Journal of Energy Systems

2022, *6*(2)

2602-2052

DOI: 10.30521/jes.1014270

Research Article

Added value of German energy companies through smart home applications

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Submitted: *24.10.2021*
Accepted: *29.04.2022*
Published: *30.06.2022*

Abstract: The existing value chains of the energy companies are eroding. Trends such as digitization, big data and AI have long since arrived in the energy industry. These demanding framework conditions are increasingly forcing energy companies to introduce new business models. A possible business model lies in smart home applications. This paper analyzes the added value of smart home applications for customer loyalty of energy companies and electricity customers, as well as to identify obstacles in the context of practical implementation. This paper examines smart home applications and the intelligent control and integration of photovoltaic systems. Above all, the avoiding of peak loads will play an important role in the energy grids of the future. The methodology describes the necessary framework conditions existing for the generation of digital innovations. Moreover, it examines the factors leading to increased customer loyalty through the value-added services and offers a load shifting potential to relieve the distribution networks. It is found that the value-added services can offer increased customer loyalty to the energy companies. Even though smart home-based services are highly relevant in a rapidly growing target market, there will only be a broad acceptance of them for the load control, if the user is offered an added value, for example by load-variable electricity tariffs. Energy companies wishing to position themselves as digital service providers must have smart home-based services such as intelligent load control and load-dependent tariff models, which enable users to add a financial value.

Keywords: *Digitization, Germany, Renewables, Smart-home, Smart-grid*

Cite this paper as:	Ensinger, A., Salzer, M-R., Bozem, K., Nagl, A., Harrison, D.K., & Wood, B.M., Added value of German energy companies through smart home applications. *Journal of Energy Systems* 2022; *6*(2): 241-252, DOI: 10.30521/jes.1014270

1. INTRODUCTION

Under the supervision of Bozem and Nagl, the future significance of smart home applications as an important trend for the future value creation of German energy companies has been examined. The questions are the following: Why are smart home applications necessary? How do they affect customer loyalty? Are load shifting potentials possible for household customers? These research questions were pursued in cooperation with the consulting firm of the energy expert Bozem, that supports the research projects with expertise in both the renewable energy and the competitive strategy.

In the evolution of Germany's energy industry, which has lasted well over 110 years now, the production has always been adapted to consumption. The demand for electricity in the individual grid levels could be predicted precisely enough. Consequently, the demand was met by a large number of power plants, which provided the electricity in sufficient quantities at any time [1]. The use of different energy sources has enabled dependencies to be identified. Moreover, the use of mostly fossil fuels led to significantly different electricity production costs, which, in turn, had an impact on the operating time of these power plants. At the same time, however, this energy mix guaranteed a high level of security of supply. This power plant deployment planning is called Merit Order Effect. The model describes the power plant deployment planning on the basis of the variable costs in the energy industry. At its core, this approach only aims at the most economically sensible power plant deployment planning. The cheapest type of electricity generation is intended to provide the most energy, thereby making energy production as cost-effective as possible. Other factors, such as ecological or social ones, are not considered in this model [2]. The power plants are sorted according to their variable costs in ascending order. The power plants with the lowest variable costs are called up first, then, the ones with the second lowest variable costs, and so on. Fig. 1 shows the Merit order effect.

