Decision Support for Optimal Investments in Building Energy Systems

Completed Research

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Abstract

In 2000, the Renewable Energy Sources Act (EEG) initiated a large dissemination of photovoltaic systems in Germany. The EEG guaranteed a fixed feed-in remuneration for 20 years, which is highly profitable for many private and commercial prosumers. Feed-in tariffs have decreased substantially, resulting in a different economic situation for prosumers. Current prosumers that are about to exit the remuneration in the near future facing the challenge of readjusting their energy infrastructure. Whereas, potential prosumers aiming to establish an efficient building energy system. Both need an artifact that introduces the idea of efficient investments in renewable energy sources technology. Our decision support system (DSS) seeks to provide guidance for private and commercial prosumers by simulating small energy systems, presenting performance indicators and thereby display investments’ impact on the building energy system’s efficiency. The Green IS based DSS reduces complexity of components and enables prosumers to follow a sustainable transformation path.

Keywords

Introduction

Since the beginning of the 21st century, the concept of energy transition has emerged on a technical and a socio-economical level. This has led to an extensive and drastic change in the global energy system. After the nuclear disasters in Chernobyl in 1986 and in Fukushima in 2011, a political and societal debate regarding nuclear power plants arose in Germany, intensifying the discussion about national energy transition. As the Ethics Commission for a Safe Energy Supply reported, energy transition requires great efforts by all levels of politics, business and society (Töpfer and Kleiner 2011). For instance, in 2000, the Renewable Energy Sources (RES) Act (EEG) initiated a dissemination process of RES technologies, especially photovoltaic systems (PVS). It guaranteed installed PVS before 2000 a feed-in tariff of 50.6 ct per kilowatt hour (kWh) for 20 years up to 5 MWp which is defined as the potential maximum power of PVS (Federal Ministry for Economic Affairs and Energy 2017, Renewable Energy Act 2017). Therefore, investments in PVS were incentivized and became more profitable. In contrast, potential prosumers who installed a PVS up to 40 kWp in February 2019, received a feed-in remuneration of 11.03 ct/kWh (Federal Ministry for Economic Affairs and Energy 2017; Federal Grid Agency 2017).

As the EEG successfully supported the dissemination of RES generation systems, the trend of energy prosumers emerged. According to Parag and Sovacool (2016), energy prosumers are agents who both consume and produce energy. This definition refers to industrial energy suppliers as well as households that use a PVS. Advances in electricity generation and energy storage technologies as well as declining costs have enabled private and commercial prosumers to establish building energy systems (RES) (Parag and Sovacool 2016). Recent studies by the Institute of Environmental Economic Research and the Institute of Future Energy Consumer Needs and Behavior state that several types of prosumers exist regarding technical setups, which indicates that there is no homogenous type of prosumer (Lautermann 2018).
Nonetheless, over 99% of all RES generation systems installed after 2013 implemented a PVS (Oberst and Madlener 2014). This data provides evidence that PVS have a wide application within BES in Germany. As the feed-in remuneration of PVS decreased substantially after the introduction of the EEG, the point of grid parity was passed in 2012 (Wirth 2018; Flaute et al. 2017). When the costs of PVS generation are equal or lower than the costs of fossil power generation, the point of grid parity occurs (Yun Lau et al. 2014). Consequently, the consumption of self-produced PVS energy is more profitable than utilizing grid electricity. Therefore, households face the challenge of readjusting feed-in orientated BES to self-consumption focused BES.

