Responsive adjustment of feed-in tariffs to dynamic PV technology development

Thilo Grau*

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Abstract

This paper reviews the adjustments of the feed-in tariff for new solar photovoltaics (PV) installations in Germany. As PV system prices declined rapidly over the last years, the German government implemented automatic mechanisms to adjust the support level for new installations in response to deployment volumes. This paper develops an analytic model to simulate weekly installations of PV systems up to 30 kW (31% market share in 2011) based on project profitability and duration. The model accurately replicates observed market developments, showing the need for (i) frequent tariff reductions and (ii) an appropriate choice of adjustment response parameters. The model can be used to compare different policy designs, and to test for appropriate parameter choices. To illustrate this, competing proposals with different adjustment frequencies, degression flexibilities and qualifying periods are simulated under multiple scenarios for PV system prices. The analysis shows that responsive feed-in tariff schemes with frequent tariff adjustments and short qualifying periods reach deployment targets most effectively.

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Keywords: feed-in tariff, photovoltaic, renewable deployment.

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* German Institute for Economic Research (DIW Berlin), and Climate Policy Initiative (tgrau@diw.de).
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1 Introduction

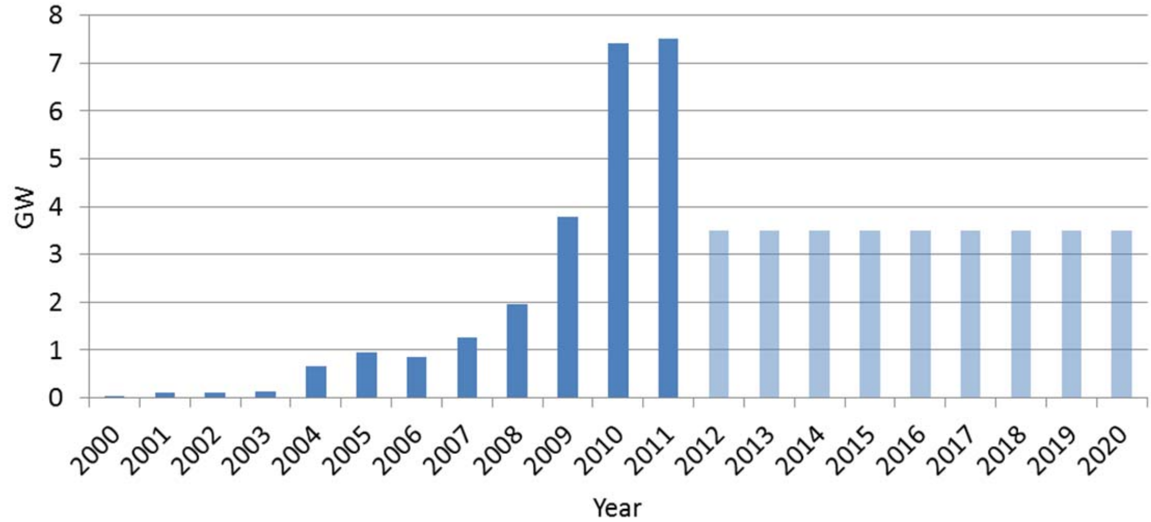
Feed-in tariffs are the most common policy instrument worldwide to support renewable electricity, having been implemented by 65 countries and 27 states/provinces (REN21, 2012). In Europe, 21 out of 27 EU member states used feed-in tariff schemes as major support instruments in 2011 (Kitzing et al., 2012). Haas et al. (2011) found that well-designed (dynamic) feed-in tariff systems are preferable to national green certificate trading schemes, as they are easy to implement and administration costs are usually lower, amongst other reasons. By comparing feed-in tariff, quota and auction mechanisms to support wind energy development in the UK and Germany, Butler and Neuhoff (2008) show that the German feed-in tariff in practice resulted in more deployment and lower prices paid per wind power delivered. Bürer and Wüstenhagen (2009) focus on private investors in innovative clean energy technology firms, and show that they perceived feed-in tariffs to be the most effective renewable energy policy. According to the European Commission, "well-adapted feed in tariff regimes are generally the most efficient and effective support schemes for promoting renewable electricity" (Commission of the European Communities, 2008). Couture and Gagnon (2010) provide an overview of different feed-in tariff remuneration schemes and conclude that market-independent, fixed price models (like the German feed-in tariff) create greater investment security and lead to lower-cost renewable energy deployment than market-dependent options.

The German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) guarantees technology-specific tariffs for electricity feed-in generated by renewable energies. These tariffs are differentiated by energy source (solar, wind, etc.) and provide a purchase guarantee for a contracted time period (usually 20 years). The respective feed-in tariff levels are reduced by specific degression rates and reviewed every three or four years to ensure that renewable energy technologies will become competitive in the long term with conventional energy forms.

Are feed-in tariffs compatible with policy objectives formulated as investment volumes in specific renewable energy technologies? The German National Renewable Energy Action Plan (Bundesrepublik Deutschland, 2010) defines a deployment target of 52 gigawatts (GW) installed photovoltaics (PV) capacity for 2020. The newly agreed version on the amended Renewable Energy Sources Act (EEG 2012) from June 2012 defines an annual target corridor between 2.5 GW and 3.5 GW for new PV installations.

This paper reviews the experience with the adjustments of the German PV feed-in tariff, so as to deliver the annual deployment target level in the presence of dynamic PV system price developments. PV feed-in tariff levels and degression rates were revisited every four years until 2009. In recent years, deployment volumes significantly exceeded target volumes, turning Germany into the largest PV market in 2009 and 2010 (accounting for 27% of global cumulative PV installations in 2011). This is seen as a challenge, as the higher volumes increase the policy costs borne by electricity consumers. Therefore, an automatic adjustment mechanism dependent on ongoing deployment volumes was introduced in 2009 in order to match PV system price reductions, followed by further adjustments to the mechanism in 2010 and 2011. Nevertheless, the deployment volume again reached 7.5 GW of new PV capacity in 2011 (see Figure 1.1). With regard to Germany's feed-in tariff degression framework, Kreycik et al. (2011) find that “uncertainties still remain over whether responsive degression frameworks can control policy costs to the degree desired by policymakers”.

Figure 1.1: Annual PV installations in Germany 2000-2011, with targets until 2020



Sources: Data from BMU (2012) and Bundesrepublik Deutschland (2010).

This paper combines a characterization of the observed market evolution with an analytic framework that allows for the disentanglement of the various drivers of this development.

The analytic model introduced in this paper simulates the evolution of new PV installations and feed-in tariffs for systems up to 30 kW on the basis of observed PV system prices. This model is based on only three factors: (i) deployment increases proportionately with project profitability, (ii) profit expectations of investors decreased after the Fukushima nuclear disaster in March 2011, and (iii) in periods prior to feed-in tariff reductions, projects are implemented faster in order to still receive the higher subsidy.

The experience of the last years shows that deployment volumes can be explained by these simple factors. Therefore, the model is used to test five policy design proposals against different price scenarios, to systematically define appropriate PV feed-in tariff adjustment parameters. Model results show that responsive feed-in tariff mechanisms with frequent tariff adjustments and short qualifying periods reach deployment targets effectively for small-scale systems with short project durations.

