A Survey of Smart Energy Services for Private Households

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Abstract. The energy sector is challenged by the ongoing digitalization with emerging smart energy products and services. Smart energy products such as smart meters leverage innovative smart energy services promising both new business opportunities and values for customers. Smart products and services could enhance energy efficiency as well as enable private households to produce their own energy. Although services are regarded as a bridge to the customer, research on smart energy services is scarce. To address the gap, we assess smart energy services discussed in research and in the German consumer market and compare the findings from literature with the real market. Our survey provides researchers and practitioners with an overview of smart energy services and can serve as a starting point for service design, which in turn can support the diffusion of energy saving technologies.

Keywords: smart energy services, smart grid services, smart services

1 Introduction

The energy industry is undergoing a transformation process resulting from various technological and economic developments [1]. The transformation is characterized by the expansion of Decentralized Energy Resources (DER) such as Photovoltaic (PV) systems and the emerging digitalization with smart technologies. With several directives (e.g. (2006/32/EC), (2009/72/EC), (2012/27/EU)) the European Union supports this transformation of the energy sector by market liberalization, investments in renewable energy, in smart energy infrastructures and services. As a result, the hierarchical structured power grid transforms towards an intelligent and decentralized grid, the so called smart grid [2].

Against the background of ongoing digitization with the smart grid, new digital energy services emerge which are referred to as smart energy services [3] and promise both new business opportunities and new values for customers [4]. Smart energy services build on smart energy products [4]. Smart meters, for instance, are smart energy products leveraging smart energy services such as energy consumption visualizations, and thus support customers to reduce their energy consumption. Smart energy products and services can not only improve energy efficiency, but can also

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enable private households to become energy producers with microgeneration units ("prosumer") [5]. Furthermore, smart energy is expected to enhance the options for product differentiation by building on data and consumer usage pattern [6]. Since smart products include smart services by nature [7], research expects a strong shift from product-oriented towards service-oriented offerings [5, 8]. In this regard, a consumer would not need to own the product or technology any more, but would rather use the service [9].

Although smart energy services appear promising and are attributed much significance for the energy domain (e.g. [10]), there is a lack of research on energy services [11], and insights on smart energy services are even more scarce. In terms of smart energy services, research has mainly investigated single services in the past such as smart metering (e.g. [12]) and specific aspects such as willingness to pay (e.g. [13]). Until now, research has provided few overviews on different market available smart energy services for private customers (e.g. [14]). Research has not yet compared conceptualizations of smart energy services found in the literature with smart energy services that exist in a market (particularly in terms of covering a broad range of different smart energy services). Furthermore, there is less research on smart energy services through the lens of Information Systems (IS) and (smart) service science [3]. Against this background, we aim to answer the following research question: *How are existing conceptualizations of smart energy services captured by commercially available smart energy services for private households?* We answer the question by conducting a literature review and analyzing the German market of smart energy services. With this market study approach, we were able to compare the findings from literature with the real market, which is a further step towards existing research. Since smart energy services are eco-efficient by their nature [3], this study also contributes to the field of Energy Informatics [15]. Concerning the practical contribution, the survey provides companies with an up-to-date overview on smart energy services and can serve them as a first step when trying to design new services.

The remainder of this paper is structured as follows: The second section introduces relevant background information on smart energy services. After explaining our method, we present the services derived from the literature review and market analysis. We compare and discuss the findings in section six and seven before drawing a conclusion in the following section.