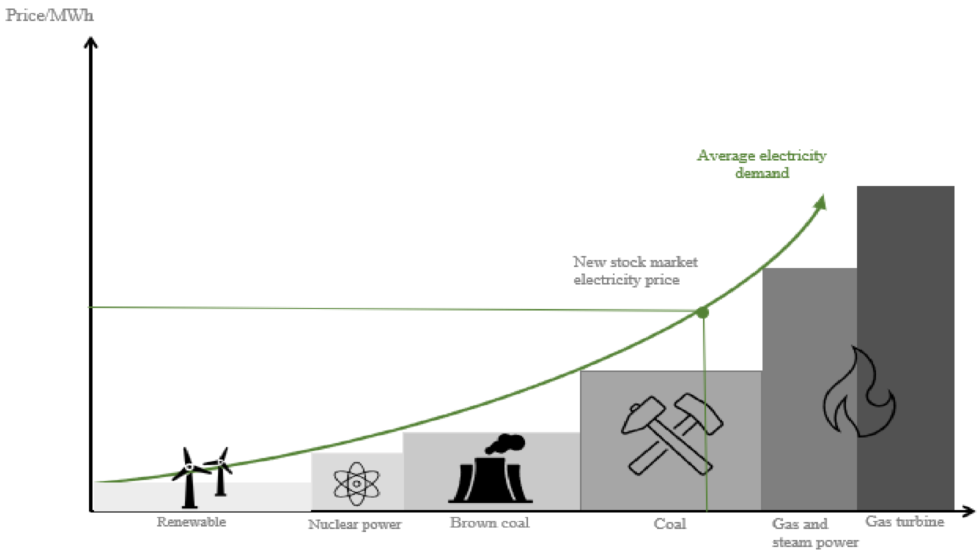

Figure 1. Merit order effect

The great advantage of this mixed generation system is the high resilience, which cannot be guaranteed by the exclusive generation of electricity using volatile generation systems. Provided the balance between supply and demand of electricity was disturbed due to a surprising unplanned event, this imbalance could always be compensated by activating sufficient control power.

However, this system, which has been in place for many decades, has now become unbalanced [3]. The share of electrical energy generated in Germany by the use of renewable, volatile energy sources is steadily increasing. Renewable energy producers benefit from feed-in priority and lead to a shift in the merit order sequence. Subsequently, secured generation capacity is replaced by volatile [4]. Due to the necessary decarbonisation as well as the resulting shift away from fossil fuels in energy production, this development will gain momentum in the future. In 2021, 490 TWh of electricity was fed into the German grid, with the share of renewables amounting to 45.7% after 50.5% in the Corona year of 2020, when demand was low. According to the coalition agreement of the current government in Germany, the share is expected to increase to 80% by 2030. In order to be able to ensure the energy supply with renewable energy plants in the future, significant construction of renewable energies plants is required. For the grid to absorb this electrical energy, they have to be expanded and part of the infrastructure needs to be modernized. In addition to the investments in renewable energies, there is also a requirement for investments in the distribution networks [5]

Despite the need to build up production output, the volatility of production will no longer make it possible to fully adjust production to consumption. However, since imbalance between production and consumption is to be avoided by all costs, the result would be a deviation of the network frequency, which can lead to a blackout event [6]. In this case, there are only two general options.

On the one hand, there is the fundamental possibility of storing excess electricity and making it available in times of high load, on the other hand, consumption can be made more flexible and adapted to production. Since there will not be enough storage capacity available nationwide in the foreseeable future, there is an increasing need for more flexible utilization in customer systems, which would also reduce the need for network expansion and save economic costs. The German Institute for Economic Research (DIW Berlin) has dealt with this in their study “The energy transition will not fail because of electricity storage” and come to the conclusion that storage requirements can be significantly reduced if generation peaks can be curtailed and more flexible loads are available in the grid [7]. Another study was carried out in 2020 in southern England on the Isle of Wight. There, it was found that the use of variable energy pricing systems can theoretically reduce the load on the grid, but then in addition to load-variable tariff components, components with variable load rates are also required [8]. The constant use of load-variable tariffs can paradoxically even lead to an increase in the electricity demand and thus the network load at peak times [9].

While in industrial plants it has long been common practice to monitor the demand for services wherever possible and to control them over time, there is no need or technical possibility to control the load for household customers, except for manual interventions. Smart home applications, which are already available on the market, are mainly systems that serve to increase comfort, whereas the load control in the home is not the focus. In addition to influencing performance requirements, innovative smart home applications can strengthen customer loyalty to the energy company, enabling energy companies to tap into new parts of the value chain. As a classic commodity product, electricity essentially only offers the differentiating feature of the electricity price level. These intelligent business models in conjunction with smart home applications could create a real differentiation opportunity, which would also increase customer loyalty. Increasing customer loyalty and thus safeguarding value creation is particularly important for small and medium-sized energy companies. As regional energy companies, they usually have no chance of winning the price war with energy discounters or pure online retailers.

The aim of the present work is to investigate the possibility of increasing the added value of German energy companies through the marketing of smart home applications, as well as the potential for load shifting through the use of smart home solutions, e.g., in connection with heat pumps. While Section 2 deals with the basic results of the literature research, Section 3 focuses on the analysis of the load shifting potential through controllable consumption devices, e.g., heat pumps and electric vehicles. Section 4 describes the methodological approach and Section 5 gives the pilot plant and the practical knowledge that could be gained from it. Finally, Section 6 summarizes the main results and gives the conclusions.

