GERMANS TRANSITION TOWARDS RENEWABLE ENERGY SUPPLY - A SYSTEMS THINKING APPROACH

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ABSTRACT

This paper presents a systems thinking approach to deal with the Germans' transition towards renewable energy supply with an emphasis on households. Systems thinking has been used in the paper to understand the main factors that influence the development of the installed capacity of renewable power generation and electricity tariffs for households. By understanding the connections, it is easier to estimate the further development and evaluate the influence of changes in the present system.

INTRODUCTION

Germany has set itself an extraordinary challenge in energy and climate policy – to move away from fossil fuels and simultaneously to abandon nuclear power, while remaining and growing as a major industrial economy.

A cornerstone of this energy transition is the German Renewable Energy Sources Act (EEG). By providing a stable investment environment, the EEG has become a success story. Due to this law, the share of renewable power has risen from 5.4 per cent in 1999 to more than 20 per cent in 2012. However, the special provisions of the EEG are the reason that we have today two parallel and mainly separated systems for generating and marketing electricity.

Firstly, this has serious financial consequences. The promotion of renewable energy has cost the electricity consumer about 17 billion euros in 2012 [1]. Secondly, the special rules of the EEG disrupt the balance on the conventional power market. As a consequence of the feed-in priority of renewable energies the order in which conventional power plants are used is shifted. Technically speaking, the merit order curve is moved and power plants with relatively high marginal costs – especially gas power plants – are seldom used to produce electrical energy. Conversely, the expansion of renewable energies requires more capacity of flexible power plants, which can fill the gap in the absence of wind or solar power.

The objective of this paper is to understand the main factors that influence the development of the installed capacity of renewable power generation (RPG) and electricity tariffs for households. By understanding the connections and main drivers in the system, it is easier to estimate the efficiency of subsequent improvement by the legislator and to estimate the further development. In this paper we focus on residential customers and RPG; thermal power generation was already described and analysed in detail in [2].

TOOL FOR VISUALIZING AND ANALYZING COMPLEX SYSTEMS

Systems thinking is a suitable method for understanding and analysing the structure and dynamics of complex systems. However, this approach requires a shift in the way we think: traditional analysis focuses on separating the individual pieces of what is being studied. Systems thinking, in contrast, focuses on how the thing being studied interacts with the other parts of the system. One important tool for systems thinking is the causal loop diagram.

Causal loop diagrams (CLDs) are used to get an overview over the causal relationships of a problem. With the use of CLDs, it is also possible to identify the characteristic behaviour of the problem. In the CLD the arrow shows causality between variables. A plus sign near the arrowhead indicates that the variable at the tail of the arrow and the variable at the head of the arrow change in the same direction. A minus sign near the arrowhead indicates that the variable at the tail of the arrow and the variable at the head of the arrow change in the opposite direction.

In the next step the connection between two factors are weighted. Whenever possible we are weighting the impact in percentage of the maximum of 100 per cent, one factor is influencing the other (indicated by blue arrows in the submodels) otherwise the connections are weighted in the three categories 'strong' (25 %), 'middle' (17 %) and 'weak' (10 %) impact.

Moreover, in this paper subsystems are used to capture the main structure of relations in the system. In these diagrams, the connections into and out of a submodel are dotted because there might be several factors connected (Fig. 1).

A SIMPLIFIED MODEL OF THE GERMAN RESIDENTIAL ELECTRICITY MARKET

In this section a simplified model of the German residential electricity market has been developed with the software CONSIDEO MODELER. Structural analyses on the simplified model help us to identify the important parts of the model structure.

The Residential Electricity Market Model

Our model (Fig. 1) consists of three main parts: the customer in the centre, the market actors and the tariff rates. The customer buys electricity from a supplier and pays a standing charge – for consumption-independent services of the supplier, distribution system operators (DSO) and the metering operator/data collector (MOP/DC) – and a unit charge for each kilowatt-hour used.

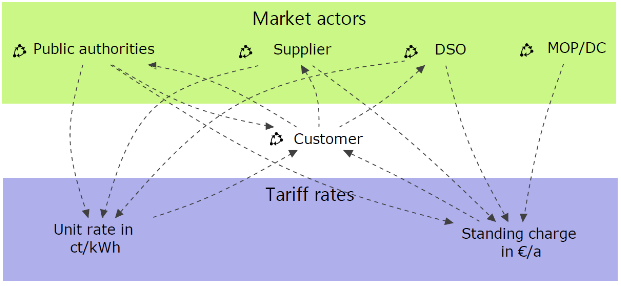

Figure 1: The German residential electricity market – submodels diagram.

