Assessing the Boom and Bust of the German Photovoltaic Market: An Analysis of the German Photovoltaic Market

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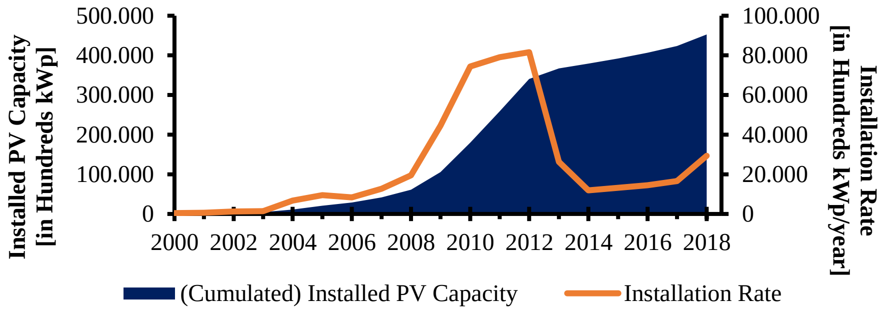
Renewable energies (RE) are a crucial component of the solution to major energy-related issues such as limiting global climate change, reducing the dependence on scarce resources and improving access to energy systems (International Renewable Energy Agency, 2019; United Nations, 2015; United Nations Development Programme, 2019).

As part of its individual climate efforts, the German government declared that RE should cover at least 80 percent of the energy supply by 2050 to meet the international climate goals (Federal Ministry for Economic Affairs and Energy [BMWi], 2015). This goal, inter alia, depends on the installed capacity of RE. While the cumulated installed capacity of RE in Germany grew constantly through the years, the installed Photovoltaic (PV) capacity did not develop gradually. The yearly PV installation rates demonstrated a boom and bust behavior that challenge the question where these dynamics originate from.



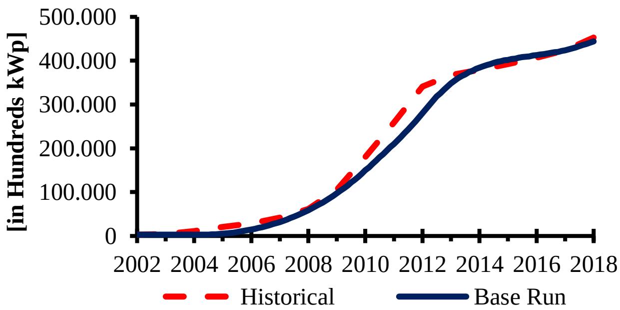
Here, we analyze and assess the PV diffusion in Germany to identify the main drivers of its s-shaped growth, in particular the flattening-out at an installed base of below 40 GWp after 2012. This is much under its potential necessary to meet the government's climate goals. The objective is to achieve a better understanding of the PV market's underlying structure and to deliver insights into the system's behavior through different scenario settings in retrospect.

We combine quantitative data with qualitative data from six expert interviews and a literature review on SD models on RE. We compared the qualitative data from interviews and the literature review with the quantitative data from secondary research. We used the findings to build confidence in the model and to investigate the resulting dynamic behavior the model creates.

The focus of our analysis is on the residential rooftop PV market. We shed light on the diffusion drivers that the literature and experts identify: profitability, space availability and familiarity with PV. Profitability or returns were the main drivers of the diffusion (BMWi, 2014; Managing Director PV Company, personal communication, October 24, 2019). Further, expectations of upcoming FIT decreases triggered investments as consumers expected PV to be less profitable (Managing Director Consultancy, personal communication, September 27, 2019; Schneider, 2010). While the availability of attractive space has occasionally been seen as a limiting factor during the boom (Energy Consultant, personal communication, September 13, 2019), nowadays there is still huge unused rooftop potential (Witsch, 2019). The spatial distribution of PV, however, is inhomogeneous and clustered among states and municipalities (Energy Consultant, personal communication, September 13, 2019; Rode, 2014). State-specific solar initiatives and differences in knowledge about PV and peer effects cause the inhomogeneity (Bollinger & Gillingham, 2012; Islam, 2014; Movilla Blanco, 2012; Müller & Rode, 2013; Rode, 2014).