2. LITERATURE REVIEW

Literature research is performed prior to the preparation of the paper. A hypothesis on which this paper is based states that in the years to come, energy consumption in Germany will increase due to decarbonisation and the resulting electrification of the heating and mobility sector. In addition, due to the generation by volatile energy sources, generation will not be guaranteed at all times of the day and night, which is why load shifting potentials also have to be made available to household customers. This hypothesis is supported by Ref. [10]. The authors of this paper have come to the conclusion that by the end of 2022, secure energy production in Germany will have decreased by 22 GW compared to 2017. This corresponds to a decrease of approx. 25 % which is further justified by the politically decided phase-out from nuclear energy and the phase-out from the generation of electricity from lignite and hard coal. The conventional generation capacities are expected to be only 70 GW. Currently, the peak load requirement in winter is already over 80 GW, which is why the supply of electrical energy could no longer be guaranteed during dark doldrums [10]. This statement is made by the final report of the 6th energy research programme of the federal government "Analysis of structural options for the integration of renewable energies in Germany and Europe taking into account the security of supply" carried out by the network partner German Aerospace Center (DLR, the University of Stuttgart and the Fraunhofer Institute for the energy industry and energy system analyses). These analyses show that, due to the necessary decarbonization, generation from secure power plant services will decline significantly. In 2050, the share of renewable energies in gross electricity generation is expected to be at least 80 %, while the electricity demand will increase from 505 TWh in 2014 to 596 TWh per year in 2050. This is shown in Table 1 [11].

Table 1. Increase in electricity demand [11].

	2014	2030	2050
Classic consumers	505	512	382
Electricity for heat (flexible)		16	66
Electricity for electric vehicles		25	44
Electricity for hydrogen			102
Total (TWh/a)	505	553	596

The second essential hypothesis describes the fact that there is only a low level of customer loyalty between energy companies and electricity purchase customers. Since product electricity is a commodity product and the provider can be exchanged at will, the product electricity offers almost no differentiation options [12]. Moreover, the empirical study "Development and Management of Energy Services" assumes that the mere supply of electrical energy is not sufficient for customer loyalty – instead, service-oriented offers are required as well [13].

One approach to solving these two problems could be the use of smart home systems. In this paper, this approach is described, and the pilot application carried out as part of the research project evaluated.

3. FUNDAMENTALS

As already pointed out at the beginning, there will be an increasing need to intelligently manage the burdens of household customers, thereby bringing consumption behaviour into line with production, especially as the demand for electricity among traditional household customers will rise in the coming years [14]. As expected, heat and mobility applications are particularly crucial for this [15]. Fig. 2, which was taken from the official data of the Federal Environment Agency, shows that around two thirds of the energy required in a private household is used to generate heat.

