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ORIGINAL ARTICLE

Creating Value From Energy Data: A Practitioner's Perspective on Data-Driven Smart Energy Business Models

Friedrich Chasin[1] · Ute Paukstadt[1] · Patrick Ullmeyer[2] · Jörg Becker[1]

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Abstract Along the energy value chain where produced energy is delivered for consumption within individual households, physical devices are being replaced by smart and connected products referred to as the Internet of Things. These smart products generate large volumes of data that can enable new data-driven business models. In the energy sector, consumers produce data by consuming energy, which is monitored and controlled by different smart energy products like microgeneration units or home automation devices. Although smart energy business models have been subject to academic research, the business value of data, which is created from smart energy products, remains unclear. Against this background, the paper presents a practitioners' perspective on the data-driven potential of smart energy technologies for new business models, the constituting elements of these business models, and the challenges associated with their implementation. By doing this, we provide trajectories for the future of the energy industry and draw guiding implications for developing data-driven smart energy business models.

Keywords Data-Driven Business Models · Energy Data · Smart Energy Business Models · Smart Energy

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✉ Ute Paukstadt
ute.paukstadt@ercis.uni-muenster.de

[1] European Research Center for Information Systems (ERCIS), University of Münster, Leonardo Campus 3, 48149 Münster, Germany

[2] 48155 Münster, Germany

1 Introduction

The energy industry is undergoing a fundamental change. The underlying reasons are manifold: the politically aspired energy transition leads to a steady shift from using conventional power plants towards decentral sources of renewable energy (Weltenergierat 2017). Commodity sales become part of a competitive market environment that is driven by the liberalization of the energy sector. Focusing on automation and optimization of the existing processes is no longer sufficient to serve lucrative business areas in the increasingly digitalized future (Amit and Zott 2012; Bucherer et al. 2012; Ibarra et al. 2018; Parida et al. 2019).

Innovative business models, especially those making use of data, have already been able to demonstrate their potential in various industries such as *Airbnb* in the lodging market and *Uber* in the transportation market. The capability to make use of data when developing innovative data-driven business models is essential for utilities and other actors in the energy industry to adapt to the market and counter the shrinking margins of the traditional energy business (Duncan 2010).

Along the energy value chain ranging from the production of energy to the consumption within consumers' premises, physical devices are being replaced by smart, connected products referred to as the Internet of Things (IoT). This new type of device is equipped with sensors, software, interfaces, and connectivity components (Porter and Heppelmann 2014) allowing them to capture and process all different kinds of data and to communicate with each other. This makes smart devices one of the most promising data sources for data-driven business models within the energy industry. The market penetration of smart and connected devices is expected to grow continuously (Newman 2018). Legal regulations play a crucial role in this process and accelerate the rapid dissemination of smart energy technologies, as can be seen in the case of the compulsory roll-out of smart meters in Germany (Bundesnetzagentur 2019).

Although smart energy business models have been subject of academic research (e.g., Rodríguez-Molina et al. 2014; Bischoff et al. 2017; Burger and Luke 2017; Bryant et al. 2018), little attention has been paid to the business value of data (e.g., for new business models) which is being created from smart energy technologies (Paukstadt and Becker 2019). One exception is the research by Shomali and Pinkse (2016) who refer to the literature base to analyze how data from smart grid technologies can be used for value creation, value delivery, and capture, for instance, by customizing the own offerings or selling the data to other actors. It remains open how companies in the energy sector evaluate the value of data themselves for new business models and how they plan to create new data-driven values for consumers.

Research assumes that companies at the retail-side of the energy value chain might most like to benefit from the new data-driven potential compared to companies without end consumer interactions (Shomali and Pinkse 2016). Moreover, the end consumer market as the last part of the energy value chain is competitive and, hence more open to new approaches (Weiller and Pollitt 2016). Focusing on this customer segment might, thus, be particularly attractive for research on data-driven business models building on smart energy technologies (i.e., data-driven smart energy business models).

Due to the novelty of the research on smart energy technologies for the end consumer market, academia has not yet provided explanation models and other theoretical constructs helping to better understand and explain the phenomenon of data-driven smart energy business models in the end consumer segment. Thus, this research serves as an explorative preliminary study and asks the following research question:

> How can data generated by smart energy technologies be used to create data-driven business models targeting the end consumer market?

To answer the research question, we conducted an explorative interview study with industry experts. The results were synthesized to depict the landscape of data-driven smart energy business model design options and to derive implications for business model design.

We first conceptualized consumer-oriented data-driven smart energy business models by referring to the academic literature. Then, we conducted nine explorative semi-structured interviews with a diversified set of experts. We enriched and verified the experts' arguments by academic research and referred to the corresponding findings in the discussion section. The comparison of the literature results and expert statements made it possible to differentiate which stated business model ideas are really new and which are already widespread in practice and scientific discourse. In particular, the little-observed value propositions and the resulting business models offer starting points for in-depth studies. After discussing the essential findings and drawing implications for research and practice, we sum up our research.

2 Research Background

The following section introduces the concept of smart energy products and services and provides relevant background information on data-driven business models. The combination of these notions enables us to conceptualize data-driven smart energy business models with the focus on the value for end consumers. It serves as a foundation for the interviews.

2.1 Smart Energy Products and Services

Smart energy encompasses the generation, storage, transmission, and consumption of energy by making use of information and communication technologies (ICT). Its rationale is to foster efficiency, eco-friendly behavior, and decreasing the emission of greenhouse gases (Kranz et al. 2015). The term energy is not limited to electricity but can also comprise other forms of energy such as heat, hydrogen, or biofuels (Lund et al. 2012).

Smart energy products and technologies can be all different sorts of physical energy-related devices with IoT capabilities such as smart meters, smart meter gateways, smart thermostats, energy management systems, electric vehicles, home automation systems, microgeneration systems, and energy storage systems among others (Strengers 2014; Schneider et al. 2013).

Their characterizing feature is the fact that these devices are being equipped with sensors and/or actuators enabling the collection of data and/or physical interaction with the environment. Through connectivity interfaces and data analytics, the collected data is processed and analyzed in the cloud and finally used to create smart energy services, for example, providing a detailed overview of individuals' energy consumption or needs-based maintenance service for a photovoltaic system (Fleisch et al. 2014; Porter and Heppelmann 2014). When bundling the service with other services or physical devices, a holistic smart energy product can be offered. Such smart energy products and services have the potential to enhance existing business models or even create new business models in the energy and neighboring domains (Paukstadt et al. 2019).

2.2 Business Models

In the business model research, there is no universally accepted business model definition. Instead, a variety of different business model definitions can be found (Morris et al. 2005). Most of the analyzed business model frameworks cover the aspects of value proposition or offering, key resources, customer segments, revenue streams, cost structure, and competition (Chesbrough and Rosenbloom 2002; Hedman and Kalling 2003; Morris et al. 2005; Osterwalder and Pigneur 2010). The major difference between the mentioned frameworks is their lens. Some focus on the importance of the strategic fit within the competitive environment (Chesbrough and Rosenbloom 2002; Hedman and Kalling 2003; Morris et al. 2005), whereas

Table 1 Underlying Business Model Conceptualization

Customer value	Value proposition/offering	Customer value describes all products and services which create value for the targeted customer segments (Osterwalder and Pigneur 2010)
Infrastructure	Key partnerships Key activities Key resources	The infrastructure describes the overall architecture of the company's value creation (Richter 2013) including the network of assets, suppliers, partners, required tasks, and activities that make the business model work (Osterwalder 2004; Osterwalder and Pigneur 2010)
Revenue model	Cost structure Revenue streams	The revenue model describes the interplay of the costs that are required in order to deliver a value proposition and the revenue streams which are generated by offering the value proposition to the customers (Osterwalder 2004; Osterwalder and Pigneur 2010; Richter 2013)
Customer interface	Customer relationship Customer segments Distribution channels	The customer interface describes the overall interaction between the organization and the customer consisting of the relationships established to the customer segments, the customer segments themselves as well as the communication with them (Osterwalder 2004; Osterwalder and Pigneur 2010; Richter 2013)
Competitive strategy	Competition	The competitive strategy comprises the strategic positioning of the organization within the market (Morris et al. 2005) and the strategy of how the organization plans to gain and hold an advantage over rivals (Chesbrough and Rosenbloom 2002)

others emphasize the customer interface (Osterwalder and Pigneur 2010), or highlight the importance of the value network (Chesbrough and Rosenbloom 2002). For the manuscript, a business model is being referred to as “the rationale of how an organization creates, delivers, and captures value” (Osterwalder and Pigneur 2010) and how it is strategically positioned within the market (Morris et al. 2005). In this regard, we do not only rely on the company-centric framework of Osterwalder and Pigneur (Osterwalder and Pigneur 2010) but also consider the strategic and external business model aspects. The latter might play an essential role, especially in the case of emerging markets and markets in upheaval like the smart energy market. The business model conceptualization in Table 1 integrates the perspective of the company-centric business model concept with the competitive strategy and serves as a basis for the manuscript.

