membership fees, transactions charges and value-added services (e.g., equipment sale, insurance contracts, procure aggregated load for sale in organized energy market) (Pouttu et al. 2017).

A BM type closely related to p2p marketplaces are energy communities which do not match the peers directly on an individual basis, but the matching is done by the community operator (Löbbe and Hackbarth 2017). Energy communities are groups of (mostly) prosumers who share energy resources, such as microgeneration units and storage. Energy communities can assume manifold forms, like micro grids or virtual power plants. Resources can consist of a SDER farm in a central place (micro grid), but they could also be distributed, e.g., on the rooftops of private households (virtual power plant) (Hamwi and Lizarralde 2017). Customers can register financially or with their energy generation plants and/or energy storage in a community. A utility organizing and administering the energy community on behalf of the participants can earn money via a subscription fee (Hatzl et al. 2016; Kuller et al. 2015). In the first instance, an energy community tries to meet their total demand through a local exchange within the community (Koirala et al. 2016). The energy generated is intelligently organized and at the same time supply and demand are balanced in order to optimize the energy produced (Geelen et al. 2013; Hyytinen and Toivonen 2015).

Smart energy supply BMs

This BM type is most closely related to the traditional BM of energy utilities as it still concentrates on the sale of energy to customers. It primarily optimizes internal processes through automatic and more accurate metering and billing, as well as improved purchase strategies for energy since the smart meter data enables better consumption predictions. The cost savings could also be transformed into better fare conditions for customers (Bischoff et al. 2017). Innovative energy supply tariffs can also play an increasingly important role in the future. Xu, Ahokangas, Yrjölä, et al. (Xu et al. 2018b) mention the blockchain-based solution "grünstromjeton" that enables transparent green energy supply. It monitors the energy consumption and rewards customers for consuming green energy.

Other smart energy supply BMs focus on differentiating the quality of the electricity supply as some customers might value tailored energy supply services that match their preferences, needs, and willingness to pay (Shomali and Pinkse 2016). Giordano and Fulli (2012) state that there are several options for power differentiation, like the type of energy source (renewables or fossil fuels), time of energy usage (day or night), priority of supply (critical or non-critical demand), quality (low or high harmonic distortion), etc. Furthermore, based on customer segmentation, value attributes (e.g., power quality or green premiums) can be added to the electricity commodity and bundled with other services (e.g., smart home equipment) (Giordano and Fulli 2012; Shomali and Pinkse 2016). A "energy as a service" flat rate is suggested by Bryant et al. (2018) which engages energy saving endeavors of utilities to increase their profit. Furthermore, Bache et al. (2010) propose a "delivery-by-call" energy tariff option that enables to switch the energy tariff within minutes based on sophisticated ICT.

In order to provide a quick overview on the smart energy BM types, we summarized all types with a short description in Table 3.

Table 3 Short description of the smart energy BM types

Smart energy BM Type	Short description
Smart Decentralized Energy Resources BMs	Smart decentralized energy resources like intelligent wind turbines or photovoltaic systems are sold, loaned or rented to customers making them partly or completely self-sufficient from the electricity grid.
Smart Home/Building BMs	Smart metering, home and building devices (including energy management systems) are sold, loaned or rented to customers. The devices visualize and control the energy consumption in order to achieve energy savings.
Smart Electric Vehicle BMs	Smart charging stations are sold, rented or publicly offered for a usage fee to customers. With an intelligent charging station, a customer can monitor the optimal charging time and can further use the EV storage as storage for the own produced energy.
Smart Energy Data BMs	The data collected through the smart energy technologies can be sold to third parties. Other forms of data-related BMs are the operation of a data management platform which gains revenues from usage fees.
Smart Grid Infrastructure BMs	Grid operators and utilities can also serve as a customer base for the sale and setup of smart grid infrastructure, e.g., sensors, control devices, distribution and automation systems, which improve the reliability of the grid and enable it to self-heal.
Flexibility & Trade BMs	Companies can earn money by aggregating the flexibility of customers and selling it. Trade BMs enable particularly larger customers to trade their own energy and flexibility, e.g., via a broker on the energy market.
Peer-to-Peer Marketplaces & Energy Community BMs	Peer-to-peer marketplaces and energy communities allow customers to sell and share their own produced energy to other consumers without an energy supplier as intermediary. The platforms are often managed by an operator who earns a subscription fee from the users.
Smart Energy Supply BMs	Consumers can be offered individual tariffs based on smart energy data. By using smart meters, cost savings can be achieved due to internal process optimizations and transformed into better fare conditions for customers.