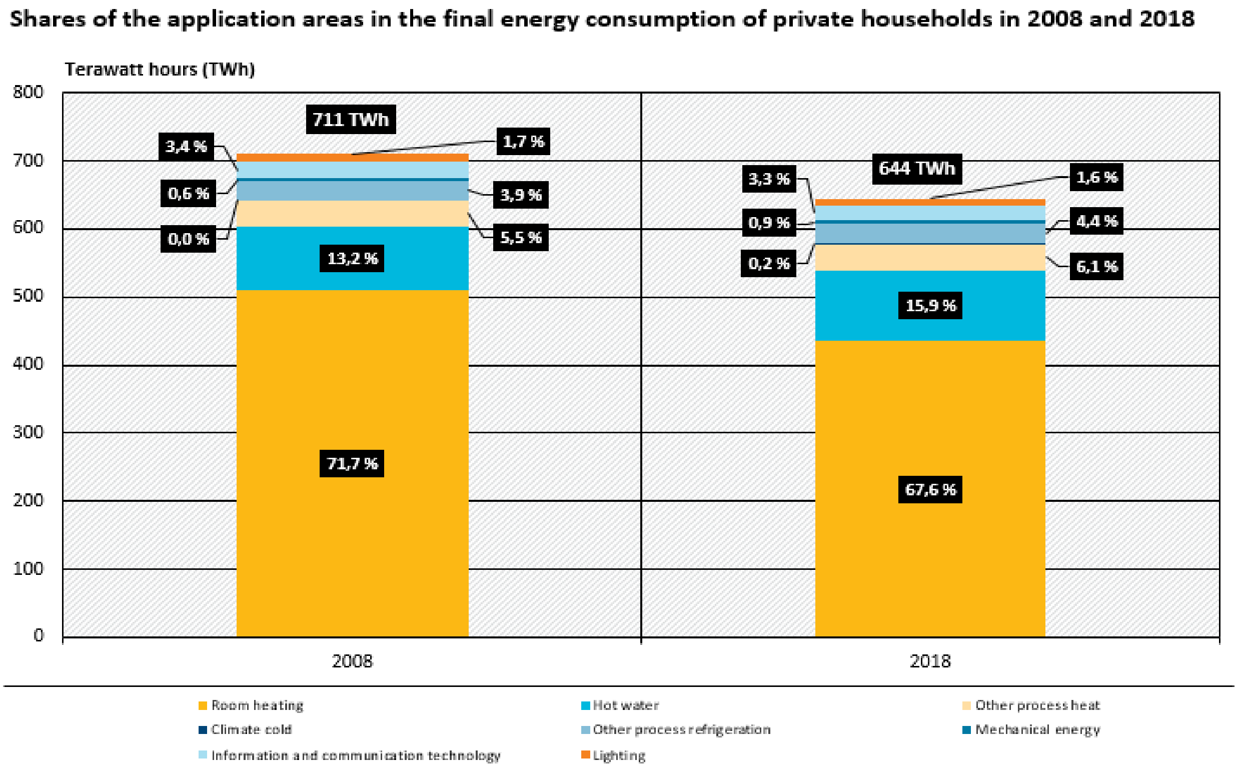

Figure 2. Energy consumption in private households.

Heat pumps offer great potential for CO_2 savings, especially when being operated with electricity from renewable energy systems. This is why their use will continue to increase in the future [16].

In addition, heat pumps provide high potential for load shifting, especially if, as common in new buildings, they are heat pumps with thermal inertia, for example when using surface heating [17]. In order to be able to estimate the added value of smart home applications in conjunction with a photovoltaic system and heat or mobility applications, it is first of all necessary to determine the average energy consumption of a heat pump. For this purpose, consumption data from 179 heat pumps of different sizes was evaluated by the author of this paper. The data source was the anonymized billing data of the ÜZW, a regional energy company. The analysis of the data provided showed that in 2019 1,121,730 kWh of electrical energy was taken from these 179 consumption points. The consumption distribution can be taken from Fig. 3. In 2019, the average consumption amounted to 6,266 kWh.

For 2018 and 2017, an identical evaluation was carried out with the same customer group, so that the different lengths of heating periods could be taken into account. In 2018, the average consumption was 5,248 kWh, in 2017 5,787 kWh. The three-year average was 5,757 kWh.

Another trend mentioned in the energy sector is the use of electrical energy for mobility applications, which will also lead to an increase in electricity demand. Here, too, the expected additional demand was determined. With an average annual mileage of 14,200 km [18], the additional consumption per electric car amounts to 2,900 kWh.

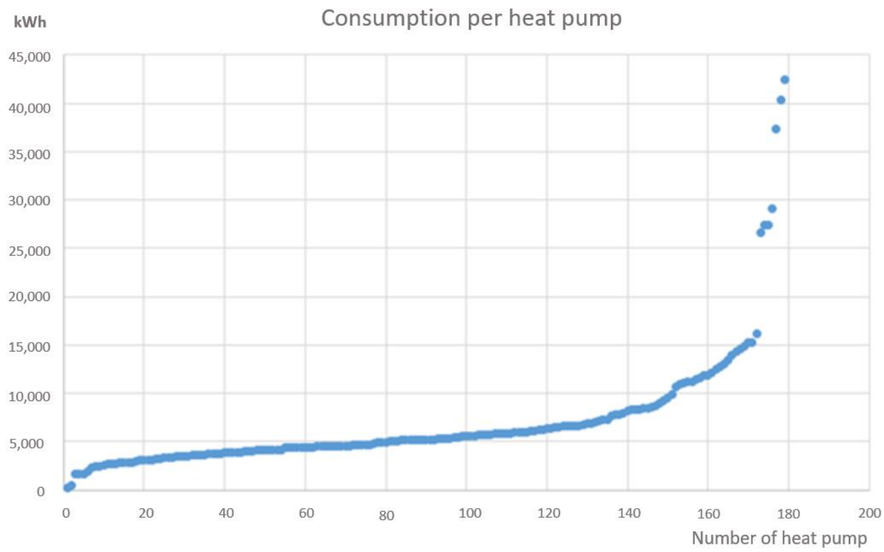

Figure 3. Heat Pump evaluation database.