2.3 Consumer-Oriented Data-Driven Smart Energy Business Models

Data-driven business models can be referred to as business models that build on data as a core resource (Hartmann et al. 2016). However, data does not need to be the only essential resource of a business model. It is important to understand *what* kind of data is being used and *how* it is going to impact the business model. To answer the first question, Table 2 shows different types of data.

A basic differentiation is the source of data, which can be internal and external of the focal company (Brownlow et al. 2015). Internal data can be further categorized into already existing data, for example, data currently stored in Information Technology (IT) systems and self-generated data, for example, obtained through customer tracking on the web (Srivastava et al. 2000). External data can be broken down into data open to everybody, that is free and publicly available, into customer-provided data, and into acquired data that needs to be specifically requested from customers or commercial third-party providers.

The second question is how data can alter a business model. Companies include data into their business models in order to achieve at least one of the following goals: Either they use data to follow a customer-centric approach striving for a higher service orientation by creating innovative value propositions, or they use data to follow a company-centric agenda aiming for the improvement of their internal productivity (Zolnowski et al. 2016). As this manuscript concentrates on creating value for end consumers, the internal productivity perspective is not in the center of the paper.

For the customer-centric perspective, Schüritz and Satzger (2016) identified three different ways in which data can be used to alter a business model. The three data-driven business model modifications enhance and adapt the value proposition, which is visible for the end consumer:

Table 2 Types of Data Based on the Data Taxonomy by Hartmann et al. (2016)

Data	Internal data	Existing data
		Self-generated data
	External data	Acquired data
		Customer-provided data
		Free available data

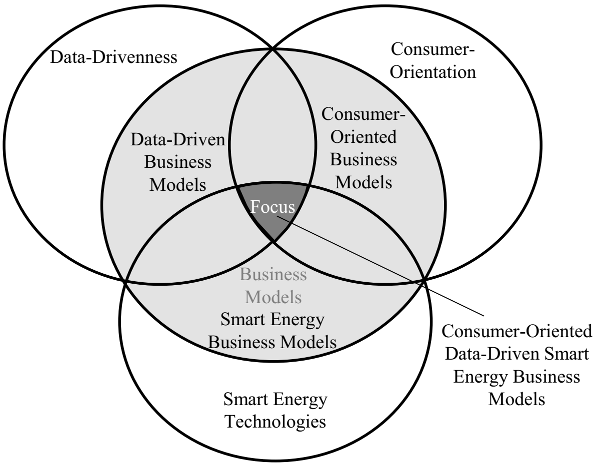
The first business model type uses data and analytics to innovate the value proposition by delivering additional value to customers, for example, by using external data. The initial value proposition is enhanced through an extra data analytics-driven service. Customers are not charged for the added values. The company profits from strengthening customer loyalty or from the differentiation from competitors (Schüritz and Satzger 2016).

The second type of data-driven business model uses data and analytics to innovate the value proposition by flexibly adapting the value capturing in response to the customers' behavior. Instead of offering the additional value for free, it improves the value capturing (i.e., the revenue stream). One example in the energy domain is to offer flexible and individual prices by rewarding or punishing customers based on their behavior when availing themselves of specific services (Schüritz and Satzger 2016).

The third relevant data-driven business model makes use of data and analytics to develop entirely new value propositions that are decoupled from the original business and purely rely on the usage of data and analytics. These innovative services are usually beyond the hitherto established core business of an organization but might still contribute to them (Schüritz and Satzger 2016). One example is to sell captured data or analytics to an external third-party organization (data-as-a-service, analytics-as-a-service), and in return for the data, the customer could be offered cheaper tariffs (Chen et al. 2011).

The focus of this paper is on a combination of the previously mentioned elements (i.e., smart energy, business models, data-drivenness, and consumer orientation). Smart energy business models are domain-specific business models in the IoT, for example, the sale of smart energy storage systems including a smartphone application for energy management. In this example, the business model would also be consumer-oriented, as it is aimed at end customers. In addition, data-drivenness requires that the focus of these business models is on generating added value from data (e.g., the sale of data or the use of data for value-added services). Accordingly, Fig. 1 helps to understand consumer-oriented data-driven smart energy business

Fig. 1 Consumer-Oriented Data-Driven Smart Energy Business Models



models as IoT business models that use data generated by smart energy devices and other data sources to create a new or improved value proposition for end consumers.

3 Method

To gain insights about current and future data-driven business models in the smart energy market, nine exploratory semi-structured expert interviews have been conducted. The interviews employed a set of pre-developed guiding questions in an open form as recommended by Kaiser (2014, p. 2–6) and Saunders et al. (2007, p. 312).

The experts have been identified by browsing corporate websites and corporate publications, such as white papers and have been selected based on the guiding questions by Gorden (1975, p. 196 f.). A set of 40 experts has been requested for interviews via email. Nine experts accepted the interview requests. All interviews have been conducted as telephone interviews. The audio recorded duration of the interviews ranges from 32–55 min with an average duration of 41 min.

We have selected a wide range of different companies in the energy domain to identify the most diverse ideas for data-driven business models. Another selection criterion was the experts' experience with consumer-oriented smart energy business models since their company offers or is involved (e.g., as a partner) in end customer related business models or plans to offer consumer-oriented offerings. For instance, energy suppliers regularly implement consumer-oriented business models such as offering energy tariffs, smart home systems, or smart photovoltaic systems. Moreover, due to the enormous change in the energy value chain, traditional companies in the energy supply chain reconsider their current role in the chain and consider tapping into new end consumer markets (Nillesen and Pollitt 2016; Shomali and Pinkse 2016). Table 3 gives an overview of the anonymized interviewed expert set. The range of functions in which the experts are working ranges from executives (chief executive officer (CEO), chief information officer (CIO), chief technology officer (CTO), director project leader) over specialists (product manager) up to cus-

Table 3 Overview on the Interviewed Employees (P1–P9 are the unique identifiers (IDs) to indicate the single Interviewees)

ID	Function of interviewed employee	Focus of the organization	Number of employees
P1	Smart grid sales director	Powerline and data communications	51–100
P2	Product manager	Energy visualization and management	11–50
P3	Platform director	Energy services	>10,000
P4	Solution architect	Energy services	251–500
P5	Product manager	Energy visualization and management	51–100
P6	Principal consultant	Peer-to-peer energy platform	11–50
P7	Project leader virtual power plants	Energy supply	>10,000
P8	CEO	Management consulting	11–50
P9	CIO/CTO	Peer-to-peer energy platform	51–100

tomer-centric problem solvers (principal consultant, solution architect). The set of organizations ranges from small startups to multinational companies.

The interviews used guiding questions which served to catalyze the interviews and gave the interviewees enough space to portray their stances and bring in the subjects relevant to them. The interview questions were influenced by the existing literature on smart energy business models and data-driven business models. The experts were asked about different types of data that the organizations can generate, process, and capture based on smart energy technologies. Another question aimed at the experts' view on the future potential of IoT technologies for the consumer-oriented energy sector. The interview questions further aimed at getting insights about the value of data and how data can be used to alter business models and create and deliver new services and products. Moreover, the experts were asked to describe the challenges implied by that. This is concluded by allowing the experts the opportunity to speak about potential business models in the future and speculate about the future of their organization and the industry itself.

We used content analysis for interview coding and interpretation (Krippendorff and Weber 1987; Julien 2008). The content analysis describes "the intellectual process of categorizing qualitative textual data into clusters of similar entities, or conceptual categories, to identify consistent patterns and relationships between variables or themes" (Julien 2008, p. 120). All nine interviews have been transcribed using the simple smoothed transcription method, according to Dresing and Pehl (2013). This method relies on intentional simple and easily learnable transcription rules, which smoothen the language significantly and focus on the contents of the speech (Kuckartz et al. 2008, p. 27).

The content analysis process of Mayring (2010) was employed to analyze the interview systematically. The elements of a data-driven business model, as defined in Sect. 2.3, were used as a starting point for the first theory-driven structuring dimensions, that is customer value, infrastructure, revenue model, customer interface, and competitive strategy. The author's knowledge from the domain of smart energy business models was also used to support the coding of the findings. This ensured that the knowledge generated by the interviews was backed up by the literature and employed known categories where possible and reasonable. For instance, the value propositions partly build on commonly used groups in the smart energy domain: energy visualization, home automation, self-produced energy. Another topic category that emerged during the coding process of the interview data were challenges that go along with consumer-oriented data-driven smart energy business models that can serve as an inhibitor or a catalyst of business models.