While we aimed to describe single BM types, we recognized that some descriptions in the literature presented rather comprehensive and ecosystem based smart energy BMs. Giordano and Fulli (2012), for instance, concentrate on greater energy ecosystems by providing two examples: One scenario is a smart home ecosystem connected to smart metering and enables demand response as well as data-based insights for new service demands. This scenario shows that one comprehensive BM can consist of several BM types, as demonstrated in our categorization. In the case of the smart home ecosystem, it consists of the BM types smart home/building, flexibility & trade, and smart energy data. Combinations of single BMs can lead to integrated energy management solutions that can also be provided as a bundled offering. Niesten and Alkemade (2016) envisage more attractive services when combining demand response services or Vehicle-to-Grid/Grid-to-Vehicle services with the supply of renewables.

Finally, we mapped the presented BM types along a simplified layered architecture (Fig. 6) which builds on the smart product architecture presented in Fig. 3 and enables a better understanding of the interrelationships between the types. Accordingly, the BMs of SDER, smart EV, smart home/building are rather product-oriented BMs. These smart energy products are primarily sold by companies to end customers with the value proposition of energy savings and increase of self-sufficiency in the home, the office or industrial buildings. Thus, they focus on the local optimization and build the basis for more complex grid-level services (Behrangrad 2015; Burger and Luke 2017; Paukstadt 2019). The data and smart grid infrastructure BMs are placed in the middle layer since they tend to be business-to-business (B2B) oriented BMs and serve to leverage the smart grid or data-based value-added services. Building on these, pure smart energy services can be offered to the end customer which are highly digital and can be market without a smart product as well (provided that the customer already has the necessary smart energy product) (Paukstadt et al. 2019). Particularly these higher-level services with flexibility & trade BMs can contribute to serve and optimize the macro smart grid level.

Discussion

Although different studies have been conducted on smart energy BMs in the energy sector, a review of the literature reveals that several themes are either still underrepresented or not properly addressed from a BM perspective. In order to provide some insights leading to further research, we list and explain the four main shortcomings as follows:

(1) Little attention has been paid thus far to BMs with an exclusive focus on smart energy (e.g., products and services), their data-driven value and potential for new BMs.

First, due to a lack of information, it is sometimes unclear whether research on smart energy BMs only considers BMs relying on smart energy technologies, such as smart meters. Thus, future research should put more emphasis on clearly differentiating "smart" BMs from other energy BMs. In this regard, conceptual work on the IoT (Yoo et al. 2010), smart products (Porter and Heppelmann 2014), and general IoT BMs (Dijkman et al. 2015; Fleisch et al. 2014; Turber et al. 2014) helps to better characterize and systematize smart energy BMs, e.g., by using the different layers of the smart product architecture (see chapter Smart Energy and Smart Energy Business Models). Particularly, BMs focusing on the middle layers of the smart product architecture are seldomly discussed in the literature although these layers (e.g., connectivity, data analytics and platforms) leverage important B2B BMs such as provision of security solutions and IoT platforms for smart energy. Apart from smart grid infrastructure and smart energy data BMs less studied BMs are also smart energy supply BMs.

Moreover, research on smart energy BMs (or at least with smart energy BMs comprising a part of the study) often neglects capabilities imposed by smart products, such as data analytics and the consequent data services. For instance, consider the example of innovative cross-selling services. The energy consumption data could be used to identify impending home appliance breakdowns and suggest replacement purchases. First approaches can be found in the real world such as the value-added service by Fresh Energy, a smart meter company for automatically ordering dishwasher tabs.[2]

Furthermore, we experienced that the energy domain almost exclusively considers the IoT in the energy sector as a solution for the overall grid optimization and to enhance sustainability by using flexibility services. However, from a business-oriented perspective, it is also worth to serve the individual customers with their local energy management (e.g., sale of smart home equipment for energy saving purpose without the necessity to participate in smart grid services) and further value-added services (e.g., assisted living).

