ZEW policy brief

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Solar Installations in Private Homes: Upfront Subsidies Preferable to Feed-In Tariffs

For investors, the decision to install photovoltaic (PV) systems largely depends on whether the investment proves worthwhile. Subsidies play an important role in this context. Currently, the German subsidy programme is based on feed-in tariffs: Property owners are guaranteed a fixed price for 20 years at which the electricity they generate can be sold. This ZEW policy brief studies the German subsidy programme, considering the different effects on homeowners and landlords. Homeowner investors are willing to pay only 67 cents for every euro of total discounted future benefits from electricity production. Despite similar investment costs and feed-in revenues, landlords adopt considerably fewer PV installations systems for tenant electricity (Mieterstrom) due to high administrative costs. For purposes of economic policy, the undervaluation of future benefits from PV investments leads to an important conclusion: Had the investment costs been subsidised in advance, over one third of the subsidies spent in the past could have been saved. If landlords are to invest more, bureaucratic hurdles within the tenant electricity programme need to be removed – which would also result in cost savings. Electric vehicles and heat pumps are key elements of the energy transition and crucial for achieving climate neutrality.

POLICY RECOMMENDATIONS

- For purposes of economic policy, the undervaluation of future benefits from PV investments leads to an important conclusion: Had the investment costs been subsidised in advance, over one third of the subsidies spent in the past could have been saved.
- If landlords are to invest more, bureaucratic hurdles within the tenant electricity programme need to be removed – which would also result in cost savings. (Currently, high administrative costs account for around 22 per cent of investments.)
- Electric vehicles and heat pumps are key elements of the energy transition and crucial for achieving climate neutrality. Future subsidy programmes should therefore draw on the insights provided by this policy brief to ensure that they are efficient and successful.

DESIGN OF RENEWABLE ENERGY SUBSIDIES MATTERS

German feed-in tariff programme as a global forerunner

Subsidies for new, low-carbon energy technologies are a widely used policy approach to bolster decarbonisation – motivated by incomplete carbon pricing and positive externalities in knowledge creation and diffusion. The German subsidy program is one of the largest renewable energy policies globally; it is widely regarded as a forerunner in establishing and popularising subsidies to promote the uptake of solar energy. Introduced in 2002, the German model has inspired more than 50 countries worldwide to implement similar policy support schemes for renewable energy.

Undervaluation of future benefits discourages investment

The German programme defines a fixed subsidy for electricity generation – the feed-in tariff – that guarantees the PV system owners a price for 20 years at which they can sell the electricity generated. Empirical and theoretical studies suggest that the undervaluation of future benefits from investments in new energy technologies can significantly hinder their adoption. Moreover, it can undermine the effectiveness of policies, particularly if subsidies target future consumption or output rather than upfront investment costs – as is the case with the German subsidy scheme.

Different investment incentives for landlords and homeowners

The adoption decision hinges on a fundamental trade-off between the immediate investment costs and the future benefits from electricity generation. Whether an investment in the new technology is considered financially attractive depends on how much households and investors discount future benefits and on the extent to which subsidies are applied to upfront investment costs versus future electricity generation. Moreover, economic incentives to adopt differ between homeowner and landlord investors. This is important because the self-consumption of the generated electricity accounts for about half of the revenues earned from a PV system. Self-consumption is more profitable than feeding electricity into the grid, since the feed-in tariff has consistently been several orders of magnitude lower than the retail electricity price for consumers. Consequently, investment incentives differ significantly between different types of investors.

Adoption of tenant electricity programme hindered by high administrative burdens

To address this disparity, the German government introduced the tenant electricity model, which allows landlords to sell PV-generated electricity directly to their tenants, thereby capturing the financial benefits of self-consumption. The federal government subsidises such contracts in addition to the regular feed-in tariff, but the high administrative burdens associated with these contracts have impeded widespread adoption of the model. Understanding landlords' investment incentives and evaluating the effectiveness of tenant electricity regulations are therefore essential to gain a comprehensive perspective on PV adoption in Germany.

The policy brief in a nutshell

In this policy brief, we provide novel empirical evidence on how much homeowner and landlord investors discount future benefits from PV investments. We evaluate the cost-effectiveness of the German subsidy programme, one of the world's largest renewable energy support programmes, presenting a retrospective assessment of the German feed-in tariff programme. We also quantify the budgetary savings the German government could have realised with an improved policy design.