For comparison: A two-person household without electrical hot water generation required an average of 3,528 kWh [19] of electrical energy in 2019. This electricity demand will increase by more than 80 % if a household-owned car is swapped for an electric car. If the heat demand is also covered by a heat pump, the electricity demand would be more than two and a half times higher. This underlines the need for intelligent smart home applications for load control in the customer system and thus to relieve the network infrastructure. A study by the Karlsruhe Institute of Technology (KIT) presented at the conference of the Federal Association of Energy Market & Communication e.V. on 21 Nov 2019 found that even with a market penetration of 15 % in 2030, the additional amount of energy required by electromobility for the distribution networks is not a problem [20]. However, the additional performance can become a challenge for the distribution networks, especially in the case of uncontrolled loading. This was also recognized on the part of the standardization bodies. In order to meet this challenge, the VDE-AR-N 4100 regulations stipulate that chargers with an output between 4.6 kW and 11 kW must be registered with the network operator, whereas charging devices with a power > 11 kW require the approval of the network operator. In addition to a large number of other possibilities [21], smart home systems represent a solution that enables the power requirements of the charging processes in the customer facility to be flexibly regulated. Without such a solution, however, the normative regulation of VDE-AR-N 4100 will fail to achieve its goal.

For electricity supply customers, flexibility in their electrical system should not be associated with a loss of comfort. The original purpose of the smart home application is to increase the comfort of customers [22]. If burdens are shifted over time, this must offer added value to the user, otherwise, they will not accept such a smart home application. If the necessary added value can be achieved, this will also strengthen customer loyalty.

Due to the lack of communication technology, the electro-technical measuring devices installed up to now do not support intelligent load control. An energy management system (EMS), as can be implemented using a smart meter, is essential here [23]. It is true that the Federal Office for Security in Information Technology (BSI) has now issued the market declaration in accordance with Section 30 of the Measuring Point Operations Act on 24 February 2020, [24] and thus the basic possibility has been created to install intelligent measuring systems, which can be integrated communicatively, with household customers. These offer the possibility to record and transfer consumption, delivery and load flows to and from the network, which is a necessary basis for the smart home application. However, as these systems are still too expensive and not yet available to the mass market, they have not yet facilitated any control interference in the customer system.

The need to manage loads more flexibly will create an important market for energy companies in the future. Still, incentives must be created for the customer to avoid peak loads during peak periods and to shift the demand for power in times of low load [25].

There are now providers who offer practicable solutions for load-variable pricing. This solution usually consists of a flexible electricity tariff in conjunction with an intelligent metering system. One provider is, for example, the company Tibber Germany. Its load variable electricity tariff is based on stock market prices, which at a certain point reflect the relationship between electricity supply and demand. In times of electricity shortages, the price of electricity can be up to four times the average price, whereas in times of low load, the customer benefits from extremely low prices. The customer only pays the purchase price of the electrical energy plus a monthly basic amount. However, if a customer wants to make use of the benefit of this tariff model, they are dependent on a controllable, flexible infrastructure in the customer's system, precisely the already mentioned smart home applications. Tibber offers value-added services around the topic of electricity in order to cover the costs of business operations and generate profit. Thus, a much greater customer loyalty can be achieved than would be possible with the pure supply of electricity.

For several years now, more and more new companies have been pushing into the market for smart home applications. One of the most popular examples of a smart home device is probably Amazon's Alexa, which enables simple control tasks such as music playback, lighting controls, online services, etc. Until now, these smart home applications have only added value through increased comfort, although load control is possible, too, which is however, currently not the priority. For this reason, the interaction of different smart home components had to be tested in a pilot application.

