Conference Proceedings

EuroSun 2016
Palma de Mallorca (Spain), 11 – 14 October 2016

Economic analysis of renewable energy production with photovoltaic- and solar thermal systems for small and medium-sized enterprises

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Abstract

The economic benefits that photovoltaic and solar thermal renewable energy (RE) producers offer under Germany's current legislative conditions (EEG 2014) have been investigated for two cases involving small and medium-sized enterprises (SMEs). The energy demands of the case SMEs are very distinct in volume, type, and profile. With the aid of a simulation, the direct consumption of the expected RE generation and the resulting energy exchange with the grid have been calculated. The results have been analyzed from an economic standpoint using economic indicators and the LCCA (life-cycle cost analysis) method. For the two cases, the results are presented with their indicator values and the designs of the PV and solar thermal systems.

Keywords: Renewable energy; small and medium-sized enterprises; simulation; cost analysis; life-cycle cost analysis

1. Introduction

While energy supply is a constant subject of discussion, focus on it has intensified due to factors such as the prediction regarding the depletion of fossil fuels or nuclear accidents. The current driver of the discussion is climate change. Approximately 80% of the world's primary energy supply comes from fossil fuels that emit greenhouse gases such as CO_2 (International Energy Agency (IEA), 2015). CO_2 and other greenhouse gases modify the planet's absorption and emission of solar radiation and are associated with the observed warming of the climate and other serious environmental problems (Pachauri and Mayer, 2015). To initiate and maintain a decrease in CO_2 emissions, several targets have been set worldwide. For instance, for 2020, the European Union has set the 20/20/20 targets. These entail reducing greenhouse gas emissions by 20% (in comparison to the 1990 levels), increasing the share of renewable energy (RE) sources in final energy consumption by 20%, and increasing energy efficiency by 20% (European Commission, 2010). Installing RE plants could improve the first two targets but would result in further challenges. One such challenge involves the change of predominantly centralized energy systems into bi-directional, decentralized ones which integrate RE producers. Another challenge involves handling the fluctuating behavior of RE producers such as photovoltaic systems (PV) and/or wind stations (WS) due to their weather dependency. Energy production is difficult to predict. The fluctuating behavior and forecast errors would lead to instabilities in the grid, resulting in higher management control efforts. Like that of many other countries, the infrastructure of the German energy system must be modified to manage such challenges; such efforts will incur major costs. To finance them, several levies and taxes have been established based on the Renewable Energy Sources Act (EEG) (Deutsche Bundestag, 2014).

The German EEG manages the expansion of RE producers and sets tariffs for the feed-in of RE into the grid for new RE producer installations. The EEG was first introduced in 2000. Initially, investors benefit from the high feed-in tariffs and lower taxes. But the regulations are constantly revised over the years. Certain conditions have drastically reduced and restricted the feed-in tariffs, bringing self-consumption into focus.

doi:10.18086/eurosun.2016.08.07 Available at http://proceedings.ises.org

For SMEs which are willing to invest in RE, a complex decision problem has to be solved. Once the technical and legal feasibility of installing and operating one or more RE producers has been verified, the issue of how the optimal RE system fits the SME's energy demand and profile has to be decided: Does it consist of one type of RE producer or of different types of RE producers? In what combinations do they occur, and of what size are they? To what extent does the RE satisfy the energy demand? How is overproduction handled? Is it suitable to store it or can it be injected into the grid – and under which conditions are such efforts possible?

This paper investigates the optimal design of a PV and solar thermal system that will supply an SME consumer with electrical and thermal RE and fit its energy demand and profile. These results are compared with the original situation, which involves the 100% feeding of RE into the grid, to illustrate the higher benefits that self-consumption offers. Two distinct cases are investigated under the rubric to achieve the best financial return for the investment within the restrictions of Germany's 2014 EEG.

The optimal design of a RE producer is highly critical for maximizing energy cost savings. Tools have been developed to calculate the economic effects of RE producers. Available tools, such as pv@now (Deutsche Gesellschaft für Sonnenenergie (DGS)), base their calculations on average yearly values for RE production and company demand. Though the results are useful for rough estimations, they neglect the seasonality of RE generation and company demand, leading to considerable deviations in efforts to balance RE supply and demand and, consequently, to differences between the expected and true economic effects. To solve this problem, the research group, "Energy Efficiency in Production," at the University of Applied Sciences Emden/Leer has developed the agent-based simulation, PREmdeK (Pechmann). It simulates a local energy system that consists of one major industrial consumer (e.g., an SME), a multi-source renewable power plant (PV, wind station, CHP, solar heat), and storage entities. The simulation runs on data produced at 15-minute intervals for the duration of a year. For the two cases, historical data regarding energy demand and local weather conditions were used (Pechmann et al., 2016). The simulation employed various PV and solar thermal machine designs that were calculated to balance RE generation with the company's consumption while using storage entities and the grid. The scenarios served as input for an economic analysis that employed economic indicators and the LCCA (life-cycle cost analysis) method. The results of the economic analysis include supplying solutions that will maximize the SMEs' energy cost savings.