Public Authorities, EEG Apportionment

Public authorities are responsible for a large share of the price paid by consumers for electricity (Fig. 2). Approximately 44 per cent of the price paid by an average household and a standard tariff will be attributable to the electricity tax, VAT, concession charge, as well as apportionments due to the EEG, the Act on Combined Heat and Power Generation (KWKG) and the new offshore liability surcharge.

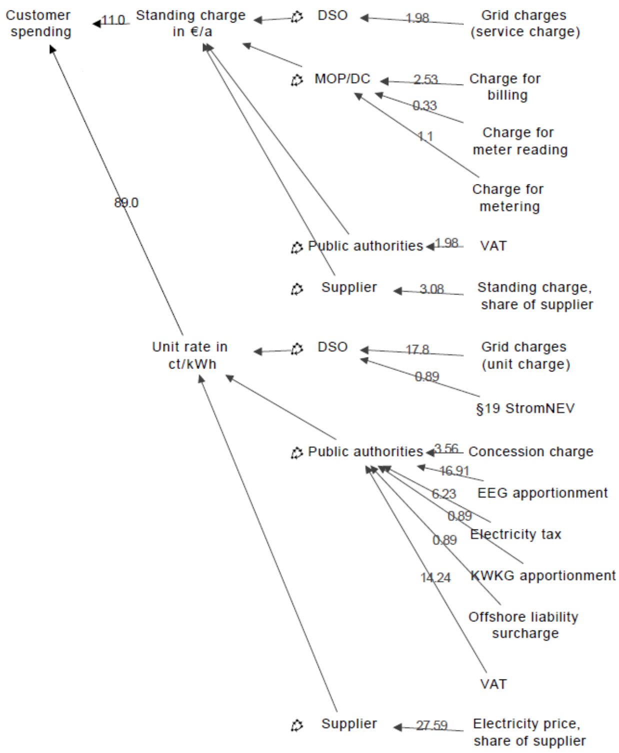

Figure 2: Breakdown of household electricity bill in per cent for an average household in 2013 (Cause tree).

In 2011 the EEG apportionment was sharply increased to 3.53 cent per kWh and will be increased to 5.28 cent per kWh in 2013. The EEG apportionment is set by the transmission system operators (TSOs) for one year on the basis of the AusglMechV. In principle, it is a surcharge of the EEG annual differential costs on the non-privileged end consumption (Fig. 3).

The end consumption for which EEG apportionment is payable is calculated on the basis of the net electricity consumption, which is the sum of the net electricity consumption of households, trade, industry and transport. Of these, the self-produced consumption of mainly industrial power generators, that is not fed into the grid as well as the self-consumption of PV system operators are subtracted. In 2011 the self-produced consumption was 9.7 per cent of the net consumption with predominance on industrial consumers [3]. This result is the end-consumption for which the EEG surcharge is generally payable. Finally, this consumption can be divided into the non-privileged and the privileged end consumption.

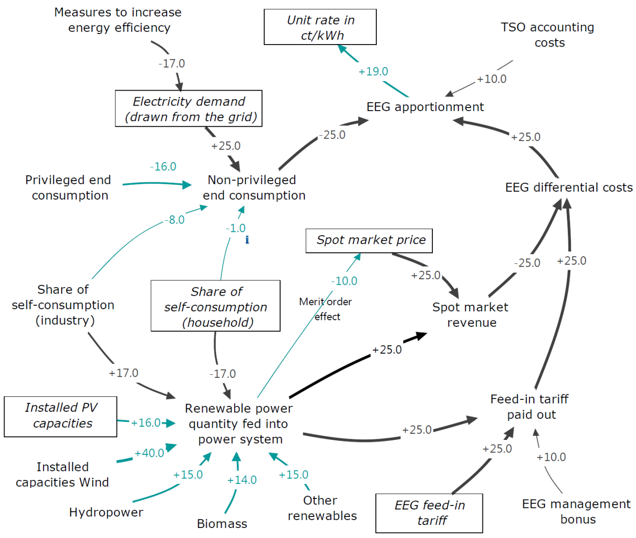

Figure 3: Submodel EEG apportionment.