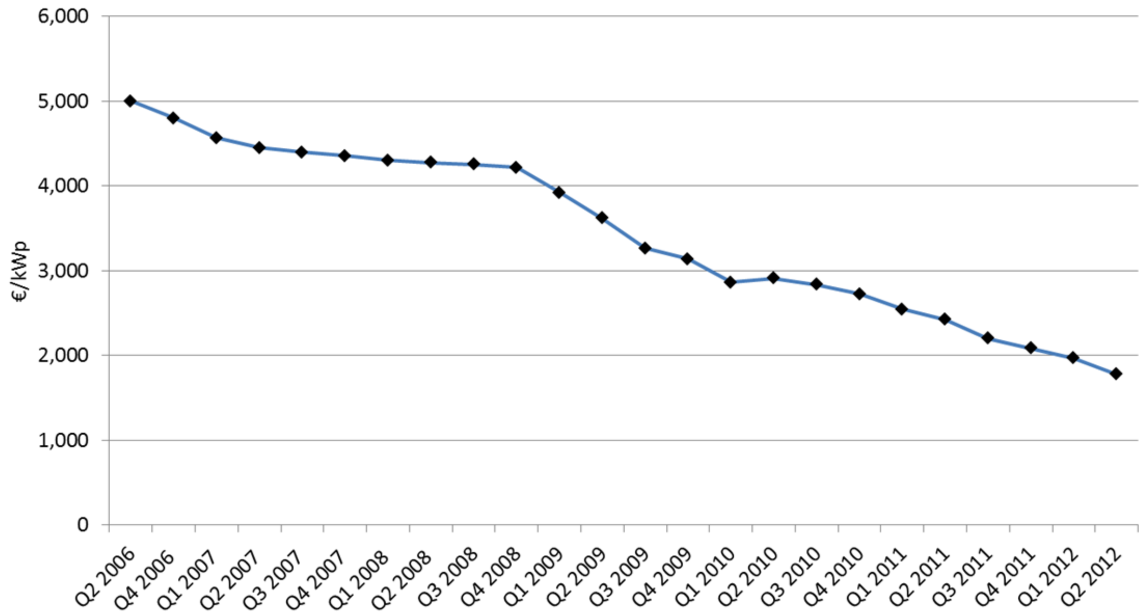
In the following, Section 2 traces the historic evolution of PV system prices and support level adjustments in Germany, and shows the responsiveness of PV deployment to feed-in tariff levels. Section 3 provides an analytic framework to explain the drivers for the observed behavior. Section 4 uses this framework to assess different policy design options under various price scenarios. Section 5 concludes the paper with a recap of findings.

2 PV technology development and feed-in tariff adjustment

2.1 Historic evolution of PV system prices

In recent years, PV system prices underwent a surprisingly rapid reduction. Figure 2.1 shows that prices for rooftop systems up to 100 kWp decreased by 64% in Germany over the last 6 years. The strong expansion of the global PV market resulted in accelerated system price declines since 2009: While the last 3 years depict the strongest annual price declines, prices show a record annual reduction by 27% during the most recent year (Q2 2011 until Q2 2012).

Figure 2.1: Average customer prices for installed rooftop PV systems up to 100 kWp



Data source: BSW-Solar (2012). Prices shown are without value added tax.

2.2 History of PV feed-in tariff adjustments in Germany

The Renewable Energy Sources Act (EEG) was established in Germany in 2000, succeeding the Electricity Feed-in Act from 1990. It regulates feed-in tariffs for renewable electricity generation. The German government's aim for renewable electricity sources is to contribute at least 35 percent of total power supply by 2020. The newly amended EEG from June 2012 defines an annual growth corridor between 2.5 GW and 3.5 GW of new PV installations, and a cap of 52 GW cumulative installations (25 GW were installed at the end of 2011).

The feed-in tariffs within the EEG are differentiated by energy source (solar, wind, etc.), and are usually guaranteed for a period of 20 years. The respective tariff levels for new installations are traditionally reduced by annual degression rates and reviewed every three or four years, thus creating the incentive for manufacturers to improve technologies, to ensure that renewables will become competitive with conventional electricity generation in the future.

In light of the dynamic cost developments of photovoltaics, anticipating PV system prices has become increasingly challenging. If the degression rate is set above the innovation potential, feed-in tariffs may become too low to allow for an economic deployment of further renewable technologies. Given the share of the German market in the global situation, this was interpreted as a high risk for the further development of the technology and the industry. Setting degression rates too low can lead to windfall gains for manufacturers or project developers, and deployment volumes that exceed initial plans can cause significant cost increases.

The first PV feed-in tariff was established at a rate of 0.99 DM/kWh (around 0.51 €/kWh), and annual degression rates were set at 5% for all systems. Since 2004, feed-in tariffs were graded according to system capacity and installation type (rooftop, façade, and free-standing installations), with rates between 0.46 and 0.62 €/kWh. Annual degression rates remained constant at 5%, and increased to 6.5% for field installations from 2006 onwards. Since 2009, there are four categories for rooftop installations (≤ 30 kW, 30-100 kW, 100-1000 kW, > 1000 kW), which have been amended in June 2012 (≤ 10 kW, 10-40 kW, 40-1000 kW, 1-10 MW).

With the amendment of the EEG in 2009, a "breathing cap" was introduced for new PV installations, to allow the tariff level to respond to deployment volumes on an annual basis (annual 2009 target corridor: 1 to 1.5 GW). The EEG 2009 envisaged a yearly 8-10% degression rate of these tariffs, which would change according to the amount of newly installed PV capacity each year. However, as PV system prices declined in 2009 much more rapidly than originally expected, deployment increased strongly, and therefore additional reductions of 8-13% and 3% were implemented on 1 July 2010 and 1 October 2010 respectively.

The new corridor degression system implemented in 2010 projected a baseline of 3.5 GW annual installations. The basic degression rate of 9% would increase by up to 4%, depending on the deployment above this baseline. As PV installations amounted to 7.4 GW in 2010, feed-in tariffs were reduced accordingly by 13% on 1 January 2011.

The EEG Amendment from April 2011 implemented a new mechanism with the following biannual PV feed-in tariff adjustments dependent on the rate of deployment:

- On 1 July 2011 by up to 15 percent.[1]
- On 1 January 2012 by a basic degression of 9 percent, with an additional adjustment of between -7.5 and 15 percent. The possible annual degression rate could therefore be between 1.5% and 24%.[2]

However, this mechanism did not result in any degression in July and September 2011 (as less than 875 MW was installed between March and May 2011), and led to a 15 percent degression in January 2012 (as 5.2 GW were installed between October 2010 and September 2011).

[1] For ground-mounted systems on 1 September 2011.

[2] When determining the new degression rate on 1 January 2012, the advanced "interim" degression from 1 July 2011 would be taken into account.

The EEG 2012, passed by the Bundestag (Lower House of German Parliament) in June 2011, defined that the valid PV feed-in tariff degression scheme was to continue. According to the German Federal Network Agency (Bundesnetzagentur), Germany set a new monthly record of 3 GW installations in December 2011, resulting in 7.5 GW annual deployment in 2011. This significant deployment strengthened calls for further tariff adjustments.

A draft version on a newly amended feed-in tariff mechanism was released in March 2012, but blocked in the Bundesrat (upper house, representing the federal states) in May. In June 2012 the German government finally released the agreed version on the revised PV feed-in tariff policy, including the following amendments:

- The law comes into force on 1 April 2012.
- There are new tariff categories for roof-top systems: up to 10 kW, up to 40 kW, up to 1000 kW, and above 1000 kW. Ground-mounted systems receive a uniform tariff. Installations above 10 MW receive no further subsidies.
- The one-off tariff reduction on 1 April 2012, ranging from 20 to 29 percent, results in the following feed-in tariffs for new installations: 19.5 ct/kWh for roof-top up to 10 kW, 18.5 ct/kWh for roof-top up to 40 kW, 16.5 ct/kWh for roof-top up to 1000 kW, and 13.5 ct/kWh for all systems up to 10 MW.
- Tariff levels will be reduced continuously by 1% on a monthly basis (compared to the respective previous month) from May until October 2012.
- Feed-in tariffs for new installations will be phased out once 52 GW cumulative PV capacity will be reached. The annual growth corridor between 2.5 GW and 3.5 GW stays constant until this target will be reached.
- Degression levels depend on deployment, are adjusted every three months and implemented on a monthly basis from November 2012 onwards.[3]

