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Article

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Macroeconomic Effects of Prosumer Households in Germany

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ABSTRACT

This paper investigates the macroeconomic effects of the evolution of prosumer households in the future energy market in Germany. In the German policy debate, these households are discussed as potential key actors for the transition of the energy system. On the one hand, prosumer households produce power from solar PV or micro combined heat and power systems; on the other hand they consume (at least partly) their own produced power or store the energy on site for later use. Thus, prosumer households increase the complexity of the energy system, but they also offer opportunities to solve existing problems for grid stability. Prosumer households have a slightly positive effect on the macro economy: Both the investments in power generating technologies and the higher income of prosumer households due to self-produced electricity lead to higher consumption and stimulate economic growth. At the same time, the increase of prosumer households reduces emissions.

Keywords: Energy Transition, Prosumer Households, Macroeconomic Effects, Economy-Energy-Environment Model
JEL Classifications: C54, C67, O11, Q43

1. INTRODUCTION

In the German policy debate, prosumer households are discussed to become increasingly important for the success of the energy transition (BMWi, 2016). The term "prosumer" is a mixture of the two words "producer" and "consumer" and emphasizes the potential new role of private households in the future energy market. Prosumer households both produce energy and consume their self-generated energy at least partly. This on-site usage (electricity self-supply) has several technical impacts: On the one hand, prosumer households release the public grid by consuming their own produced electricity and reducing peak demand. On the other hand, prosumer households can provide ancillary services by applying their technical equipment appropriate for the public grid (Leenheer et al., 2011). Solar PV or micro combined heat and power (Micro-CHP) systems are suitable for prosumer households. These systems can be upgraded with battery storage or an electrical heating system (Gährs et al., 2015; Shandurkova et al., 2012 for possible prosumer technologies). Thus, prosumer households increase the complexity of the energy system, but they also offer opportunities to solve existing problems for grid stability. On the micro level, prosumer households have an increasing disposable income due to both imputed benefits in form of the saved expenses for electricity from the public grid and unused excess as well as the guaranteed feed-in remuneration. Prosumer households have a slightly positive effect on the economy: Both the investments in power generation technologies and the higher disposable income of prosumer households due to self-produced electricity lead to higher consumption and slightly increase economic growth. In total, the growing number of prosumer households leads to a reduction of greenhouse gas (GHG) emissions.

The role of residential energy generation has evolved throughout the last decade. In Germany, the diffusion process of electricity generation based on renewable energy sources (RES) was especially encouraged by the RES Act (EEG) (guaranteed feed-in tariffs, preferential dispatch, connection requirement) and the ambitious goals of the energy transition (nuclear phase-out until 2022, shift to RES and reduction of GHG emissions to a large extent until 2050) (Brunekreeft et al., 2016). In recent years, feed-in tariffs and the electricity generation costs of solar PV are decreasing, while the price of purchasing power from the electricity grid is increasing. Since 2012 the own produced electricity from solar PV on the roof is for households even cheaper than buying electricity from the grid, what is called grid parity (Aretz et al., 2016, Weniger et al., 2014a, Oberst and Madlener, 2015). Thus, it is more and more beneficial for households to consume their own produced electricity instead of feeding it into the grid. Weniger et al. (2014a) state, that grid parity is the starting point for the transition from feeding-in electricity to a self-consumption age. Quickly decreasing costs for the required technologies along global learning curves (Wiebe and Lutz, 2016) support prosuming. Beside these economic factors, several other motivations and intentions for becoming a prosumer have been analyzed in field experiments with representative groups of households. Among these intentions are environmental concerns, technology drivers (affinity with technology and energy) and behavioral drivers (security of supply, power outages) (IEA-RETD, 2014, Leenheer et al., 2011; Michelsen and Madlener, 2017). Michelsen and Madlener (2017) highlight the importance of information and education campaigns. Currently, the number of prosumer households in Germany is still small and no official statistics are available on residential prosumer households' electricity supply and self-consumption (EWI, 2014).

As prosumer households may play an important role in the future energy system, it is also important to consider these types of households separately. In order to evaluate the macroeconomic potential of prosumer households in Germany, the macroeconomic top-down model PANTA RHEI was enlarged accordingly. The results presented in this paper are derived from a quantitative and empirical analysis of different scenarios, applied to the model PANTA RHEI.

Relatively little is known about the macroeconomic effects of prosumer households. Most of the relevant literature is about the technical integration of prosumer households and their consequences and impacts on the (smart) grid and for the utility sector. While the integration of volatile renewable energy generation into the power grid creates electricity system reliability challenges, a significantly growing number of prosumer households contribute to this problem, particularly at the distribution grid level (IEA-RETD, 2014). Agora Energiewende (2015) states, that the power system is becoming multi-directional: Real-time flows of electricity and information between consumers and producers have to be realized and controlled. Shandurkova et al. (2012) state, that on the production side, the smart grid widens prosumers' opportunities in the electricity market by giving them incentives to optimize their use of micro generation technologies in conjunction with the grid. This needs technologies that enable control, continuous price information and the measurement of demand.

