



# Disentangle the price dispersion of residential solar photovoltaic systems: Evidence from Germany

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## ARTICLE INFO

### JEL classification:

C31  
D40  
D47  
C55  
C81  
D52

### Keywords:

Residential solar PV  
Price dispersion  
Hedonic model  
Quantile regression  
Quote data

## ABSTRACT

Although Germany has the largest capacity of installed residential photovoltaic (PV) systems in Europe, comprehensive evidence on transparent pricing information remains missing. This study disentangles why PV quote prices are subject to significant dispersion and analyzes which factors influence particularly low- and high-priced systems in Germany. We create a comprehensive cross-sectional dataset of 19 561 PV system quotes from 2011 to 2022 and use regression analyses to investigate the effects of system characteristics, installation scope, and location-related parameters on quoted prices. Our results reveal highly volatile annual price dispersion consistent over 11 years and large price differences despite similar system characteristics. Applying hedonic regression techniques, we reveal spatially fine-resolved price heterogeneity with up to 20% difference in the German PV market. System characteristics such as battery usage, installation scope, and system capacity have the most significant effect sizes and are instead control variables. More insightful, the installer density shows price-lowering effects, whereas more PV installations per region, higher solar radiation, and higher labor wages cause price-increasing effects. Quantile regression results reveal that installer density promotes the price reduction of high-priced systems more. Scaffolding, AC installation, and elevation are significant price-increasing factors but with small effect sizes. Finally, DC optimizers affect the levels of high-priced systems more than low-priced ones.

## 1. Introduction

The expansion of residential rooftop photovoltaic (PV) systems represents an important pillar for achieving internationally defined climate targets. With 58.4 GW, Germany has the largest installed PV system capacity in Europe (Federal Statistical Office, 2022). The available potential for this technology is estimated to be about 208 GW for municipalities in Germany (Mainzer et al., 2014). The German Federal Grid Agency presented corresponding scenario frameworks for expanding renewable energy sources, which are a guideline for the German grid expansion in the upcoming years. Regarding PV systems, this calls for an additional 17.9 GW each year (Federal Grid Agency, 2022).

Rooftop PV's particular advantage is the installation on sealed surfaces, which are not in spatial competition, a common barrier to expanding renewable energies. Furthermore, solar PV is society's most accepted renewable technology (Cousse, 2021), enabling people to participate directly in the energy transition. Rising electricity prices and debate about Germany's dependence on fossil fuels have increased public interest and strengthened various stakeholders' willingness to actively contribute to sustainable energy transformation. Nevertheless,

PV systems are preceded by an economic decision, which represents a common barrier against implementation (Karakaya and Sriwannawit, 2015). A PV system's economic viability depends on the total system cost, feed-in tariff, electricity price, and the electricity yield achieved. In some cases, installing solar PV systems may seem too expensive compared to their economic benefits. Therefore, reducing PV system prices and fostering price transparency are crucial pillars to accelerate the further adoption of rooftop solar systems.

Various studies have examined residential PV prices' dependence on system characteristics, installation scope and location-related factors (Dong and Wiser, 2013; Gillingham et al., 2016; Nemet et al., 2017a,b; O'Shaughnessy et al., 2018). These analyses are mainly based on the *Tracking the Sun (TTS)* report series (Barbose et al., 2021); however, this series is specifically focused on the United States (US), which represents a rapidly growing market that has to date, accumulated an installed capacity of 24.3 GW in the residential sector (Solar Energy Industries Association, 2022). Seel et al. (2014) compared the US PV market using *TTS* data with the German market using price data collected from the market research company *EUPD Research* and found

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<https://doi.org/10.1016/j.eneeco.2023.106649>

Received 14 September 2022; Received in revised form 13 March 2023; Accepted 24 March 2023

Available online 6 April 2023

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