2 Smart Energy Products and Services

Kranz et al. [3] define smart energy "as the use of ICTs in energy generation, storage, transmission, and consumption, aiming at increasing efficiency, encouraging eco-friendly behavior, and decreasing the emission of GHG [Greenhouse Gas]" (p.8). Moreover, Lund et al. [16] consider smart energy systems as the broader concept in contrast to smart grid, which is an ICT enhanced intelligent grid, and thus, is a part of an overall smart energy system. Moreover, smart energy refers to several kinds of energy not only electricity [13]. A smart energy system can also exist on a household level (e.g. by using a PV-system, storage and intelligent energy manager), and thus does not necessarily need to be connected to the overall power grid [17, 18]. On the household level, smart energy involves smart energy products such as smart meters and intelligent battery storages. Smart energy products consist of physical objects embedding intelligent components, i.e. sensors, controls, software, micro-processors, data storage as well as connectivity, which enable monitoring, control, optimization and autonomous capabilities [4, 19]. Smart services are services made possible by intelligent products, since they use the generated and collected data from smart products, the user and the environment to create new and enhanced customer values such as more convenience and individualized offerings [4, 19]. Following this, smart energy services are an integrated aspect of smart products blurring traditional distinctions between goods and services [7]. Smart products are often regarded as product-service systems, since they combine physical products and digital services as a single solution to the customer [8, 20]. Apart from the use of single smart energy products, smart energy services are enabled by the combination of different integrated smart household appliances, PV-systems, storages, electric vehicles (EVs), etc. and the combination of the data they deliver and their controlling capabilities. Since smart energy services require smart products, which in turn frequently include supporting services, e.g. the financing and installation of DER (such as a PV-system and storage), we would also summarize these services in combination with smart products as smart service offerings [12, 14, 21]. In the following, we analyze smart energy services with a focus on end consumer values and by drawing on the concept of smart products and services (e.g. [4, 19]). Thus, smart energy services can be offered as a pure digital service (e.g. monitoring of energy consumption), but can also be an embedded part of a smart product (e.g. a smart light bulb) and include optional (physical) support services (e.g. installation by a technician).

3 Methodology

To assess a broad range of different smart energy services, we conducted a literature search followed up by a market analysis. For the literature review, we oriented ourselves to established guidelines [22, 23] to ensure a proper procedure and to find a comprehensive sample covering the most important smart energy services. As a first step in identifying relevant articles, we used different keyword combinations of the terms "service", "services", "smart energy", "smart grid", "smart grids", "demand side management", "smart meter", "smart metering" and "smart home" to search common databases (EBSCOhost, Web of Science, Scopus) between February and April 2018. We restricted our scope to peer-reviewed articles from 2010-2018 and excluded literature not covering the private household sector. As we were primarily interested in literature describing, analyzing and classifying smart energy services from a (smart) service science understanding (e.g. [19, 24]), we did not consider strong technical papers, e.g. describing only system architectures or web-services without considering end consumer services. We also scanned the references (backward search) of proper texts and looked for articles citing these publications (forward search) [22]. After filtering the literature, we identified 28 relevant articles. Consequently, we analyzed the papers by trying to identify services that fulfill our understanding of smart energy services [4, 19]. We grouped related services into clusters by using a combination of deductive and inductive category building in an iterative way [25]. For instance, we grouped services which are often regarded as eco-feedback services in the category monitoring & guidance, whereas other services enable controlling and further autonomous services regarding the energy consumption [4, 9]. Where appropriate, we adopted some already proposed groups in literature, e.g. energy community services and e-mobility services [18, 26].

While the literature review sheds light on the theoretical as-is state on different smart energy services, the aim of the market analysis is to identify a wide range of existing smart energy services for private households in the consumer market. Since the overall research project is embedded in Germany, the search was limited to the German market. Various sources (e.g. rankings of energy companies, blogs, news portals, keyword search in Google) were searched to find a comprehensive amount of German companies offering smart energy services until we noticed a saturation in the findings. After the identification of the companies, we looked specifically for smart energy services on the company's websites. While analyzing the services [25], we tried to apply the service categories from our literature review. However, since the services are often product-oriented and bundled, we differentiated the services as the companies offer them to the customer. This means that one existing smart energy service offering could comprise several single services we identified before according to literature. Furthermore, we only considered services with enough information found on the company site (e.g. information on "smart" features). Since the boarders between different domains become increasingly blurred, we focused on services with a strong connection to energy. For example, we included smart home offerings with a focus on energy and EV charging services but did not include manufacturer of EV. After excluding 29 services not fulfilling our search criteria (e.g. smart home without energy efficiency use cases), our database from the market analysis consisted of an initial sample of 114 smart energy services. Since we were interested in the distinctive elements of different smart energy service offerings and many service providers provide similar offerings, we grouped together similar services.