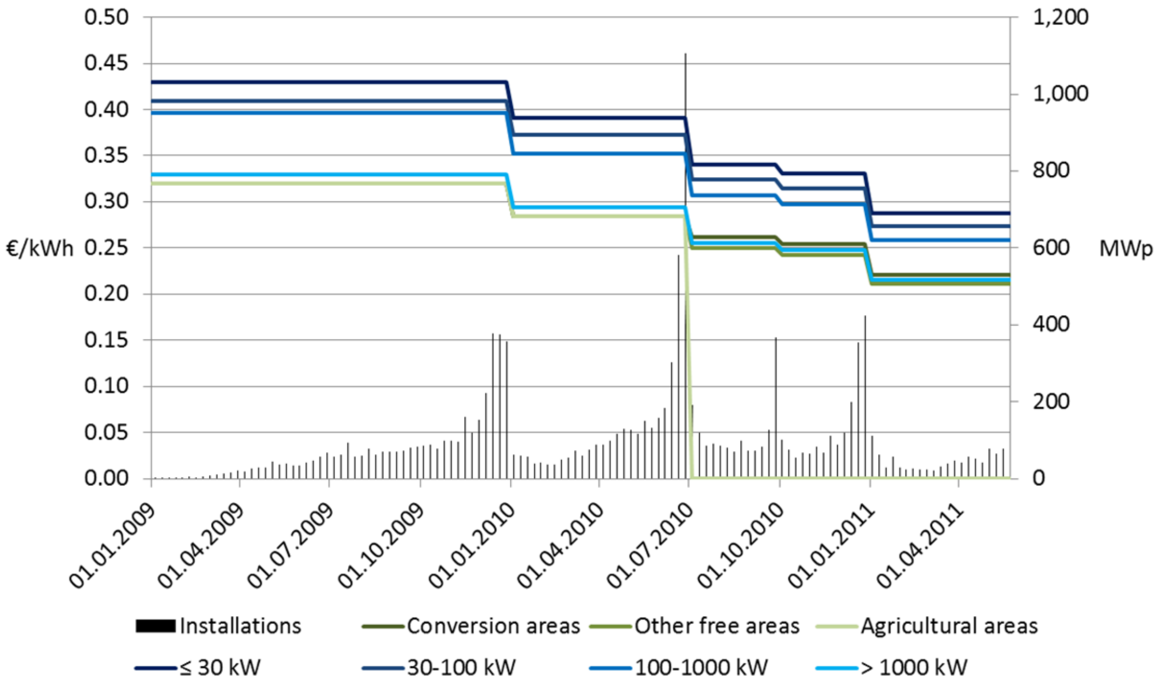
2.3 Weekly PV deployment and market responsiveness

To improve monitoring of market development, new PV systems must be registered at the Federal Network Agency (Bundesnetzagentur) since January 2009. Although these systems are categorized according to their date of registration, and not their date of commissioning, the data allows for a realistic assessment of actual market volume, according to Reichmuth (2011, page 8).

[3] The adjustment of the feed-in tariff on 1 November 2012 depends on deployment in the period July until September 2012, projected on a yearly basis. The calculation of the degression levels from 1 February 2013 and 1 May 2013 onwards is based on the following qualifying periods: July until December 2012 and July 2012 until March 2013 respectively (projected on a yearly basis). From 1 August 2013 onwards, the degression will depend on deployment in the respective previous 12 months. The Federal Network Agency has one month to determine deployment and new feed-in tariff rates. If installations stay considerably below the growth corridor, the degression will be paused or tariff levels will even be increased.

Figure 2.2 shows weekly PV installations and feed-in tariff levels in Germany since January 2009. In periods prior to a reduction of the feed-in tariff, the volume of PV installations increased as house owners and project developers still wanted to profit from the higher subsidies. While Reichmuth (2011, page 211) states that the degression in October 2010 had no comparable impact (on a monthly basis), our weekly data analysis also shows a demand peak in the last week of September 2010.

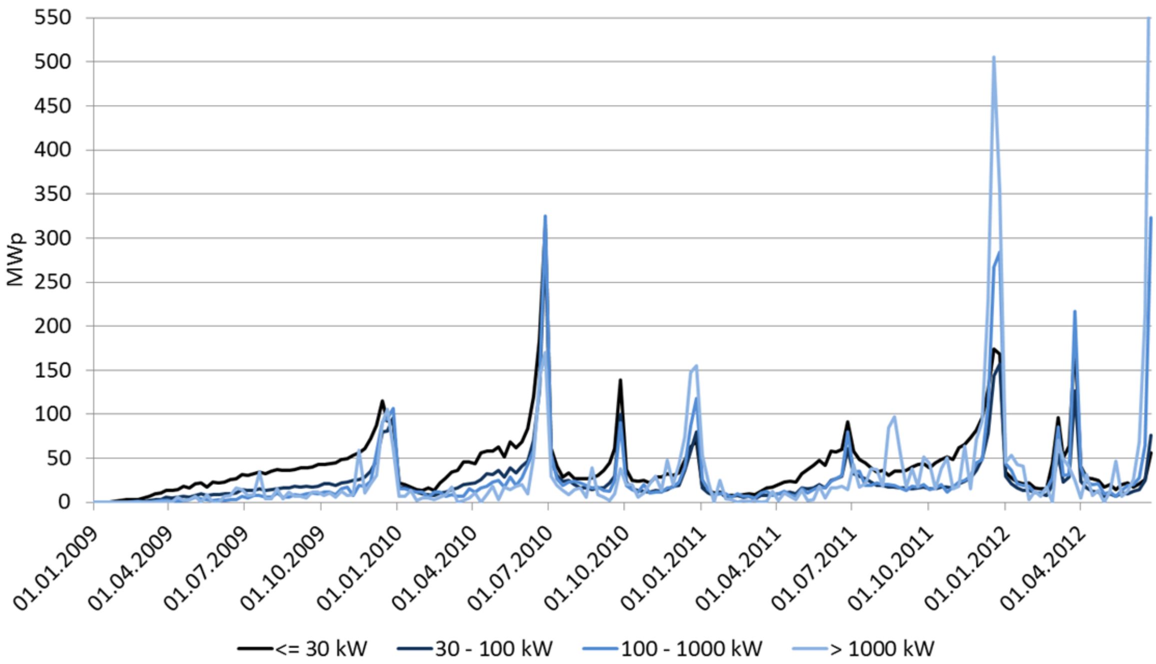
Figure 2.2: Weekly PV installations and feed-in tariff levels in Germany between January 2009 and May 2011



Installations based on data from Bundesnetzagentur.

These characteristic demand peaks can be observed in all relevant sub-categories, as shown in Figure 2.3. However, market responsiveness of these categories varies. Larger projects are usually more responsive to changing support schemes, if we compare PV deployment within the last week (or the last two weeks) before a feed-in tariff reduction to cumulative installations within the whole period of the same feed-in tariff levels. For instance, PV deployment was three times higher within the last two weeks of 2009 than the annual average for systems up to 30 kW, five times higher for systems between 30 and 100 kW, eight times higher for systems between 100 and 1000 kW, and seven times higher for installations above 1 MW.

Figure 2.3: Weekly PV installations for relevant size categories in Germany between January 2009 and June 2012



Based on data from Bundesnetzagentur.

This work focuses on the small-scale rooftop category up to 30 kW of the German PV feed-in tariff, as installations up to 30 kW accounted for 35% and 31% of total installations in Germany in 2010 and 2011 respectively. Weekly deployment of PV systems up to 30 kW is shown by the dark curve in Figure 2.3.

3 Analytic framework

The deployment effectiveness of a feed-in tariff scheme is analyzed using a simple model. The model depicts three factors impacting deployment:

(i) Deployment increases proportionately with project profitability.
(ii) Profit expectations of investors decreased after the Fukushima nuclear disaster in March 2011.
(iii) Deployment is responsive to feed-in tariff changes: In periods prior to feed-in tariff reductions, project implementation accelerates to still receive the higher tariff levels.

3.1 Basic model

The basic model (without simulation of demand peaks) is as follows. We consider a discrete-time economy. At the beginning of every period *t*, each household decides whether to invest in a PV project, that would be finalized at date *t+d*, taking into account the average project duration *d*. PV installations Y_{t+d} at time *t+d* depend on profits π_{t+d} according to the function

$$Y_{t+d} = \alpha * \pi_{t+d} - c, \tag{1}$$

with parameters α and *c*. To account for increasing interest and changing profit expectations of households after the Fukushima nuclear disaster, both parameters α and *c* are determined for the periods before March and after April 2011.