A study investigated the preferences of homeowners regarding the adoption of RES-based technology in 2014 and determined that self-supplied electricity was the most important preference of prosumers (Oberst and Madlener 2014). Additionally, recent studies have analyzed the impact of battery storage systems on the degree of self-consumption (DSC) and the degree of autarchy (DoA) (Moshövel et al. 2015; von Appen et al. 2015; von Appen et al. 2014). Besides the option of battery storage, various technologies provide promising alternatives to increase the DSC and DoA of households. Previous research has extensively examined the combination of PVS and various energy system components (Moshövel et al. 2015; von Appen et al. 2015; von Appen et al. 2014; Luthander et al. 2015; Staudacher and Eller 2012; Staudacher and Eller 2015; Tjaden et al. 2014) and Luthander et al. (2015) presented a comprehensive review of photovoltaic self-consumption in buildings with storage technologies like water storage and electrical vehicles (EV) used to increase the DSC. Additionally, heat pumps are an useful option for converting electrical energy into thermal energy (Luthander et al. 2015). Different BES have been examined extensively in recent studies, especially from a technical perspective. Many of the mentioned studies neglect the relationship between the technical potential of BES and economic criteria, however.

According to Flaute et al. (2017), there are no official statistics available regarding the number of residential prosumer households. These researchers suggest that residential prosumers play an important role in the process of energy transition in Germany (Flaute et al. 2017). As of now, existing and potential private and commercial prosumers must face two issues. First, PVS installed before 2001 will start to exit the EEG remuneration service by the end of 2019. Second, the fallen feed-in tariffs for potential PVS up to 40 kWp demand that established prosumers increase their DSC. These trends, developments and research insights lead to our research question:

*How can incremental investments optimally enhance a BES’ efficiency?*

To answer this question, we have developed a decision support system (DSS) which facilitates performance monitoring and efficiency optimization of a BES. The DSS is based on the numerical computing environment of MATLAB R2018b.

**Research Background and Research Design**

As the DSS addresses the fields of energy system simulation and optimization, we draw a comparison between established software tools and our DSS. A wide range of literature emphasizes the numerous software tools that belong to the field of RES simulation and optimization (Bernal-Agustin and Dufo-Lopez 2009; Zhou et al. 2010; Sinha and Chandel 2014; Trillat-Berdal et al. 2007; Bahramara et al. 2016). Bahramara et al. (2016) and Sinha and Chandel (2014) highlighted the hybrid optimization model for electric renewables (HOMER) software. Hybrid energy systems use more than one RES and include fossil energy generation. By applying a techno-economic analysis through several input parameters like load demand, component details, component costs and emission data, HOMER can determine the optimal sizing of components and minimize net costs. HOMER utilizes mainly technical input parameters to generate a techno-economic analysis.

Furthermore, Bernal-Agustin and Dufo-Lopez (2009) and Sinha and Chandel (2014) emphasized the hybrid system simulation software HYBRID, which uses precise time series and statistical methods to predict the performance of hybrid energy systems and to provide an economic analysis. Both computer models are powerful tools that facilitate a comprehensive technical and economic analysis. HOMER and HYBRID enable engineers to create and plan microgrids that are based on various RES and include multiple
consumers. They primarily create a targeted energy system that is optimized by certain parameters while the transformation path towards the targeted system cannot be displayed. In contrast to that, our DSS focuses on single-family houses, i.e. private prosumers and provides investment and transformation paths for established as well as potential prosumers. Since the approaches of HOMER and HYBRID differ fundamentally from our DSS focused approach, they cannot answer our research question. Our DSS is initiated by an incremental investment that leads to a transformation of components and computing of performance indicators like DSC and DoA. It then presents a chronological investment order based on the scenario parameters and economic conditions. This distinction highlights the DSS character of our tool as it gives prosumers an aggregated report of how to optimally invest in their BES.

To maintain methodological and scientific rigor, the research process is based on the principles of the design science methodology (DSRM). Initially, Hevner et al. (2004) defined the fundamental principle of design science research as the creation of knowledge and understanding of a design problem and its solution by the application of an artifact. Our postulated research question frames a complex decision problem of prosumers that justifies the application of a problem solving focused approach as the DSRM. Peffers et al. (2007) presented the application of DSRM in the field of information systems research (ISR) and the nature and motivation of our research question connects the DSRM to the upcoming fields of Green IS and Energy Informatics. The latter field contemplates electricity supply and storage in buildings and Goebel et al. (2014) defined energy supply by RES as a key research objective of Energy Informatics. As Green IS is a novel field, various definitions of it have emerged (Hassan 2014; Malhotra et al. 2013; Recker 2016; Gholami et al. 2016).