Privileged end consumers are electricity-intensive companies and railways. To protect them against disadvantages in international competition, the EEG apportionment for these companies was limited to 0.05 cent per kWh. For the non-privileged consumers thereby the EEG surcharge rises. By the EEG amendment 2012 the circle of privileged consumers was expanded and the EEG apportionment is graded according to the consumption. It is expected that in 2013 round about 96 TWh (16 % of end consumption) are privileged by this regulation [4].

Supplier, Procurement Strategy

After public authorities the supplier is responsible for the second largest share in customers spending – 30.7 per cent (Fig. 2, 4). However, the suppliers share is dominated by the procurement costs and the underlying procurement strategy (Fig. 5).

Based on the forecast of the electricity demand of its customers the supplier buys electric power in bilateral, over-the-counter (OTC) trades or at the European Energy Exchange (EEX). The standard products traded at the EEX are hourly day-ahead contracts as well as bundled base and peak contracts. The following discussion about the procurement process is organized along the time line, from long before to after the actual delivery and consumption of electricity [5]. Futures are traded long before the actual delivery of the traded electricity. Typically, the procurement process for residential customers starts three to four years in advance.

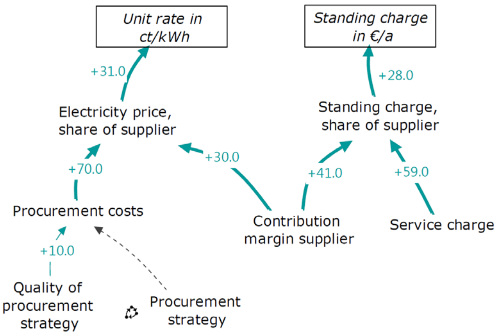

Figure 4: Submodel supplier.

At a time close to delivery more detailed information is available and market participants can predict their electricity consumption or production more accurately. Market participants are therefore urged to balance any open position in their estimates. This fine tuning of portfolios is achieved on the day-ahead market which is also referred to as the spot market. After the day-ahead market is closed, further adjustments to the portfolio are made in an intraday market. After the gate-closure the planned electricity consumption and production should be in equilibrium. However, despite all planning efforts the electricity system will always be affected by unforeseen events which have to be balanced in the balance energy market.

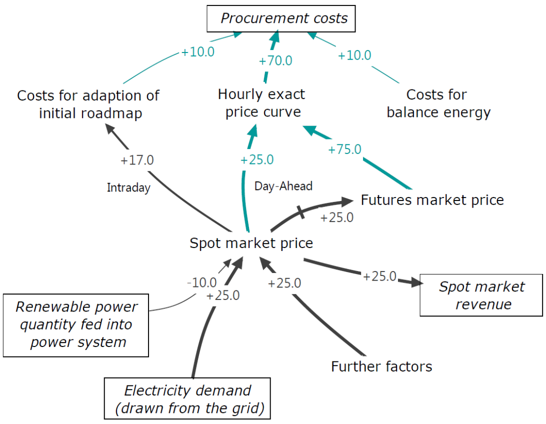

Figure 5: Submodel procurement strategy.

Customer, Energy System

The emphasis of this section is on the customer especially on the so-called Prosumer. In the past, investments in RPG systems were mostly driven by the expected profitability of the RPG (Figure 6). Although Figure 6 in principle is valid for all RPG systems/plants, we focus on rooftop mounted PV systems. The profitability of a PV system that only feeds in the grid is given by the following equation:

$$Profitability = kWh\ produced \cdot FIT - Total\ cost\ of\ ownership\ (TCO) \tag{1}$$

The amount of electrical energy produced depends on the life-time of the PV system, environmental factors and the efficiency factor. FITs were lowered continuously in the past to consider technology improvements and cost reductions due to the learning curve. Additionally, the EEG 2012 introduced a volume-responsive, or 'corridor', degression system for PV under which the FIT decrease is based on the amount of installations in prior periods. Also a 52 GW limit for the FIT for PV was defined.