Profits of PV projects are defined as net present value:

$$\pi_{t+d} = v_{t+d} - p_t \tag{2}$$

where p_t is the average system price at date *t* and v_{t+d} is the present value of the feed-in tariff at time *t+d*.

The present value v_t of the feed-in tariff is given by the equation:

$$v_t = f_t * h * \sum_{j=0}^{n} (1+i)^{-j}, \tag{3}$$

where f_t is the feed-in tariff at date *t*, *h* is the amount of full load hours per annum, *n* is the amount of years which the feed-in tariff is paid for, and *i* is the annual interest rate.

3.2 Advanced model with peak simulation

To account for the characteristic demand peaks of historic PV market evolution (see Figure 2.3), the basic model is extended as follows. The assumption is that, in periods before the feed-in tariff is reduced, investors make use of the flexibility to accelerate project execution so as to still qualify for the higher tariff levels. This market behavior then leads to the observed "clearance sale" effects. The representative investor choses the project duration d_t at time *t* according to the function

$$\begin{gathered} d_t = \max l \\ subject\ to\ \pi_{t+l} \geq \pi_{t+d_{ave}} \\ d_{min} \leq l \leq d_{ave}, \end{gathered} \tag{4}$$

where d_{min} and d_{ave} are the minimum and average project duration respectively. While projects are usually implemented within the average duration, implementation accelerates in periods prior to feed-in tariff reductions.

Thus, the volume of PV installations at date $t+d_{ave}$ is given by the equation:

$$Y_{t+d_{ave}} = \sum_{\substack{-\infty \leq m \leq \infty \\ if\ (m+d_{t+m}=d_{ave})}} (\alpha \pi_{t+d_{ave}} - c) \tag{5}$$

4 Quantitative evaluation

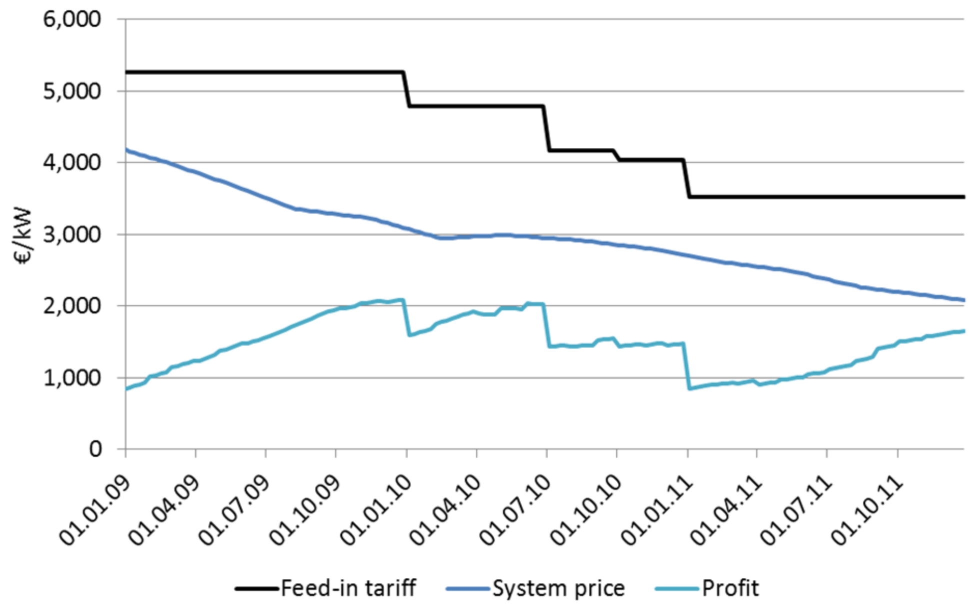
4.1 Parameter choices

For the purpose of this model, a period *t* corresponds to one week. PV modules can achieve around 900 full load hours per year on average in Germany, and the feed-in tariff is paid for a time period of *n*=20 years. Annual interest rates *i* are based on monthly data published by Deutsche Bundesbank (2012).

The overall process duration of PV projects depends on system sizes. In Germany, according to the PV LEGAL project (PV LEGAL 2011), it varies between 3 to 8 weeks (6 weeks on average) for small-scale installations on residential buildings, 6 to 24 weeks (12 weeks on average) for small to medium-scale installations on commercial buildings, and 53 to 132 weeks (85 weeks on average) for medium to large-scale ground-mounted installations on open lands. To calculate profits of small-scale rooftop systems, the model uses their average project duration of 6 weeks.

The analytic framework is based on price and interest rates data that was available in summer 2012. BSW-Solar (2012) provides quarterly PV system price data (Q4 2008 – Q2 2012) for installations ≤ 100 kW. In the model, this reflects the price within the middle of each quarter, the weekly price data for the intermediary weeks is linearly approximated. To use price data for systems ≤ 30 kW, the data (which is reported for installations ≤ 100 kW) is adjusted with a fixed shift factor.[4] The evolution of profits, as well as system prices and present values of feed-in tariffs, is shown in Figure 4.1.

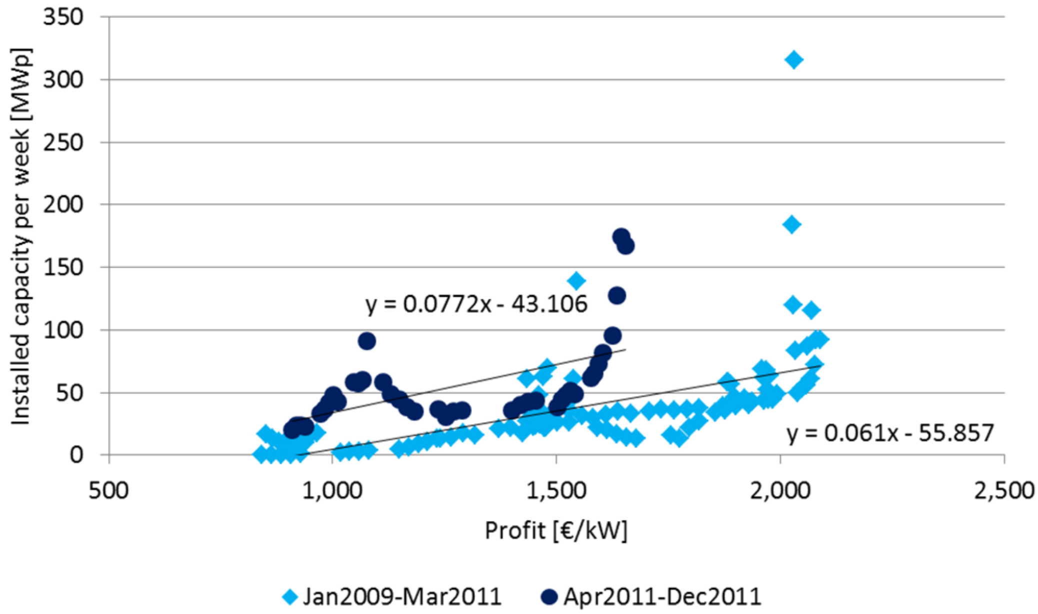
Figure 4.1: PV feed-in tariff, system prices, and profits for solar panels of up to 30 kW in Germany between January 2009 and December 2011



[4] This shift factor is calculated from monthly system price data (0-10 kW and 10-30 kW, June 2009 – May 2011) from Photon (2010, 2011) and based on installation data (2009-2010) from Reichmuth (2011, Figure 1-4).

To analyze the first two factors (see section 3), Figure 4.2 shows the relationship between historic PV installations and profits (margins to cover risks like e.g. the failure of components during 20 years lifetime). The amount of weekly installations largely increases with rising profits. However, there are several outliers, which represent “clearance sale” effects in weeks before the feed-in tariff was reduced. Moreover, this figure illustrates that the relationship between installations and profits has shifted over time. Compared to the period before the Fukushima nuclear disaster, lower margins are needed for the same amount of installations from April 2011 onwards. Environmental awareness and motivation of households to invest into clean energy sources seem to have clearly increased thereafter. A maturing market with increasing experience and decreasing risk for project developers might be further reasons for this shifting behavior over time. These observations validate the first two factors of the model.