If the IS can help organizations’ decision-making processes to become more environmentally friendly, the Green IS approach is applicable (Calero and Piattini 2015; Paton-Romero et al. 2017). In general, the practices of design, software, and communication systems that effect the environment in a positive way support the definition of Green IS (Paton-Romero et al. 2017; Loock et al. 2013). Both definitions support the characterization of Seidel et al. (2017), as they depicted Green IS as an interdisciplinary research field that includes computer and environmental science, software engineering and environmental psychology. Additionally, Recker (2016) added substance to the field, as he introduced a design theory construct of Green IS that defines three important functions (Recker 2016). These include the formation of belief about environmental sustainability, the formation of action for environmental sustainability and the outcome assessment of environmental sustainability on an individual as well as organizational level. Our artifact refers to two of the three functions within the design theory construct of Recker. First, the artifact processes, analyzes and visualizes data to review the environmental sustainability of investments. Second, the artifact provides decision support by identifying environmental friendly options for action. The criteria of Recker (2016) apply, as our DSS develops a sustainable investment strategy for prosumers.

**Decision Support for Optimal Investments in Building Energy Systems**

**DSS Structure**

Fig. 1 visualizes the overall DSS structure and defines investments into BES as the starting point of the iteration. In the first stage, investments change certain attributes of the BES’s components. Following the examination of the mentioned studies (Moshövel et al. 2015; von Appen et al. 2015; von Appen et al. 2014; Luthander et al. 2015; Staudacher and Eller 2012; Staudacher and Eller 2015; Tjaden et al. 2014), the BES includes a PVS, battery storage, hot water storage, and a heat pump. Additionally, demand data determines the essential needs of a household and includes information about the demand of electrical devices, EV, space heating and hot service water. Demand data is modeled exogenously by a load profile generator that is customized to generate load profiles of households (Pflugradt et al. 2013). It includes a full behavior simulation of 60 predefined households. The total demand distinguishes thermal and electrical load. Since the heat pump is the only component that converts electrical energy into thermal energy, the thermal demand is translated into electrical demand. Therefore, the total demand can be defined as electrical demand in kWh. Regarding heat pumps, the coefficient of performance (COP) defines the relationship between electrical input energy and thermal output energy. By including the mentioned components, the BES is purely based on electric energy and causes no emissions regarding the energy supply. Each component is characterized by several technical parameters, highlighted in Tab. 1, to maintain a realistic modulation.
To maintain a precise performance monitoring, the time resolution of the BES simulation is set to one hour. Consequently, the operational management iterates each hour of one year, resulting in 8,760 iterations. During each hour, several performance indicators are tracked. This is necessary to determine the overall performance and efficiency of the BES and to evaluate the investments in components.

### Table 1. Technical Parameters of considered Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Technical Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVS</td>
<td>Area [$m^2$]; Maximum power output [$kWp$]; Efficiency Rate $\eta_{PVS}$ [%]; Inclination [$^\circ$]; Alignment of PV Modules [$^\circ$]; Shading Coefficient [%]</td>
</tr>
<tr>
<td>Battery Storage</td>
<td>Capacity [$kWh$]; Maximum Charge Rate [$kW$]; Maximum Discharge Rate [$kW$]; Efficiency Rate $\eta_{BS}$ [%]</td>
</tr>
<tr>
<td>Hot Water Storage</td>
<td>Capacity [$kWh$]; Maximum Charge Rate [$kW$]; Maximum Discharge Rate [$kW$]; Efficiency Rate $\eta_{WS}$ [%]</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>Maximum Nominal Power [$kW$]; COP $\frac{P_{out,th}}{P_{in,el}}$</td>
</tr>
<tr>
<td>Electrical Vehicle (EV)</td>
<td>Mileage [$km/\text{a}$]; Relative Consumption [$kWh/100km$]</td>
</tr>
</tbody>
</table>