4 Literature Review of Smart Energy Services

Based on the analysis of the literature, we grouped the smart energy services in superior service categories, which we describe in the following.

Energy Supply & Billing Services (ES&B): Energy supply as a service is the guarantee to supply a specific level of heat, lighting, cooling, which can be facilitated by the collected data (e.g. from smart meter) [11, 27]. In this regard, Pitì et al. [28] state that contracts can be customized based on the measurements. Remote and real-time metering can offer current, e.g. monthly, more accurate and informative billing based on smart metering data [9, 10]. Remote meter reading is also a new service, since no technician needs to get to the household's home to read the meter any more [10].

Monitoring & Guidance (M&G): In this category, we summarized smart energy services that use the data of smart metering and other smart appliances for monitoring the energy consumption and eventually production of private households. The resulting services can offer a wide range of real-time consumption information, feedback and advice. Monitoring and visualization of energy consumption can support consumers to save energy by identifying inefficient behavior and energy guzzlers [9, 13]. When combined with DER a service can also monitor and visualize the own production level [13]. Other services are appliance level energy monitoring, alarm notifications regarding irregular consumption, historical comparison, forecasting, simulation or the comparison of energy consumption with others [9, 13, 29]. Gamified energy consumption information and serious games where participants have to achieve challenges, earn points and can compete with others can also be combined with social media/ social comparison services [5, 30, 31]. Community level feedback provides users with feedback on a community level, e.g. when the neighbor's PV-system is available, or feedback on the contribution users make to the overall system [9]. More concrete feedback and guidance for energy efficiency is provided by setting and monitoring of goals combined with instructions given on how to best achieve certain objectives [21, 32]. Personalized real-time information combined with individual human advice for certain users, devices and user contexts, are particularly interesting for private households [29]. Personal consulting could even include to install the proposed energy efficiency measures [32]. Since the installation of energy efficient measures needs to consider the people and their consumption behavior, we assigned energy efficiency contracting in this category. Regarding this service an energy service company (ESCO) profits from the energy savings [5] in exchange for efficiency measures.

Control & Automation (C&A): Control and automation services enable private households to control smart energy products remotely [9, 21, 33]. Instead of direct control, advanced control mechanisms allow using automatic controls such as using pre-defined rules and settings, e.g. time-setting and configuration of scenarios [33]. By using artificial intelligence some services facilitate self-learning autonomous systems based on user pattern and optimize the energy consumption [34].

Energy Trading (ET): An energy company can undertake smart energy trading services to market the energy produced by consumers [12]. Energy brokering enables energy trading in online marketplaces by automated agents that act for the customers and consider, e.g. user behavior, his calendar, statistical information [6, 35, 36].

Demand Response (DR): Demand response (DR) services aim to induce behavioral change to shift loads to times when renewable energies are available or to hinder peak loads and thus help to stabilize the grid [13]. DR services can comprise incentives that are given to consumers for enabling the utility to shut off household's appliances. Other DR services send signals to the consumers who respond on their own to shift their loads in exchange for financial compensation. Flexible prices (real-time prices, time-of-use pricing etc.) can be further used for load shifting [6, 13, 14].

E-Mobility Services (EM): In the context of e-mobility Niesten and Alkemade [14] name EV batteries to offer "Vehicle to Grid" (V2G) and "Grid to Vehicle" (G2V) services. Further smart energy services are "Vehicle to Home" (V2H)/ "Vehicle as storage” and “Vehicles for DR” [18]. V2G means the use of a fleet of plugged-in EVs as power sources for the ancillary services market and as energy reserves for wholesale markets. Regarding G2V service the consumer charges the EV and pays for the electricity that is charged. V2H uses the storage of the EV to save energy and can be used within the Energy Management System (EMS). “Vehicle for DR” shifts the EV charging process at times of low energy demand or interrupts the charging due to grid instability [18]. Another smart energy service is the provision of EV charging solutions, which can include the sale, installation and management of charging points [32]. In our understanding this would imply smart charging technologies, e.g. a charging station which can respond to price signals and/ or can be integrated to the EMS [18, 28, 37].