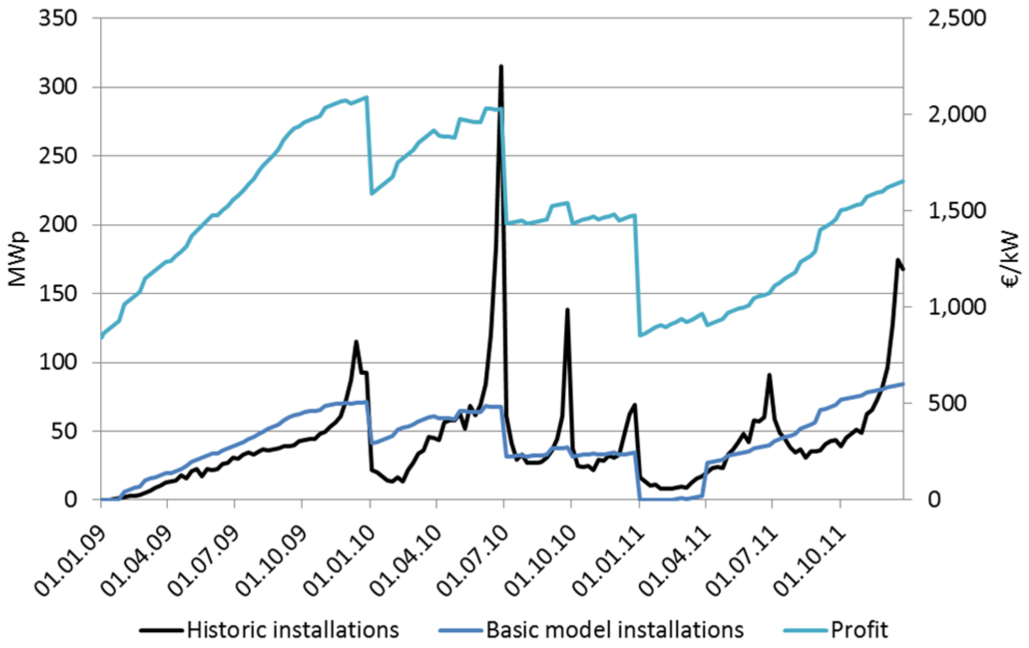
Figure 4.2: Weekly PV installations and profits for systems of up to 30 kW in Germany, 2009-2011



The analytic framework assumes a linear correlation between weekly installations and profits in Germany. By adjusting for changing investment behavior and maturing market conditions before and following the Fukushima disaster, estimations lead to the parameters α_1=0.06 and c_1=55.86 for January 2009 until March 2011, as well as α_2=0.08 and c_2=43.11 for April 2011 until December 2011. The post-Fukushima correlation between installations and project profitability is assumed to stay constant in later periods.

Based on these parameters, Figure 4.3 shows the resulting evolution of PV installations according to the basic model (see section 3.1).

Figure 4.3: Historic and model-based weekly PV installations (basic model) for systems up to 30 kW



The basic model delivers a relatively realistic match of historic and model-based installations. However, the largest deviation to historic PV deployment are the demand peaks observed in periods before feed-in tariff reductions. The advanced model (see section 3.2) is used to simulate these peaks.

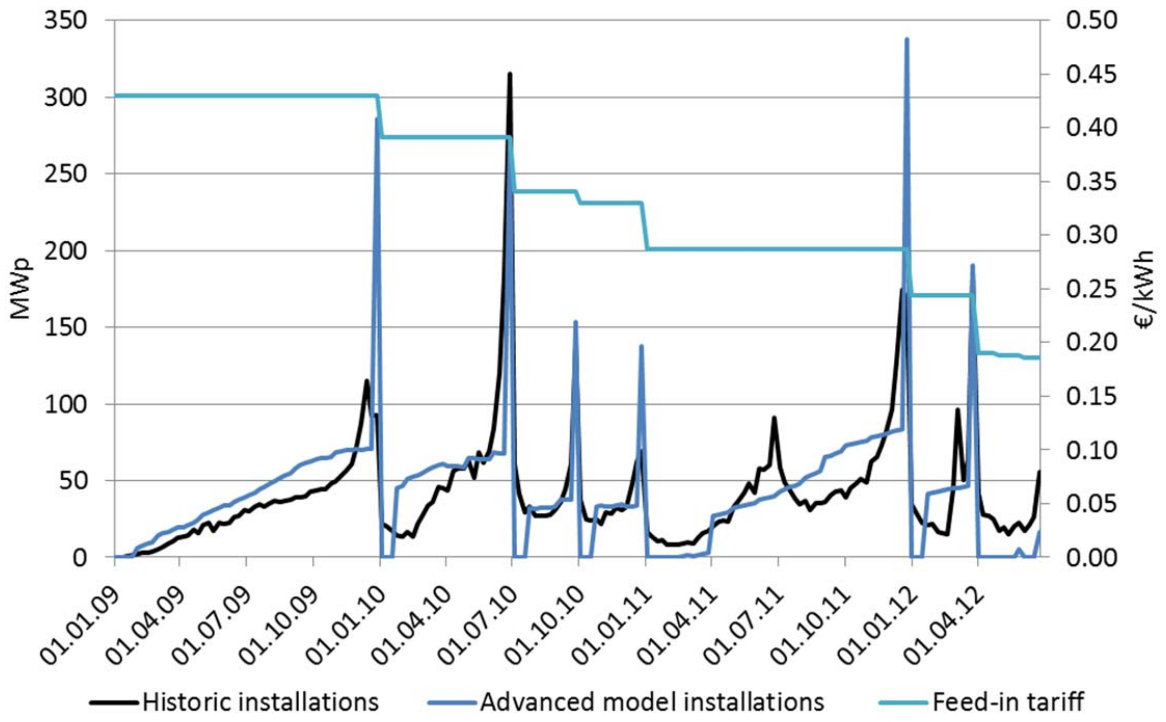
As mentioned above, the overall process duration of PV projects in Germany varies between 3 to 8 weeks (6 weeks on average) for small-scale installations on residential buildings. The basic model uses the average project duration of 6 weeks to calculate profits of roof-top systems of up to 30 kW. However, project developers have an interest in accelerating the implementation process in periods prior to feed-in tariff reductions. Therefore projects which are started 3 to 5 weeks before a feed-in tariff reduction are implemented more rapidly, so as to be completed in the last week before the tariff cut. In the next sections, this advanced model is used to simulate PV deployment between January 2009 and December 2014 for different feed-in tariff designs and system price scenarios.

4.2 Model results for the current adjustment mechanism

In this section, the advanced model (see section 3.2) is used to simulate weekly PV deployment for the current feed-in tariff adjustment mechanism implemented in June 2012 (as described in section 2.2). The model calculations of the feed-in tariff levels from January 2012 onwards use rooftop systems of up to 30 kW as representative category. As the feed-in tariff adjustment is formulated based on total deployment volume, the model assumes that the market share of projects of up to 30 kW (31% in 2011) stays constant. Feed-in tariff rates for systems up to 30 kW from April 2012 onwards are calculated as average rates between the tariff levels of the newly implemented size categories for systems up to 10 kW and up to 40 kW respectively (see section 2.2). To simulate PV installations from January 2012 onwards, the model uses observed system price data until Q2 2012 from BSW-Solar (2012), and assumes a further yearly continuous price decline by 16% (equal to average price decrease over the last 6 years).

In comparison to the basic model, the advanced model is able to simulate PV deployment with its characteristic demand peaks. Figure 4.4 shows that historic and model-based PV installations match fairly well.

Figure 4.4: Historic and model-based weekly PV installations (advanced model) for systems of up to 30 kW



There was no feed-in tariff reduction on 1 July (and 1 September) 2011, as less than 875 MW of PV systems were registered at the Federal Network Agency between March and May 2011. However, market demand peaked before July 2011, due to temporary uncertainty about potential subsidy cuts. On 1 January 2012 the degression amounted to 15%, as 5.2 GW were registered between October 2010 and September 2011.