### Operational Management

The operational management controls the energy flows within the BES hour by hour. Due to recent trends like decreasing feed-in remunerations, fundamental premises must support the decision patterns of the operational management. First, the utilization of PVS power within the BES has priority for maximizing the DSC. Second, as soon as the total demand is covered and a solar energy surplus remains, charging the battery storage has the main priority. This premise is technically justified due to the high flexibility of the battery storage, which can supply electrical demand directly or thermal demand indirectly via heat pump. As the battery reaches its maximum capacity, the heat pump converts the remaining electrical surplus to charge the hot water storage. The reconversion of thermal energy into electrical energy requires additional components, is rarely cost efficient and is, therefore, not considered. Third, if the state of charge (SoC) of the battery storage reaches its maximum capacity, the charge of the water storage has priority. Furthermore, certain premises define the decision patterns if a power deficit arises. For instance, if an electrical deficit occurs, supply via battery storage is preferred. When the battery storage cannot fully cover the electrical...
deficit, grid power compensates for the remaining deficit. Another deficit occurs when the water storage is insufficient to supply the hot water demand. Therefore, the heat pump is utilized to provide hot water and is powered by electrical energy of the PVS, battery storage, or the grid. In general, grid power is the final process that compensates when an energy storage fails to match the demand. Fig. 2 summarizes the mentioned premises in an energy flow diagram.

**Figure 2. Operational Management and Energy Flow Priorities in the BES**

As the operational management represents the key element of the BES, it controls the interaction of all energy system components in each hour of one year. To provide an overview, we summarize the underlying assumptions of the operational management:

- The total demand is covered for each hour of the year as the PVS output, the discharged power of the energy storages, and the grid power equals the total demand.
- The SoC cannot exceed the maximum or minimum capacity. By defining the maximum charge rate (MCR) and maximum discharge rate (MDR), the permitted discharge and charge processes are ensured.
- The operational management feeds in power to the grid as soon as the demand is covered and the storages are fully charged.

**Performance Monitoring**

While the operational management controls the energy flows, the performance monitoring tracks several parameters within each iteration, as the computation of DSC and DoA requires a variety of parameters from each BES component.

\[
\text{DSC} = \left( P_{\text{PVS}}^{\text{IC}} + P_{\text{Storage}}^{\text{Ch}} \right) / P_{\text{PVS}}
\]

\[
\text{DoA} = \left( P_{\text{PVS}}^{\text{IC}} + P_{\text{Storage}}^{\text{Dish}} \right) / D_{\text{Total}}
\]

Equation (1) determines the ratio of PVS output used for the internal demand \( P_{\text{PVS}}^{\text{IC}} \) and for charging the energy storage \( P_{\text{Storage}}^{\text{Ch}} \) to total PVS output \( P_{\text{PVS}} \), i.e. the DSC. The DoA is defined by equation (2), which computes the ratio of the total PVS output utilized directly \( P_{\text{PVS}}^{\text{IC}} \) or via energy storages \( P_{\text{Storage}}^{\text{Dish}} \) to the total demand of the BES \( D_{\text{Total}} \). The parameters \( P_{\text{Storage}}^{\text{Ch}} \) and \( P_{\text{Storage}}^{\text{Dish}} \) include the electrical and thermal energy.
charged or discharged by the storages. First, the performance monitoring determines the total PVS output and the share of PVS output that is utilized directly. In addition, the discharged and charged power of the battery and hot water storage must be considered to update the SoC for both storages within each iteration. Furthermore, the value of total demand $P_{\text{total}}$ must be defined to create the key performance indicators of DSC and DoA at the end of one year. The total demand of grid power, total feed-in power and energy losses are also monitored.