In the subsequent section, related work is discussed. Next, section three presents background information on "energy" business models (BM) for SMEs that are feasible under the German EEG 2014, the two case SMEs and energy supply scenarios, and the calculation methods that are applied in the economic analysis. Section four evaluates the case SMEs' results. Then the article ends with a conclusion and a description of possible future work, followed by the references.

2. Related Work

Choosing the right machine design is very important when investing in an RE plant for full or partial self-supply to achieve maximum energy cost savings. It is not sufficient to solely consider energy production costs per plant though they have been researched widely and calculated (Michaelis et al., 2013; Balks and Breloh, 2014; Oliveira e Silva and Hendrick, 2016).

Several conditions affect the benefits that the RE producer offers and should be analyzed for each specific consumer. An overview of possible methods is presented and reviewed in the recent article, "Decision-Making in Renewable Energy Investments," by Strantzali and Aravossis (2016). This literature review shows that the choice of the method mostly depends on the preferences of the decision-maker and the analyst. Industrialists prefer the use of economic indicators for decision-making, and LCCA is dominant in the fields of energy policy and management (Strantzali and Aravossis, 2016). To calculate the economic indicators and the LCCA value, the right input parameters (e.g., investment, installation, and operational costs) must be defined, depending strongly on the types and sizes (designs) of the RE producers and necessary storage devices. Studies on the methodologies that define the input parameters associated with the design and size of the RE producer exist as well (Baños et al., 2011; Erdinc and Uzunoglu, 2012). There is a need for case examples that present the technical design of the RE producer in relation to costs and benefits during the operation of the system. Though there are a few such case studies, they focus on private households and buildings (Achtnicht, 2011; Marszal et al., 2012). Case studies that focus on manufacturing SMEs with real data are not publicly available. SMEs account for half of the industry's power consumption (BMWI, 2016). It is therefore expected that the results of this study will be of great interest to SMEs that are looking for ways to reduce their energy costs with RE.

3. Background and Methods

3.1 Feasible business models under the German EEG 2014

Generally speaking, the operator of an electrical RE producer has different ways to handle RE (see Figure 1): as a mix of self-consumption and feeding into the grid (BM1), as self-consumption alone (BM2), and as feeding into the grid alone (BM3–BM5). This paper investigates BMs for supplying an SME consumer within the operational scope; therefore, it does not take into further consideration the BM of selling to a third person. Only BM3 (market premium model) is considered to compare the benefits of self-consumption and those of 100% grid feed-in under the current EEG.

