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

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Conference “The Economics of Energy Markets”
Toulouse, 18 January 2013

Research question: Are feed-in tariffs compatible with quantity targets? (1/3)

Feed-in tariffs: Implementation in Europe and worldwide

- 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).
- Feed-in tariffs have become increasingly attractive as the guaranteed off-take price facilitates low-cost financing and administrative procedures.

Research question: Are feed-in tariffs compatible with quantity targets? (2/3)

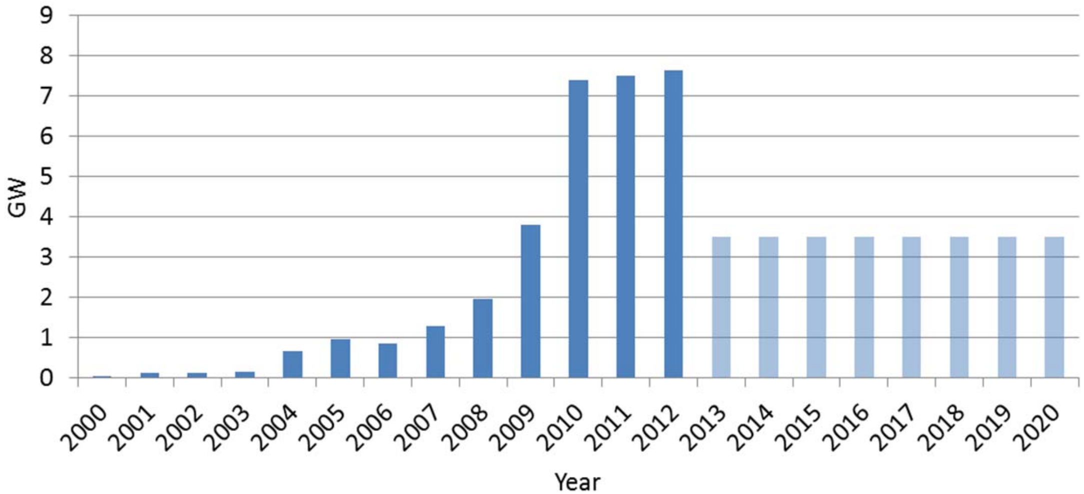
Literature: Feed-in tariffs effectiveness and efficiency

- 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.
- Haas et al. (2011) find 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.

- 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.
- 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.

Research question: Are feed-in tariffs compatible with quantity targets? (3/3)

Annual photovoltaic (PV) installations in Germany 2000-2012, with targets until 2020

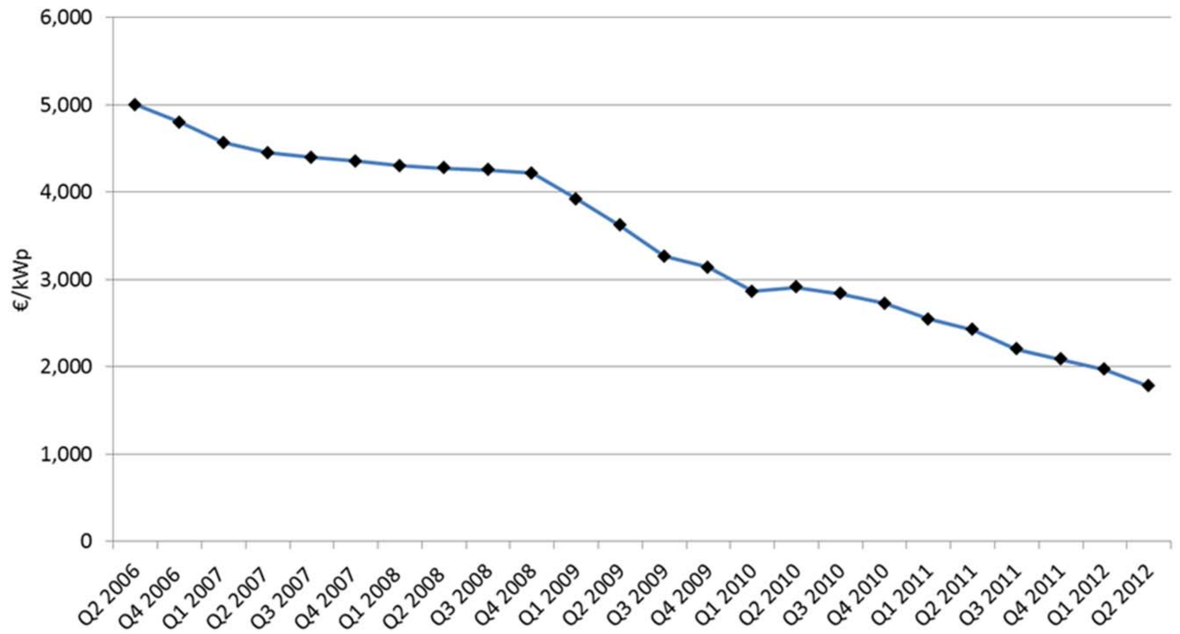


- Germany projects 2.5-3.5 GW annual PV installations, targeting 52 GW cumulative capacity by 2020.
- As PV system prices declined faster than expected since 2009, PV deployment amounted to around 7.5 GW per year between 2010 and 2012.
- Germany accounted for 27% of global cumulative PV installations in 2011.
- This raised concerns about the continued suitability of feed-in tariffs to support PV deployment.
- How to design PV feed-in tariff to achieve deployment targets?