Another aspect examined in the literature concerning prosumer households is the regulatory framework to encourage households to produce electricity with micro-generation technologies. IEA-RETD (2014) provides a comprehensive overview of prosumer related aspects and discusses different forms of policy strategies concerning residential prosumer households. Namely, constraining, enabling and transitioning policy strategies are reconsidered. It is pointed out, that "currently no agreed upon best policy roadmap to assist policy makers with prosumer transition" exists, and "it needs to be created as markets evolve." In order to support policy makers, IEA-RETD (2014) provides information on potential benefits as well as costs and risks of residential prosumers. IEA-RETD (2016) widens the perspective and focuses on commercial prosumers. It provides a selection of national case studies and policy options to support these prosumers.

As acceptance and adoption of the new technologies are required for the integration of prosumer households, research is focused on creating new business models and an adequate market framework. Traditional business models are designed around large centralized power plants. The increasing decentralization of the energy system requires a better coordination to match supply and demand. According to Aretz et al. (2016) prosumer households provide starting points for new business models by different actors (utility, grid operator, finance). At the moment, there exist too many individual solutions, which could be professionalized to realize synergies. PWC (2013) provides an overview of the future energy transformation and the impact on the power sector business models. As decentralized power generation is already today partly marginalizing conventional generation, a growing number of prosumer households will force companies' business models to be adjusted to the changing power environment. In their survey, 94% predict complete transformation or important changes to the power utility business model. Rosen and Madlener (2016) take a novel market-based approach towards the integration of distributed energy generation. The involvement of the owners of small scale-devices, characterized as prosumers, is the key for connecting private households with and without electricity generation in a micro grid to organize a local market. Local markets are pointed out to be a way to make household investments in distributed generation more attractive.

This paper is organized as follows. Section 2 gives an overview of the possible types of prosumer households and discusses the integration of prosumer households in the model PANTA RHEI. Different scenarios for the evaluation of macroeconomic effects of prosumer households are presented. In Section 3 results are reported. Beside the macroeconomic effects, also microeconomic and environmental effects of prosumer households are considered. Section 4 concludes and formulates some policy implications.

2. METHODS: INTEGRATION OF PROSUMER HOUSEHOLDS IN THE MACROECONOMIC MODEL PANTA RHEI

The term "prosumer" refers to consumers who also produce commodities or services (IEA-RETD, 2014; Toffler, 1980) for the historical introduction of the term "prosumer"). In the case of electricity, a prosumer household produces electricity and (at least partly) consumes his own-produced electricity. Shandurkova et al. (2012) even see a prosumer as an economically motivated entity, optimizing the economic, technological and environmental decisions regarding its energy utilization. In order to be a prosumer household, it is necessary to buy the technical equipment. Several different types of power generating technologies and further technical equipment can be considered, but not all types and combinations are suitable or economically feasible for prosumer households. Gährs et al. (2015) contribute detailed information for the different types of prosumer households and their optimal technical equipment, based on profound household modelling. These prosumer households differ in the usage of technologies for producing electricity and heat, which results in different energy consumption and different potential for load management (demand side management [DSM], battery storage). Thus, each type of household has a different self-production and self-consumption. Shandurkova et al. (2012) also give an overview of possible distributed energy resource devices suitable for prosumer households.

PANTA RHEI (Lutz et al, 2005; Lehr et al., 2008; Meyer et al., 2012) is an environmentally extended version of the macro-econometric simulation and forecasting model INFORGE. A detailed description of the economic part of the model is presented in Maier et al. (2015). For more details of the extended model, see Frohn et al. (2003), Lehr et al. (2011) and Lutz (2011). PANTA RHEI has been used to answer several questions on the economic effects of environmental policy instruments. In 2010, economic effects of different energy scenarios were compared to each other, which were the basis for the German energy concept (Lindenberger et al., 2010; Prognos et al., 2010). Recent applications include an evaluation of green ICT (Welfens and Lutz, 2012), employment effects of the increase of renewable energy (Lehr et al. 2012), economic evaluation of climate protection measures in Germany (Lutz et al., 2014; Lehr and Lutz, 2016) and economic impacts of climate change (Lehr et al., 2016). In a recent IEA overview (IEA, 2014) the model is classified as "input-output", but it is rather "econometric" plus "input-output," as parameters are econometrically estimated and input-output structures flexible (West, 1995).

Oberst and Madlener (2015) investigate the preferences of homeowners in Germany regarding the adoption of renewable energy-based micro-generation technologies using data from a survey with a discrete choice experiment. IEA-RETD (2014) also states several different drivers, why households may become a prosumer household. Among them are economic, behavioral, and technological drivers, as well as underlying national conditions. These drivers all influence the choice of the prosumer technology. Ten different types of prosumer households were integrated in the model PANTA RHEI (Table 1). As power generating technologies, both Micro-CHP and solar PV are considered. While the gas-fired CHP device needs natural gas to produce power and heat, solar PV absorbs and converts sunlight into electricity. To increase the rate of self-consumption, additional technical equipment is available: A battery storage can be used to store the self-produced electricity on site for later use; heat pump (HP) and immersion heater (IH) convert the self-produced electricity to heat and can increase the households demand in times of a high production; DSM shifts the load to times of high production either.