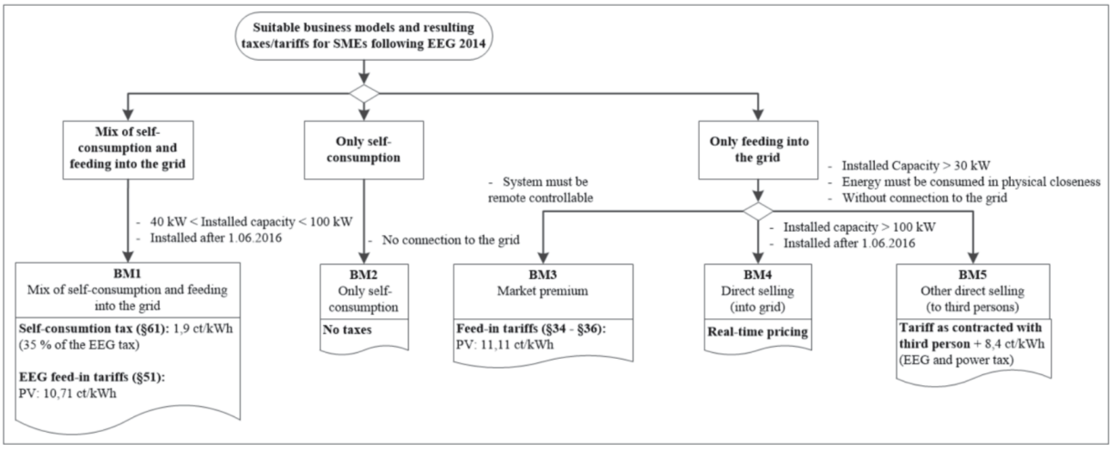

Figure 1: The range of possible applications for RE according to the German EEG

In **BM1**, the operator has the following options for using the electrical RE produced (P_{elRE}) (see Equation 1): consuming the RE ($P_{elRE\text{-}elC}$) and/or feeding the RE produced into the grid ($P_{elRE\text{-}G}$). Additionally, it is possible to temporarily save the energy in electrical storage ($P_{elRE\text{-}elS}$) for its later consumption and/or feeding in. According to the EEG 2014, BM1 is only possible if the machine design value of the RE producer is lower than 100 kW.

$$P_{RE} = P_{elRE-G} + P_{RE-ES} + P_{RE-elC} \qquad \text{(eq. 1)}$$

Equation 2 calculates the cash inflows for BM1 (C_{BM1}). The operator gets the tariff for feeding RE into the grid from to §51 ($P_{elRE\text{-}G}$ * $c_{RE,i}$). The self-consumption of electrical RE saves energy costs less the tax for own consumption of energy (($P_{elRE\text{-}elC}$ + $P_{ES\text{-}elC}$) * (c_{el} - c_{EEG})) according to §61. For electrical storage systems, special conditions are applied. The self-consumption tax must be paid twice: for charging the electrical storage and for discharging it.

$$C_{BM1} = P_{elRE-G} * c_{elRE,i} + (P_{ES-elC} + P_{elRE-elC}) * (c_{el} - c_{EEG}) + P_{elRE-ES} * c_{EEG} \qquad \text{(eq. 2)}$$

If the machine design value is greater than 100 kW, the option of consuming and/or feeding the RE into the grid is not allowed. For **BM2**, the RE plant may not be connected to the grid. Therefore, in the event of the overproduction of electrical energy, it cannot be injected into the grid. If the consumer makes no demand and is not able to store the energy, it will be wasted. ($P_{elRE\text{-}EO}$) (see Equation 3).

$$P_{elRE} = P_{elRE-EO} + P_{elRE-ES} + P_{elRE-EC} \qquad \text{(eq. 3)}$$

The advantage of BM2 over BM1 is that the tax for self-consumption does not apply to it. The operator saves the full purchasing costs for its own consumption of electrical energy ($P_{elRE\text{-}elC}$ * c_{el}). The disadvantage lies with the overproduction: It is wasted. Hence, it does not lower any costs ($P_{elRE\text{-}EO}$ * 0). Equation 4 calculates the cash inflows for BM2 (C_{BM2}).

$$C_{BM2} = P_{elRE-EO} * 0 + (P_{elRE-elS} + P_{elRE-EC}) * c_{el} \quad \text{(eq. 4)}$$

For the thermal RE producer, no regulation is in place due to the EEG 2014. The thermal energy supply via local and/or district heating grids is not considered in this paper. Because of this, no thermal energy is fed into a grid, and the calculations are made in analogy to those for BM2 (see Equations 5 and 6).

$$P_{thRE} = P_{thRE-EO} + P_{thRE-TS} + P_{RE-thC} \quad \text{(eq. 5)}$$

$$C_{BMTh} = P_{thRE-EO} * 0 + (P_{RthE-thS} + P_{thRE-EC}) * c_{th} \quad \text{(eq. 6)}$$

In the case of the market premium model (**BM3**), the grid operator must have access to remote control of the RE producers. The RE produced is completely fed into the grid (see Equation 7).

$$P_{elRE} = P_{elRE-G} \quad \text{(eq. 7)}$$

The operator gets a tariff according to §34 - §36 ($c_{PM,i}$). In case of a shutdown by the grid operator (for various reasons), the amount for the non-fed-in energy is reimbursed as it would have been if it were feed-in. Equation 8 calculates the cash inflows for BM3 (C_{BM3}).

$$C_{BM3} = P_{elRE-G} * c_{PM,i} \quad \text{(eq. 8)}$$

3.2 Characterization of case companies and scenarios

For two case SMEs, the capital and operating costs for energy supply are investigated for several scenarios for the year 2014. For each SME, the scenarios are then compared. All scenarios are technically feasible and applicable. The energy demand (see Table 1) is known, and load metering data from the SMEs' energy provider is used. Additionally, individual load metering is performed on the most energy-intensive machines using metering devices. The installation of these devices is part of a long-term effort by the PREmdeK Project (Ernst et al., 2013).