**Investment Optimization**

The previous subsections classify the component data and depict the operational management and the foundation of the performance monitoring. These elements are essential for evaluating incremental investment in BES components. An incremental investment changes the technical attribute of one BES component. For instance, investing in one battery module attached to the established battery storage increases the total battery capacity. As the technical attribute of a component changes, the DSS proceeds with the new component setup and determines the total cost reduction that result from the investment, see (3). Consequently, the evaluation of an investment includes two different options. In general, the prosumer can choose to invest in a storage (BS or WS) or PVS. Extending the PVS raises the total power output which can be either used for self-consumption or generate incomes via energy sale. The power output that is preserved within the BES substitutes grid power that ultimately results in energy cost reduction. Whereas an investment in one storage increases the energy capacity and strengthens the flexibility of the BES to deal with the temporal offset of power output and demand. The DSS supports the decision-making process by identifying the investment, which initiates the highest cost reduction in one year $CR_t$, defined by (3). An investment changes the setup of a BES as well as the total grid power and feed-in power. Since the total demand of a household is assumed to be constant each year, the parameters of total grid and feed-in power will change from one year to another. At first, the DSS calculates the difference of total grid power $(p_{\text{grid}}^{t-1} - p_{\text{grid}}^t)$ and multiplies the difference by the delta of electricity price $\tilde{p}_{\text{grid}}$ and the feed-in remuneration $\tilde{p}_{\text{feed-in}}$. By using an amount of PVS output within the BES, it results in electricity cost savings. Furthermore, as PVS output was used it cannot generate feed-in remuneration. Therefore, we include the difference of electricity price $\tilde{p}_{\text{grid}}$ and the value of feed-in remuneration $\tilde{p}_{\text{feed-in}}$. The positive delta of feed-in power $(p_{\text{feed-in}}^t - p_{\text{feed-in}}^{t-1})$ provides additional income. In case a feed-in remuneration mechanism does not exist, the prosumer has the opportunity to sell not required surplus at the price of the electricity exchange $\tilde{p}_{\text{EEX}}$. Then, $\tilde{p}_{\text{EEX}}$ substitutes $\tilde{p}_{\text{feed-in}}$ in (3).

$$CR_t = [(p_{\text{grid}}^{t-1} - p_{\text{grid}}^t) * (\tilde{p}_{\text{grid}} - \tilde{p}_{\text{feed-in}})] + [(p_{\text{feed-in}}^t - p_{\text{feed-in}}^{t-1}) * \tilde{p}_{\text{feed-in}}]$$

In the following PVS, battery storage (BS) and hot water storage (WS) are the components whose attributes are affected by investments. In contrast, the heat pump was not involved intentionally within the investment decision process as it cannot be expanded modularly, whereas the PVS, BS, and WS can. By defining relative gross investments (including acquisition and installation costs), see Tab. 2, we display an investment’s impact on the technical extension of a component.

**Case Study: Hanover (Germany)**

This section applies the methodology of our DSS. Tab. 2 provides an overview of the predetermined parameters for different scenarios. Overall, we distinguish between a household size of two inhabitants (Scenario A) and four inhabitants (Scenario B). They differ regarding the living space and the total energy demand. Identical parameters were applied regarding the relative space heating demand, EV settings and the evaluation of investments via relative gross investments of the BES components. An incremental investment accounts for 2,500 €. The demand data is derived from the mentioned load profile generator (Pflugradt et al. 2013). The daily charging of the EV initiates an additional demand between 8 pm and 6 am. A feed-back option of electricity from the EV to the BES creates additional charge cycles and reduces battery lifetime and is therefore neglected. Each scenario is divided into two cases. The first case assumes a feed-in remuneration of 11.0 ct/kWh, which is the value that will be expected in Germany in 2019. Whereas in the second case, the prosumer sells not required surplus at the price of the electricity exchange.
### Table 2. Scenario Parameters of two Households