The integration of prosumer households in the model PANTA RHEI follows a two-step procedure: Firstly, prosumer households are linked to the energetic part of the model where energy supply and demand for different energy carriers is recorded following the energy balance systematic. Secondly, prosumer households are integrated into the economic part of the model to consider income effects due to the compensation for electricity fed into the grid as well as expenditures related to investments in Micro-CHP or solar PV.

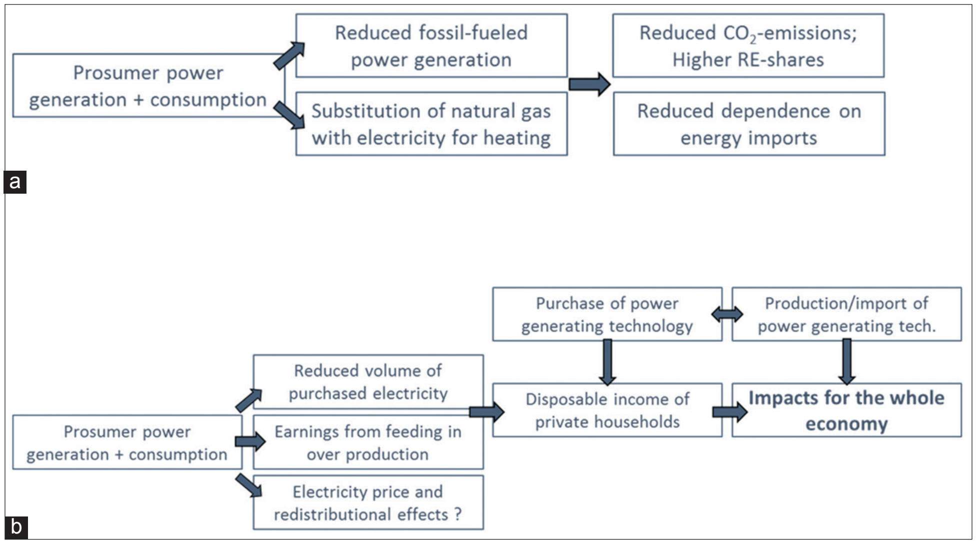
The basic linkages of prosumer households are described in Figure 1. Prosumer power generation and consumption means reduced fossil-fueled power generation in the economy. By using electricity for heating, the natural gas consumption can be reduced. The higher shares of renewable energy and the decreased natural gas consumption lead to reduced CO_2 emissions and less dependence on energy imports (Aretz et al., 2016). In monetary terms, prosumer households benefit from a reduced volume of purchased electricity from the grid due to their own power generation. As their own power generation exceeds their self-consumption, prosumer households also benefit from earnings from feeding in over production into the grid. Both effects increase the disposable income of prosumer households. On the other hand, a certain amount of the disposable income has to be spent for the purchase of the power generating technology and may replace expenditures for other consumer goods or reduces savings. The demand for power generating technologies leads to a higher production and/or import of these technologies. Thus, prosumer households induce macroeconomic impacts. For reasons of simplicity, the price of electricity remains untapped by the growing number of prosumer households. As will be discussed later on, prosumer households benefit from several monetary privileges and exemptions, which lead to a redistribution of the monetary

Table 1: Important technical characteristics of prosumer household types

Technical characteristics	Power			Heat
	Total consumption (kWh/a)	Self-consumption (kWh/a)	Degree of autarchy (%)	Fuel consumption (kWh/a)
MCHP	3.877	1.317	34.0	16.738
MCHP+BAT	3.944	2.010	51.0	16.738
PV+BAT	3.738	1.898	50.8	13.984
PV+HP	7.479	1.273	17.0	0
PV	3.658	872	23.8	13.984
PV+IH	5.031	2.248	44.7	12.440
PV+MCHP	3.877	1.989	51.3	16.738
PV+IH+DSM	4.892	2.322	47.5	12.593
PV+MCHP+DSM	3.877	2.230	57.5	16.738
PV+DSM	3.658	1.085	29.7	13.984

Source: Based on Gährs et al. (2015)

Figure 1: Energetic and economic links of prosumer households in the model PANTA RHEI. (a) Energetic link, (b) economic link



Source: Own figure

burdens (EEG-surcharge, grid charge). The exact impact on the electricity prices and the burden for consumers and prosumers will be determined by future policy strategies. Prognos (2016) calculate only small impacts on electricity prices until 2035.