Energy Community Services (EC): Smart energy services for community management support not only the pure exchange of information but also the share of energy resources, such as microgeneration units and storages. Private households can register financially or with their capacities such as energy storages and generation plants in a community. The smart energy services organize the generated energy intelligently to balance supply and demand within the community [9, 11]. The energy community services are also referred to as Microgrids (MGs) and Virtual Power Plants (VPPs). In contrast to MGs, VPPs do not need to be locally and physically connected to the smart grid but are virtually aggregated and thus are not bound to a local region [11]. MGs and VPPs can be used for aggregation purposes, i.e. the produced energy of the distributed small generation plants is bundled and is marketed [32].

Smart Home & Smart Metering Set-Up & Support Services (SH&SM): Although not smart in a narrow view, smart energy products must be installed at the customer site first before smart services can be used. In this regard, basic services are the offering of smart home (SH) and smart meter (SH) infrastructures, e.g. via an online marketplace [12, 32]. By SH, we understand smart home systems as part of the home infrastructure, Do-It-Yourself SH systems and corresponding smart electricity appliances from lighting, heating system, washing machine, air-condition, etc. Supporting services can consist of consulting, installing/ integrating, financing and technical support during usage [12, 21, 32]. During system operation the manufacturer can offer remote and predictive maintenance and security services, e.g. by monitoring the status of the appliances remotely, deploying upgrades to the firmware, detecting potential failures and notifying the customer or planning maintenance actions proactively [38].

Decentralized Energy Resources Set-Up & Support Services (DERS): DER can include different microgeneration types such as PV-systems, hybrid heat pumps, micro-combined heat and power (CHP) systems, wind turbines or mini gas turbines. Energy storages are also subsumed under this category, since they are primarily referred to in the context of microgeneration and interesting for prosumers. Especially for DER, supporting services are needed, which can have different contract depths from DER planning, installation/ integration, operation, maintenance and/ or financing. As an alternative for sale of DER, there are options for renting a DER, [11, 26, 32] or infrastructure contracting [26, 32]. Smart services can support asset management in terms of predictive maintenance, intelligent fraud detection and risk management.

Accordingly, the system can detect risks based on data and can take intelligent actions such as switching off assets or sending messages due to irregular events of assets [34].

Integrated Energy Management (IEM): An integrated energy management builds on monitoring and controlling capabilities [4] and intelligently manages and optimizes the consumption, storage and the production autonomously, e.g. in terms of feed-in of excess power and additional energy demand from the grid. The sophisticated services connect numerous production- and consumption-oriented smart energy technologies (e.g. EV, PV-systems, storages, household appliances) and consider diverse context, usage and external data (e.g. tariffs, user preferences, and weather conditions) [28, 34]. We regard an integrated energy management to take place primarily on a household level to optimize the energy flows within the own "smart energy home", but it can also contribute to the overall grid.

5 Market Analysis of Smart Energy Services

Building on our market sample of services, we formed groups according to the offerings made by the service providers, which we explain in the following.

Innovative Energy Supply Tariffs: Innovative energy tariffs are based on smart metering data. For example, Stadtwerke Bielefeld[1] offer a flexible tariff with a smart meter which divides the day into six different price categories.

Smart Home Packages: SH appliances with a focus on energy efficiency are bundled. Basic SH systems consist of a central hub/ gateway and a mobile Application (App), which enable monitoring and controlling features of SH products. Energy efficiency packages (e.g. "Smart Home Paket Energie"[2] by Innogy) bundle different components such as smart lighting, smart heating, smart plugs and different sensors and actuators. The "Viessmann ViCare App"[3], which is included when buying a Viessmann heating systems, enables not only App based automatic control of heating, e.g. scenarios away/ home, but also offers remote maintenance through the service provider.