Sources: Data from BMU (2012), German National Renewable Energy Action Plan (2010), EEG (2012), Photon (2013).

PV technology development and feed-in tariff adjustment (1/3)

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



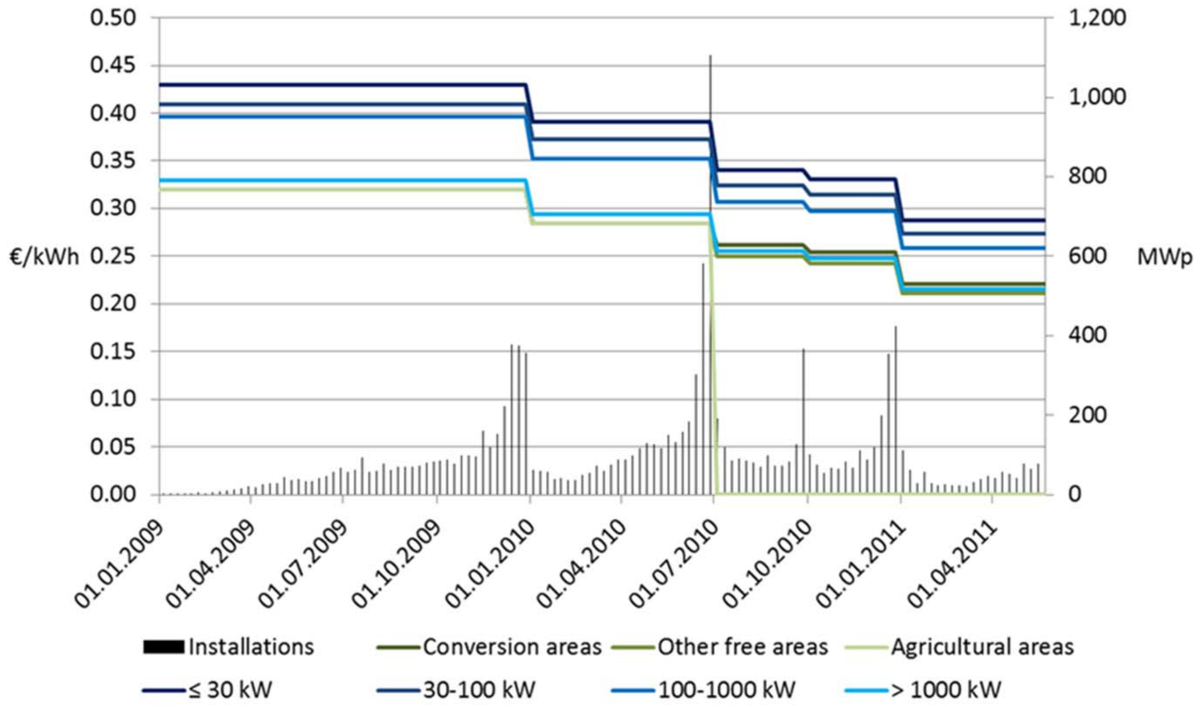
PV system prices decreased by 64% since 2006.

Before 2006, the cost of PV has declined by a factor of nearly 100 since the 1950s (Nemet, 2006).

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

PV technology development and feed-in tariff adjustment (2/3)