<table>
<thead>
<tr>
<th>Scenario Parameters</th>
<th>Scenario A</th>
<th>Scenario B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household Size</td>
<td>2 adults</td>
<td>2 adults and 2 children</td>
</tr>
<tr>
<td>Living Space [m²]</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Relative Space Heating Demand [kW/m²a]</td>
<td>80.0</td>
<td></td>
</tr>
<tr>
<td>Relative EV Demand [kW/h/km]</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>EV Mileage [km/a]</td>
<td>20,000</td>
<td></td>
</tr>
<tr>
<td>Total Demand D&lt;Total&gt; [kWh/a]</td>
<td>8,116.3</td>
<td>12,181.1</td>
</tr>
<tr>
<td>Electricity Price $\bar{p}_\text{Grid}$ [€/kWh]</td>
<td>0.290</td>
<td></td>
</tr>
<tr>
<td>Feed-In Remuneration $\bar{p}_\text{Feed-in}$ [€/kWh]</td>
<td>0.110</td>
<td></td>
</tr>
<tr>
<td>Electricity Exchange Price $\bar{p}_\text{EEX}$ [€/kWh]</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>Relative Gross Investment PVS [€/kWp]</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>Relative Gross Investment BS [€/kWh]</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>Relative Gross Investment WS [€/kWh]</td>
<td>50.0</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3 and Fig. 4 visualize the results of the respective scenarios including the mentioned cases. In general, the red dots highlight the selected component with the highest cost reduction of each iteration and thereby display the optimal investment strategy. Furthermore, the colored graphs present the energy cost reduction of one incremental investment in PVS (green), BS (orange) and WS (red) considering the previous optimal decisions. The dashed line shows the progression of the DoA, while the dotted line relates to the DSC. Finally, the progressions of both performance indicators are based on the optimal investment strategy.

Figure 3. Overview of Energy Cost Reduction for Scenario A: (3.1) With Feed-In Remuneration $\bar{p}_\text{Feed-in}$, (3.2) Without Feed-In Remuneration, Selling at Market Price $\bar{p}_\text{EEX}$

Regarding Fig. 3.1, investments in PVS dominate over storage investments. Thus, the PVS output increases constantly and cannot be kept in the BES and result in a low level of DSC and DoA. However, the cost reduction of WS approach those of PVS investments at the 50,000 € mark. In contrast, Fig. 3.2 shows a different investment strategy. The third investment already goes into the WS and afterwards the investments in PVS and BS alternate up to cumulative gross investment of 35,000 €. As the PVS output and storage capacity increase simultaneously, the level of DoA rises steadily up to 75%. The level of DSC decreases moderately and ends up approximately at 33%.
Fig. 4.1 shows a similar investment strategy as Fig. 3.1, i.e. investments in PVS dominate. The cost reduction of WS exceeds the one of PVS in the last investment step, which leads to a sharp increase of DoA and DSC. Regarding Fig. 4.2, cost reductions of WS already surpass those of PVS in the fourth investment step. Then, PVS investments dominate except of four investments in BS. Similar to Fig. 4.1 the DoA rises steadily up to almost 65 %, whereas the DSC starts at a high level of 88 % and finishes at 42 %.