4. APPROACH AND METHODOLOGY

If energy companies want to offer their own smart home solutions that are able to influence the performance requirements of household customers, the development of new, innovative business models is urgent. This, however, will only be possible on the basis of digital innovations. The necessary technological boost is shown in Fig. 4

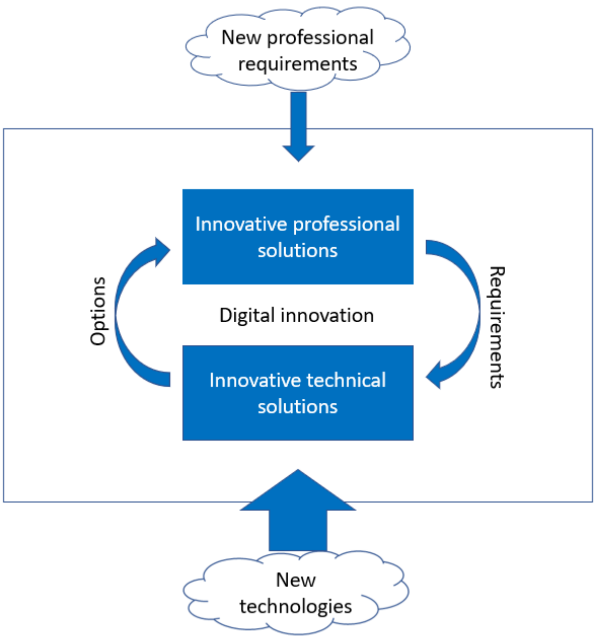

Figure 4. Technology push [26]

Fig. 3 illustrates both drivers of digital change, while the impetus for these innovations traditionally often resulted from new professional requirements and led to new, innovative technical solutions. Today, the impetus often comes from new existing technologies. As a result of the digital transformation in almost all areas of the economy, new business areas have emerged that the established companies have usually not filled quickly enough. New players, especially start-up companies, have already established themselves in many industries and stolen business shares from existing companies [26]. The small and mid-sized energy companies are currently at the beginning of the digital transformation process. Although they are well aware of the need for this and also see the existential threat, the right strategy for the digital transformation process is still missing in most companies.

The first step for small and mid-sized energy companies is to develop a digital transformation framework that describes the essential guard rails within which the transformation must move. Fig. 5 shows the schematic representation of the Digital Transformation Framework.

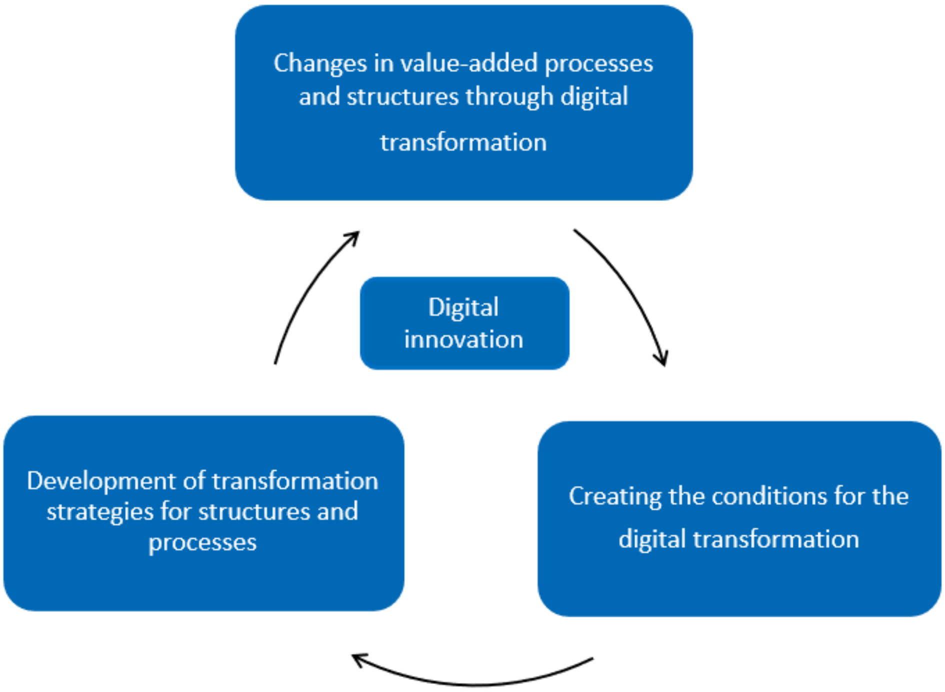

Figure 5. Digital transformation framework [27].