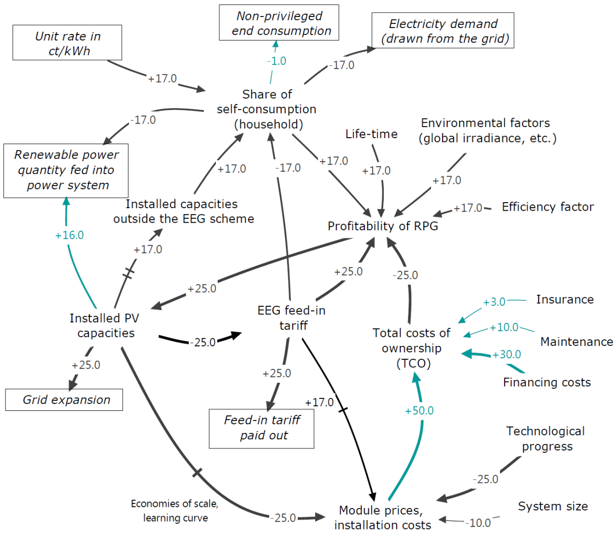

Figure 6: Submodel energy system. Notice, there are hash marks: one hash mark (|) represents a delay in the medium-term; two hash marks (||) in the long-term.

A second goal of the EEG amendment is to continue to encourage the integration of PV into the electricity grid and into electricity markets by continuing to drive PV to grid parity, encouraging onsite consumption through the 90 % sales limit and through technical requirements such as the curtailment capacity [6].

Since the present FITs for PV systems are lower than retail electricity rates it is more economical for private plant operators to use their own generated electricity themselves instead of feeding into the distribution grid. Furthermore, the usage of battery systems is going to be more economical because of the increasing share of self-consumption. All these developments result in more and more self-consumption and, therefore, in less electrical energy consumption from the public electricity grid and revenue losses for utilities. Thus equation (1) was expanded upon:

$$Profitability = kWh\ self\text{-}consumed \cdot Unit\ rate + (kWh\ produced - kWh\ self\text{-}consumed) \cdot FIT - TCO \tag{2}$$

Finally, in the long-term more and more PV capacities will no longer be part of the EEG scheme since they reach the age of 20 years. Nevertheless, these systems will still produce electrical power and it is very likely that many of these systems will be used for self-consumption.

DYNAMICS IN THE MARKET – THE MAIN FEEDBACK LOOPS

Consumer prices for electricity have risen considerably in Germany in recent years. This development can be explained with the main feedback loops illustrated in the CLD in Figure 7. Different reinforcing feedback loops and balancing feedback loops can be identified.

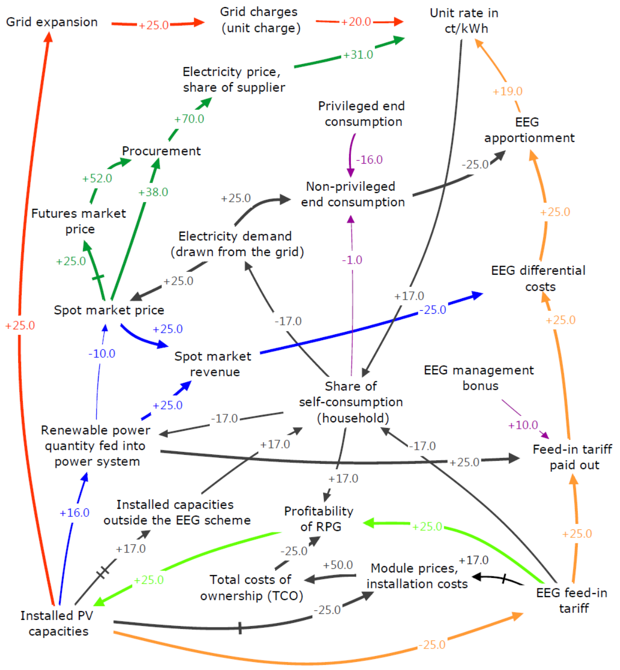

Figure 7: CLD of the main feedback loops that influence the development of the unit rate for residential customers.

Every new installed capacity of RPG increases the unit rate for residential customers in two ways: by a higher EEG apportionment due to a higher amount of FITs paid out (orange line) and higher grid charges (red line). EEG capacities also cause lower spot market revenues and consequently higher EEG differential costs (blue line). To limit these costs the initial idea of the legislator was to lower the FITs continuously (lime line). Hereby innovation should be encouraged and the annual extension should be limited. However, the solar industry was able to lower prices for modules – due to economies of scale and the learning effect – faster than the legislator the FITs so that the government wasn't able to control the process as desired. Since November 2012, the FIT has been reduced by 2.5 % per month until April 2013. The Ministry of the Environment and the solar industry claim that this FIT reduction shows the desired effect on the installation rates.