In the industry sector, the self-consumption of self-produced energy is already widespread. EWI (2014) states that the rate of self-consumption in the industry sector lies in a range of 10-20% (equivalent to 20-50 TWh/a) in the past years. As residential self-consumption is economically relevant since 2012 (decreasing feed-in tariffs, increasing electricity prices), the number of prosumer households in Germany is still quite small. The number of possible prosumer households also depends on the boundaries of the considered prosumer potential. A focus only on homeowners seems to be reasonable, because they are able to easily install the necessary technical prosuming equipment and use the self-produced electricity and heat in their own households. Apartment buildings also have a large potential for installing the necessary prosuming-technologies, but the diverging roles of landlords (investing in the prosumer technology) and tenants (benefiting from self-produced electricity) are a major barrier. Though, in case of adequate business models, one could multiply the macroeconomic effects by using this prosumer potential (Aretz et al., 2016). Andor et al. (2015) also state from ongoing surveys on energy consumption of private households in Germany, that 90% of the interviewed households with today installed solar PV systems are homeowners living in their own property and 80% of the interviewed households with today installed solar PV system live in a one- or two-family home. By only taking into account homeowners in self-inhabited one- or two-family homes, the prosumer potential is reduced to around twelve million households: The homeownership rate of one- and two-family homes owned by their occupants is about 31.5% (Gährs et al., 2015) and the number of private households is around 40 million. Already existing solar PV systems, the orientation of the roof and clouding reduce the possible prosumer potential.

In order to analyze the macroeconomic effects of prosumer households in Germany, three different scenarios were created. Namely, these scenarios are called MIN, MEDIUM and MAX. The scenarios only differ in the assumed number of the ten different prosumer household types. In each case, the time horizon is the period 2015-2030. Assuming an economic lifetime of 20 years for each prosumer technology, no replacement investments have to be done. Figure 2 shows the assumed development of the number of prosumer households in the scenarios MIN, MEDIUM and MAX.

In the case of the MIN scenario, we assume that no further prosumer households will appear on the market in the future. The number of prosumer households is assumed to be around 70,000 throughout the observation period. The MIN scenario serves as a baseline or reference scenario to compare the impacts of a higher number of prosumer households in the MEDIUM and MAX scenario on the whole economy. In the MEDIUM scenario, only a part of the prosumer potential decides to become a prosumer household. The number of prosumer households increases up to 4.8 million households in 2030. According to a typical technology adoption life cycle, the number of prosumer households follows the shape of an S-curve (Christensen, 1992; Oberst et al., 2016). In the MAX scenario, a large part of the prosumer potential becomes a prosumer household. The number of prosumer households increases up to 10.7 million households (Prognos, 2016 calculates with an upper possible limit of prosumer households of around 10.15 million households). Both the MEDIUM and MAX scenario can be feasible scenarios in the future, but the main reason for this selection was to analyze the macroeconomic effects of different levels of used prosumer potential.

3. SCENARIO-BASED ANALYSIS OF EFFECTS OF PROSUMER HOUSEHOLDS

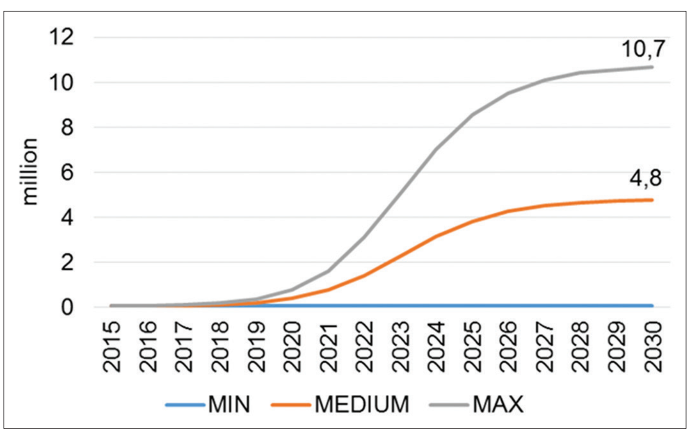
A scenario is a consistent set of assumptions that are used to deal with uncertainties of the future such as policy measures or exogenous variables (e.g., population, oil price). The scenario assumptions are implemented into the model and the economic and environmental effects are calculated. Usually, the results are compared to a reference scenario (here: MIN scenario) to evaluate impacts of the scenario assumptions. The impacts are measured in deviations for example in physical units (e.g., energy consumption), in monetary terms (e.g., household consumption) or in persons (e.g., employment). The use of a comprehensive E3 (economy-energy-environment) model, which depicts the inter-industry structure of the economy and the interrelations between the economy, the energy system and the environment, has the advantage of covering and exploring the complex interactions within the economy and the interplay of e.g., economic growth and energy consumption.

3.1. Household Level

The different technical equipment of the ten prosumer household types leads to different investment costs, different levels of self-production and self-consumption of power and heat. Thus, every type of prosumer household is faced with individual costs and earnings, derived from an individual self-production and self-consumption.