Tab. 1: Yearly energy demand of the case SMEs considered for 2014

SME	1	2
El. demand in [kWh] (day)	199.099	3.454.636
El. demand in [kWh] (night)	47.363	934.972
Th. demand [kWh]	1.236.802	-

SME 1 is a small production company that specializes in fruit processing. The company fills 10.000 bottles of different types of fruit juice per hour for five workdays in a one-shift system. The main energy consumer on the production floor is the bottle cleaning system, which cleans reusable glass bottles. The system works at water temperatures between 40 °C and 95 °C, and it is feasible to integrate thermal RE into it. The integration details are not relevant to the investigation and, therefore, are not explained further here.

SME 2 is a medium-sized manufacturing company that specializes in metal processing. The company produces mainly small to medium-sized product series with some repetitive orders on a five-day week in a two-shift system. The main energy consumers in production are big smelters. The smelters need to achieve about 1.500 °C to melt the metal and account for most of the energy costs (purchase of foundry coal, gas, and power). Because of the required high temperature level, the use of thermal RE is not feasible. In addition, the company has a waste heat system in place. Because of this, the amounts of gas and foundry coal used, and the location of the company site, this paper only considers the electrical supply and the demand side of the company.

For the investigation, in addition to the load profiles of the SMEs, the weather conditions at the company sites are necessary for calculating energy generation. The PREmdeK simulation uses the following meteorological data: air temperature, air moisture, air pressure, global radiation, wind speed, and wind direction. The weather data is measured by a local weather station that the University of Applied Sciences Emden/Leer operates. The data is aggregated to 15-minute intervals (Ernst et al., 2012). Different scenarios for the RE supply have been investigated for the SMEs. The scenarios differ in terms of the composition of the RE plant (PV and solar thermal systems), the use of storage systems, and the machine design value (see Table 3 for elements used in the RE plant).

3.3 Cost calculation data and methods

For both SMEs, Table 2 lists the actual energy supply costs for 2014 and the $LCCA_{Reff}$ value. The costs are the product of the energy demand and the specific energy cost.

Tab. 2: Actual energy costs of the case SMEs in 2014

	Energy price c_i [ct/kWh]	**SME 1 [Euro]**	**SME 2 [Euro]**
El. energy cost (day)	20,5	40.752	707.095
El. energy cost (night)	18,5	8.747	172.671
Th. energy cost	6,5	56.892	-
Total cost	-	106.391	879.766
$LCCA_{Reff}$	-	1.172.275	9.693.702

For the alternative supply (according to the investigated scenarios) and for each RE producer and storage system different suppliers have requested offers related to machine design value (see Table 3), which industry experts have verified. Based on the weather and energy demand data (split into electrical demand data and thermal demand data), simulations have been run with scenarios involving different combinations and designs. For each scenario, the PREmdeK simulation gives values for the energy generated according to plant type, storage usage, and energy exchange with the grid.

Tab. 3: Overview of the capital and operating costs for the RE producer

RE producer	**Supplier**	**Machine design value (P_i)**	**Capital cost (CC_i)**	**Operating cost (OC_i)**
Photovoltaic	Heckert Solar NeMo 60P	40–2.000 kW	$1036,9 * P_{PV} + 7309,6$	2% of the capital cost
Solar heat	Paradigma Aqua Plasma 19/50	5,01–1002 m²	$801,69 * P_{SH} + 63,934$	2% of the capital cost
El. Storage	EP Solarpower EnergieS 18	18,4 kWh	26.983,09 Euro	-
	EP Solarpower EnergieS 55	55,2 kWh	59.769,20 Euro	
	EP Solarpower EnergieS 110	110,4 kWh	120.758,17 Euro	
Th. Storage	Paradigma Aqua Expresso ll 110	441–4410 kWh	$13,831 * P_{ThS}$	-

Based on these results, the following indicators have been calculated for the three BMs considered: net present value (NPV), internal rate of return (IRR), payback period (n_{dyn}), and life-cycle cost analysis (LCCA) value. The calculations of the indicators and the LCCA values are explained below. The NPV is used in capital budgeting to analyze the profitability of an investment ($CC_{RE\ plant}$) for a certain time (here k = 20a) at a specific discount rate (here j = 6.5%) (see Equation 9) (Poggensee, 2009).