When comparing historic and model-based deployment, we observe that historic demand peaks are higher in summer 2010 and 2011, and lower at the end of each year. These seasonal peak variations can be explained by (i) weather conditions (e.g. snow) at the end of December being more difficult concerning project implementation, and (ii) lower demand at the end of the years due to Christmas holidays.

4.3 Model results for alternative design options

During political discussions in 2011 and 2012, alternative options for the precise design of the PV feed-in tariff adjustment mechanisms were brought forward by different political parties. In this section, different design options are discussed based on the advanced model calibrated in section 4.1, to explore their respective implications. In particular, the focus of this analysis is on the impact of the following variables:

- degression frequency,
- adjustment flexibility, and
- qualifying period.

Table 4.1 defines five different design options with their respective parameters. These design choices contain monthly and quarterly degression frequencies, with adjustment rates being either fixed or dependent on installations in previous months, and in the latter case with qualifying periods of either 3 or 12 months.

Table 4.1: PV feed-in tariff design options with parameters

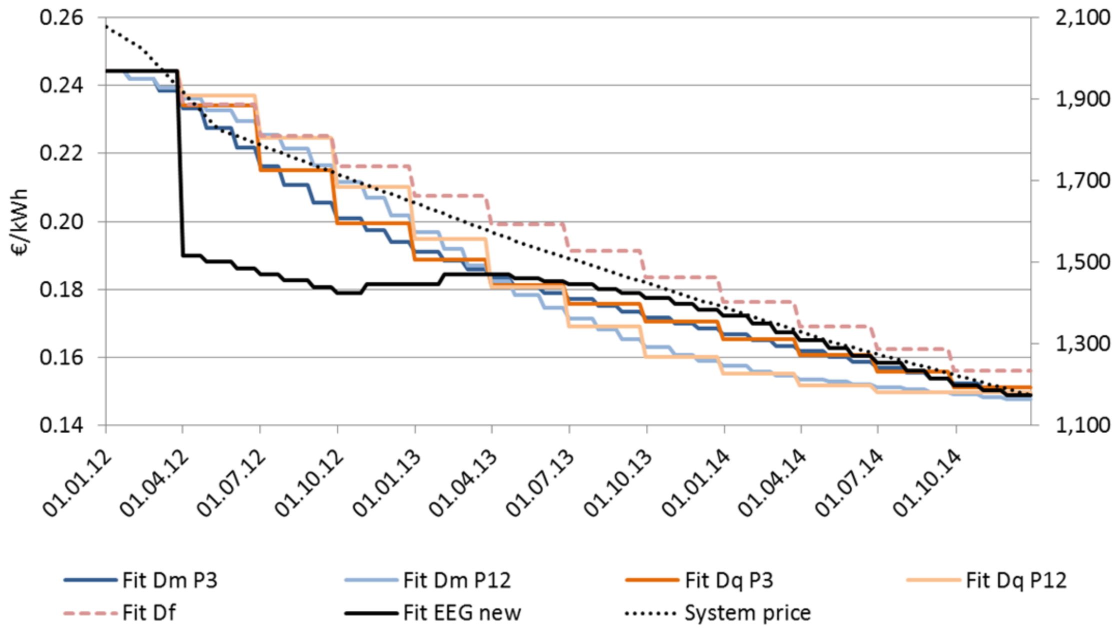
Name	**Dm P3**	**Dm P12**	**Dq P3**	**Dq P12**	**Df**
Degression frequency	monthly	monthly	quarterly	quarterly	quarterly
Basic degression	1%	1%	2.97%	2.97%	4%
Degression corridor	-1.5% (p.q.) – 2.8% (p.m.)	-1.5% (p.q.) – 2.8% (p.m.)	-1.5% - 8.17%	-1.5% - 8.17%	-
Qualifying period	3 months	12 months	3 months	12 months	-

The “Dm P3” and “Dm P12” designs contain a monthly 1% degression, which can vary between 0% (-1.5% each quarter) and 2.8% according to the amount of installations in the previous 3 and 12 months respectively. Degression rates are calculated and implemented each month, compared to the current feed-in tariff design with quarterly determinations and monthly implementations. The “Dq P3” and “Dq P12” designs use a quarterly frequency with a basic 2.97% degression (which corresponds on a yearly basis to a monthly 1 % degression). As there is a time buffer of one month between qualifying periods and corresponding degression dates in the adjustment design currently in place, the same is implemented in all four flexible design options in Table 4.1. The “Df” design includes a fixed quarterly 4% degression.

All parameters of these adjustment schemes build on historic design proposals of different political parties. In February 2011, the Green Party suggested a PV feed-in tariff mechanism with four advanced tariff reductions during the year (and qualifying periods of 2 months), and a passing on of remaining reductions to the following dates. In December 2010, the Social Democratic Party proposed the feed-in tariff to be reduced by 4% every three months. However, since then, the option to adjust the PV support level in response to ongoing deployment volumes has been positively received by most stakeholders.

Figure 4.5 shows the evolution of model-based PV feed-in tariffs (for systems up to 30 kW) for all feed-in tariff design options in the period January 2012 – December 2014. To calculate feed-in tariff levels from 2012 onwards for the flexible adjustment designs with their different qualifying periods (see Table 4.1), the model assumes that deployment in 2011 corresponded to the 3 GW annual target corridor (with 250 MW monthly installations).[5]

Figure 4.5: PV feed-in tariff rates for systems of up to 30 kW for different adjustment design options



The newly implemented feed-in tariff scheme ("EEG new") includes a one-off tariff reduction in April 2012, ranging from 20% (up to 10 kW) to 24% (up to 30 kW) for small-scale PV systems. After fixed monthly 1% degression rates between May and October 2012, the model-based feed-in tariff level increases by 1.5% in November 2012 and February 2013 (since installations in the respective qualifying periods are below 1 GW on a yearly projected basis), and decreases again from May 2013 onwards with changing degression levels.

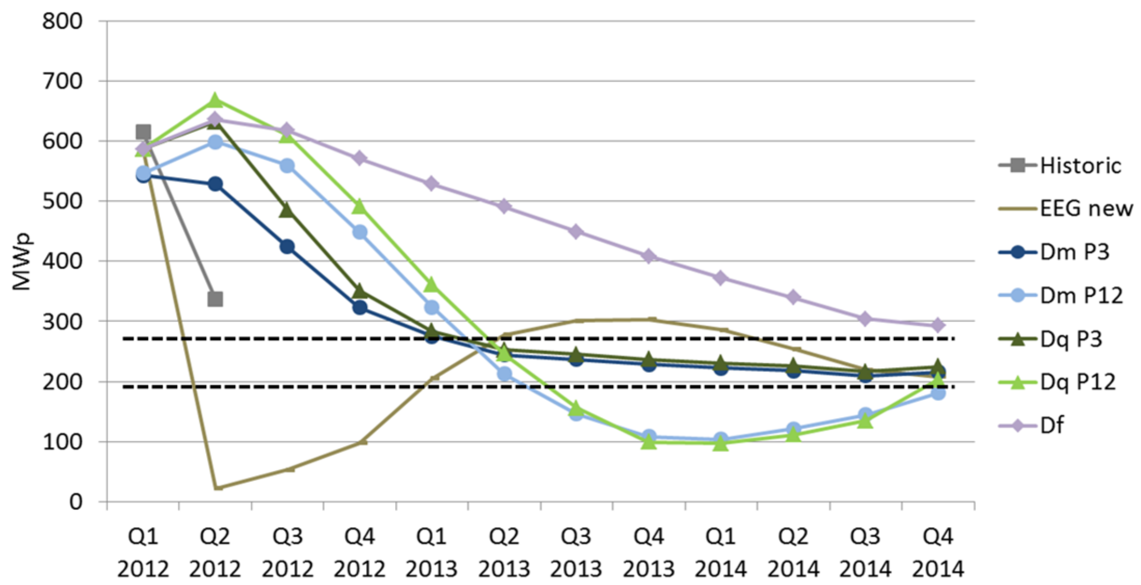
The "Dm P12" design option with monthly degressions and a qualifying period of 12 months reaches the lowest tariff level (14.75 ct/kWh) at the end of 2014. The design options with qualifying periods of 3 months show relatively high degression rates in 2012, and converge towards the basic monthly (1%) and quarterly (2.97%) degressions from June (Dm P3) and July (Dq P3) 2013 onwards respectively. The differentiation between monthly and quarterly degression frequencies has a relatively low impact on

[5] This assumption is implemented to avoid that the record month of December 2011 with its 3 GW of solar installations has a relatively long impact within the feed-in tariff calculations of the adjustment design options with qualifying periods of 12 months.

the long-term evolution of tariffs, given a continuous decline of system prices. The fixed “Df” design leads to the highest tariff rates from August 2012 onwards, resulting in levels at the end of 2014 being 5% larger than under the “Dm P12” design.