The power consumption of the households depends on the usage of electricity for heating. Basically, the households with a single PV-(3.1 kW_p) or Micro-CHP-plant (1.3 kW_{th}, 0.5 kW_{el}) have the lowest power consumption. The combination of PV with a heat pump shows the highest total power consumption, because these households use electricity only for heating and thus have no fuel consumption. If the households use electricity for heating, they can increase their self-consumption, because an IH or a heat pump can use normally unused excess. The unused excess of own produced power can also be stored on site for later use, which also increases the self-consumption. The degree of autarchy is the percentage of consumption that is self-produced (Gährs et al., 2015; Prognos, 2016). A high degree of autarchy is crucial for cost savings: The higher the degree of autarchy, the less electricity has to be bought from the grid (Weniger et al., 2014a). In addition to the costs, the potential savings and recoveries play an important role in the purchasing decision, which are highly dependent on the expectations about future prices however.

Figure 2: Development of the number of prosumer households in the three considered scenarios MIN, MEDIUM and MAX in million households



Source: Oberst et al. (2016)

Table 2 summarizes the monetary effects for selected prosumer household types. To become a prosumer household, initial investment in technical equipment is necessary. The consumption of self-produced electricity reduces the amount that has to be bought from the grid, reducing the prosumer households' spending on electricity. In addition, the disposable income of prosumer households is increased by a compensation for feeding in over production into the grid. Due to diverging times of electricity production and consumption, each type of prosumer household produces more electricity than he can consume. In the case of a (partly) substitution of the low-temperature boiler by electric heat generation, a substitution of natural gas by electricity takes place. Depending on the fuel prices, this substitution also has an impact on the disposable income of the prosumer households, as well as the higher gas consumption of CHP-plants.

CHP is the most expensive technology considered. Assuming sinking investment costs due to learning curve effects (Wiebe and Lutz, 2016), a new CHP-plant in 2015 accounts for 750 €/a throughout its expected lifetime (20 years). In 2030, a new CHP-plant accounts for 525 €/a. The cheapest technology is solar PV (195 €/a in 2015). The installation of a DSM accounts for additional 60 €/a. While the net total of costs and earnings from a CHP-plant is negative, the monetary effect of solar PV is positive. Prognos (2016) also states that small CHP-plants can only be operated profitable, if they satisfy base load. In 2015, the additional DSM causes higher costs than additional earnings, which makes the DSM economically not profitable. Because of the learning curve effects and changing electricity prices, DSM gets more and more profitable. Thus, in 2030 the total monetary effect of an additional DSM is ten Euro higher compared to a single solar PV system.

3.2. Energy and Environmental Effects

As prosumer households are discussed as potential key actors for the transition of the energy system in Germany, it is also important to look at the ecological effects of prosumer households. In the scenarios, prosumer households are supposed to be new players

Table 2: Monetary effects for a choice of prosumer households [in €/a]

Costs and savings	2015			2030		
[€/a]	CHP	PV	PV+DSM	CHP	PV	PV+DSM
Depreciation	−750.0	−195.0	−255.0	−525.0	−175.5	−223.5
Feed-in of over production	82.3	262.1	235.4	82.3	262.1	235.4
Savings from not purchasing electricity	387.9	256.9	319.7	526.3	348.6	433.7
Savings from reduced gas consumption	0.0	0.0	0.0	0.0	0.0	0.0
Higher gas consumption	−200.4	0.0	0.0	−248.6	0.0	0.0
Net total	−480.2	324.0	300.1	−164.9	435.2	445.7

Source: Own calculation

on the market: If a household decides to become a prosumer household, this household will install new power generating capacity. Thus, every new prosumer household with a solar PV system increases the share of renewable energy power generation. The environmental effect of gas fired CHP-plants is neutral, assuming that these power plants replace gas fired low temperature boilers in case of heating and natural gas power generation in case of electricity. The number of these prosumer households is small.

Compared to the MIN scenario the growing number of prosumer households in the MEDIUM and the MAX scenario increase gross electricity consumption. In addition to the absolute number of prosumer households, the amount of additional consumption depends on the distribution of the prosumer households to the individual prosumer household types. In particular, the technical facilities for electrical heat generation (heat pump, IH) account for higher electricity consumption than in a household with heat solely from natural gas. Compared to a household with a solar PV system the electricity consumption of a prosumer household with a heat pump is more than twice (Table 1).

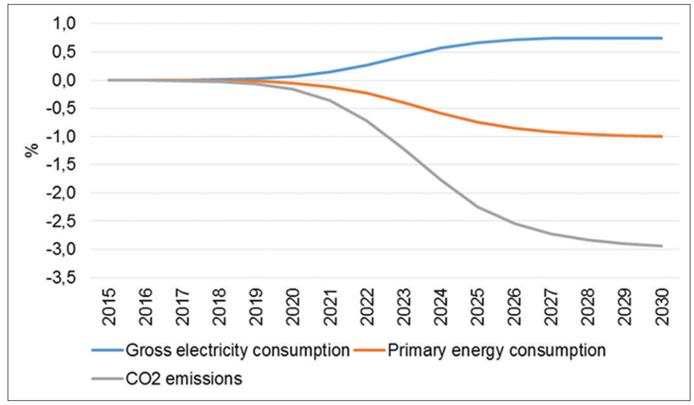
Compared to the MIN scenario, the gross electricity consumption in the MEDIUM scenario is increased by 0.33% in 2030 and in MAX scenario by 0.73% (Figure 3). This higher gross electricity consumption comes along with an increased renewable power generation by the prosumer households. In total, the higher renewable power generation is used for self-consumption by the prosumer households, or is fed into the grid.