Digital Add-Ons: In most cases the service provider supplies the physical products with the digital smart service included. However, Innogy sales the App "Storage vario control"[4] for monitoring and controlling its storage separately. Furthermore, on the website of Innogy the consumer can buy add-ons for their Innogy "Smart Home App". For example, the service "Premium-Auswertungen"[5] promises extended functionality for SH through the configuration of scenarios and visualization of consumption data, consumption in € and historic comparisons.

Smart Meter Packages: Another package are smart meters offered together with an App or web portal access for monitoring of energy consumption and further energy

1 https://www.stadtwerke-bielefeld.de/privatkunden/tarife/strom/enerbest-strom-smart.html
2 https://www.innogy.com/smartstore/SmarthomeCatalog/SmartHome-Paket-Energie-zid11168110
3 https://www.viessmann.de/de/viessmann-apps/vicare-app.html
4 https://www.innogy.com/smartstore/AppCatalog/Storage-Vario-Control-zid10175961
5 https://www.innogy.com/smartstore/SmarthomeCatalog/Apps/Premium-Auswertungen-zid70011714

efficiency guidance based on smart meter data. As an example, Discovergy[6] offers monitoring and visualizing of real-time, historical and appliance level consumption data. They further provide data-based personalized services in terms of energy reports (e.g. cost control, comparison with others), energy saving tips, tariff consulting and predictive maintenance through analysis of devices and plants to identify defects, consumption analysis with notifications in case of irregular consumption.

Storage Packages: Smart storages are not only provided in combination with PV-systems but also offered as single systems in combination with Apps for monitoring and controlling the storage (e.g. "Voltstorage Smart Storage"[7]). A very innovative service is the "Caterva-Sonne"[8], a smart battery storage. By intelligently networking all storages to a virtually connected intelligent huge storage, the "Caterva-Sonnensystem" provides flexibility to the grid. In exchange for the flexibility, the "Caterva-Sonne" owners earn a financial bonus.

Cloud Storage Services: Another service offering are energy cloud storages, such as the "SolarCloud"[9] by E.ON, which are virtual storages for solar power without the need to own a physical storage. The cloud storages primarily address prosumers with a PV-system and without a physical storage. They can save surplus energy produced by the PV-system in the cloud and get it later when needed.

EV Charging: In terms of e-mobility, the most identified service is the sale of EV charging stations including installation and an App for monitoring the EV charging process. In case of the EV charging station by smartRED[10] they further provide a billing tool, e.g. for billing guests and the integration with a PV-system in order to adapt the charging process to the availability of the produced electricity. Closely related to charging at home is the provision of a public charging infrastructure which is, for example, provided by Innogy and can be accessed with the "eCharge App"[11].

PV-System Bundles with (optional) Storage: Energy companies frequently offer bundles of a PV-system together with a storage and energy management system. It can include the installation, integration and further support services such as maintenance, additional guarantees and insurances. The smart services reach from simple monitoring of energy production and consumption (e.g. RheinEnergie AG "Solarkomfort"[12]) to an intelligent energy management to optimize the level of self-sufficiency (e.g. "E.ON Aura Manager" with PV-system/ storage[13]). Some systems even integrate and control SH appliances and EV charging intelligently for load shifting and further efficiency improvements. Accordingly, a good example for an integrated energy management

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6 https://discovergy.com/functions
7 https://voltstorage.com/service-und-voltstorage-app/
8 https://www.caterva.de/?produkte#caterva-sonnen
9 https://www.eon-solar.de/eon-solarcloud
10 https://www.smartred.de/e-mobilitaet
11 https://www.innogy.com/web/cms/de/3813766/fuer-zuhause/elektrisch-fahren-und-laden/produkte/produkte-fuer-unterwegs/app-echarge/
12 https://www.rheinenergie.com/de/privatkunden/energieloesungen/photovoltaik_anlage_pachten/photovoltaik_anlage_pachten.html
13 https://www.eon.de/de/pk/solar/aura/manager.html

solution is the "SWM Energiemanager"[14], which is provided in a PV-system and storage full-service bundle. It monitors the energy consumption, enables the control of household appliances with an App, provides recommendations for consumption activities and automatic control, e.g. via time-settings. Further, it considers the energy production, is self-learning and creates a revenue forecast for the PV-system and for the individual consumption. Based on forecast data, it optimizes own consumption and production to increase self-sufficiency, e.g. by scheduling and switching off- and off integrated appliances (e.g. dish washer, heat pumps, EV charging stations). The bundles can also include peer-to-peer (P2P) marketplaces, energy communities, cloud or battery-based flexibility services.