This process has not yet been carried out by the small and medium-sized energy companies, which is why this pilot application had to be carried out using a combination of existing solution approaches. Prior to practical implementations in the pilot application, a market analysis of the available load variable tariffs had to be carried out by answering the questions which additional components are required, how they need to be installed and what control options exist. The scope of the pilot plant had to be determined and a suitable pilot user had to be found.

An essential criterion for customer benefit lies in the customer-friendly setup: especially for less IT-savvy users, a “plug and play” solution is necessary.

Different expansion stages were planned for the pilot application. The pilot system was installed by an electrician in the house he used himself and made available to the author for analysis. Due to his professional background, the electrician is familiar with modern control systems. The converted residential building is heated by means of a heat pump with an additional heating rod. Suitable arrangements were made for a later photovoltaic installation.

5. PILOT APPLICATION

As a first step, the basic functions were implemented in the smart home system, so that the heating control as well as the control of the lighting and the shading were carried out by the smart home user-oriented system right from the very beginning.

In addition, a large number of other applications are possible with a smart home system, some of which were implemented in the following steps [28]. Access control was one of the first building blocks. A sensor bar, which is firmly installed in the masonry near the access door detects the smartphone of the user and the authorized persons and the front door is automatically unlocked. These first functions were only used to increase comfort. This would not allow for a shift in load or increased customer loyalty.

The subsequent expansion of the smart home system enabled the first efficiency improvements and load shifts to be realized. For example, a 10 kWp photovoltaic system and a 3.15 kWh storage system were installed, which made it possible to shift parts of the load, for example that of the heat source, into the low load time.

Within the last expansion stage, the performance of the photovoltaic system was increased to 15.28 kWp and the storage capacity doubled to 6.3 kWh. The purchase of intelligent household appliances, an air conditioning system coupled to the smart home system, as well as an electric vehicle with a communication-capable charging infrastructure have created great potential for load shifting. Furthermore, the multimedia system has been fully integrated into the smart home system, which significantly increases the control comfort due to the possibility of voice control. Fig. 6 shows the schematic structure.

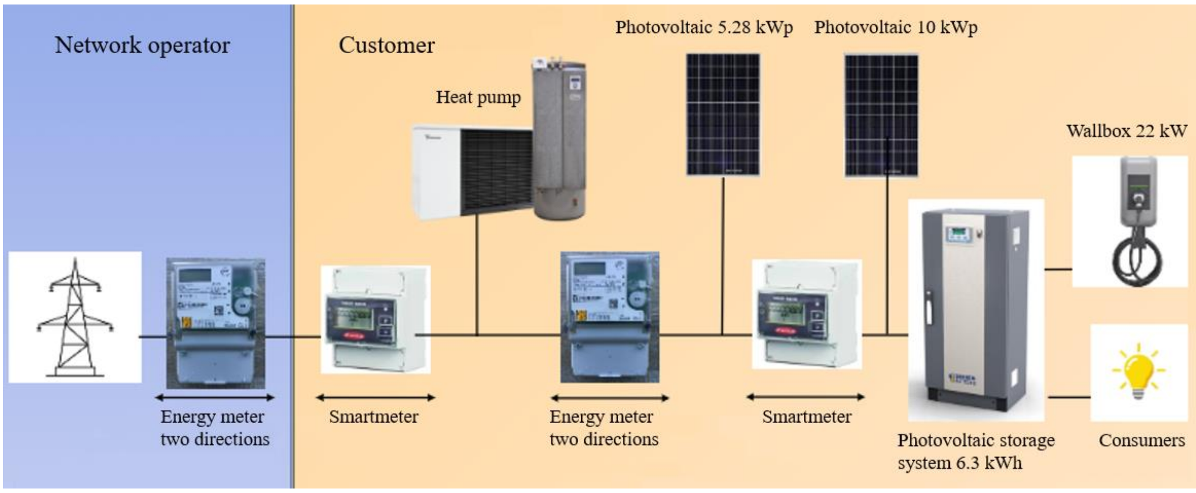

Figure 6. Schematic structure of the pilot plant installation

The controller provides for the following prioritization for the use of the self-generated electrical energy:

1. Dishwasher, washing machine and dryer,
2. Water heating,
3. Storage of overproduction in the storage system,
4. Passive cooling by means of shading,
5. If this is not sufficient, active cooling via air conditioning,
6. Charging of the electric vehicle.