The NPV is the difference between the present value of cash inflows and the present value of cash outflows ($C_{BMi} - OC_{RE\ plant}$).

$$NPV = \sum_{k=0}^{k=20} \frac{(C_{BMi} - OC_{RE\ Plant}) - CC_{RE\ Plant}}{(1+j)^k} \qquad \text{(eq. 9)}$$

The IRR is the discount rate, where the NPV of all cash flows from a particular project equals zero. IRR calculation (see Equation 10) is similar to NPV calculation (Poggensee, 2009) but sets the NPV at zero.

$$NPV = 0 = \sum_{k=0}^{k=20} \frac{(C_{BM} - OC_{RE\ Plant}) - CC_{RE\ Plant}}{(1+IRR)^k} \qquad \text{(eq. 10)}$$

The discounted payback period gives the number of years it takes to break even after undertaking the initial investment by discounting future cash flows and considering the value of money in relation to time (see Equation 11) (Poggensee, 2009).

$$NPV = 0 = \sum_{k=0}^{n_{dyn}} \frac{(C_{BM} - OC_{RE\ Plant}) - CC_{RE\ Plant}}{(1+j)^{n_{dyn}}} \qquad \text{(eq. 11)}$$

The LCCA value takes into account all cash outflows related to future activities and the business model but does not consider cash inflows (Fuller and Petersen, 1996). The following cash outflows are considered: operation costs, taxes for self-consumption, and electrical and thermal energy costs. All costs are discounted and total to an NPV (see Equation 12).

$$LCCA = \sum_{k=0}^{k=20} \frac{CC_{RE\ Plant} + \text{cash outflows}}{(1+i)^{-k}} \qquad \text{(eq. 12)}$$

For the evaluation, the ratio of the LCCA for the RE plant to the reference LCCA has been calculated (see Equation 13).

$$\text{LCCA ratio} = 100\% * \frac{LCCA}{LCCA_{Reff}} - 100\% \qquad \text{(eq. 13)}$$

4. Evaluation of the Scenarios for the Case SMEs

4.1 Results of the economic indicators and LCCA for SME 1

Figure 2 shows the electrical RE self-consumption ratio in relation to the PV machine design value and the electrical storage capacity for SME 1. As expected, the self-consumption ratio increases as the storage capacity increases and decreases as the PV machine design value increases.

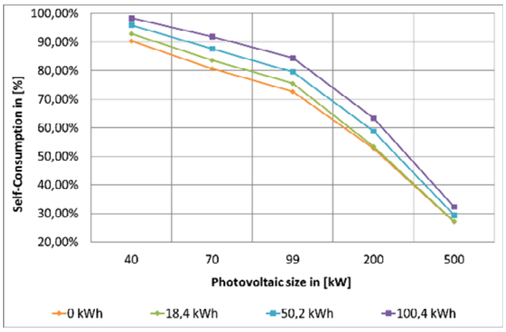

Fig. 2: Self-consumption ratio of the electrical RE for SME 1

Figure 3 shows the results for the IRR and payback period in relation to the PV machine design value and BM for SME 1. For easier comprehension, the figures only show the results for the electrical storage capacity of 18 kWh. It is not necessary to show all the results because the conclusion is the same for all the storage capacities. As expected, a comparison of BM1 and BM2 with BM3 shows that BM1 and BM2 offer higher benefits. Only with higher machine design values can BM3 achieve better benefits, but this is not applicable to SMEs. Typically, the SMEs do not have a sufficiently large free area for bigger PV machine design values and for the efforts required to operate big RE plants. BM2 has the best IRR and payback period at 40 kW. As Figure 2 shows, there is also a maximum point for the self-consumption ratio. BM1 has the best IRR and payback period at 70 kW. The combination of the high self-consumption ratio and RE overproduction feed-in lead to an enhanced benefit. In both BMs (BM1 and BM2), using storage systems leads to lower profitability. As Figure 2 shows, it is possible to increase the self-consumption of the electrical RE with storage systems, but that cannot compensate for the higher capital cost and higher taxes for self-consumption (BM1 alone).

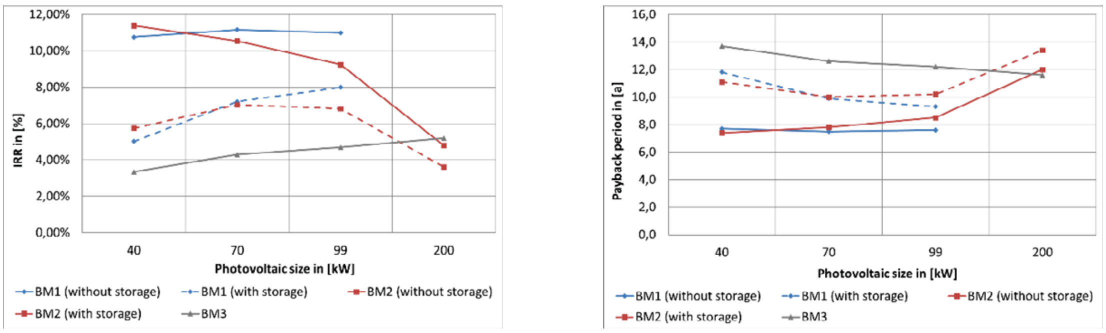

Fig. 3: Relationship between PV machine design value and IRR (left) and between PV machine design value and payback period (right) for SME 1 and all BMs