We developed a SD model that incorporates the theoretical background and the individual characteristics of Germany's PV diffusion. The model adheres to various concepts of reporting guidelines by Rahmandad and Sterman (2012) and Sterman (2000). We set the time horizon for our simulation from 2002 to 2018, enabling the model to capture the full scope of the boom and bust and to provide an overview of the current dynamics. We identified PV system prices and FIT as key variables, whose interplay caused the boom and bust dynamics. Data for PV system prices were retrieved from Kosten der Photovoltaik (2016) and Wirth (2019) (Figure 3). We used both datasets for confidence building and added data for the FIT (Netztransparenz, 2019) exogenously. We used substructures from Struben and Sterman (2008) and Movilla Blanco (2012) to develop our model. The complete simulation report, including the model structure, simulation settings and equations are in the Appendix.

The simulation run reveals that the boom and bust dynamics arose from profitability changes of PV, politically triggered through the feed-in tariff (FIT). The base run of the 'Installed PV Capacity' reproduces the real behavior well, with a slight underestimation of the actual developments until 2013. One reason may be that demand formation is too simplified in the model, omitting other driving factors.



We test two policy scenarios in retrospect to provide additional insights into the system's behavior. The first policy tests the effect of a different incentive system. Our interviewees stress that the PV market is primarily politically triggered and that massive FIT reductions between 2009 and 2012 have caused the demand to decline. Contrary to the base run with abrupt FIT cuts, this policy run includes harmonized FIT degression rates of 5% starting from 2009. Considering the insights from the interviews, we expect that the demand had not collapsed. Confirming these initial values, PV in this policy gains attractiveness because of a higher expected profitability, leading to a higher demand than in the base run.

In the second policy run, we address that potential adopters were not sufficiently informed about the new PV technology. We test how the market will behave when the industry and government invest more in marketing campaigns to educate potential adopters. Marketing actions could include increasing the PV visibility through building more PV systems on public buildings or harnessing the neighborhood effect by incentivizing PV installers to organize information events in districts with yet few PV users. Triggered by these higher marketing expenditures, we find that the installed capacity is likewise higher in this policy scenario as more potential adopters are familiar with PV.

Note that the behavior of the model in both policies needs to be assessed with care. Several variables assume somewhat unrealistic values because of the simplicity of the model. The installation capacities, for example, presume extremely high values without natural constraints by supply availability and grid overloads. Additionally, more campaigns in the second policy affect the marketing expenses to an unknown, possibly unrealistic extent.

Our analysis indicates that while the boom and bust behavior of the PV market in Germany was primarily politically triggered, endogenous structures such as familiarity with PV and investment impulses also play a critical role. Demand reacts to changes in attractivity which is mainly determined by the profitability of PV systems. The profitability is formed by the investment costs and the guaranteed returns for feeding in energy, i.e. the FIT. As initial high FITs have triggered the adoption through secured high returns, cost reductions in PV systems were realized due to learning effects. PV systems hence gained attractiveness. The developments were reinforced by an increasing population familiarity with PV. Announced FIT decrements have caused additional investment impulses. The developments of PV flattened-out as massive FIT cuts were realized and the system price developments slowed down. Our paper concludes that the dynamics of the German PV market are primarily politically triggered through the FIT, thus emphasizing the importance of policy actions in fostering the diffusion of RE.

In the context of Germany's energy transformation, it is crucial to mention that policymaker's actions should not be limited to fostering the adoption of PV. Instead of isolated actions, coordinated actions as part of a holistic strategy are needed to cover 80 percent of Germany's energy supply with RE. Whereas PV alone cannot ensure energy grid stability, the combined use of wind power and PV possibly can (Quaschning, 2012; Schill, Zerrahn, Kemfert, & von Hirschhausen, 2018).

Nevertheless, to offset extreme surpluses or deficits during periods with fluctuating sunshine and wind, new large storage capacities are still needed (Crome, 2019; Quaschning, 2012). Moreover, high PV installation rates have sometimes overstretched the carrying capacity of the energy grid during the boom. Hence, PV systems only fed fluctuating power into the grid and were switched off if the frequency or voltage was outside the permissible range (German Solar Association [BSW-Solar], 2017). Thus, it is inevitable that the PV deployment is accompanied by an efficient grid integration through, inter alia, the promotion of prosumer energy storages, the expansion of electricity grids or digitization through intelligent electricity meters, smart household appliances and smart grids. (BMWi, 2016; Kemfert, 2017)

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