One author was in charge of the coding, while the other two authors repeatedly reviewed and checked the coding. The previous coding was discussed by the three authors and adapted where necessary. In a first iteration, the transcripts have been subdivided into thematically coherent sections, which were then assigned to a suitable category or sub-category. If a part could not be assigned to an appropriate category or sub-category, a new category or sub-category has been created. After every iteration, the categorization system and the definitions have been revised and sections have been recategorized if necessary. Four iterations were necessary to achieve a result which all three authors agreed to. As a final step, the categorized passages have been extracted, interpreted, and consolidated according to the underlying categorization system. In this context, scientific literature was used as well in order to support the expert's arguments (Mayring 2010).

Although the interviewees mentioned some interesting facts on general business model innovation topics regarding necessary competencies, error culture and organizational changes of energy suppliers, we omitted these parts in this paper as they were not in the center for answering of our research question.

4 A Practitioner's Perspective

The next section synthesizes the findings from the interview data supported by academic research, which can be regarded as a vision for data-driven smart energy business models and is also depicted in Fig. 5 (see Appendix). Fig. 2 lists the percentage frequency with which the main categories appeared in the interviews for these identified topic categories. It shows that the interviews are mainly dominated by the topics of customer value, the underlying infrastructure to deliver the value, and the competitive strategy, for example, how the companies are trying to position themselves within the market. In the following, we go into detail to the findings that helped to answer the research question.

4.1 Customer Value

The experts mentioned ten value propositions that address different consumer needs, such as autonomy, transparency, and energy efficiency. The value propositions are grouped according to the three data-driven business models from Schüritz and Satzger (2016) introduced in Sect. 2.3. In the following, the value propositions are described.

4.1.1 Data-Driven Value Propositions as Added Value

Consumption Visualization This value proposition aims at aggregating energy consumption data and processing it in order to present customers with a detailed

Interview topic coverage	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**
Business model element related contents									
Customer value	17%	20%	33%	31%	25%	28%	33%	16%	22%
Infrastructure	24%	17%	31%	22%	25%	17%	31%	16%	30%
Competitive strategy	22%	35%	13%	27%	12%	21%	10%	22%	10%
Customer interface	2%	9%	5%	4%	15%	11%	6%	14%	14%
Revenue model	0%	4%	9%	6%	12%	11%	10%	4%	14%
Other contents									
Challenges	34%	15%	11%	8%	12%	11%	12%	26%	10%

Fig. 2 Interview Topic Coverage

visualization of their energy consumption on a website or within a mobile application [P6, ll.37–61][1]. This value proposition is based on the monitoring capabilities of smart products (Porter and Heppelmann 2014) by providing energy monitors that are connected to the households' smart meter (Giordano and Fulli 2012; Geelen et al. 2013).

Home Automation The value proposition of home automation concentrates on the customer need of comfort increase [P9, ll.181–205], time-saving, and efficiency improvement [P7, ll.240–247]. The experts expect "small, sharp, low-energy use cases in the IoT environment," combining on-site sensor technology with specific background algorithms to save time for customers [P7, ll.240–247]. These value propositions can build on energy management systems and smart home devices that are offered to control devices and the energy consumption at home (Bischoff et al. 2017; Burger and Luke 2017).

4.1.2 Data-Driven Value Propositions Enhancing the Revenue Stream

Self-Produced Energy The value proposition of self-produced energy addresses the customer's wish for autarky and autonomy, thus independence of external energy providers. These customers often also have an increased eco-friendliness due to higher efficiency and cost savings compared to regular energy supply [P6, ll.162–181]. This can be achieved, for example, by operating a photovoltaic system in combination with an energy storage system and selling residual current to the smart market [P3, ll.161–166] (Burger and Luke 2017; Bryant et al. 2018).

Energy Communities The value proposition of energy communities has many faces: peer-to-peer energy trade, local communities, and virtual power plants (the three main types are explained in the Appendix, Table 5). These energy communities match and group prosumers[2] and consumers so that the energy demand and supply are balanced among the peers (Koirala et al. 2016; Löbbe and Hackbarth 2017). Thereby, the energy communities address the wish for transparency regarding the energy origin, for consuming eco-friendly energy, and the desire to become independent from utilities by sharing electricity within a regional or virtual community and enabling a mutual supply of electricity between prosumers and consumers [P7, ll.285–292].

Demand Side Management The use of decentralized renewable energies increases the need to balance between the unsteady electricity production and consumption [P3, ll.100–116; P1, ll.144–149; P4, ll.373–390]. Due to the unpredictable nature of electricity, consumers are activated to provide flexibility of their energy-related resources (e.g., load, photovoltaic systems, electric vehicle batteries, battery storages) to stabilize the grid. This is also referred to as demand response

[1] The interview IDs (P1–P9), together with the lines (ll.) of the transcript serve as evidence of the corresponding statements.

[2] Prosumers are consumers producing their own energy (Rodríguez-Molina et al. 2014).

or, more general, demand side management (Behrangrad 2015; Bischoff et al. 2017; Burger and Luke 2017). The value proposition of demand side management leverages saving potentials for consumers by flexibly managing the consumers' energy production and consumption according to the state of the grid using smart energy technologies [P2, ll.261–266; P9, ll.313–372]. One option for demand side management is to introduce flexible tariffs, which dynamically change according to the energy demand (Faruqui et al. 2010; Shomali and Pinkse 2016). In case of oversupply and negative electricity exchange prices, consumers could charge their energy storage systems for free [P6, ll.66–67] and uncooperative consumers could be charged significantly higher rates when overstraining the grid [P4, ll.393–401].

Beyond the consumers' own four walls, a variety of possible applications and intersections to other industries can be developed. For example, when offering a public supercharging station, the understanding of consumers' refueling behavior is crucial. It enables the service provider to know when to buy the energy and whether it is possible to market the flexibility [P7, ll.296–308].

Temperature-as-a-Service/Innovative Energy Supply Assuming the majority of customers is not interested in continuously supervising their room temperature manually, it is reasonable to offer customers the value proposition of a specific room temperature-as-a-service instead of selling them sources of energy such as oil, gas or electric current [P3, ll.576–600]. Similar research refers to energy-(supply)-as-a-service by guaranteeing to supply a specific level of heat, lighting, cooling, which can be facilitated by the collected data (e.g., from smart meter) (Fox-Penner 2009; Giordano and Fulli 2012; Shomali and Pinkse 2016). Interviewee P3 mentioned a pilot project where all units of an apartment house have been equipped with various smart energy equipment including smart meters, thermostats, window contacts, and door contacts including a central heating system. In this project, tenants only pay for their actual room temperature in comparison to the outside temperature. This service creates a value proposition for several parties: due to the smart energy technologies, the energy consumption is transparent and efficient, customers have the ability to change their desired room temperature within a mobile application. Additionally, the management and control of the central heating system are optimized due to the collected data leading to an overall reduction in energy consumption and lower prices for the customers [P3, ll.576–600].

4.1.3 Data-Driven Value Propositions Beyond Energy

Assisted Living An assisted living service remotely monitors people in need of assistance such as elderly or disabled people and comfortably alerts relatives if necessary [P5, ll.306–316]. This service might be attractive for municipal utilities that can make use of their position of trust within the region [P3, ll.556–569]. Data is collected from smart meters and further available smart energy appliances and analyzed to identify patterns in energy consumption and to detect noticeable deviancies in the behavior of the monitored people. Based on that, an algorithm makes assumptions about the possible reasons for these deviancies and informs relatives if required. High demand for such a service is estimated from housing associations [P8, ll.187–195] and people with relatives in need of care [P8, ll.299–309].

Anomaly Detection of Smart Energy Systems The ability to automatically detect irregularities and anomalies in the energy consumption of a household can also be used to perform benchmarks by comparing the consumers' smart energy devices to other structurally identical devices [P2, ll.275–278]. Based on the type of device, the respective data patterns can be further enriched with other data, for example, weather-related data in order to get a better understanding of variable dependencies [P2, ll.240–245]. One application example is the monitoring of privately-owned photovoltaic systems. The identified energy production data patterns can be used to detect the declining performance of the photovoltaic system automatically. Building on this, the intelligent system can give recommendations for actions and countermeasures (e.g., via an application) to the operator of the system like cleaning the plant to increase its performance [P4, ll.196–217; ll. 221–252]. A service provider could also offer predictive maintenance services by proactively sending a technician or switching off assets (Byun et al. 2011; Wu et al. 2012; Porter and Heppelmann 2014).

Data-Driven Cross-Selling When load profiles of electrical devices can be captured and analyzed, it is possible to identify appliances with remarkably high energy consumption. Apart from informing customers about their energy consumption, recommendations for a more efficient replacement device can be provided. This recommendation can include a calculation of the customer's capital expenditure for a new equipment, the customer's possible savings, and the break-even point in case the customer decides to invest in such a new device with higher energy efficiency [P2, ll.252–261]. The linking of energy usage information of a consumer with other supplementary information for product recommendations can be regarded as a cross-selling service [P9, ll.181–205]. Cross-selling services are not limited to the home environment but can also be used for non-physical applications such as partnerships with insurances, allowing for cheaper household insurances. The latter can be interesting in case the customer enables the company to supervise his or her smoke detectors [P5, ll.281–293].