Smart home applications have achieved a degree of self-sufficiency of around 60 % despite mobility and heat applications, with 7,500 kWh of the 10,000 kWh produced annually. This corresponds to a self-consumption rate of 75 %. To increase the economic efficiency, the regional energy company offered a power-to-heat electricity tariff, which enables the use of the self-generated energy for household electricity demand and heat generation thanks to the special measurement concept. In accordance with § 14a of the EnWG (Energy Economics Act), a reduced grid charge and thus a lower electricity price are offered for the electricity used for heat generation. According to the local network operator, particularly this energy tariff makes it possible to increase customer loyalty, as this tariff enables the customer to achieve real added value without additional effort. However, this solution is still a long way from a real load variable tariff, the digital innovations for this are missing. With the integration of a correct load-variable tariff, the control of smart home applications, especially intelligent household appliances, can be further optimized [9]. Unfortunately, during the pilot project, it turned out that the installed smart home components are not interoperable. The individual system components had to be purchased by different manufacturers and a plug and play solution was not possible. Due to the high effort of system integration, the installation takes a lot of time, which is usually to be provided by a specialist company. This, in turn, has a negative effect on the implementation costs and thus on the cost-effectiveness of the solution. Even after commissioning, regular adjustments and software updates provide ongoing maintenance which are, however, not feasible in this complexity of the smart home solution for laymen at this time.

Despite the huge savings, the high investments in technology, installation, commissioning and maintenance do not enable any economic operation at this stage. Offering the power-to-heat tariff model has enabled customer loyalty. A load shift in load-free times is possible within the frame, but the limiting factor here is the available storage capacity which has already been doubled as part of the implementation of the pilot project. The electric vehicle was primarily charged via the power grid during the low-load phase, since the electric vehicle, as a flexible load, offers great potential for load shifting. In case of a generation surplus during the day and the need for a vehicle charge, the self-consumed energy was also used for this.

6. CONCLUSION

In summary, the implementation of the pilot application shows that the appropriate investment in the smart home infrastructure can enable the shifting of the customer's peak load. To what extent the investment in smart home technology can be compensated by the savings potential of e.g. load-variable tariffs was not examined in the context of this scientific work. In this way, the control of the electric vehicle could be coupled to the generation of the photovoltaic system, which significantly reduced the electricity demand in the summer months. It was also possible to operate the heat pump in connection with photovoltaic generation, but due to the frequently missing generation current during dark months, this measure alone has only little influence on the electricity demand. If a drastic reduction in performance is to be achieved, much more consumables must be flexibly controlled. In the absence of a load-variable tariff, the controllability in the customer system currently refers exclusively to the needs of the user or to the optimization of the self-consumption rate of the photovoltaic system. The grid operation of the smart home components requires control by the energy company. However, it is precisely here that digital innovations by small and medium-sized energy companies are necessary, which are currently still missing. Moreover, approaches to a solution that enable the energy company to control the load in the customer system according to the needs of network operation without ignoring the user's comfort needs plays an important role. Within this context, a flexible tariff system must create a monetary incentive for the user.

The goal of increasing customer loyalty was achieved through the use of smart home components in conjunction with a power-to-heat electricity tariff. This tariff enables the use of self-generated electrical energy for both domestic and heating requirements while maintaining the cheaper heat electricity tariff. However, this tariff is not a load-variable tariff, but rather enables users to only use the electricity they have generated themselves for household applications and heat pump operation and at the same time to take advantage of reduced network charges for heat pump electricity. However, this alone does not enable any potential for load shifting in the customer system. In addition to the missing tariff structures, the corresponding non-standardized smart home components are also required for this.

Investments in plant technology are taken into account, and no financial added value can be created for the user at present. Although the self-consumption rate can be increased and thus the necessary power supply from the public grid significantly reduced, this is far from sufficient to cover the investment costs. In particular, the high installation effort has a negative impact on the business case. If a positive business case is to be created for the user, smart home components must be standardized. This, on the one hand, reduces purchase price and installation costs, and on the other hand, a load-variable tariff would be required that uses the potential for fluctuating electricity procurement costs. However, in order to implement correct load-variable tariffs and standardize the necessary hardware components, the digital transformation process must first be implemented in small and medium-sized energy companies.

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