Overall, the primary energy consumption in the MAX scenario is reduced by the prosumer households by about 107 PJ (equivalent to 1%) in 2030. The fossil primary energy consumption is partly replaced by renewable energy. While the fossil primary energy consumption in the MAX scenario gets reduced against the MIN scenario by almost 215 PJ in 2030, the renewable primary energy consumption is higher by about 108 PJ. The net total arises to a reduction in primary energy consumption by approximately 107 PJ. In the MEDIUM scenario, the primary energy consumption in 2030 is reduced by 47 PJ.

All in all, the effects and adaptations triggered by prosumer households cause a reduction of the CO_2 emissions in Germany[1]. Against the MIN scenario, energy-related CO_2 emissions in the MEDIUM scenario can be reduced by 7.8 million tonnes (minus 1.3%) in 2030 and in the MAX scenario, the reduction increases to 17.7 million tonnes (minus 3.0%, Figure 3) in 2030. Beside the reduction of CO_2 emissions due to the changes in energy consumption, higher private consumption leads to a small increase of the CO_2 emissions. In total, emissions are decreasing.

While the reduction of CO_2 emissions is caused originally by the prosumer households, the largest part of the reduction takes place in the energy sector. Table 3 gives an overview of the different

Figure 3: Energy and environmental effects in the MAX scenario against the MIN scenario (in %)



Source: Own calculation

reduction levels for private households and the energy sector. In the MAX scenario, private households reduce their CO_2 emissions against the MIN scenario by 1.9 million tonnes, the reduction in the energy sector is about 17 million tonnes.

3.3. Macroeconomic Results

In total, the above mentioned effects on the microeconomic level of prosumer households result in adaptive responses on the macroeconomic level. Beside the direct effects of a higher consumption due to a higher disposable income and the expenditures on the power generating technologies of the prosumer households, also indirect and induced effects can be considered: The higher consumption of prosumer households result in a higher demand in those industries producing consumer goods. These industries need several inputs and goods from other industries. The initial investments in the prosumer technologies also increase demand.

The disposable income of private households in Germany increases with a growing number of prosumer households. In the MAX scenario, the disposable income is up to 4 bn. Euro (0.17%) higher than in the MIN scenario. The smaller number of prosumer households in the MEDIUM scenario increases the disposable income by 2 bn Euro (0.07%). Not all types of prosumer households have a positive monetary total net value (Table 2). After the year 2025, the growth in prosumer households declines slowly, so that the accumulated depreciations outweigh the positive effects on the disposable income. Since all types of prosumer households in the model are considered with an increasing number of households, the disposable income could even be higher, if the households would choose a system with a positive total net value. Particularly those technologies with low initial costs, a high self-production and a high degree of autarchy are economically attractive.

The development of energy prices (natural gas, electricity) and the height of the compensation payment for feeding in over production are crucial for the additional disposable income of the prosumer households. In the model, the compensation payment is assumed to be 12.5 Eurocent/kWh and stays at this level throughout the observed time period. The electricity price is calculated

1 The production of the imported prosumer technologies causes additional CO_2 emissions elsewhere in the world. The effect of the increasing number of prosumer households in Germany on the worldwide CO_2 emissions could not be quantified with our model.

Table 3: Changes in CO_2 emissions in the housing and energy sector in the MIN and MAX scenario in 2030

CO_2 emissions	Absolute levels in 2030 (in million t CO_2)		Absolute deviation (in million t CO_2)	Relative deviation (in %)
	MIN	MAX	MAX − MIN	MAX − MIN
CO_2 emissions private households	58.0	56.1	−1.9	−3.3
CO_2 emissions energy sector	289.3	272.2	−17.1	−5.9

Source: Own calculation

endogenously in the model and increases from 30 Eurocent/kWh in 2015 to 40 Eurocent/kWh in 2030. Prosumer households benefit from several monetary privileges and exemptions, e.g., they don't have to pay a grid charge for their self-produced and directly consumed electricity, although they are still connected to the electricity grid for times, in which their self-produced electricity is not sufficient to meet their demand. The grid also maintains the frequency of the AC voltage signal, which is still necessary for the operational quality and reliability as known today (Shandurkova et al., 2012).