Nevertheless, we have also a stabilising effect: the merit order effect. As indicated by the green line, lower spot market prices result in lower procurement costs and consequently lower unit rates. According to a recent study [7] and our own investigations, solar power has reduced the price of electricity on the spot market by 10 per cent on average and up to 40 per cent in the early afternoon when the most solar power is generated.

In addition, the differences between the base price and the peak price decreased considerably in 2010 and 2011. These are the two years in which the most photovoltaic systems were installed. At the same time, power demand did not change. The base and peak prices used to be 20 to 25 per cent apart, but that difference has shrunk to around 12 per cent [7]. Of course, the effect is greater in the summer than in the winter, but it is there all year.

As shown in Figure 5, only one quarter of the total electricity demand for residential customers is procured on the day-ahead market. If we additionally take into account that the procurement costs account for only about one third of the households' electricity price (Figure 4), the share of procurement costs on the spot market is round about 8 per cent. In practice this means that a reduction of the spot market price by the merit order effect of 10 per cent for example means a price advantage of only 0.8 per cent for the end-user. However, the question arises as to whether these savings are passed on to the customer by the supplier. On the other hand, a reduction of 10 per cent on the spot market increases the EEG differential costs by 3.3 per cent (assumptions: average spot market price 6.1 ct per kWh; average FIT 24.8 ct per kWh). Taking into account that the EEG apportionment accounts for 19 per cent of the unit rate, we have a price increase of 0.6 per cent due to reduced spot market revenues. So these two effects almost balance each other.

Finally, the legislator has made some changes in the system either (violet lines) to prefer customer groups (electricity-intensive companies) or to offer incentives for a grid- and market-compliant action (self-consumption, market premium model). Although these changes are a positive development they currently increase the EEG apportionment.

Up until now, we have identified only few feedback loops so that the system is more an open than a closed loop control. That brings self-consumption into focus. Until now the installation of RPG plants was mainly driven by the FITs. In the future, especially installations of PV systems will be driven by customers' electricity prices. As described above, more and more PV systems will be installed with the focus on self-consumption instead of feeding into the distribution grid. Consequently one of the main control factors, the FIT, will become ineffective and the unit rate will dominate investment decisions. Also the German Solar Energy Industry Association projects that these considerations will begin to gain momentum starting in 2017 [6]. So the residential market of electrical energy is located on a self-reinforcing spiral with dramatic consequences for all market actors.

OUTLOOK

After the identification of the driving factors we can now estimate the efficiency of changes in the present system and give some recommendations.

The main objective of the EEG has been to increase the share of renewable energies on the electrical energy supply to the desired values (cf. sec. 2 para. 1 EEG). Therefore, in the past, the focus was on installed capacities and not on market and grid integration. These topics have come to the fore in the last few years. The present EEG remuneration scheme focuses solely on the kilowatt-hours produced. Mathematically speaking, we have only one dimension. In future, we need a three-dimensional system with the dimensions: where, when and how much electrical power is fed into the system. Additionally, power producers have to be encouraged to sell directly into the wholesale electricity market rather than receiving the fixed FIT payment. The first steps in this direction have been implemented in the EEG by the legislator. It must also be discussed whether every RPG plant can feed into the system free of charge.

Nevertheless, in our view it is impossible to implement all these thoughts into the present EEG as long as production and consumption of electrical energy of residential customers is handled in two separate systems. Therefore, new business models must be developed. First approaches are discussed in [8].

CONCLUSION

In this paper a systems approach has been used to investigate the German end-user electricity market. With the model presented the cause and effect relationships in the German residential electricity market were visualized and analysed. The analyses have shown that

- new installed EEG capacities have an increasing effect on the unit rate,
- one of the main control factors, the FIT, will become ineffective and
- a reinforcing feedback loop is closed by self-consumption which will gain momentum with higher electricity prices.

Especially the first and the last point make it particularly apparent that the present EEG scheme must be changed fundamentally in order to turn the transition towards renewable energy supply towards an integrated and stable energy system.

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