Weekly PV installations and feed-in tariff levels in Germany

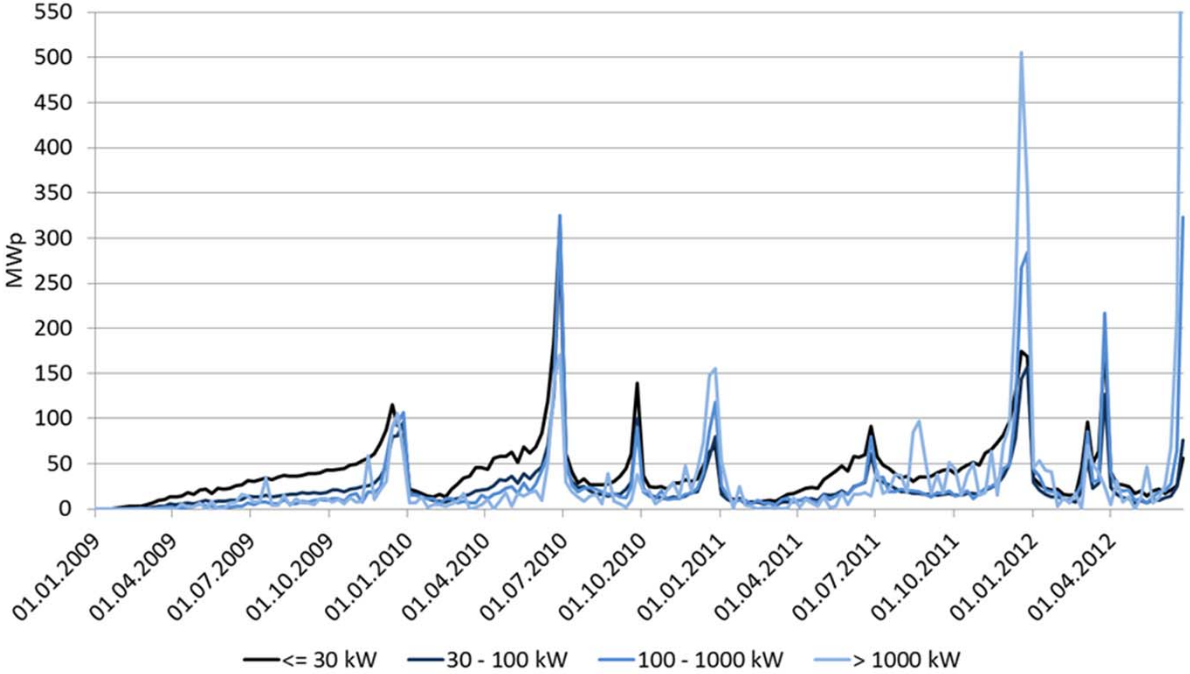


High demand peaks always appear before feed-in tariff reductions.

Source: Installations based on data from the German Federal Network Agency (*Bundesnetzagentur*).

PV technology development and feed-in tariff adjustment (3/3)

Weekly PV installations for different size categories in Germany



Large installations are more responsive to changing support schemes.

Source: Based on data from the German Federal Network Agency (*Bundesnetzagentur*).

Analytic framework (1/2)

Analytic model with three factors impacting deployment

- Deployment increases proportionately with project profitability.
- Profit expectations of investors decreased after the Fukushima nuclear disaster in March 2011.
- 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.

Analytic framework (2/2)

Model framework

(1) Basic model

Installations: $$Y_{t+d} = \alpha * \pi_{t+d} - c$$

Profits of PV projects: $$\pi_{t+d} = v_{t+d} - p_t$$

Present value of the feed-in tariff:

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

(2) Advanced model with peak simulation

Project duration: $$d_t = \max l$$

$$subject\ to\ \pi_{t+l} \geq \pi_{t+d_{ave}}$$

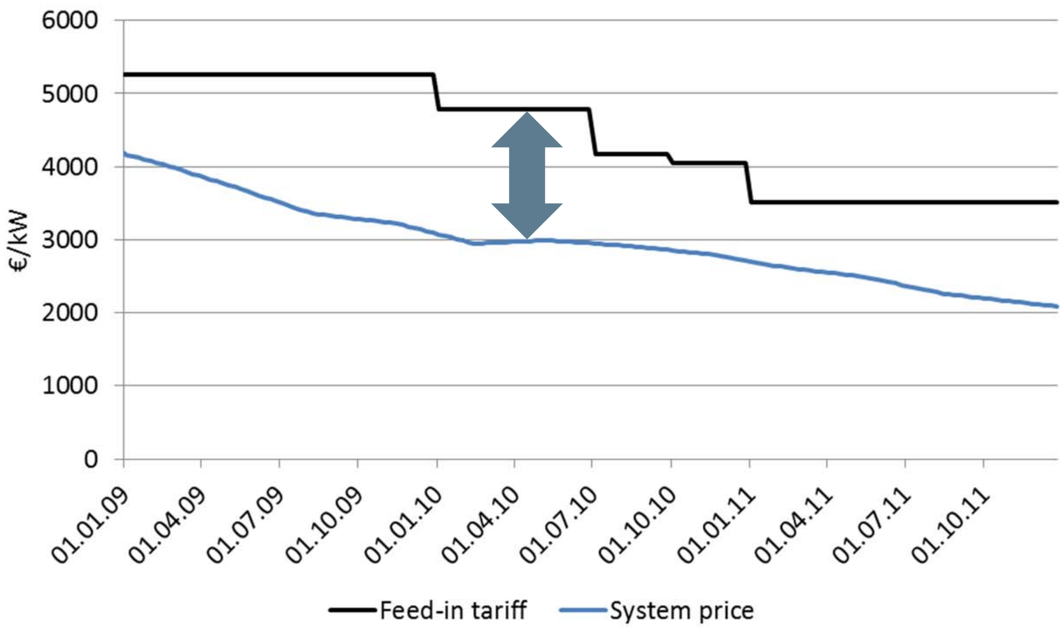
$$d_{min} \leq l \leq d_{ave},$$

Installations:

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

Parameter choices (1/2)

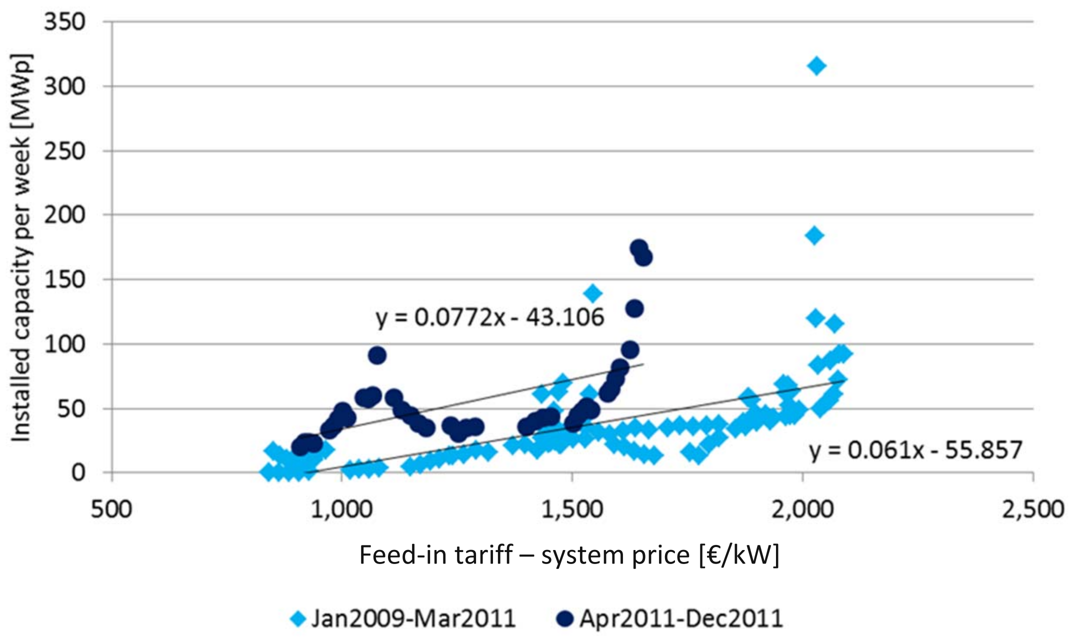
PV feed-in tariff and system prices for solar panels of up to 30 kW



Present value calculations are based on a time period of 20 years, 900 full load hours, and interest rates from Deutsche Bundesbank.

Parameter choices (2/2)

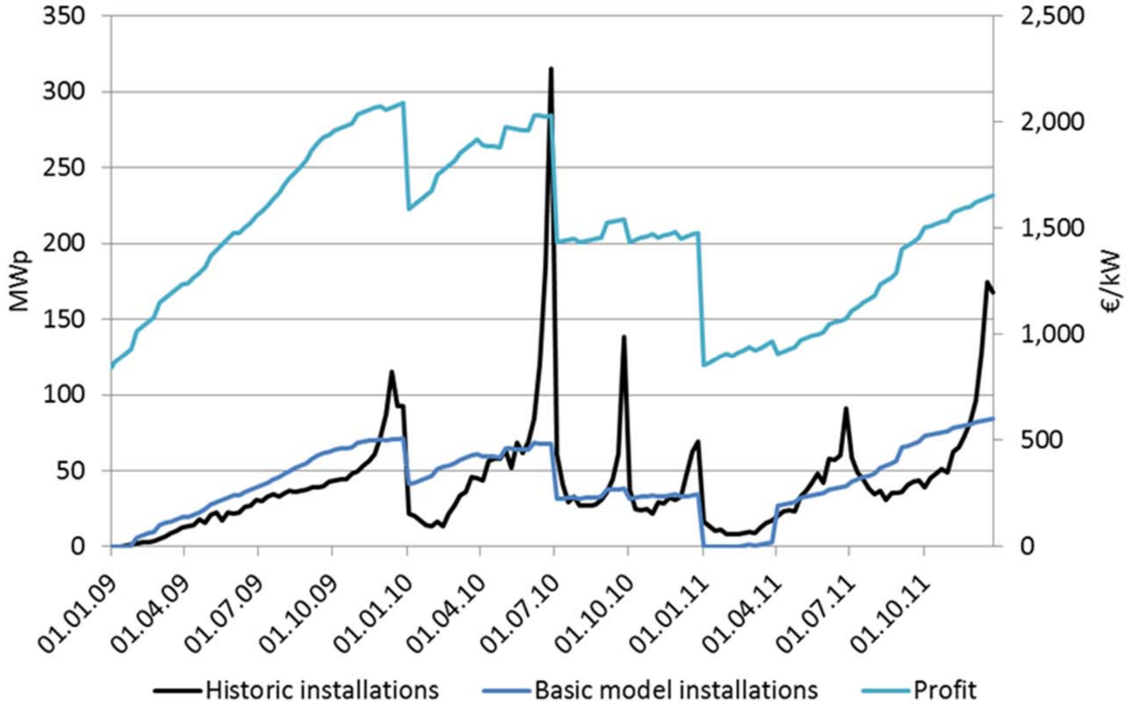
Weekly PV installations and profits for systems up to 30 kW in Germany