Figure 4 shows the results of the NPV and LCCA ratio in relation to the PV machine design and BM for SME 1. As Figure 3 shows, the profitability of BM3 and of the systems that have storage is lower than that of BM1 and that of BM2. In contrast to the IRR and payback period, the NPV achieves the maximum points at different machine design values: BM1 at 99 kW and BM2 at 70 kW. For BM1, the profit is higher because more electrical RE is fed in, and for BM2, more electrical energy is saved in total compared to the scenarios involving lower machine design values. Higher machine design values save more electrical energy in total, but the higher profit cannot compensate for the higher capital and operation costs, leading to a lower IRR. The LCCA ratio has the best value in BM2 at 70 kW. At this point, the combination of high cost savings and no taxes for self-consumption leads to a low operating cost for the electrical energy supply for SME 1.

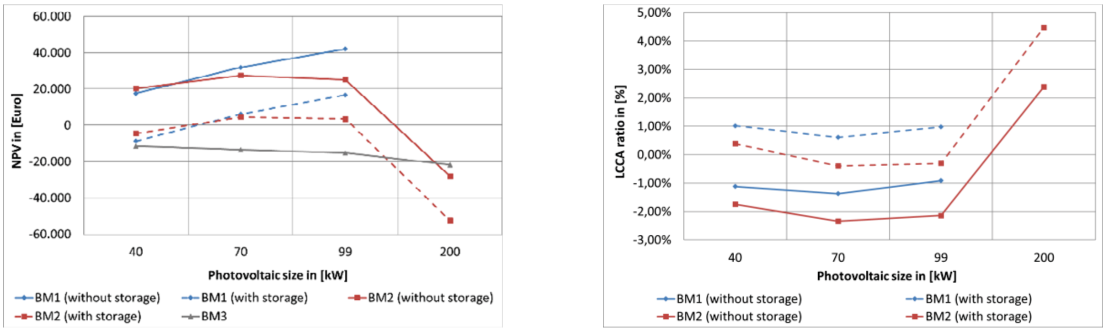

Fig. 4: Relation between PV machine design value and NPV (left) and between PV machine design value and LCCA ratio (right) for SME 1 and all BMs

Figure 5 shows the thermal RE self-consumption ratio in relation to the solar thermal machine design value and the thermal storage capacity for SME 1. As expected, the self-consumption ratio increases with the rise in the storage capacity and falls with the rise in the solar thermal machine design value.

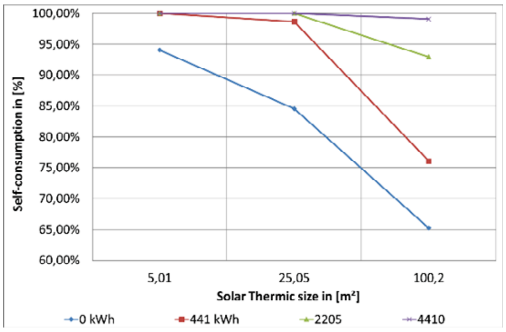

Fig. 5: Self-consumption ratio of the thermal RE for SME 1

Figure 6 shows the results for the IRR and payback period in relation to the solar thermal machine design value for SME 1. Contrary to expectations, the profitability of the thermal RE producer is in the negative range. In comparison to the PV system, the maximum point is experienced with this system, which has the highest self-consumption ratio. Moreover, the storage usage shows that the higher benefits due to higher self-consumption do not compensate for the higher capital costs.

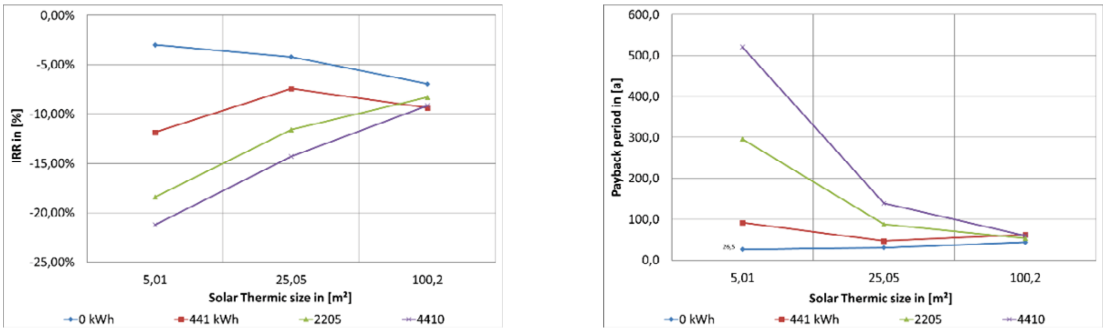

Fig. 6: Relation between solar thermal area and IRR (left) and between solar thermal area and payback period (right) for SME 1 and all BMs