Energy Management Systems: EMSs are likewise offered as single software solutions with a central hub/ gateway and thus come without a PV-system or other smart energy products, e.g. "gridBox Energiemanager". They integrate different smart energy products to monitor, control and optimize (autonomously) the energy flows within the home.

Asset Management: We also identified single specialized smart services for asset management. By automatic remote monitoring "GreenSynergy"[15] provides predictive maintenance and asset performance optimization, e.g. detection of pollution and clouding which minimize the performance. The further deliver status reports as a service for owners of PV-systems.

Energy Communities: Prosumers with and partly without a storage can take part in an energy community in which surplus energy is fed into a "virtual cloud" or directly shared with other community members. Concerning storage provision, the energy community service offers additional benefits such as a free electricity flat rate. For example, the "sonnenFlathome" provides electricity for free, which comes from the community and is refinanced through provision of flexibility for power stabilization. The participation in the community costs a monthly contribution and requires a "sonnen" battery for the virtual network. In case of surplus energy in the "myEnergyCloud"[16] the service provider EWE markets the energy and the revenues are given back to the community. A vendor-independent open approach is the "Energiegruppe" [17] by buzzn GmbH that is open to consumers without a PV-system as well. This energy community is focused on local energy groups, e.g. multi-family houses with a PV-system on the roof. Furthermore, it assists distributed energy groups with the sharing of own produced energy with other energy groups, e.g. with friends or neighborhoods, and in exchange getting produced energy of others. The service provider takes over necessary administrative processes, e.g. billing, regulatory approvals, and change of tenants.

P2P Marketplaces: Energy communities that enable prosumers to buy and sell energy on their own (e.g. defining prices on their own), can be regarded as marketplaces. Digital peer-to-peer energy market platforms directly link decentralized

14 https://www.swm.de/privatkunden/m-strom/photovoltaik/energiemanager.html
15 https://www.greensynergy.de/anlagenbetreiber/#block1098
16 https://www.ewe.de/energy-cloud
17 https://www.buzzn.net/

generation and consumption ("peer-to-peer"). To be financial attractive, P2P marketplaces require highly automated processes, e.g. with blockchain technology to reduce administrative cost. One example here is "OEEX"[18], a blockchain based P2P energy trading platform.

6 Comparison and Analysis of Findings

The literature review and market analysis allowed us to identify smart energy services, which are currently discussed in literature and are already commercially available. To better illustrate and compare the findings, we wrote the number of occurrences of smart energy services in brackets behind the corresponding service types:

The literature frequently concentrates on flexibility and grid stabilization with *Demand Response* (20), but even more relates to energy *Monitoring & Guidance* (22). *Control & Automation* is also a group of services regularly named in the assessed papers (18). Less research is concerned with *Energy Trade* (10), *Energy Community Services* (8) and *Integrated Energy Management* (4).

Although the smart grid is not yet available in Germany, many smart energy services have already entered the German market. In this regard, the market analysis revealed a focus on offering smart products, particularly *SH Packages* (53). Another major part of smart energy services comprises *PV-System Bundles with (optional) Storage* (18), which is not surprising, since the German government has introduced the energy transition away from fossils to renewables and promotes this heavily. We only identified one *Innovative Energy Supply Tariff,* which is a flexible tariff. Furthermore, few offerings are made in terms of pure digital services such as *Digital Add-Ons* (2), *Asset Management* (1), *Cloud Storages* (2), or stand-alone *Energy Communities* (6) and *P2P Marketplaces* (2).