- Deployment depends mainly on project profitability.
- Investment behavior changed following the Fukushima disaster.
- Outliers represent “clearance sale” effects.

Model results for the current adjustment mechanism (1/2)

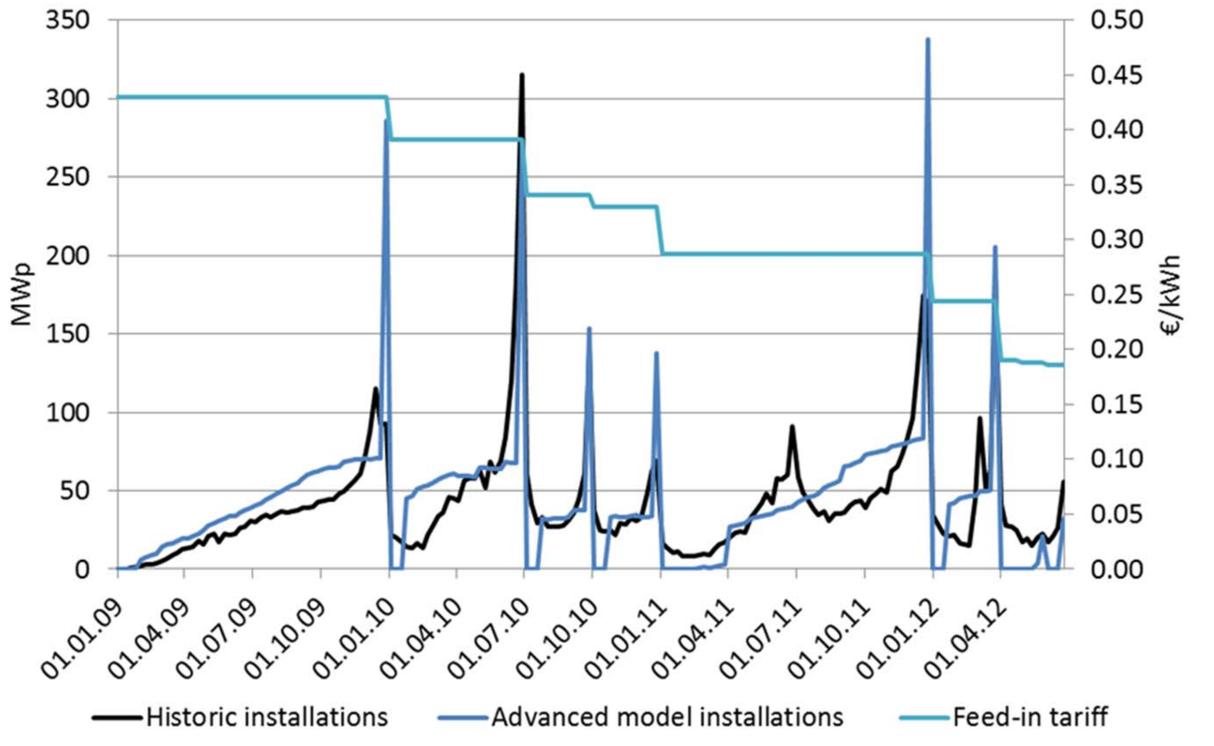
Basic model: Evolution of weekly PV installations for systems up to 30 kW



Installations are modeled based on profitability …

Model results for the current adjustment mechanism (2/2)

Advanced model: Evolution of weekly PV installations for systems up to 30 kW



… and project duration.

Feed-in tariff design is intensely discussed in Germany (1/2)

Current PV feed-in tariff design, introduced in June 2012

- One-off feed-in tariff reduction on 1 April 2012, ranging from 20 to 29 percent for new installations.
- Between May and October 2012, tariff levels are continuously reduced by 1% on a monthly basis.
- From November 2012 onwards, degression levels depend on deployment, are adjusted every three months and implemented on a monthly basis.