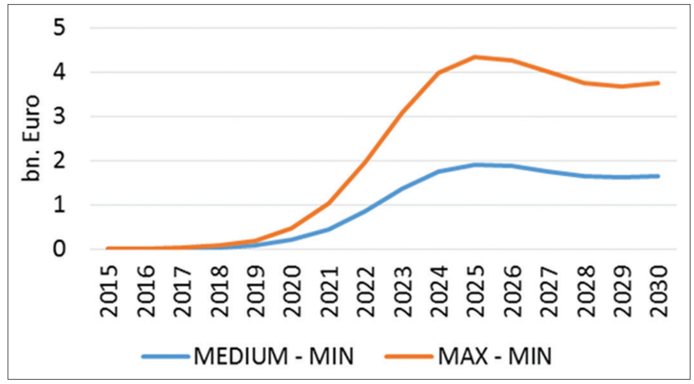
The cost of power for supplier makes up 25% (7.12 Eurocent/kWh) of the German electricity price in 2015. More than half of the electricity price for households in Germany consists of components determined by the state. Beside the mentioned grid charges (6.7 Eurocent/kWh in 2015, 23% of electricity price), these include levies e.g., for financing investment in renewable energy (EEG-surcharge; 6.17 Eurocent/kWh in 2015, 21% of electricity price), a concession levy, electricity taxes and other small levies (Data from Eurostat, see also Neuhoff et al., 2013).

While on the one hand, prosumer households benefit from the privileges and exemptions, grid operators, cities, communes and the government on the other hand are faced with decreasing revenues. In the model it is assumed that in the case of grid charges, consumer-households have to compensate the missing grid payments from the prosumer households. These payments reduce the disposable income of private households that are not prosumer households.

Besides from the impacts of electricity generation and consumption, the disposable income of the private households gets influenced by the changes in heat generation. In the model, the reduced gas consumption is valued with the endogenous gas price and increases the disposable income. The higher demand for electricity from the grid for heating reasons (especially from heat pumps) decreases the disposable income. All in all, the effects on the disposable income result in a positive difference with an increasing number of prosumer households (Figure 4).

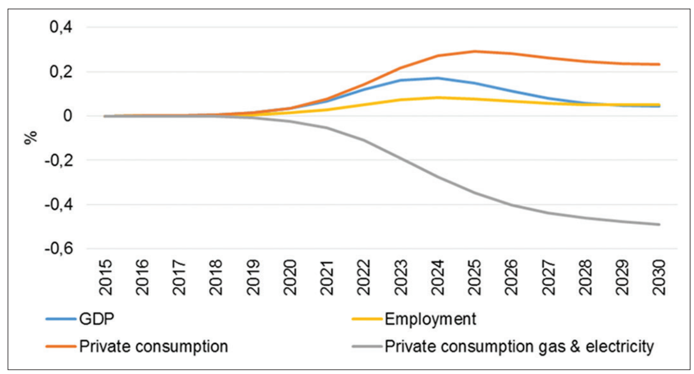
Figure 5 summarizes the effects of prosumer households on the most important macroeconomic indicators for the MAX scenario in comparison to the MIN scenario. As the saving rate of German households was about ten percent in the recent years, most of the disposable income is used for consumption purposes. Private consumption is growing with an increasing number of prosumer households due to a higher disposable income. In 2025, the private consumption in the MAX scenario is 0.3% higher than in the MIN scenario. The reduced expenditures for energy due to own power generation and consumption are reflected in the decreasing curve

Figure 4: Changes in disposable income of private households in MEDIUM and MAX scenario against MIN scenario (in billion Euro)



Source: Own calculation

Figure 5: Macroeconomic effects of prosumer households in Germany in the MAX scenario against the MIN scenario (in %)



Source: Own calculation

representing the private consumption of gas and electricity. In 2030, private households save up to 0.5% from producing and consuming their own energy in the MAX scenario.

Both, the prosumer investment in the power generating systems as well as the additional consumption lead to a higher production activity in the whole economy. Depending on the considered technology, the components and preliminary products are either produced domestically or are imported. In case of solar PV, e.g., the inverters are produced in Germany, while the modules are imported. Battery storages can be imported ready to install or they are assembled in Germany and only parts of it are imported. The additional consumption triggered by induced effects is distributed over all consumption purposes.

A higher demand leads to an increasing production activity in the economy. In order to satisfy the higher demand, it might be necessary to increase the production capacity and employment.

Especially the industries with the highest additional demand by the prosumer households are hiring additional staff. In 2025, the employment in the MAX scenario is approximately 0.1 % higher than in the MIN scenario. This corresponds to 30,000 additional jobs. As the growth in prosumer households declines slowly after the year 2025, the number of additional jobs is slowly decreasing too. In 2030, the surplus of employed people is still 19,000 in the MAX scenario compared to the MIN scenario.