Data Sales to Third Parties In the banking sector, consumers can use mobile applications that offer contract optimizations based on account movements, living conditions, payment behavior, and creditworthiness of the customer. Similar applications could make use of the detailed energy consumption data of customers to optimize the electricity tariffs for the customers [P8, ll.168–179]. Moreover, the mobile application provider could sell the customer data to third parties allowing for lower prices for the customers [P8, ll.183–186]. Other players from the internet business might also be interested in the insights that can be drawn from actual energy consumption data, such as deriving the number, age, gender, behaviors, and habits of the people living in a household [P8, ll.180–188]. If a consumer consents to regularly passing on his data to a third party, the associated earned revenues can be shared with the customer by providing energy visualization equipment for free or giving discounts (Shomali and Pinkse 2016).

4.2 Infrastructure

In terms of infrastructure the predominant topics are **data**, the (underlying technical) **platforms** and the **key partnerships**.

The interviewees describe the different kinds of **data** they currently use or intend to use as a resource for further analysis and for enhancing their business models. To cluster the data types, the data taxonomy is used (see Sect. 2.3). The data sources in Table 6 (Appendix) are only a snapshot of the status quo. The trend towards the IoT is constantly monitored and the organizations are looking for new types of data, which might have the potential to enhance their services [P2, ll.203–210]. For all gathered data, the main prerequisite is that the data is subject to analysis and evaluation. The experts agree on the fact that data in itself has no value at all and the value can only be gained by making use of the data [P3, ll.354–356; P7, ll.310–312]. Energy consumption related data can be "the backbone of one's own four walls" [P8, ll.186–188] allowing for deep insights into the life of the inhabitants such as waking up and going to bed patterns if captured and made sense of [P8, ll.183–185].

As the key infrastructure element, all interviewees regard a **platform** architecture as important for their organizations to make sense of the data. The research backs it and discusses the need and value of platforms for the empowerment of smart energy business models (Giordano and Fulli 2012; Niesten and Alkemade 2016; Hamwi and Lizarralde 2017). An extreme view of one interviewee is that offering energy-related products and services is "only possible with a platform business" [P9, ll.177–178]. A smart energy platform allows the processing of different kinds of data from different decentral sources in a central place [P3, ll.9–13] and allows a wide range of applications (visualization and monitoring functions, demand and consumption matching, demand side management and control functions) [P6, ll.5–9]. A modular platform architecture is particularly useful since not all added values that might be important in the future can be named and quantified as of today. The advantage of a platform is that it offers flexibility and can quickly be adapted and extended based on upcoming future requirements [P1, ll.184–186; ll. 306–308].

Apart from the resources (i.e., data and platforms), **partnerships** play a key role for the infrastructure of a data-driven smart energy business model. Especially in business-to-business-to-consumer (B2B2C) models where IT companies and utilities "are sitting in the same boat on different sides," [P3, ll.503–504] strong trustful partnerships are vital because IT companies depend on the utilities and utilities require the know-how of IT service providers (Shomali and Pinkse 2016). Collaboration can lead to a win-win situation for both parties if executed successfully [P3, ll.500–504]. For instance, an essential reason for partnerships between smart grid infrastructure providers offering smart meters and IT companies is the discrepancy between their primary interests. While grid operators aim at keeping the infrastructure stable, the interest of digital service providers is to optimally deliver smart energy services to customers [P1, ll.431–440].

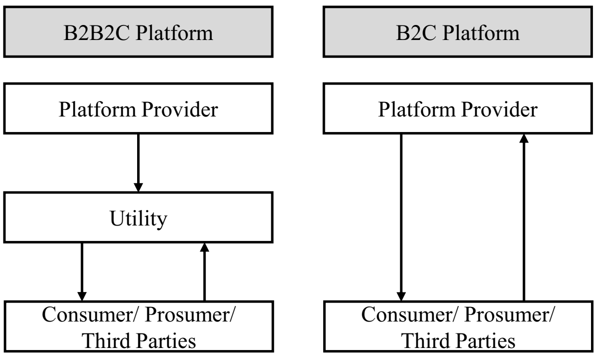
4.3 Competitive Strategy

The business models and the strategy of an organization are highly interrelated (Zott et al. 2011). The smart energy market gives organizations various opportunities for differentiation strategies that can be divided into **product-related** and **platform-related strategies**.

For instance, **product-related strategies** can consist of bundling products, orchestrating services, developing a product portfolio strategy or product differentiation. The advantage of bundling smart energy products and focusing on service orchestration is in creating a comprehensive offering that helps companies to position themselves as a solution and service provider [P1, ll.54–64; P3, ll.528–554]. A product portfolio strategy that combines conventional and smart energy products is regarded as beneficial since it reduces the business risks due to the unstable energy market developments. As for the product differentiation, expert interviews revealed a vivid example: A smart meter gateway can be used in ways that significantly exceed the legal hardware requirements being able to download and run applications on the smart meter device itself (similar to a smartphone application store) [P1, ll.172–177]. Thus, the product provides more functionality compared to other smart meter devices which only monitor energy (Johnson 2010; Weking et al. 2018).

Besides of product-related strategies, **platform-related strategies** are required. For instance, companies have to decide which smart capabilities are necessary and how flexible the platform should be with regard to future requirements. With regard to capabilities, platforms can support monitoring of the energy consumption, controlling electrical devices or they can even optimize the energy management autonomously (Porter and Heppelmann 2014). Furthermore, companies must decide over a B2B2C or business-to-consumer (B2C) platform model (see Fig. 3). Since the development of smart energy platforms requires a high monetary investment and IT know-how, complex IoT-driven platforms are mostly realized in a B2B2C model. This means that a platform provider makes his smart energy platform available to utilities as a white label solution [P2, ll.37–42] who then, in turn, offer the respective services to end consumers, prosumers or other third parties. Particularly smaller utilities lack financial capacities to develop a platform on their own [P3, ll.480–484] and hence is regarded as the "sweet spot" for B2B2C solutions [P2, ll.434–449].

Fig. 3 Comparison of B2B2C and B2C Models



If white label solutions are marketed to utilities with a B2B2C model, the platform software provider usually remains unnoticed by the end consumers. However, being unknown to the end consumer market can be acceptable for the platform provider if the platform provider does not aim to establish a consumer brand and rather concentrates on the delivery of well-designed and successful software to gain a reputation within the utility sector [P2, ll.387–397].

4.4 Customer Interface

The customer interface was addressed in the interviews by identifying customer segments and establishing a positive relationship with customers. Although the focus of the interviews was on the private end consumer as **customer segment**, the interviewees refereed to utilities as a customer and industrial customers in order to highlight that smart energy business models addressing these customers are already exploited by companies. In this regard, most of the currently implemented use cases concentrate on the industrial consumer market [P3, ll.145–157]. The advantage of the industrial consumer is that it is comparably easy to create concrete products (e.g., energy management systems or predictive maintenance services) [P8, ll.210–215; P2, ll.164–172], they scale quickly, and if these products allow achieving savings for industrial consumers, they are easy to sell [P8, ll.221–224]. For the future, these functions can then easily be customized to fit private customers' needs later on as well [P3, ll.153–157].

With regard to **customer relationships**, smart energy product bundles such as an energy community product optimize customer retention. With product bundles that have an intended life cycle of several years, the relationship to a customer can be prolonged. Especially if such a complex system is purchased from a single provider the complexity for the customer can be reduced as there is only one counterpart with whom all issues (e.g., contractual and technical problems regarding the product) the can be managed [P6, ll.134–146].

4.5 Revenue Model

When creating innovative new products or services, it is required that they generate revenue in the long term. Products and services that fail to do so, will be canceled sooner or later by the board of management [P3, ll.131–135].

For **B2B2C models**, smart energy platform providers gain **revenues from utilities** through mainly four sources: provision fees for platform setup, usage fees, subscription fees, reseller models for hardware, and the financing of new smart energy services (for a more detailed explanation of these types see Appendix, Table 7).

Regardless of whether a B2B2C or B2C platform model is implemented, the platform-based business models also require **revenue streams from private consumers** to create sustainable business models. In this context, the experts mentioned seven different revenue streams which include shifting margins from electricity sales towards value-added services, basic product sales, subscription-/transaction-based models for platform memberships, flat rates and capacity sales for energy supply contracts, and margins on energy savings (for a more detailed explanation of these types see Appendix, Table 8).

4.6 Challenges of Data-Driven Smart Energy Business Models

In the following, we synthesized the main challenges associated with data-driven smart energy business models, which can be divided into a **lack of profitability, complexity, low market penetration**, and **regulation**.