Feed-in tariff design is intensely discussed in Germany (2/2)

Alternative PV feed-in tariff design options

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	-

Different price scenarios to analyze the adjustment designs

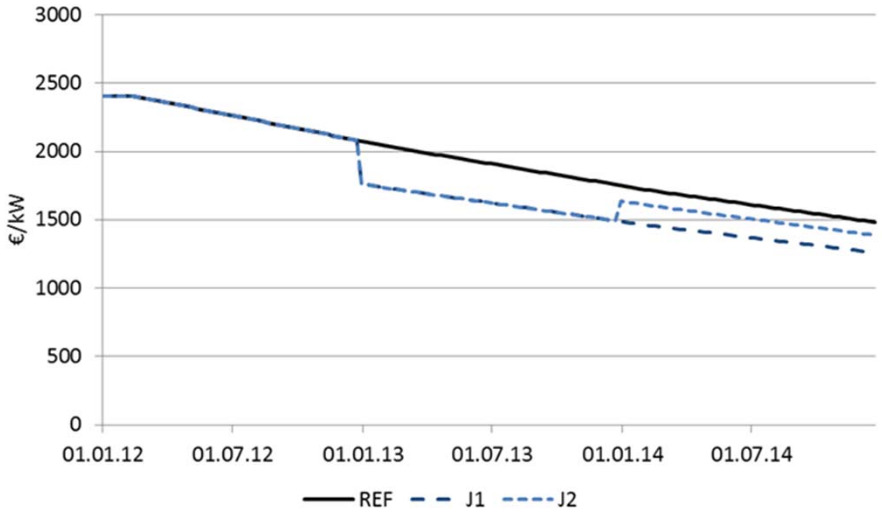
PV system price scenarios for installations up to 30 kWp

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

Reference (REF) scenario: The starting price is calibrated to ensure the adjustment model meets the deployment trajectory in Q1 2012. The price then continuously declines from 19 February 2012 onwards at an annual rate of 16 percent.

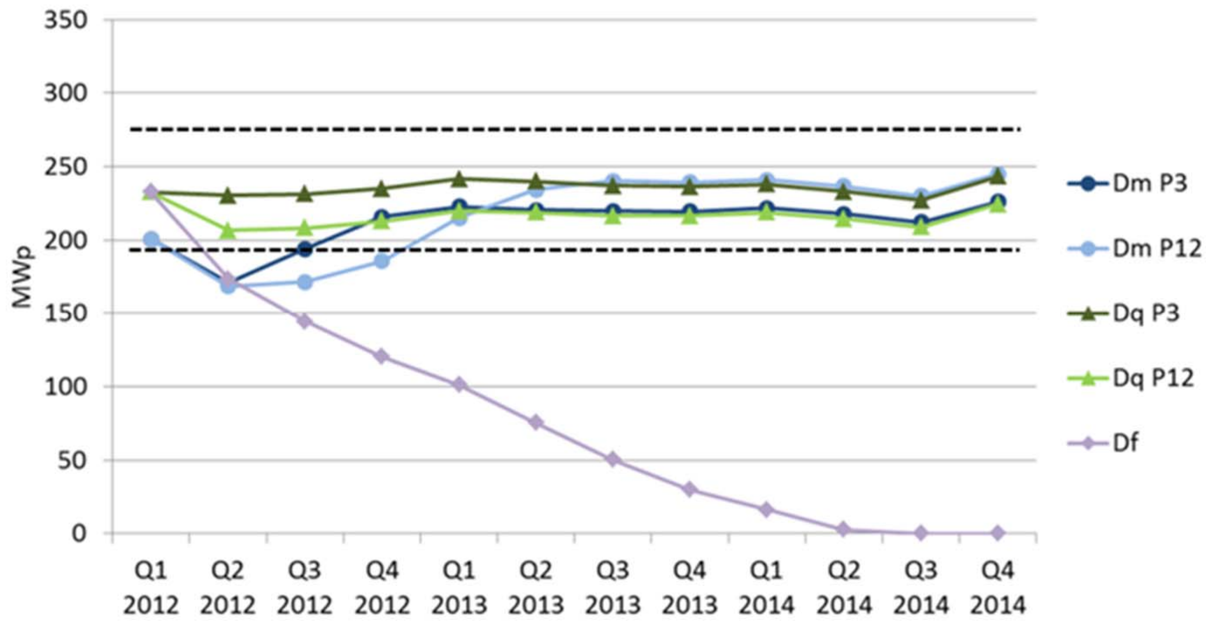
Jump 1 (J1) scenario: The price evolves as in the REF scenario, with a one-off price reduction of 15 percent on 1 January 2013.