Discussion, Implications and Limitations

The two cases with a feed-in remuneration in Fig. 3.1 and Fig. 4.1 demonstrate that investments in storage technology still appear to be inefficient regarding the energy cost reduction of a household. Even though the feed-in remuneration has significantly decreased in Germany, it is still more profitable to feed in power into the grid than storing it in order to increase the DSC and DoA. In contrast, Fig. 3.2 and Fig. 4.2 showcase that an absence of a feed-in remuneration mechanism supports the investments in storage technology. As the prosumers only sell energy surplus at a market price, the feed-in option becomes less rewarding. Therefore, the importance of storage components increases, since both have a relevant effect on DSC and DoA. Additionally, the investment order of Fig. 3.2 and Fig. 4.2 slightly differs. The smaller total demand of Scenario A, also resulting in a lower utilization of PVS output, leads to a significant lower DSC than in Scenario B. Therefore, an investment in storage has a substantial impact on the DSC in Scenario A, leading to earlier investments in WS (and later BS) than in Scenario B. Overall, the difference in both scenarios between the first and the second case appears to be similar. It leads to the assumption that the feed-in remuneration has a significant impact on the investment behavior of prosumers regardless of the household size. As we assume that established prosumers already have installed a PVS, we recommend adding storages depending on the size of the PVS according to Fig. 3.2 and Fig. 4.2. Potential prosumers should follow the investment paths of Fig. 3.2 and Fig. 4.2 to maximize the BES efficiency. These recommendations are based on the absence of a feed-in remuneration. On the contrary, potential prosumers that have access to recent feed-in tariffs of 0.11 €/kWh or higher, should invest in PVS to maximize total energy cost reduction, see Fig. 3.1 and Fig. 4.1.

A main assumption of the DSS is the modular expansion of BES components, therefore, several issues must be mentioned. For instance, investments in PVS also include the extension of the inverter module that enables the household to utilize the generated electric energy. This kind of technical barrier also relates to WS and BS. Another issue is limited space as additional solar modules, battery modules, and especially hot water storages require a certain amount of space. As BES include a large range of technologies, their modulation and simulation can become highly complex. Consequently, certain technical parameters and processes must be simplified from a technical point of view, which is a fundamental premise of the DSS as it aims to have a high applicability.
To ensure a comprehensive economic analysis, further parameters must be added, i.e. interest rate, payback period, development of feed-in tariffs and electricity price as well as decreasing relative gross investments of components. These aspects would improve the precision of the model. Since we cannot assume an average investment behavior of prosumers, we also cannot define a specific investment period. Furthermore, falling relative gross investments of components would favor them regarding the investment decision-making. Nonetheless, the future development of component costs is based on forecasts and would add uncertainty to our model.

Regarding the case study, the results are based on data from Hanover (Germany). Accordingly, data from different geographical locations may yield different results. Demand, temperature and solar radiation data is strongly connected to the geographical location. Information about feed-in remuneration, electricity price and national incentives as well as restrictions needs to be available. To apply the DSS to a different BES, additional components may have to be implemented within the operational management. Nevertheless, the structure of the DSS provides an extensive foundation that can be adapted to different BES setups.

Conclusions and Outlook

Energy prosumers have emerged within the global energy transition. As RES technology advances and acquisition as well as installation costs have decreased, households are able to realize BES and contribute towards a renewable energy supply. On the one hand, BES include various technical components that enhance complexity. On the other hand, prosumers have to establish their BES while considering the given political as well as economic conditions. This framework impedes efficient decision-making of current and potential prosumers. To provide guidance for energy prosumers, we develop a Green IS motivated DSS based on a numerical computation environment that simulates energy flows within a BES and monitors relevant performance and efficiency parameters. We applied the DSS methodology on four scenarios, to analyze how incremental investments optimally enhance the efficiency of a BES and present several investment orders of different prosumer scenarios. The case study results are based on current demand, technical and economic data, which verifies the applicability of our DSS.

Despite its discussed limitations, our DSS delivers meaningful results for private energy prosumers. As the presented artifact supports decision-making of prosumers towards a sustainable transformation and provides an actionable investment strategy in their BES. Through its high applicability and complexity reduction, it facilitates an entry in BES for potential prosumers. Current private prosumers gain recommendations for retrofitting their BES properly. To present insights for commercial prosumers, verified demand data needs to be available. Due to the heterogeneous demand data of the commercial sector, our DSS can recommend investment paths for specific cases, which cannot be generalized, however. In our further research, we aim to address the mentioned limitations and fine-tune our DSS. Future Green IS research should investigate the decision problem of prosumers in more detail as they will play a dominant role within the global energy systems’ transition. Additional insights and results could have a greater impact on a large scale.

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