According to the newly amended Renewable Energy Sources Act (EEG) of June 2012, the future growth corridor for supported PV installations amounts to 2.5 to 3.5 GW per year. Assuming that the 31% market share of small-scale systems up to 30 kW in 2011 will stay constant in the future, this corresponds to a quarterly growth corridor of 194 to 271 MW for these installations. Figure 4.6 shows historic and model-based installations for the different feed-in tariff adjustment designs on a quarterly basis for the simulated period 2012 until 2014, as well as the respective target corridor.

Figure 4.6: Quarterly PV installations up to 30 kW for different feed-in tariff designs and target corridor



Following the strong one-off tariff reduction in April 2012, historic PV installations in the second quarter of 2012 decreased less than model-based deployment under the current feed-in tariff adjustment mechanism. This can be explained by the retrospective nature of this one-off adjustment, which was implemented in June 2012, leading to investment uncertainty in the previous months. Thereafter, model-based installations grow steadily for this design option to reach the target corridor in Q1 2013 and to converge there from Q2 2014 onwards.

After a certain adjustment period, the feed-in tariff designs with qualifying periods of 3 months are able to reach the targeted installations corridor from Q2 2013 onwards. In comparison, adjustment schemes with qualifying periods of 12 months lead to more deployment in 2012, but fall below the target corridor between mid 2013 and the end of 2014. Installations under the fixed degression design are always exceeding the target corridor.

However, the future price development is not known at the time of decisions on the adjustment mechanism. Therefore, the designs need to be tested against different potential scenarios. The evolution of system prices from Q2 2012 onwards is difficult to predict, especially because of the following characteristics of the global price for PV modules:

- There are global production capacities for around 50 GW new PV modules[6], which have been operated with low utilization factors often already over the last years.
- Demand for PV modules depends on the evolution of feed-in tariffs and other policy schemes in many countries, and is difficult to predict.

This analysis uses the following scenarios for the evolution of system prices for small-scale PV installations in Germany. Figure 4.7 shows the respective prices in all scenarios in the simulation period.

Business-As-Usual (BAU) scenario: The price continuously declines from Q2 2012 onwards by yearly 16% (average during last 6 years, as defined in section 4.2).

Reference (REF) scenario: The price is fixed at a specific level in the period 20 November 2011 until 18 February 2012, so that model-based installations result in the respective target deployment in Q1 2012 (18 MW per week and 930 MW per quarter respectively for systems up to 30 kW). The corresponding price level is calculated as:

$$p_{20.11.11-26.11.11} = (v-\pi)_{1.1.12-7.1.12} = \left(0.2443\frac{€}{kWh} * 900h * \sum_{j=0}^{20} 1.0364^{-j}\right) - \frac{18+43.106}{0.0772} = 2408\frac{€}{kW}$$

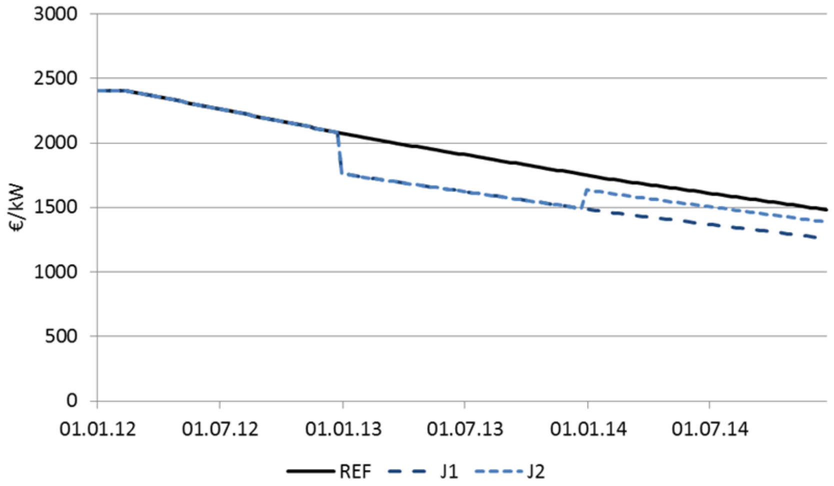
This corresponds to a 12.5% price increase on 20 November 2011. From 19 February 2012 onwards, the price continuously declines by yearly 16% (similar to BAU scenario).

Jump 1 (J1) scenario: The price evolves as in the REF scenario, with a one-off price reduction by 15% on 1 January 2013.

Jump 2 (J2) scenario: The price evolves as in the J1 scenario, with a one-off price increase by 10% on 1 January 2014.

[6] According to Sarasin (2011), there are 21 GW of demand and around 50 GW of production capacity for solar modules at the end of 2011.

Figure 4.7: PV system prices for installations up to 30 kWp in model scenarios



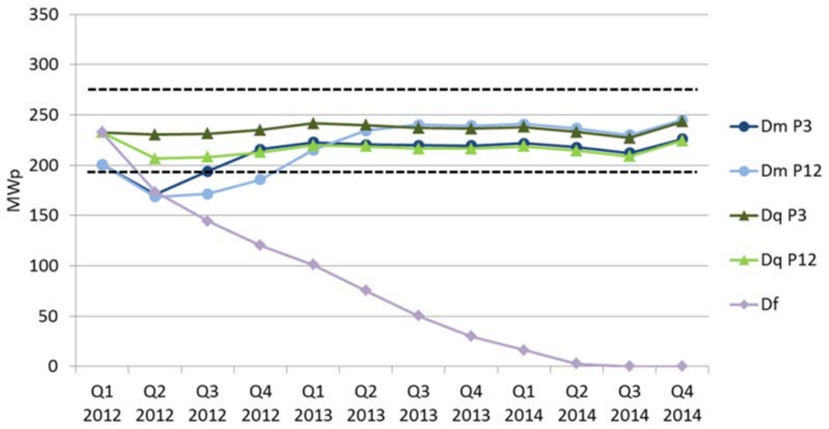
While the "Df" feed-in tariff design includes fixed 4% reductions every three months, feed-in tariff cuts in the flexible adjustment designs depend on the amount of PV capacity installed in the previous months, and thereby differ in the respective system price scenarios. Table 4.2 summarizes model-based feed-in tariff rates for all adjustment designs in the different price scenarios. While the "Dm P12" design leads to the lowest feed-in tariff at the end of 2014 in the BAU and J1 scenarios, the "Dq P12" and "Df" designs reach the lowest levels in the J2 and REF scenarios respectively. With regard to the flexible design options, the "Dq P3" design results in the highest tariff rates at the end of the simulation period in all scenarios. The respective deployment levels for price scenarios REF, J1 and J2 are shown in Figure 4.8.