One reason for the product-oriented strategy by companies could be that the domain is still in its infancy and many households first need to have the smart products, such as a smart meter, before being able to buy or consume "pure" (i.e. digital) smart energy services. Moreover, it might not be financially attractive to offer small digital add-ons for private households.

To better contrast the findings from the literature with the market analysis, we assigned the categories from the literature review to the offerings (Table 1). Table 1 shows that most of the identified commercial services relate to *Monitoring & Guidance, Control and Automation, SH & SM Set-Up & Support Services* and *DER Set-Up & Support Services*. Among similar services in one group, different levels of maturity in terms of monitoring, controlling and autonomous actions can be identified, which depends on the integrated components and software algorithms. Above all, services providing control functions such as SH devices normally deliver monitoring functions as well [4].

Our literature review also revealed a fine granular perspective on smart energy services. For instance, we identified several atomic services for energy consumption

[18] http://www.oeex.org/

information (e.g. historic comparisons), which we summarized under the category *Energy Monitoring & Guidance*. In practice, these atomic services are not offered individually, but are also bundled to a comprehensive solution (e.g. smart meter or smart home App offering energy visualizations, historic comparisons, remote control options), which are often provided for free in a smart product bundle. One reason for this can be that literature is not focused on monetization aspects, and thus investigates single smart energy services. Moreover, some services from literature can hardly be monetized through the consumer, since they rather provide process optimizations and improve customer satisfaction, e.g. remote smart meter reading.

Table 1. Service categories mapped to service offerings (numbers in brackets are the frequency of occurrence in the market analysis; abbreviations correspond to the categories from literature)

Market Offering	*Smart Energy Service Category*	*Exemplary Market Offering*
Innovative Energy Supply Tariffs (1)	ES&B, M&G, DR, SH&SM	Stadtwerke Bielefeld Enerbest Strom Smart
SH Package (53)	M&G, C&A, SH&SM	Innogy "Smart Home Paket Energie", Viessmann ViCare App
Digital Add-Ons (2)	M&G, C&A	Innogy "Premium Auswertungen"
SM Packages (9)	ES&B, M&G, SH&SM	Discovergy Smart Meter,
Storage Packages (8)	M&G, C&A, DERS, EC	Voltstorage Smart, Caterva-Sonne
Cloud Storages (2)	M&G	E.ON SolarCloud
EV Charging (7)	M&G, C&A, EM	smartRED EV Charging station, Innogy eCharge App
PV-System Bundles with (optional) Storage (18)	ES&B, M&G, C&A, DERS, EC, ET, IEM	RheinEnergie AG SolarKomfort, SWM Energiemanager, E.ON Aura Manager Leipziger Sorglos-Servicepaket, ENBW solar+
EMS (5)	M&G, C&A, IEM	gridBox Energiemanager
Energy Communities (6)	M&G, ET, EC, ES&B	EWE myEnergyCloud, sonnenFlathome, buzzn
P2P Marketplaces (2)	ET, IEM	OEEX
Asset Management (1)	DERS	GreenSynergy

When comparing the literature-based conceptualization with the existing services in the market, it becomes clear that some smart energy service offerings introduced in literature are up to now only existing theoretically, e.g. due to regulations, lack of smart grid infrastructures or financial attractiveness. For example, in terms of EV charging there is currently no provider who supports V2G services [18]. Similar demand response services are often not possible, and moreover are not economically feasible due to fixed energy prices [13]. Moreover, we could not find companies offering innovative *Energy Supply & Billing Services* such as tailored contracts or "energy as a service". This can be due to the domain maturity, since in Germany smart meters are not widespread. Even though no company seems to offer demand response programs in terms of demand shifting, flexibility in forms of resource aggregation (e.g. the storages of Caterva GmbH) has already found its way in the consumer market. Moreover, the flexibility services are not offered separately, but are bundled in a comprehensive product-service offering. Intelligent EMS such as the "SWM Energiemanager" can provide DR on a micro-level by shifting loads to times of higher energy production of the integrated PV-system and storage. Such solutions enable high levels of energy self-sufficiency from the superior power grid and energy utilities. In this regard, "smart home grids" are already realized. Moreover, a commercial service we did not identify in our literature sample is the cloud storage.