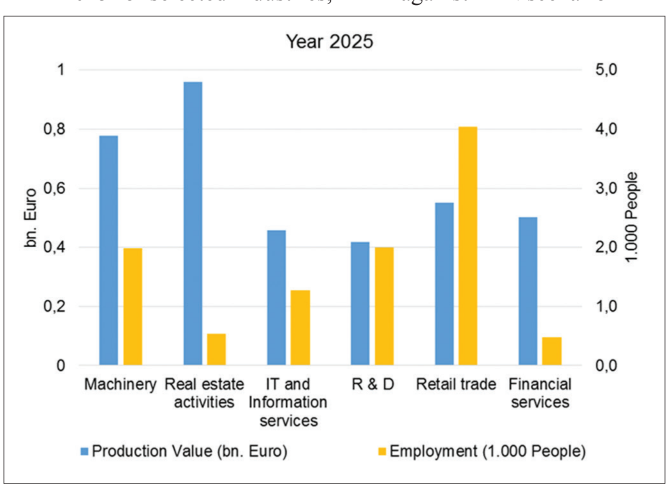
Figure 6 visualizes the increasing production activity and the resulting employment effects for a selection of six industries with the highest growth in production value for the MAX against the MIN scenario. The manufacturers of machinery (+0.78 bn. Euro) and the industry of real estate activities (+0.96 bn. Euro) account for the highest additional production value in 2025, followed by retail trade, financial services, information technology and research and development. The higher production value comes along with a higher rate of employment. In absolute numbers, retail trade makes for additional 4,000 employees in 2025 in the MAX scenario while in the other industries the additional employment is below 2,000 employees.

An increasing number of prosumer households have an impact on the public budget. However, these effects depend on the adopted framework. While a possible government support for prosumer technologies would directly lead to a burden of the public budget, the increased demand for prosumer technologies and additional consumption have a positive effect in terms of employment, which in turn increases the government revenues of income taxes and social security payments. To that extent, a resultant additional burden of the public budget cannot be proved.

4. CONCLUSION AND POLICY IMPLICATIONS

Households in their new joint role as prosumers play a vital role in the transformation of the energy system in Germany. With their power generating technologies and additional equipment these

Figure 6: Deviation of production value and employment in the year 2025 for selected industries, MAX against MIN scenario



Source: Own calculation

households are able to change the typical known demand patterns and facilitate peak shaving of electricity. By increasing the share of renewable energy in the market, fossil fueled must run generating technologies are pushed out of the market and CO_2 emissions can be reduced. Beside these technical and environmental benefits of prosumer households, macroeconomic effects of prosumer households in Germany are presented.

Three scenarios with different numbers of prosumer households are analyzed. A growing number of prosumer households leads to a reduction of CO_2-emissions and has a slightly positive effect on macroeconomic indicators. Investment of prosumer households in power generation equipment pays off. While the impact on a single household can be large, the overall effect for the economy remains quite small, which is in accordance to Prognos (2016).

The inclusion of other prosumer potentials in the private sector, especially apartment buildings and rented apartments, will further enlarge the effects of prosumer households on the economy. Taking into account households with micro generation technologies with an expiring EEG funding beyond 2030 can also significantly influence the results and effects. If the installed systems continue to function after the EEG payments, it could be used for self-supply (Prognos, 2016).

The number of prosumer households is also expected to rise further by the promotion and/or cost decreases of batteries. Battery systems increase the attainable self-consumption, which is attractive for prosumer households. The usable battery capacity has to be suitable for the installed solar PV systems in order to realize a high degree of self-consumption. Nevertheless, the economic assessment of battery systems depends on a variety of impact parameters, which are quite uncertain today (Weniger et al., 2014b).

The monetary assumptions in the model are quite simplified and could be changed to analyze different forms of regulation and evaluated for more differentiated household types. Since the prosumer households still depend on a grid connection and the electricity from the grid despite their own self-supply, it is currently being discussed to cancel the monetary privilege of the prosumer households of not paying grid charges to reduce the burden for the "non-prosumer" households (BMWi, 2016). The future development of feed-in tariffs and regulations for prosumer households are further important factors for the development of prosumer households.

Furthermore, an investigation of incentives to exhaust the prosumer potential could provide further interesting results. In particular, the categories of prosumer and consumer households as well as homeowners or non-homeowners should be analyzed with regard to different promotion mechanisms, feed-in behavior and remuneration as well as the resulting distributional effects. The accommodation of decentralized energy generation in local energy market settings in Rosen and Madlener (2016) is only one example for a possible regulative framework with important consequences for the different stakeholders. However, such an analysis requires detailed information of the particular framework design and additional data about the stakeholders (e.g., income structure of the households).

In order to encourage households to become a prosumer household, a reliable regulatory framework for prosumer households is necessary, ensuring security for planning and investment. As not all private households are familiar with details on the energy market, they need detailed political objectives and a consumer protection. Aretz et al. (2016) give recommendations for the support of prosumer households. As self-consumption is crucial for the economic operation of solar PV systems, the basic conditions must be designed to enable an economic operation even in consideration of a possible burden with grid charges and other levies for the prosumer households. Prognos (2016) states that over the past few years, the government and the parliament have sent mixed signals about self-consumption (e.g. on the one hand a promotion of self-consumption with a bonus scheme introduced in 2009 and on the other hand charges for self-consumption levied by the 2014 revision of the EEG), which did not support a reliable regulatory framework. Beside the regulatory framework, prosumer systems must support grid stability to keep grid costs low and foster the social acceptance of prosumer households.

Prosumer households can contribute to a reduction of CO_2 emissions in the economy. If Germany has to achieve a reduction of GHG emissions by 95 % by 2050, which is to be expected under the Paris Climate Agreement, prosumer households will certainly be needed to achieve the ambitious climate mitigation targets.

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