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



Model results for alternative design options (1/4)

Quarterly PV installations up to 30 kW for different feed-in tariff designs in REF scenario

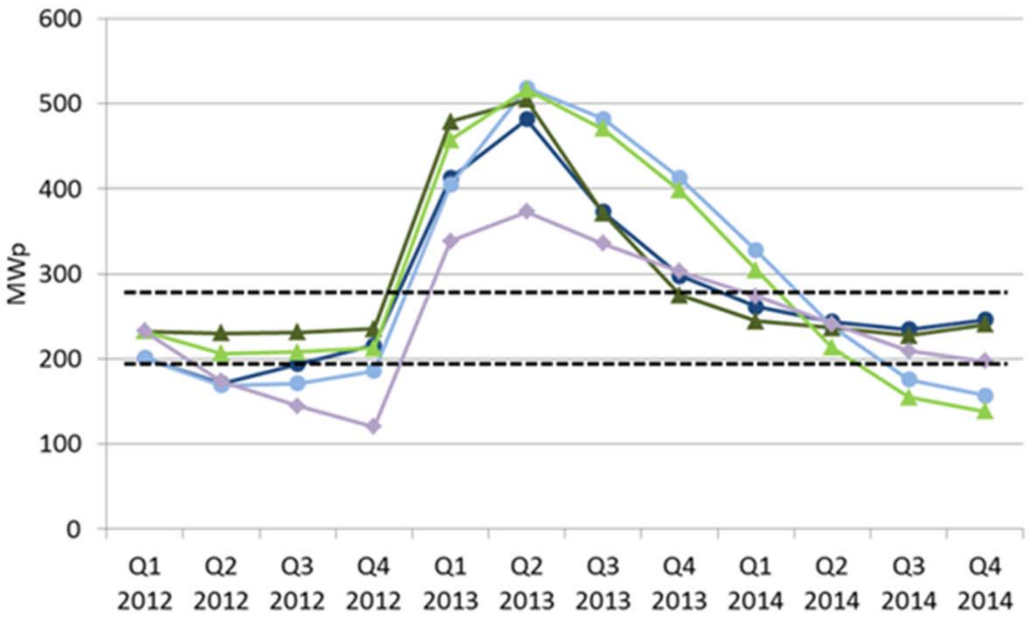


	Degression frequency	Qualifying period
Dm P3	monthly	3 months
Dm P12	monthly	12 months
Dq P3	quarterly	3 months
Dq P12	quarterly	12 months
Df	quarterly	-

- **Deployment effectiveness**: defined as the extent to which the annual **target corridor** between 2.5 and 3.5 GW of installations is met.
- This annual corridor corresponds to a quarterly corridor of 194 to 271 MW for systems up to 30 kW (assuming that their 31% market share in 2011 will stay constant).

Model results for alternative design options (2/4)

Quarterly PV installations up to 30 kW for different feed-in tariff designs in J1 scenario

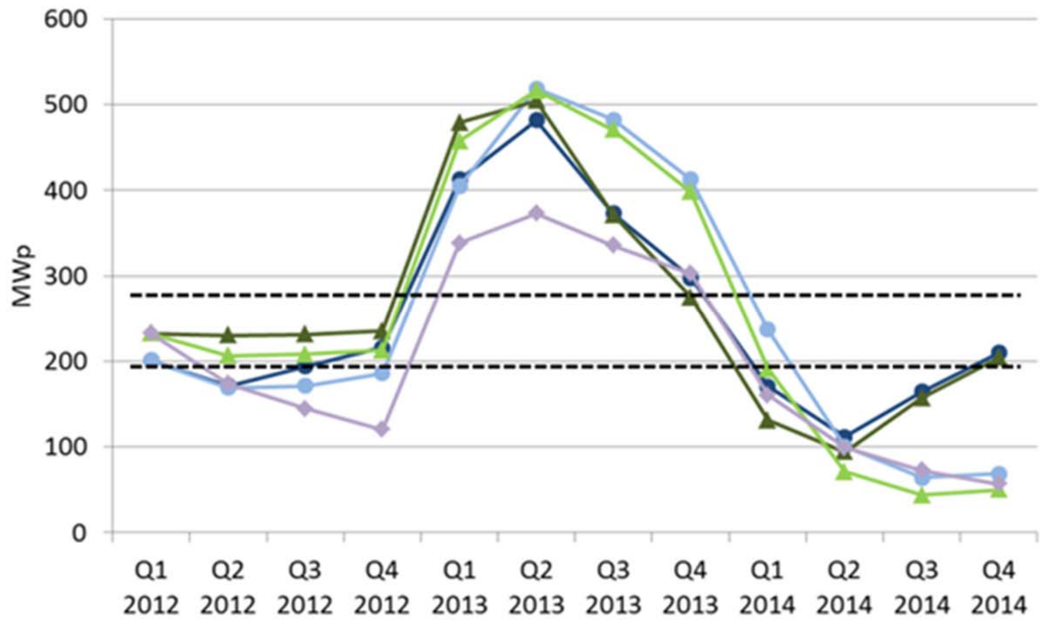


	Degression frequency	Qualifying period
Dm P3	monthly	3 months
Dm P12	monthly	12 months
Dq P3	quarterly	3 months
Dq P12	quarterly	12 months
Df	quarterly	-

The degression schemes with long qualifying periods take relatively long to revert to the target corridor and subsequently undershoot.