Figure 7 shows the results of the NPV and LCCA ratio in relation to the solar thermal machine design value for SME 1. The NPV is like the IRR, and the payback period is in the negative range. The operation costs are at the lowest point (0,4 % higher than they would be without the solar thermal system). The problem is the low cost savings due to the low gas price. In comparison to the electrical energy price (20,5 ct/kWh), the thermal energy price (6,5 ct/kWh) is significant lower, which leads to lower profits.

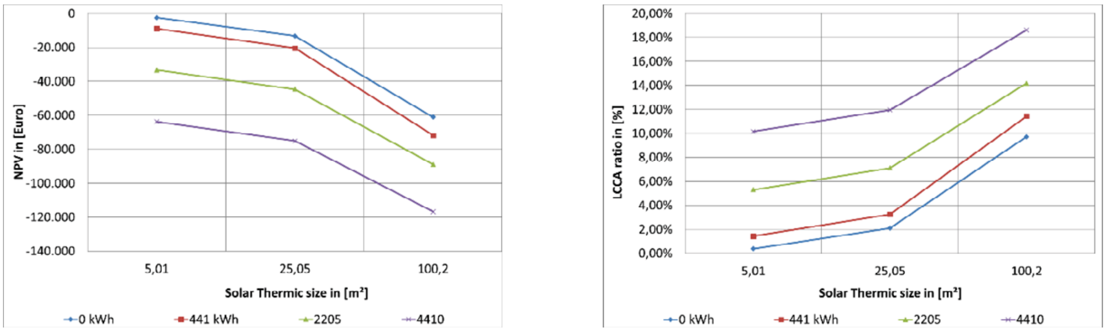

Fig. 7: Relation between solar thermal area and NPV (left) and between solar thermal area and LCCA ratio (right) for SME 1 and all BMs

4.2 Results of the economic indicators and LCCA for SME 2

Figure 8 shows the electrical RE self-consumption ratio in relation to the PV machine design value and electrical storage capacity for SME 2. As expected, the self-consumption ratio rises with the increase in the storage capacity and falls with the increase in the PV machine design value. In comparison to that for SME 1, the increase is lower because of the higher total electrical energy consumption.

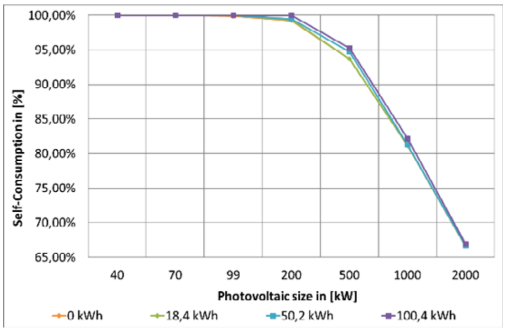

Fig. 8: Self-consumption ratio of the electrical RE for SME 2

Figure 9 shows the results of the IRR and payback period in relation to the PV machine design value and BM for SME 2. For easier comprehension, the figures for SME 2 only show the results for the electrical storage capacity of 55 kWh. In contrast to SME 1, BM2 always offers the best benefits. The advantage due to BM1's feeding of overproduced RE into the grid is not applicable because the self-consumption ratio (Figure 8) is still 100% for the 99-kW PV system. The best IRR and payback period are achieved at 200 kW. The results for the storage system are similar to those for SME 1.