7 Discussion

Since many smart energy services are embedded in product-oriented offerings, consumers often face high upfront costs. Apart from classical financing options (e.g. renting, leasing), attempts for a stronger (smart) service orientation can be seen in offering *Digital Add-Ons, Cloud Storages* and allowing consumers to participate in DER in form of communities without owning a PV-system. Digital add-ons can include lower prices for the basic product which then can be updated with additional content for an extra fee. Companies further try to lower adoption barriers by integrating more attractive smart energy services in smart products such as the smart battery storage of Caterva offering consumers extra revenues. Moreover, recent practice projects to study V2G under real conditions are being conducted in Germany, which could also support the diffusion of EVs in the future.[19] Another option to create more attractive offerings are combinations of different smart energy products and services. For instance, an EV can be more valuable if the EV battery storage can be used together with the PV-system in a household (V2H) [18]. Since this is often not yet realized in practice[20], there are promising options such as to use a cloud storage (e.g. E.ON SolarCloud) which can store the own produced energy. The stored energy in the cloud can then be accessed by public charging stations of the service provider. In this regard, (IS) research could study different bundles of smart energy offerings and their acceptance by consumers.

Moreover, to reduce the complexity of smart energy products, physical supporting services are needed, especially to integrate different products, e.g. PV-systems, smart appliances, and EV which is highlighted by the widespread of existing full-service bundles in the market. In this regard, companies should try to develop open systems which can integrate products from several manufacturers. Open systems could also facilitate more stand-alone digital offerings such as digital add-ons or energy communities. Furthermore, complexity is reduced by emerging "plug & play" systems such as PV-systems[21], which are moreover interesting for tenants. To lower financial barriers, literature refers to contracting of smart products and services and usage-based

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[19] https://www.electrive.net/2018/10/23/nissan-startet-mit-partnern-v2g-projekt-in-deutschland/

[20] First attempts are shown by the Nissan Leaf with the service "leaf-to-home": https://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/vehicle_to_home.html

[21] http://deal.yello.de/mini-solaranlage/

payment modes such as refinancing in terms of energy savings or certificates on the private household level [5, 14] which could be tested and implemented in practice.

Data-based product differentiation and personalized smart energy services are only partly realized. Research could study both innovative ways for monetization and which data-based services (e.g. product recommendations for replacement purchases for old household appliances) could be attractive under which conditions (e.g. privacy, willingness to pay) for end consumers. Due to the forthcoming smart meter roll-out in Germany, more flexible tariffs and demand response programs could emerge for which research could conduct studies with German households to identify promising services. Since we concentrated the market analysis on Germany, there might be different services available in other countries which could be interesting for adopting in the German market as well.

8 Conclusion

Due to the digitalization in the energy industry, smart energy services appear promising for new business opportunities and customer values. Nevertheless, research on smart energy services is scarce. To shed more light on this, we reviewed the literature and the German market and identified not only important characteristics of smart energy services but also the differences in the conceptualizations in literature from the current market offerings. The overview of the as-is state of smart energy services in literature and in the German market landscape might help practitioners to find white spots for new service development and ways how to position their services best. Since smart energy services foster a more sustainable energy production and higher energy efficiency, our work contributes to the IS related Energy Informatics field [15].

One limitation of our paper is the assessment of market available services which relies on website data and is further focused on the German market. Moreover, we did not aim to identify the entirety of literature, but to find a proper sample covering the most important smart energy services. Additionally, we had partly difficulties assessing services to a group during the literature review as several authors do not define, but simply enumerate smart energy services. Accordingly, it also does not always become clear whether the authors refer to “smart” technologies and services. In general, trying to differentiate and describe services is a complex task, since services are partly challenging to isolate [13]. Due to the complexity of isolating single services, not all categories could be arranged without any overlaps.

Notwithstanding the limitations, we are convinced that our survey presents a recent and useful overview on the smart energy service landscape and indicates options for new smart energy service design and fruitful avenues for future research.

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