The experts consider the majority of innovative value propositions discussed in the context of smart energy to be ahead of time, claiming that the market is not ready yet. Moreover, budget restrictions and the current **lack of profitability** discourage companies from particularly addressing the private consumer segment [P3, ll.145–157]. For private consumers, energy is also a low involvement product in which the majority of private consumers are not interested [P8, ll.224–228], and accordingly, the willingness to pay for such services is considered being low [P6, ll.223–225]. For instance, it is considered unlikely that the value proposition of energy visualization services (i.e., providing consumption transparency) will be strong enough to generate enough revenues for a sustainable business model [P6, ll.199–218; P9, ll.181–205]. Similar, home automation services like switching devices remotely on and off are seen as expensive "gimmicks" [P9, ll.181–205, ll.354–357]. The profitability of demand side management services for private consumers is also to be determined. The regulatory requirements (at least in Germany) inhibit making use of energy price differences since fees need to be paid in both directions when buying and selling energy in the context of a battery storage system. Moreover, the prequalification in order to prove the ability to deliver flexibility services to the grid operators is costly for companies. As a result of the current market conditions, the margins that can be provided to the consumers seem to be rather. Hence, it is difficult to motivate private households to participate in demand side management services without being able to offer adequate incentives like substantial cost savings [P6, ll. 233–259; ll.267–277; ll.313–330].

The **low market penetration of smart devices** in the private households is a barrier for creating value propositions. For instance, for the marketing of assisted living services, smart energy devices are required in the households of care-dependent people to collect a sufficient data basis and to deliver such a service. Data-driven services also require clarification in terms of which data is visible to whom and relatives of the care-dependent people need to consent to the comprehensive collection and analysis of their data [P8, ll.187–195].

Other value propositions such as energy communities and demand side management are difficult to establish because of **high complexity** and **lacking technological feasibility** [P6, ll.162–181]. Complexity is a result of the required orchestration of many thousands of decentral energy systems particularly in the private household market [P3, ll.100–116; P6, ll.313–330].

The case of demand side management mentioned above shows the **role of regulation** which is one of the main barriers of data-driven smart energy business models. Regulations can make a business model work in one country and prevent the execution of the same business model in another country. For instance, access to energy data is regulated differently in every country (Weiller and Pollitt 2016). However, changes in regulation can also be an enabler for new business models. For instance, "Erneuerbare-Energien-Gesetz (EEG)"-regulation in Germany was named in the interviews as an example, which has been changed in 2017 and since then has allowed the peer-to-peer sales of green energy without having to fear the loss of the market premium [P9, ll.54–60].

5 Discussion

In this section, we discuss key issues behind the expert's interviews and provide guiding implications for the design of data-driven smart energy business models. By using literature to enrich the findings from the experts we also present main similarities and differences that became obvious when comparing the data-driven smart energy business model aspects stated in literature and by the experts.

5.1 Future Potential of the Data-Driven Value Propositions and Coverage by Literature

Since the value propositions emerged during the coding process, we did not specifically ask for the expectation on the future potential of the value propositions. Nevertheless, most experts expressed an assessment of the future potential of the value propositions for new business models which we depicted in Table 4. As we did not specifically ask for their evaluation, no expert gave an assessment regarding assisted living, anomaly detection and data selling. The expected future potential of the experts was also estimated by the authors in a similar way, so that there is a congruence of the opinion of experts and the authors. Where several experts had expressed a value proposition, they agreed on the assessment. Only with regard to data-driven cross selling the experts disagreed, with one expert rating the potential as high, while another sees only low potential. We will further discuss the estimations in what follows. Afterwards, we will also discuss our estimation on the coverage of the business model value propositions by the scientific literature which is also depicted in Table 4.

According to the expert interviews, **consumption visualization** is expected to have low future potential for viable stand-alone consumer-oriented business models. Energy companies might provide tools for consumption visualization such as smartphone applications for free to increase customer relationships (consumers appreciate services for free) and their image (e.g., being state-of-the-art and modern). However, sustainably profitable business models are rather difficult to realize since the willingness to pay for these services is low. One exception for viable standalone business models might be B2B2C models. Here, we see companies such as *GreenPocket*[3] who provide energy monitoring tools for grid operators or metering point operators. The grid operators themselves offer the tool towards their residential customers. Although selling or renting energy visualization tools to private households is prob-

[3] https://www.greenpocket.com/de/home.

Table 4 Future Potential of the Value Propositions and Coverage by Literature

Value Propositions	Expected Future Potential	Covered by Literature (exemplary references)
Consumption visualization	Low	Frequently mentioned (Bischoff et al. 2017; Burger and Luke 2017)
Home automation	Medium	Frequently mentioned (Bischoff et al. 2017)
Self-produced energy	High	Frequently mentioned (Burger and Luke 2017; Hamwi and Lizarralde 2017)
Energy communities	High	Frequently mentioned (Koirala et al. 2016; Xu et al. 2019)
Demand side management	Low	Frequently mentioned (Behrangrad 2015)
Temperature-as-a-service/ innovative energy supply	Medium	Only rudimentary mentioned (Fox-Penner 2009; Giordano and Fulli 2012; Shomali and Pinkse 2016)
Assisted living	–	Not covered by literature
Anomaly detection of smart energy systems	–	Not covered in terms of a business model but as part of a smart energy management system (Byun et al. 2011)
Data-driven cross-selling	Low/High	Only rudimentary mentioned (Shomali and Pinkse 2016)
Data sales to third parties	–	Only rudimentary mentioned (Shomali and Pinkse 2016)

ably not a viable stand-alone business model for most companies, network operators and energy suppliers in particular benefit from equipping end consumers with smart metering devices because it gives them a better understanding of energy demand and supply and allows them to optimize their internal processes accordingly (e.g., by optimizing the coordination of supply and demand, they can avoid having to switch on cost-intensive large-scale plants).

Many of the experts also regard **home automation** business models as an “add-on” business model but not as a standalone sustainable business model for them. Nevertheless, the consumers continue to buy smart devices like smart thermostats, smart plugs, and voice-controlled assistants. The Statista digital market outlook 2019 expects US-$ 73.6 billion in 2019 with growth to US-$ 153.0 billion in 2023 for the global smart home market (Statista 2019). Hence, there might be a market addressing wealthy, lifestyle-oriented consumers even though energy management might only be a by-product. Moreover, the example of the smart thermostat *Nest* shows that hardware differentiation by implementing intelligent algorithms, neat design and collaboration with others (*Nest* Rush Hour Rewards utility program[4]) can lead to success. Another already existing example with a highly innovative, but also controversial and partly skeptically discussed value proposition is *Inspire*, whose vision is to make a comprehensive smart energy offering. Their key resource is a big data platform, which is used to predict prices for each consumer’s electricity supply flat rate and considers several inputs such as the number of people in the home and the home’s material. This electricity flat rate is then combined with other smart

[4] https://support.google.com/googlenest/answer/9244031?co=GENIE.Platform%3DAndroid&hl=en.

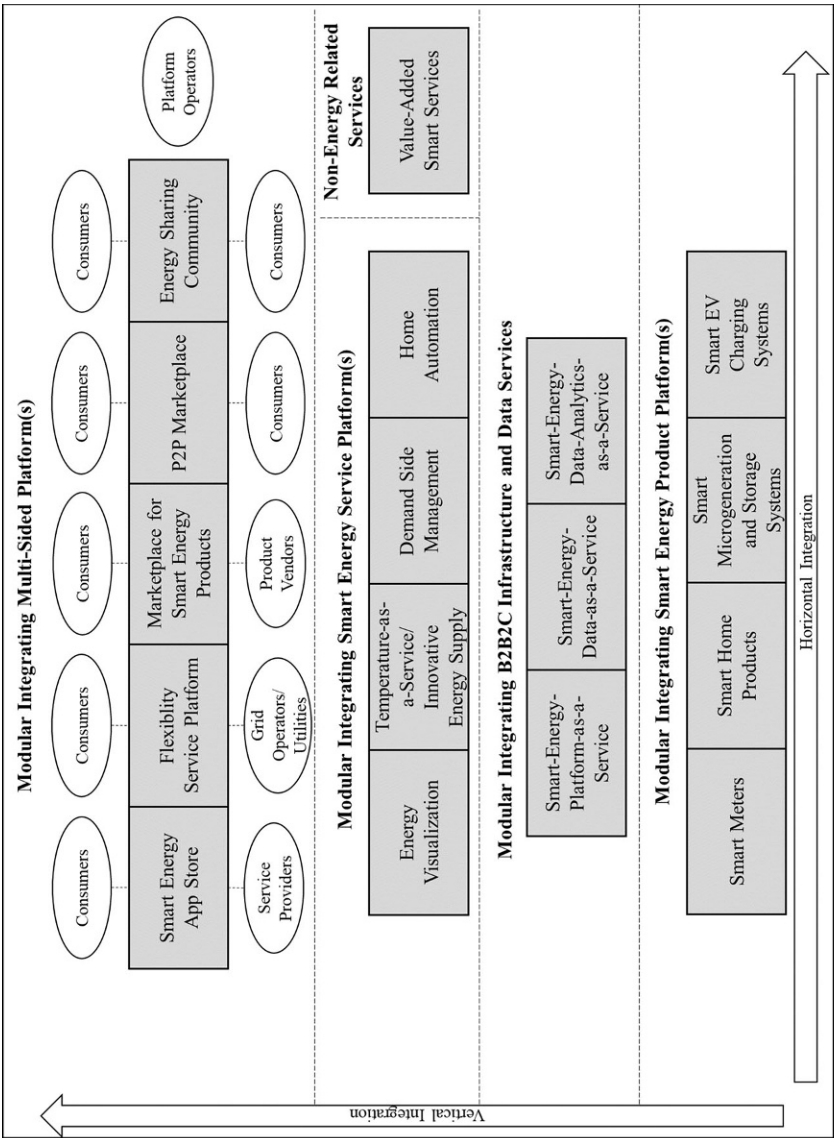


Fig. 4 Integrating Smart Energy Platform Business Model

energy products like smart thermostats and plugs which can be used to incentive the consumers to reduce energy (Pyper 2018).