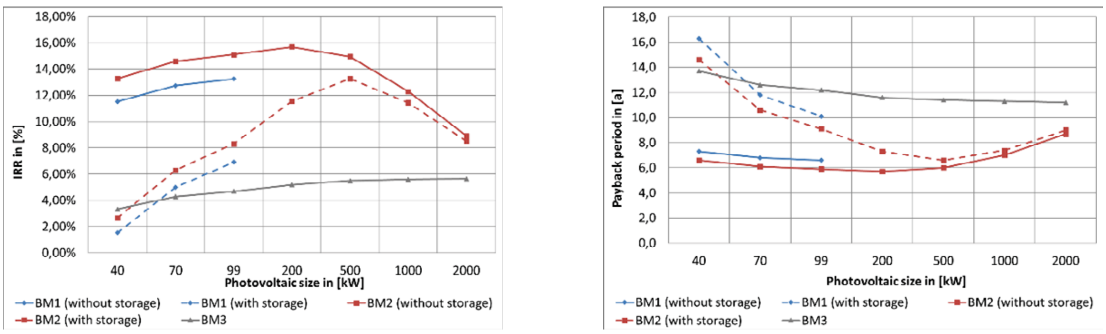

Fig. 9: Relation between PV machine design value and IRR (left) and between PV machine design value and payback period (right) for SME 2 and all BMs

Figure 10 shows the results of considering the NPV and LCCA ratio in relation to the PV machine design value and BM for SME 2. Similarly to those for SME 1, the best NPV and LCCA ratio occur at a different machine design value (like the IRR and payback period). The best NPV and LCCA ratio occur with the

1,000-kW PV machine design value.

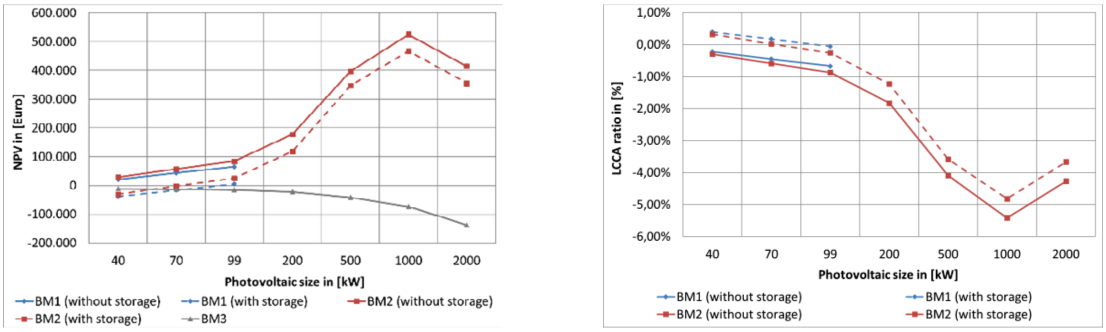

Fig. 10: Relation between PV machine design value and NPV (left) and between PV machine design value and LCCA ratio (right) for SME 2 and all BMs

5. Conclusion

The comparison of all investigated systems and BMs shows that the most beneficial scenarios are always the ones with high, direct, self-consumption of electrical RE from PV systems and the ones with minimal use of storage systems or no storage systems. The benefits that BM3 (which solely involves the feeding of RE into the grid) offers are too low to compete against those that BM1 (self-consumption and/or feeding into the grid) and BM2 (self-consumption alone) offer. The main reason for this is that the feed-in tariffs (10,7 ct/kWh) for the RE from PV systems are low compared to the cost savings due to self-consumption of electrical RE (20,5 ct/kWh). The use of storage systems in BM1 and BM2 is not economically reasonable. Though it is possible to increase RE self-consumption with a storage system, the following factors make it less profitable than a situation that involves no storage: The main problem in BM1 and BM2 is the high capital cost. The benefits due to higher self-consumption are too low to compensate for the higher capital costs. Another factor concerns BM1 alone: German´s EEG "double tax" for electrical storage systems decreases their profitability. Under the investigated conditions, if the PV system is optimally designed for RE self-consumption, no storage systems are required. For demand-side management or other applications, new analyses must be undertaken regarding the need for storage systems.

The use of solar thermal energy to decrease the SME's thermal energy cost makes cannot be recommended, the cost savings (6,5 ct/kWh) are too low to have a satisfying effect on overall energy costs.

Considering the currently electrical energy prices (including taxes and levies) and the political conditions that the EEG 2014 for RE producers promotes, SMEs warrant PV systems for self-consumption with no storage systems. The choice between BM1 and BM2 and the design of a PV system depends on the company's size and on the amount of energy that is consumed. The final decision regarding the most ideal machine design and BM should be analyzed individually for each SME.

6. Future Work

The legislation regarding RE and the grid system is in a state of constant change, at least with respect to the German EEG. The next version, EEG 2017, is currently under preparation and will need to be taken into account in future research. Controllable demand (e.g., demand-side management) and other business models (e.g., real-time pricing or selling to third persons) should also be considered in the future. This will become possible with a new PREmdeK simulation design. The verification of measured data and the easy use of historical local weather data via a direct connection and databases should constitute another future task.

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