Further, to identify how smart energy BMs can enable their disruptive potential, Giordano and Fulli (2012) suggest to deepen the research on greater ecosystems and multi-sided platforms for the energy sector. Here, BMs from other domains such as electronic commerce could be analyzed in order to apply principles to the energy sector. Moreover, the collaboration between the different actors such as utilities and ICT companies and their roles in such ecosystem BMs could be further investigated.

In addition, a focus on single important BM elements such as innovative revenue streams that are enabled by data collection would be interesting. Revenue streams like shared savings and performance-based contracting that reward companies and customers for their energy efficiency are already established in the business sector (Burger and Luke 2017), but they could be increasingly applied to the residential sector as well, as data collection is becoming more cost-effective and finely granular.

(2) Little research has systematically studied (smart) energy BMs under the umbrella of the BM concept.

Second, previous research on smart energy BMs mostly has not studied smart energy under the umbrella of the BM concept (Al-Debei and Avison 2010; Osterwalder and Pigneur 2010). Most of the research which is from the energy domain concentrates on mathematical optimizations demonstrating profitability of BMs or discussing policy issues. Another big amount of literature presents research prototypes with their corresponding BMs and the evaluation of the BMs. Consequently, there is a paucity of research systematically describing and analyzing (smart energy) BMs in the energy sector against the background of the BM concept (Rodríguez-Molina et al. 2016). Thus, research should put more emphasis on considering the BM concept in their studies. This also helps to better understand the value creation logic of the proposed BMs and helps to identify options for BM innovation (Lambert 2015).

(3) There are no rigorously developed and overarching classifications (e.g., taxonomies, value networks) of available smart energy BMs.

Third, future research should deepen the development of classifications of IoT BMs for the energy sector (e.g., by building on our proposed categories). Trying to differentiate the BMs based on one characteristic makes it impossible to categorize them without overlap. For example, energy communities can only share energy within the group; however, their resources could also be aggregated and marketed as a flexible resource. Additionally, energy communities could sell their resources on their own in p2p marketplaces. Set against this background, and to better systematize BMs, a classification of single elements and characteristics in the form of a taxonomy is a promising research approach. One taxonomy on smart energy BMs has recently been published in a IS

[2] https://www.energate-messenger.de/news/188098/fresh-energy-startet-mehrwertdienst

conference proceedings and classifies different smart energy BMs for the residential customer segment (Paukstadt et al. 2019). This taxonomy helps to describe and analyze current smart energy BMs for private households on the market. A taxonomy can also be used to derive and describe BM patterns and archetypes, i.e., how the archetypes are configured based on specific BM elements. In turn, this would ensure that the archetypes are comparably and comprehensively described (Lambert 2015). Further BM taxonomies could be employed to identify white spots for new BMs and thus are a tool for BM innovation (Peters et al. 2015). Another useful form of classification which concentrates on dynamic aspects and actors in BMs are value networks which are already applied in other domains (Pousttchi and Hufenbach 2011; Riasanow et al. 2017) and could be particularly interesting due to the increasing importance of ecosystems within the energy sector and across domain boundaries.

In terms of classification categories, it could be fruitful to assess the BMs according to their maturity and profitability. Giordano and Fulli (2012) argue that smart energy technologies should not only be used as an additional component in the BM but should exploit the systemic effects so that their disruptive impact can be captured. However, not all BMs may be transformed to a profitable standalone BM. For instance, Bischoff et al. (2017) consider energy efficiency services not as a separate BM, but as a BM extension. Nevertheless, the BM can contribute in terms of added value. For example, Beckel et al. (2014) highlight the importance of smart meter data to tailor campaigns and products and services such as energy efficiency measures to specific customers which are really interested in the respective offering. Accordingly, a more direct customer interaction and better energy saving advice could improve customer satisfaction and finally customer retention which is more and more important due to the market liberalization and emerging competition. Therefore, research could determine if a BM can be profitable as a standalone model, as an extension or in combination with specific other BMs. Further, BMs can be studied according to their level of market maturity. For example, Weiller and Neely (2014) assessed the market maturity of EV BMs by assigning different BMs according to whether they are already available or in the near time. The market maturity could be referred to in terms of analyzed country-specific regulations, technological progress and technology diffusion and the time frame of the (possible) realization, e.g., near time or (far) future. This approach could especially be useful for practitioners to identify already possible BMs.