GENEROUS GERMAN SUBSIDY PROGRAMME

Costs and benefits of a PV system over time

To illustrate the financial assessment on which a PV-system purchase decision is based, Figure 1 compares the costs and benefits for 6kW partial feed-in systems over time. While the upfront investment cost is incurred at the time of purchase, the benefits of a PV system are realised over its lifetime through the generation of electricity. Electricity savings are calculated based on an average of historical retail electricity prices. The lifetime of PV systems is estimated at 20 years. To convert future benefits in present value, we use a real interest rate of 3 per cent. Benefits outweigh the cost throughout the sample. In 2012, most of the benefits were due to feed-in subsidies. This changed during the following decade although own consumption only accounted for 22 per cent of the electricity generated with 6kW PV systems. Profitability was almost at zero before the

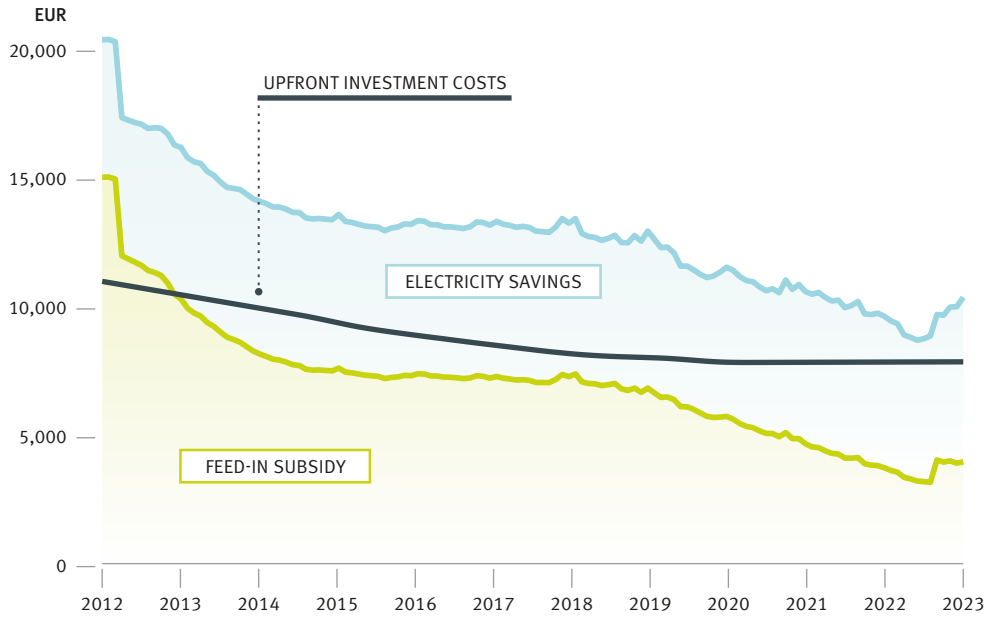
new government increased the feed-in tariffs. Moreover, the higher electricity prices due to the war in Ukraine have led to an increase in the net present value of future benefits from own electricity generation.

Overall, the combined revenues from the feed-in tariff and electricity savings indicate that the investment case for the adoption of PV systems in Germany was strong between 2012 and 2021 (when discounted at a market interest rate).

Partial feed-in tariffs are preferred

Given the considerable benefits derived from electricity savings, it is not surprising that private households mostly install partial feed-in systems (and prefer them to full feed-in systems). Figure 2 provides empirical evidence of a strong preference for partial feed-in systems. It also shows that there was a huge spike in adoptions in 2012. Bearing in mind that feed-in subsidies dropped significantly, this is an indication of the dynamic nature of investment decisions by households. Private households decided to invest before rather than after the drop in subsidies, thus shifting a major proportion of investments to just before subsidies dropped. Figure 2 also illustrates that full feed-in PV systems are extremely unpopular among households: They are largely unprofitable, even when discounted at the market interest rate.