Model results for alternative design options (3/4)

Quarterly PV installations up to 30 kW for different feed-in tariff designs in J2 scenario

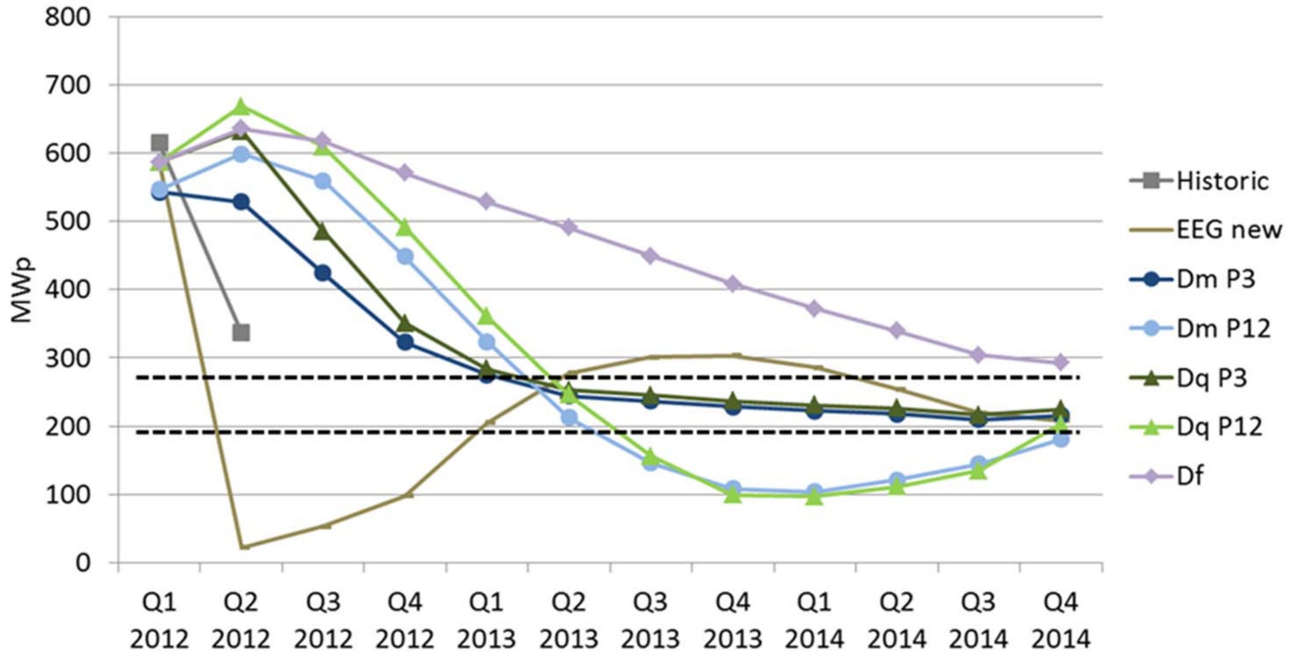


	Degression frequency	Qualifying period
Dm P3	monthly	3 months
Dm P12	monthly	12 months
Dq P3	quarterly	3 months
Dq P12	quarterly	12 months
Df	quarterly	-

The design options with qualifying periods of 3 months are relatively fast in responding to quickly changing PV system prices.

Model results for alternative design options (4/4)

Quarterly PV installations up to 30 kW for different feed-in tariff designs in BAU scenario



For the current feed-in tariff adjustment mechanism, installations converge within the target corridor from Q2 2014 onwards.

Conclusion

- PV deployment has been highly responsive to changing support schemes and rapidly declining system prices in Germany.
- This paper develops an analytic framework to simulate PV feed-in tariffs and weekly installations based on project profitability and duration.
- The analytic model allows to compare different feed-in tariff adjustment designs, and to test for appropriate parameter choices under various price scenarios.

- Model results show that specific responsive adjustment mechanisms are suited to stabilize deployment and to avoid strong pull-forward effects.
- Flexible design options with qualifying periods of 3 months are relatively fast in responding to quickly changing PV system prices.
- Feed-in tariffs are compatible with quantity targets for small-scale PV systems.

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