Due to the low saving potentials of private households, the future potential of the **demand side management** business models is estimated to be rather low as well. However, with more efficient and intelligent smart energy technologies and services, for example, for demand response, we expect that there might be actors who are able to scale the business model making it viable. Approaches such as *OhmConnect* show the right direction: *OhmConnect* is a startup that became a large behavioral demand response player building on an independent platform that pays for consumers for reducing their energy consumption at peak hours. One giant hurdle was to get a large consumer base in order to show the other side of the platform, namely the grid operators and utilities, their reliability to provide megawatts into the market. To increase the customer base *OhmConnect* first paid consumers without getting money from the other side of the market, hence, it is a risky and costly approach to establish the business model. However, they managed it, also due to funding, and now there are several market mechanisms to gain revenues from (e.g., they participate in *California's* state *Proxy Demand Resource Program* and the *Demand Response Auction Mechanism Program*) (John 2018).

In contrast to these value propositions, **energy communities** have a higher expectation for future business model innovation and have the most potential to disrupt the established utility business model and could even replace it. According to our expert interviews, the more renewable energies are connected to the grid, the more the intelligent management of the grid in the form of virtual power plants is going to gain in value [P9, ll.436–465]. As a result, the prices for secondary control power could be increasing and could enable profitable business models for virtual power plants [P9, ll.436–465]. However, if all utilities jump on the bandwagon and offer peer-to-peer marketplaces from the same or similar B2B2C provider, it is really questionable whether the scaling effects are enough to be profitable. We could imagine here, that platform economics might lead to a "winner takes it all" situation in which one platform will win the competition due to the largest customer base (Rysmann 2009; Ko and Shen 2016).

Innovative **data-driven cross-selling** opportunities were discussed controversially from praising high potentials [P3, ll.252–261] to signaling skepticisms [P4, ll.416–434]. The role of energy consumption data as an own product or as a key resource for cross-selling and value-added services might be also depending on data privacy policies and the interest of other players regarding energy consumption data. Promising ideas and approaches can be seen in other industries, for example, the banking application *Cleo*[5] that uses artificial intelligence to analyze and optimize consumers' financial transactions. Similar applications could use the detailed energy consumption data to optimize the energy bill on the consumer's bank account, for example, by evaluating other energy suppliers. Companies like *Facebook* and *Amazon* rely on data-based advertising and could be interested in smart energy data for cross-selling recommendations. Hence, companies in the energy domain could sell energy consumption data to such internet companies.

[5] The corresponding company recently got a $10 million funding (Ohr 2018).

Such innovative approaches might disrupt the industry in the future. This could be also driven by changing regulations, for instance, triggered by increasing citizen engagement against climate change. Even if not all energy companies might profit from the data-driven value propositions, there might be interesting startups and niches for players with new sustainable business models even in areas where little importance for the future energy industry business models is attached nowadays.

Apart from the expert's expectations regarding the potential of the business models, we also highlighted the coverage of the business model value propositions by the scientific literature. We provided some exemplary references for each value proposition. As one can observe in Table 4, widely discussed value propositions are energy visualization, home-automation, self-produced energy, and energy communities. Some value propositions such as anomaly detection can be found in the literature. For instance, Byun et al. (2011) present a smart energy management system that is able to detect anomalies. However, they do not develop a business model or propose this feature as a value proposition for end consumers which would enable a stand-alone business model that creates and captures its main value from this feature. Value propositions that are not covered at all is the assisted living services. Moreover, other pure data-driven value propositions such as the data-driven cross-selling or selling data are not or not sufficiently covered by the literature. The same goes for the value proposition of "temperature-as-a-service" which is only which in literature is only casually addressed in one sentence and would deserve more attention in future research.

5.2 Going Beyond Industry Boundaries

In a smart connected world, it is important to think outside the box of one's own "traditional" domain and to reinvent the own established business model by expanding towards new domains. For instance, intermodal mobility services offer customers the ideal combination of means of transport based on the time of the day, traffic, and personal preferences go way beyond smart energy but are in the scope of municipal utilities since they are connected to electric mobility shaping the infrastructure of the future [P7, ll.277–285; P3, ll.636–644]. Moreover, such services could be connected with charging infrastructure and flexibility services. The new data-driven value propositions mentioned in Sect. 4.1.3 (e.g., data-driven cross-selling, assisted living) also follow this strategy and try to gain revenues by expanding the business model beyond energy-related values.

5.3 Building on a Platform Architecture

The experts and the literature in the smart energy domain agree on the importance of platform-based business models. However, it is unclear what shape these platforms will take. Whereas the expert's discourse refers to platforms from a technical perspective highlighting the modular architecture for being flexible and adding new services, the academic literature rather discusses multi-sided smart energy platforms and platform economics (Giordano and Fulli 2012; Shomali and Pinkse 2016). In multi-sided platforms, the key is to get a critical mass of users (e.g., consumers and service providers) on both sides of the platform for profitability (Eisenmann et al. 2006; Clastres 2011; Shomali and Pinkse 2016).

One interesting literature contribution combining both perspectives is from the Information Systems domain: Yoo et al. (2010) conceptualize a new organizing logic for digital innovations. Their organizing logic builds on a modular layered architecture of smart products which was also used for the understanding of smart energy products in Sect. 2.1. In this regard, a smart product consists of several modular layers and serves both as a single product and as a platform. Different companies can develop new components such as devices, networks, services, and content, for the platform like new applications on the service layer since these components are loosely coupled on different layers of the product architecture. Companies can collaborate on one layer of the platform and compete on another layer (Yoo et al. 2010). Particularly in competitive markets, smart product platforms are regarded to foster multi-sided platforms and to enable dynamic ecosystems (Eisenmann et al. 2006; Yoo et al. 2010).

Fig. 4 depicts both platform perspectives towards an integrated smart energy platform business model. The vertical layer depicts the smart components and services which are co-created on the different layers of the smart product architecture, for example, by combining product platforms with data and connectivity components and consumer-oriented services. The middle layer primarily comprises B2B business models, for example, the sale of data or the provision of software platforms and connectivity components for utilities, and thus addresses companies rather than end customers. Multi-sided platforms are placed at the top since these platforms are often service- and end consumer-oriented. Moreover, they are more difficult to realize as they underly platform economic conditions (e.g., the critical mass of users on both sides of the platform). However, multi-sided platforms also appear promising for the future as other industries have already put forth disruptive multi-sided platform business models (e.g., in the retail industry with *Amazon Marketplace, Uber* in the taxi business or *Airbnb* in the hotel industry).

The horizontal layer connects the different application areas, for instance, smart home products can be integrated with microgeneration units enabling more efficient energy management in the home, and hence increasing the overall customer value.

The platform approach is attractive for companies and for the consumers. In an optimal scenario, energy companies build on a modular architecture and start with one use case. They can then expand their business model and supplement it with other offerings like data selling or value-added services for assisted living and cross-selling recommendations. The energy companies could also build different multi-sided service platforms for diverse scenarios. Moreover, consumers have requirements that might change over time; hence they might want to start with a small package and then be able to extend it later. Energy companies could offer consumers an integrated energy management experience. In the future, it is possible that there might be only one general platform integrating all technologies or there might be many specialized platforms competing with each other or complementing each other.

5.4 Collaboration Between IT Companies and Energy Companies

The B2B2C platform model is regarded to be important for established utilities since they profit from software know-how of IT companies. Research also doubts if utilities have the capabilities and competencies to develop own platforms (Shomali and Pinkse 2016). However, the simple adoption of a B2B2C platform can be also dangerous because many utilities might sell the branded platform to their customers and might not be able to achieve a critical mass of users due to the competition and lack of differentiation. Moreover, the utilities are dependent on the software provider and are bound to their solution.