FIGURE 1: PRESENT VALUE OF BENEFITS AND COSTS OF A 6KW PV SYSTEM

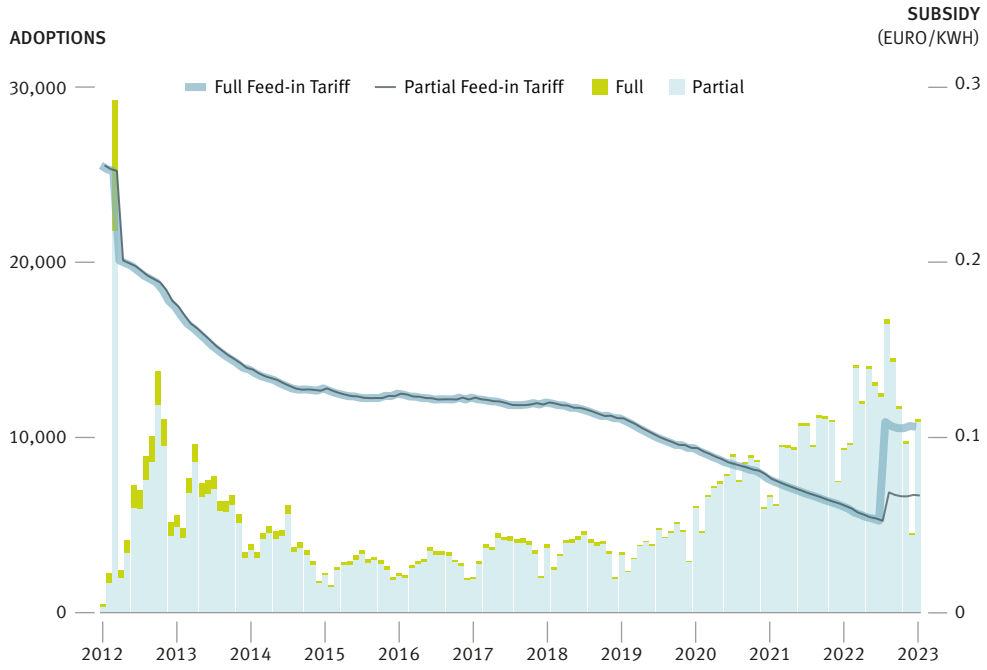


ASSESSING THE EFFECTIVENESS OF THE GERMAN PV SUBSIDIES

Method and data

Our assessment is supported by an econometric model of new technology adoption that describes the investment decision and the investment time. The model is estimated using data on PV adoption between 2012 and 2021 from the Core Energy Market Data Register (Marktstammdatenregister) as well as data on PV investment costs, electricity prices and feed-in tariffs. From this model we obtain estimates on the discount factor that values future benefits from electricity generation relative to today.

FIGURE 2: PV ADOPTION NUMBERS AND FEED-IN RATES OVER TIME



We find that homeowner investors, or households, significantly undervalue future benefits from PV investments. The implicit interest rate is 8.7 per cent (with a standard error of 2.4 per cent) and thus several orders of magnitudes higher than comparable market interest rates during the sample period 2012–2021. For example, the risk-free interest rate ranged between 0 per cent and 1 per cent, while medium-risk investments yielded around 2 per cent of interest. In addition, the government-owned German development bank KfW provided favourable loans for environmentally friendly investments, which further reduced the effective borrowing costs compared to market conditions. Despite these financing options, private households appear to require a significant return premium to make investments into new PV technologies. Put in different terms, the implicit interest rate of 8.7 per cent means that homeowner investors are willing to pay only 67 cents for every euro of total discounted future benefits from electricity generation.

Considerable undervaluation of future benefits from PV investments

In comparison, landlord investors are willing to pay only 51 cents for each euro of total discounted future benefits. Landlords therefore appear to require a significantly higher return premium to adopt new PV technologies than what is required by homeowner investors. We argue that this may largely be attributed to administrative costs associated with the regulation of tenant electricity.

Undervaluation by landlord investors even higher

Despite identical investment costs and feed-in revenues, landlords have adopted considerably fewer PV systems for tenant electricity. This strongly suggests the presence of substantial unobserved administrative costs. We find that the implicit administrative costs for landlords account for about 22.5 per cent of the total benefits of a PV system, corresponding to approximately 2,240 euros. Given the low adoption rate of the tenant electricity programme, this result is unsurprising; the administrative costs seem to pose a significant barrier to landlord participation in the scheme. Policymakers took steps to reduce bureaucratic hurdles in 2021 and again in 2023, but it remains unclear how effective these reforms have been in bringing administrative costs down and incentivising adoption.

High administrative costs as drawback for landlords

Subsidising initial investments would have increased number of PV installations and …

… saved around a third of budgetary cost

The fact that (homeowner) investors significantly undervalue future benefits has an important policy implication. The same number of PV installations could have been achieved, at a significantly lower budgetary cost, by replacing the future subsidies, which guarantee an income stream from electricity generation over 20 years, with an equivalent upfront subsidy for PV investment costs (paid as a lump-sum subsidy at the time of installation).

Based on the actual feed-in tariff rates and adoption rates observed, we estimate the actual budgetary cost over our sample period to be 7.5 billion euros. The value of the feed-in subsidies is estimated at 4.8 billion euros by homeowner investors. Therefore, we estimate potential savings of 2.7 (= 7.5–4.8) billion euros (or 36 per cent of the amount spent) for the German government. This is the amount that could have been saved while still achieving the same number of PV adoptions.

POLICY CONCLUSIONS

Upfront subsidies are more effective

The considerable undervaluation of future benefits from PV investments has immediate implications for the design of policy support schemes in the future. Governments aiming to accelerate renewable energy adoption should prioritise upfront subsidies over long-term feed-in tariffs and subsidies with payments in the future. This will ensure that funds are utilised more effectively. Our findings align with evidence from other countries regarding similar subsidy programmes.

Leveraging investment potential of landlords by reducing administrative costs

Removing bureaucratic hurdles in the tenant electricity programme is crucial to unlock the investment potential of landlords and to expand solar energy access for tenants. Assuming (hypothetically) that landlords have the same incentives as homeowners, the number of potential PV adopters in Germany could more than double, given that about 52 per cent of households live in rental properties. This, in turn, could reduce the extent of subsidies required even further and increase cost-effectiveness.

Leveraging investment potential of landlords by reducing administrative costs

While many countries have transitioned to auction-based subsidies or other market-driven mechanisms to promote solar energy, the insights gained from a large-scale, multi-annual scheme like Germany's programme are valuable for designing future financial support schemes. This applies, for example, to financial incentives for electric vehicles and heat pumps, which are critical for decarbonisation and the energy transition – not only in Germany but also in other countries.

REFERENCE

Jakob von Ditfurth and Sebastian Rausch (2025). How Cost-Effective Were Subsidies for Solar Energy in Germany? ZEW Discussion Paper 25-018.

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