(4) Few empirical investigations have been conducted by studying existing smart energy BMs in start-ups or incumbent companies or by investigating customer demands for new BMs.

Fourth, more empirical research to identify already existing BMs or to assess the needs and requirements of customers could help to better understand already realized smart energy BMs and to design new BMs.

Similar to Burger and Luke (2017) and Bryant et al. (2018) research could conduct larger empirical investigations on existing BMs since there are already innovative start-ups and corresponding BMs which might not be covered by previous research on smart energy BMs.

Furthermore, recent research has begun to study marketplaces particularly for the household level and smaller facilities which is not surprising since large industrial and business customers tend to trade their energy on their own or participate in demand response programs more easily due to higher capacities and financial gains (Burger and Luke 2017). Hence, with the emergence of smart energy technologies, direct (p2p) energy trading, sharing options and flexibility services are now becoming more attractive for smaller customers, as well. A customer group worthwhile to study here are small and medium sized companies as they are often overseen by energy companies (Burger and Luke 2017). This is predominantly interesting since the research often concentrates on small scale customers that can also include small companies aside from households.

Finally, Fig. 6 is a conceptualization that is derived from the literature and builds on logical argumentation (Wilde and Hess 2007). Thus, we hope to see more empirical work on this, e.g., to prove and evaluate the interrelationships of the parts in a case study.

Conclusion

The IoT is expected to be the next wave of disruption, giving birth to new competitors, changing current business operations, and generating new customer demands. Since the IoT has already gained ground in the energy sector under the umbrella of smart energy, the energy industry needs to embrace smart energy technologies and the corresponding new BMs. Against this background, we asked which smart energy BMs have been discussed in the literature so far (*RQ 1*) and how has the existing research addressed them (*RQ 2*). Since the literature has not always taken a structured approach to describing BMs, we classified the BMs according to their core offering to identify commonly used BM types. The majority of the smart energy BM research deals with different demand response services and the aggregation of resources (e.g., loads, SDER, and smart EV), which is not surprising since most research is published in energy and sustainability journals. Building on the findings and the shortcomings in the literature, we addressed *RQ3* and derived options for future research on smart energy BMs. As highlighted in a special issue on smart energy in *Electronic Markets* a few years ago, IS scholars in particular can contribute in a plethora of ways to research on smart energy innovation (Kranz et al. 2015)—in this case, smart energy BMs. Consequently, we identified options for future research in terms of BM taxonomies, more detailed archetypes, classification categories, adaptation of concepts from other domains (e.g., a proper application of the smart product concept), and more empirical investigations of smart energy BMs. Additionally, future research could focus on data-driven BMs for smart energy technologies or could develop innovative BMs for smart energy by drawing on other domains, for instance, marketplaces (from e-commerce) and sharing economy approaches (such as *Airbnb* or IoT applications from the manufacturing industry).

Therefore, the overview of the as-is state of smart energy BMs in literature might serve researchers and practitioners as a starting point for in-depth studies of specific models and the development of new BMs.

The paper has some limitations. Even though we followed a well-established guideline for carrying out our literature review, we cannot guarantee that we found all the relevant literature. However, our overall objective was not to identify the whole of the existing literature, but to identify key scientific literature that covers a wide range of smart energy BMs. Moreover, the literature review is only a snapshot and reflects our decision making, for instance, by defining certain exclusion criteria or choosing the selection of databases. Furthermore, instead of looking for different BM types, the literature could have been analyzed with a different focus (e.g., regulatory issues). Due to the lack of proper descriptions it was sometimes difficult to identify and classify the BMs. In general, trying to differentiate and describe smart energy BMs is a complex task since BMs are partly challenging to isolate. Thus, not all categories could be arranged without any overlaps. Additionally, as we tried to cover a broad range of different smart energy BM types, we could not discuss every detail of the single smart energy BMs.

Notwithstanding, we are convinced that our literature review provides a useful overview of the different smart energy BMs and offers new insights into the topic to encourage more IS work on this important research topic.

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