5.5 Bridging the Monetization Gap

As highlighted by the experts, there are several innovative ways to monetize the value propositions. Companies should try to experiment with different payment modes for consumers and in the case of multi-sided platforms, both user sides have to be considered.

Since reality does not always follow rational economics, sometimes a simple change of the revenue stream can make the business model successful and many famous examples like *Google* and *YouTube* show that a revenue stream can come to a later stage making the business profitable (Lance 2010). This is similar to the example of *OhmConnect* who managed to achieve a large customer base by own upfront payments and then later on making money. However, they already knew the potential revenue stream from their service, but there was a challenge to convince grid operators to trust their service promise. Moreover, similar to the famous examples, first unprofitable business models like energy consumption visualization for end consumers could be profitable in the future if a company detects a niche where to earn money directly or indirectly (e.g., by advertising) from consumers. In this regard, the stated revenue model "subscription model including freemium for the membership in a closed platform environment" of one of the experts seems to follow the logic from the famous examples who first tried to scale up the customer base and afterward tried to find a sustainable revenue stream.

6 Conclusion and Limitations

Since research has not yet empirically studied the data-driven potential of smart energy technologies for future business models in the energy sector, we used expert interviews to explore how the data generated by smart energy technologies can be used to create new values and affect the business model elements of companies in the energy industry. The paper specifically highlights the challenges that are currently associated with the single value propositions and the design of viable business models.

We identified ten value propositions for future data-driven business models building on smart energy technologies which are consumption visualization, home automation, energy communities, self-produced energy, demand side management, temperature-as-a-service/innovative energy supply, assisted living, anomaly detection, data-driven cross-selling, and data selling. The smart energy data is mainly captured from the consumers' smart energy devices in order to reduce energy costs and address their needs for increased transparency, efficiency, and comfort. As a key resource, research and practice highlight the importance of platforms building the foundation for creating value from data. The platform architecture also allows the modular extension of use cases. While industrial consumers have comparably clear requirements, and an intrinsic motivation to reduce their operating costs by making use of smart energy-based solutions, the segment of private consumers seems to be less attractive. However, practitioners also see the many challenges coming along with smart energy business models and seem to be waiting for the "big bang" of one player. Revenue streams tend to shift from the physical sale of energy quantities and assets towards periodic fees for the use of smart energy services in the future. Since smart energy business models are rather complex, often collaboration with other parties such as software companies is necessary to create value. IT companies seem to benefit from the increasing smart energy technology dissemination by offering consulting services and smart-energy-platforms-as-a-service to utilities. The high uncertainty within the energy industry leads to different strategies pursued by the industry actors in order to find a way to differentiate themselves from competitors and position themselves within the industry.

Despite its contribution, the paper is subject to limitations. Conducting explorative interviews with a set of nine experts provides a valuable but limited insight into the energy industry. Even though semi-structured interviews are a powerful tool to gain valuable insights, they are likely to be affected by the interviewer. The ability to deviate from the pre-defined interview guideline and the possibility to follow up on specific topics mentioned by the expert can lead to biased interview results which may profoundly impact the subsequent processing. Not all experts were willing to talk about concrete innovative pricing models that are currently in development. Moreover, the experts were from Germany, and hence due to discrepancies in legislation between different countries even within the European Union, the value of this research might be limited outside the German market. Nevertheless, we expect similar results in other countries since a majority of the results is also supported by the academic literature. Moreover, even if regulation now deters a business model, this may change in the future. Differences might particularly occur due to challenges regarding regulations and data privacy concerns. Hence, to validate the findings, future research could conduct interviews with experts from other countries and compare the expert's opinions.

Limitations notwithstanding, we discuss trajectories for future data-driven business models by showing data-driven changes in the business model elements and providing new ideas on how future business models could be designed.

Appendix

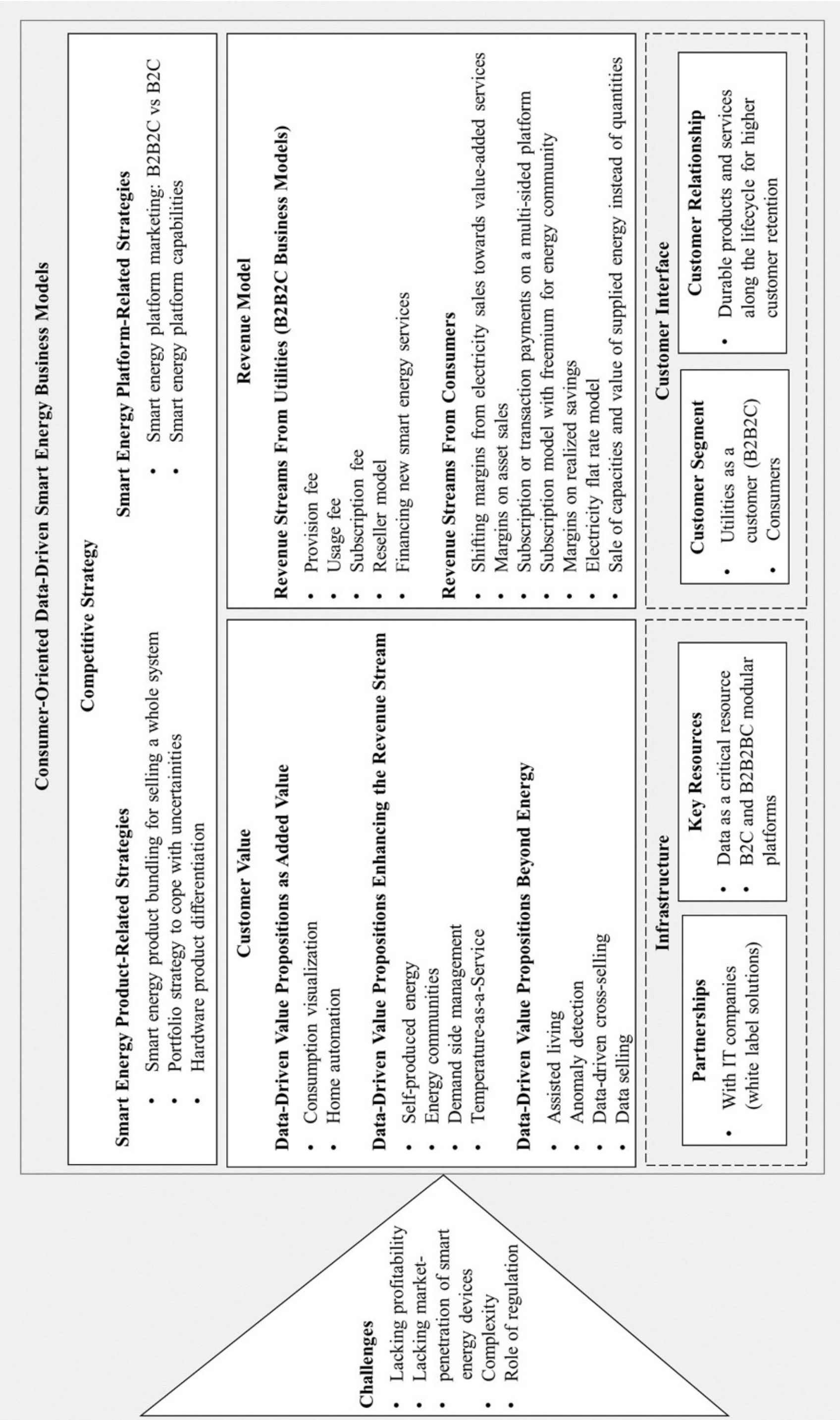


Fig. 5 A Practitioner's Perspective on Data-Driven Smart Energy Business Models

Table 5 Main Types of Energy Communities

Peer-to-peer energy trade
Peer-to-peer energy trade describes the possibility for private consumers to exchange electricity in an online marketplace. Private energy producers offer their renewable energy to environmentally conscious consumers, who would like to know exactly where their energy comes from [P9, ll.60–65] (Koirala et al. 2016; Löbbe and Hackbarth 2017)
Local energy communities
Local energy communities concentrate on the value proposition of regional energy that is mainly emotional, giving consumers a grip on where their energy comes from, without affecting the cost dimension [P6, ll.115–120]. They achieve this value by installing and operating co-generation plants or photovoltaic systems, for instance, in the form of landlord-to-tenant electricity supply in leased apartment buildings or local microgrids (i.e., several neighboring homes sharing generation plants). In this scenario, it is not a single home that is seen as the prosumer but the entirety of the members of the local energy community, which locally produces and shares energy. The excess energy is being fed into the grid and sold on the market. Prospectively, this enables the mutual supply of microgrid communities [P6, ll.71–85] (Lasseter 2002; Koirala et al. 2016; Martin-Martínez et al. 2016)
Virtual power plants
Virtual power plants do not focus on regionality but emphasize the stability of the grid and enable consumers an extra cost-saving potential due to their explicit contribution to grid stability (Morales et al. 2014; Koirala et al. 2016). A private consumer is able to become a member of an energy community by buying a photovoltaic and battery storage system in combination with a service package. The service consists of buying excess electricity and selling it to other members of the community who are in need while also providing residual current from the community in case the own production is not sufficient at a given time. This may lead to a self-sufficiency degree of up to 70%, while the remaining 30% can be a combination of the community's residual current and energy from the grid if still needed [P6, ll.37–61]. The task of the virtual power plant manager is to aggregate and virtually consolidate the electricity in a regional accounting grid and match which part of the consumption has actually been produced [P6, ll.32–37]