Table 4.2: Feed-in tariff rates [ct/kWh] for systems up to 30 kW at the end of 2012 and 2013 for different adjustment design options and price scenarios

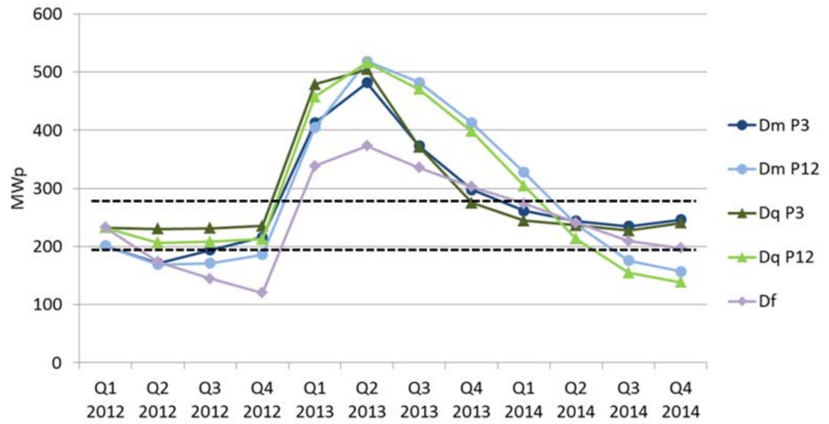
Scenario	Year	Feed-in tariff design				
		Dm P3	Dm P12	Dq P3	Dq P12	Df
BAU	2012	19.38	20.19	19.94	21.01	21.61
	2013	16.83	15.90	17.05	16.00	18.36
	2014	14.92	14.75	15.11	14.95	15.59
REF	2012	22.15	21.98	22.49	22.32	21.61
	2013	19.63	19.78	19.93	19.78	18.36
	2014	17.40	17.53	17.67	17.53	15.59
J1	2012	22.15	21.98	22.49	22.32	21.61
	2013	18.05	18.85	18.15	19.08	18.36
	2014	15.80	15.16	15.89	15.17	15.59
J2	2012	22.15	21.98	22.49	22.32	21.61
	2013	18.05	18.85	18.15	19.08	18.36
	2014	16.58	15.57	16.63	15.54	15.59

Figure 4.8: Quarterly PV installations for systems up to 30 kW for different feed-in tariff designs and price scenarios between 2012 and 2014

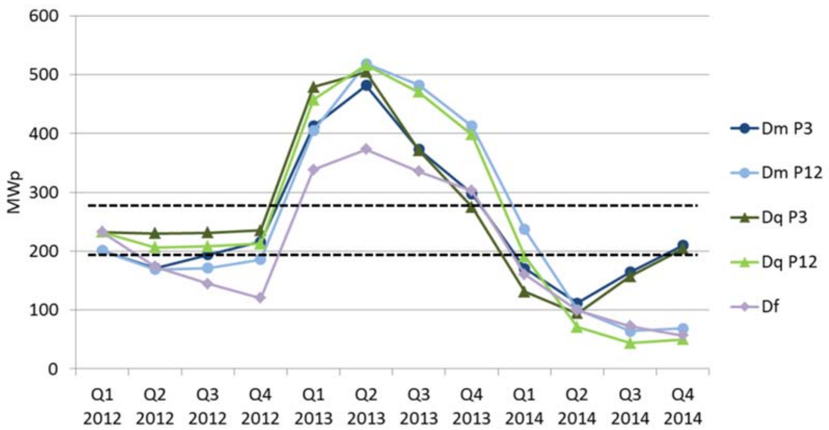
REF scenario:



J1 scenario:



J2 scenario:



Mitchell et al. (2011) define policy effectiveness as “the extent to which intended objectives are met, for instance the actual increase in the amount of RE electricity generated or share of RE in total energy supply within a specified time period”. In the following, the focus is on the effectiveness of the different PV feed-in tariff design options as the extent to which the annual target corridor between 2.5 and 3.5 GW of installations is met.

The growth corridor for systems up to 30 kW, assuming that they continue to constitute 31% of the market (as in 2011), corresponds to a deployment volume between 775 and 1085 MW on a yearly basis, and between 194 to 271 MW on a quarterly basis respectively.

In the reference scenario, both feed-in tariff designs with quarterly degression adjustments lead to quarterly deployment being permanently within the growth corridor. Therefore, the “Dq P12” design continuously results in the basic quarterly degression of 2.97%, similar to the “Dq P3” design which only shows one lower degression of 2.23% in April 2012. Installations for both monthly adjustment designs fall below the target corridor at the beginning of the simulation period, as system prices are fixed for one quarter while feed-in tariffs decrease every month. In response, degressions temporarily decrease to 0.75% per month, until deployment reaches the growth corridor again. While deployment under the fixed tariff scheme continuously decreases and finally stops in 2014, all flexible mechanisms converge within the target corridor.

The abrupt price reduction in January 2013 in the J1 scenario leads to a strong deployment increase for all feed-in tariff design options. Accordingly, degression levels increase within the flexible adjustment schemes, so that from mid 2013 onwards all mechanisms result in decreasing quarterly installations again. The degression schemes with qualifying periods of 3 months are fastest in correcting the excess deployment and converge within the target corridor from 2014 onwards. While the design options with longer qualifying periods reach the growth corridor in Q2 2014, they fall below thereafter.

In the second price jump scenario, quarterly installations for all adjustment mechanisms fall below the target range at the beginning of 2014. The design options with qualifying periods of 3 months are quickest in leading to growing deployment again, and are the only mechanisms to finally reach the growth corridor at the end of the simulation period. Because of their long qualifying periods, the other flexible schemes are relatively slow in responding to quickly changing PV system prices.

5 Conclusion

This paper reviews the experience with the adjustments of the feed-in tariff scheme for solar photovoltaics in Germany. The National Renewable Energy Action Plan of the German government targets the installation of 52 GW of PV power generation capacity in Germany by 2020. The amended Renewable Energy Sources Act (EEG) from June 2012 defines a yearly growth corridor between 2.5 GW and 3.5 GW for new PV installations. However, in both 2010 and 2011 yearly PV deployment was around 7.5 GW.

This shows that setting appropriate levels for feed-in tariffs has been a challenge in recent years, especially as PV system prices decreased faster than expected since 2009. The feed-in tariff for new installations was adjusted thereafter by several short-term political interventions. Despite the differences between these individual adjustments, the market responded in a similar manner in all cases. In periods prior to feed-in tariff reductions the volume of installations always peaked as investors aimed to still qualify for the higher tariff levels. In this regard, larger projects are usually more responsive to changing support schemes. However, as small-scale PV installations up to 30 kW account for a large share of total installations in Germany, and as they have relatively short planning and construction periods, this work focuses on the small-scale roof-top category of the German PV feed-in tariff.

The analytic model developed in this paper is able to simulate the evolution of new PV installations and feed-in tariffs on the basis of observed PV system prices. This simple model is based on only three factors: (i) deployment increases proportionately with project profitability, (ii) profit expectations of investors decreased after the Fukushima nuclear disaster in March 2011, and (iii) in periods preceding feed-in tariff reductions, projects are implemented faster to still qualify for the higher tariffs.

Model results show that demand responds very quickly (as project duration of small-scale PV systems is only six weeks on average) to declining system prices. The larger profitability leads to increasing installation numbers. The demand peaks result from accelerated projects which are completed in the last week before a feed-in tariff reduction. The simulated installations closely match the observed weekly deployment numbers. This suggests that the analytic framework has identified the main factors driving deployment choices. However, in the future or for other project sizes, investors might also respond to other factors changing deployment volumes, like uncertainty of policy development or a mobilizing effect if there are perceptions of a last opportunity to qualify for support.

The model allows to analyze different feed-in tariff adjustment designs in various price scenarios. If a trajectory for PV installations is predetermined, feed-in tariff rates can be aligned with the pace of deployment. The focus of the analysis is on the impact of the degression frequency, adjustment flexibility, and qualifying periods of feed-in tariff adjustment schemes. Thus, the model is used to simulate PV deployment and feed-in tariff levels for five policy design options in four PV system price scenarios. Model results show that responsive adjustment mechanisms of PV feed-in tariffs are suited to stabilize deployment and therefore avoid overfunding, provided that tariff adjustments are appropriately aligned with actual deployment. As forecasts for PV system prices are very uncertain, a rigid degression scheme is fraught with risk. Responsive adjustment schemes with high degression frequencies can avoid strong pull-forward effects in periods preceding tariff reductions. Flexible feed-in tariff designs with qualifying periods of 3 months are fastest in responding to quickly changing PV system prices.

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