Table 6 Overview of Data Sources

Internal data	Existing data	Internal existing data comprises "all corresponding customer data which is required to perform the termination of contracts, the change of the energy supplier, the grid registration, the calculation of grid utilization charges, etc." [P9, ll.504–512]. This type of data is standardized [P9, ll.514–517]
	Self-generated data	This type of data only plays a marginal role within the set of interviewees. Even if services such as Google Analytics are being used to track customer behavior on the organization's web interfaces, the organizations mainly rely on data provided by the customer instead of generating data themselves [P9, ll.500–503]
External data	Acquired data	Some organizations request external non-public data from external service providers, for example, direct marketing service providers offer professional, high-quality electricity production and weather forecasts [P9, ll.536–548]. The most important data types mentioned in the context of weather are wind, temperature, brightness, swell [P3, ll.347–351], and precipitation [P4, ll.143–153]
	Customer-provided data	Since the energy industry is highly standardized in terms of data [P3, ll. 363–364; ll.375–379], a large part of transactional data such as meter readings and energy quantities are legally defined [P5, ll.230–236]. A majority of data is generated in the field by devices installed at the consumers [P5, ll.196–198] which measure energy consumption data, such as electric current, gas, oil, water [P2, ll.200–203], and historical and actual state data [P5, ll.196–225]. Also, overarching data beyond the energy industry could be provided manually by consumers such as information on homeowners' insurances, which in combination with IoT data enables an even broader range of services [P8, ll.179–188]
	Free available data	The primary source of free available data used within the energy industry seems to be weather data since in Germany, the "Deutsche Wetterdienst" is required by law to provide necessary weather data for free [P4, ll.143–153]. Moreover, the time zone might play an important role when conducting international business [P3, ll.368–374]

Table 7 Revenues From Utilities (B2B2C Models)

Provision Fee

For a software-as-a-service solution, utilities regularly need to pay a fixed provision fee, which also includes the setup and customization of the platform [P2, ll.101–105]

Usage Fee

With the usage fee model, platform providers charge utilities based on the services they use and based on the extent to which they use it such as the number of managed metering points [P2, ll.107–116; P4, ll.59–64], the number of managed megawatt-hours or the number of active users [P6, ll.373–387]. This is realized as a pay-per-use model with a fixed price per single unit [P4, ll.42–44]. This usage fee is usually degressive for higher quantities realized through staggered tariffs. This means that the first 500 metering points are significantly more expensive than the last 10,000 [P2, ll.107–116]

Subscription Fee

The subscription model is characterized by billing utilities with a fixed regular fee, such as a monthly or yearly subscription fee depending on the customer [P5, ll.162–174]. In return, the utility is provided with a software-as-a-service package, where the price is defined by the pre-booked services and not the actual use itself [P3, ll.210–211]. This renting model reduces the high upfront investment costs coming along with licenses [P3, ll.224–229]. Additionally, utilities can upgrade their subscription with additional modules and service packages, such as second-level support [P5, ll.162–174]

Reseller Model

The reseller model describes that hardware or an asset such as a smart meter is not sold directly to end consumers but is instead sold to utilities for a fixed unit price. The utilities then create a product bundle consisting of the respective hardware and other products and services and market them to end consumers as a system solution [P5, ll.162–174]

Financing new Smart Energy Services

Due to the high uncertainty associated with the implementation of new and useful use cases into smart energy platforms, platform providers give utilities the option to contribute to the future development of smart energy platforms actively. A platform provider creates a roadmap of functionality they want to implement within the next years. If a utility would like to prioritize a specific functionality and bring it forward, the utility gets charged for a certain percentage of the development cost. In case a utility would like to include an individual functionality that is not part of the planned roadmap, it gets charged for the full development costs but influences all specifications and technical requirements [P2, ll.119–125; ll. 132–135]

Table 8 Revenues From End Consumers

Shifting Margins From Electricity Sales Towards Value-Added Services
The traditional business model relies on the margins that are added to the electric current before selling to consumers. As of today, utilities still profit from the lethargy of consumers to change their energy provider [P9, ll.123–128; P6, ll.119–123]. However, the perception of electricity changes. Since electricity is such an elementary good, it is claimed that electricity should be free or at least should not cost much [P9, ll.173–177]. For this reason, startups tend to offer electric current at purchasing conditions and shifting the margins towards the offered services [P9, ll.129–134]. Even utilities increasingly offer value-added services, which might lead to a self-cannibalization in terms of their electricity sales but might pay off in the long term in revenues for IT services such as the orchestration of virtual power plants [P7, ll.351–355]
Margins on Asset Sales
One traditional revenue stream is the sale of hardware on a platform, which is a one-time payment [P9, ll.383–388]. If private consumers decide to join an energy community, the margin when bundling hardware and energy services for the customer is mainly on the hardware side as of today, such as a photovoltaic system and an energy storage solution, whereas the margins for energy services are neglectable in comparison [P6, ll.131–137]
Subscription or Transaction-Based Model for Single Individual Services on Multi-Sided Platforms
One organization envisions a platform similar to the platform architecture of the smartphone industry: energy service applications are offered in a digital marketplace and can be downloaded into their smart meter gateway by paying a one-off fee or make a subscription to the service. The specific service offerings of such an application are highly flexible and can be adapted and complemented over time [P1, ll.178–186]. This idea is similar to the multi-sided platforms, particularly for flexibility services discussed in the literature with different transaction-based, subscription-based, and hybrid payment modes (Weiller and Pollitt 2016)
Subscription Model Including Freemium for the Membership in a Closed Platform Environment
A freemium subscription model has been identified for a peer-to-peer green energy platform provider in which the basic functionality of the platform is available for free, but additional services and features are only accessible when subscribing to a premium platform membership [P9, ll.388–399]. When having reached a certain number of users on the platform, the freemium model is going to be changed to a two-stage subscription model to cover the costs for platform development, transaction handling, and operations. The basic subscription fee aims at 2.99 € per month with an additional 0.99 € or 1.99 € for the premium service package [P6, ll.255–259]
Margins on Realized Savings
When consumers achieve energy savings due to the use of flexibilities, the earned savings can be passed on to the customer while a small margin is put on the saving, which has been enabled by the smart energy service provider [P4, ll.355–363]. In the same way it is possible to incentivize a prosumer owning a wind turbine for turning it off in case of negative standby power [P9, ll.455–462] or earning money with a prosumer's battery by charging it at low or even negative energy prices and feeding energy in the grid when electricity is expensive [P6, ll. 147–161]
Electricity Flat Rate Models
Similar to the experts, the authors Weiller and Pollitt (Weiller and Pollitt 2016) name the example of the telecommunication industry, which moved away from transaction-based fees towards subscription plans (flat rates). Hence, consumers might pay a subscription fee for the used electricity in the future. Particularly, the active use of flexibilities through smart energy technologies allows for new flat-rate models. Consumers owning a photovoltaic system including a battery storage might get a flat-rate tariff for residual current, based on the performance of the photovoltaic system. With this solution, the energy management provider gets incentivized to manage the system in a way that the self-sufficiency degree is as high as possible. The consumer has the advantage of not carrying the risk of inclement weather and is able to plan the expenditures for electricity ahead [P5, ll.376–380]

Table 8 (Continued)

Sale of Capacities and Value of Supplied Energy Instead of Quantities
Another model of this kind aims at selling capacities instead of quantities, where consumers who are willing to shift their loads can strongly benefit. The model works as follows: A consumer signs a contract of always receiving a specific power, for example, 600 watts for a highly competitive price. So, every time the 600 watts threshold is exceeded, the consumer needs to pay an additional fee [P4, ll.365–367]. This payment model motivates the consumer to reduce the energy consumption in order to stay beyond a specific threshold. Similar to the sale of capacities, the type of energy usage (e.g., heating, lighting, cooling) and the value provided by the service (e.g., delivery of 24 degrees in Room A and 20 degrees in Room B) (Fox-Penner 2009; Shomali and Pinkse 2016) can be charged which goes together with the temperature-as-a-service value proposition. In this regard, the service provider is incentivized to reduce the amount of electricity used to provide the service

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