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Plug-in PV

How Germany Made Solar Accessible to All

March 2026

Renewable Energy Institute

Renewable Energy Institute is a non-profit think tank which was established in August 2011, in the aftermath of the Fukushima Daiichi Nuclear Power Plant accident. It aims to build a safe and secure society based on renewable energy, along with a sustainable energy system and economy that mitigates climate change.

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Key findings

1. **Plug-in PV succeeded because it was clearly distinguished from other PV systems**
   In Germany, plug-in PV was progressively recognized and consolidated as a distinct small-scale generation category (less than 800 W_{AC}). By differentiating these devices from conventional PV systems, regulators reduced legal ambiguity and established simplified rules for installation, connection, and registration. This regulatory clarity laid the foundation for market growth.

2. **Administrative simplification was the main enabler of diffusion**
   Plug-in PV adoption accelerated only after procedures were simplified:
   - No prior notification to the grid operator
   - No complex permitting process
   - Online-only registration
   - Permission to use standard household plugs
   - Permission to self-install

   By treating plug-in PV as a low-risk consumer device, Germany significantly lowered entry barriers for households.

3. **Safety was ensured through technical standards**
   Rather than limiting deployment due to safety concerns, Germany integrated plug-in PV into existing technical frameworks:
   - Mandatory anti-islanding protection and inverter safety requirements
   - Compatibility with RCD and household protection devices
   - Clear output limits

   The 2025 product norm clarified electrical, mechanical, and structural safety requirements and shifted responsibility clearly to manufacturers.

4. **Solar access beyond homeowners**
   The 2024 legal reform classified plug-in PV as a “privileged measure.” Landlords can no longer reject installation without justified reason. This significantly increased availability for tenants and opened the multi-family housing sector, a decisive factor in expanding participation.
   By enabling solar installations on balconies and façades, plug-in PV also broadens the usable solar potential beyond traditional rooftop systems, increasing the scope for distributed household generation nationwide.

5. **The broader impact is societal rather than energetic**
   Although plug-in PV contribution to total electricity generation is limited, its systemic relevance lies in:
   - Enabling participation of renters and apartment dwellers
   - Increasing social acceptance of renewable energy
   - Strengthening energy awareness at household level and increasing energy independence
   - Serving as an entry technology for further PV adoption

   Plug-in PV represents not only a technical device, but a mechanism for broadening participation in the energy transition.

1. Introduction: Small systems with a big impact

The energy transition is often discussed in terms of large scales: gigawatts of renewable capacity, national targets, or large infrastructure projects that cost millions. While these are undoubtedly essential, they do not include everything. A successful energy transition also depends on who can participate in it, and this is where plug-in PV shines.

Until recently, solar power was limited to larger-scale projects, agri-photovoltaics or people who owned a house with a suitable roof. For millions of people living in rented apartments or multi-family buildings, direct participation in solar energy generation was effectively out of reach. Plug-in photovoltaic systems address exactly this gap. Plug-in PV does not replace large rooftop systems or utility-scale solar. Instead, it complements them by enabling broad, low-threshold participation. It allows ordinary households to take part in the energy transition with minimal cost, effort, and administrative burden. For this reason, the importance of plug-in PV lies less in its individual system size and more in its systemic impact: it lowers barriers, increases social acceptance of solar energy, and brings the energy transition into everyday life.

What is plug-in PV?

Plug-in PV refers to very small solar power systems, typically with an inverter output of up to around 600-800 W, designed primarily for self-consumption. A standard system usually consists of:

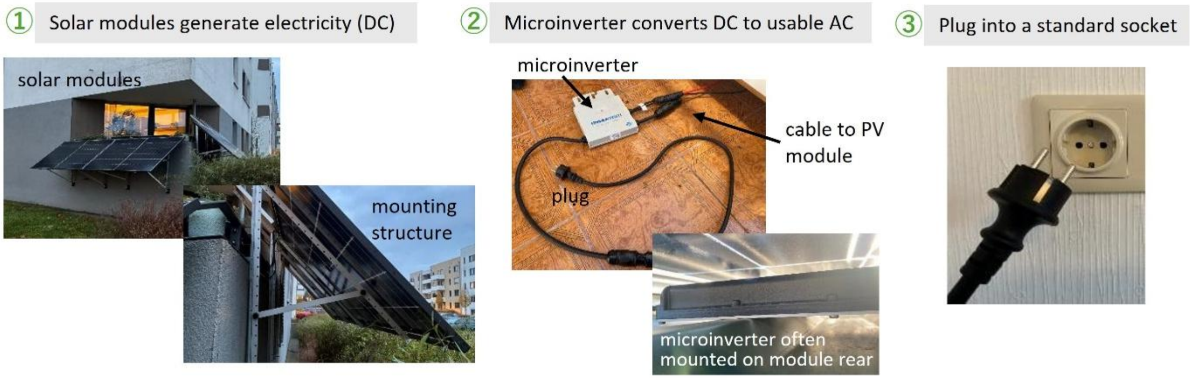
- one to four solar panels
- and a simple mounting system (for example for a balcony railing)
- a microinverter that converts DC to AC electricity and contains safety features
- a cable with a plug

What makes plug-in PV unique is its simplicity. Instead of being permanently wired into a building's electrical system, the system is **connected directly to a household socket**. Once plugged in, the electricity generated by the solar panels is immediately consumed by appliances in the home, reducing electricity drawn from the grid. Because of this simple design, plug-in PV systems:

- do not require major construction work,
- can often be installed by users themselves,
- and can be removed and taken along when moving.

This makes them particularly attractive for tenants and apartment residents, who have traditionally been excluded from rooftop solar installations.

Figure 1: Basic structure and operating principle of plug-in PV



Source: Created by REI. Pictures taken by REI.

Small systems can have a big impact

From a purely technical perspective, plug-in PV systems are small. Even under ideal conditions, a single system covers only a portion of a household's electricity demand. However, focusing only on output misses their broader relevance.

First, plug-in PV enables distributed generation exactly where electricity is consumed. Electricity is produced and used locally, reducing losses and easing pressure on distribution grids in times of high load.

Second, plug-in PV has a behavioral effect. Households that produce even a small amount of their own electricity tend to become more aware of their consumption patterns. This can lead to:

- higher energy literacy,
- shifts in consumption to daytime hours,
- and increased interest in energy efficiency or larger PV systems later on.

Third, plug-in PV plays an important role in democratizing the energy transition. By lowering financial, technical, and administrative barriers, it allows participation across income levels and housing types. In countries like Germany, plug-in PV has therefore been described not primarily as a capacity driver, but as a social innovation: a tool that increases acceptance of renewable energy and citizen engagement.

Furthermore, recent energy crises have highlighted the vulnerability of centralized energy systems and the importance of energy resilience. Rising electricity prices, geopolitical risks, and climate targets have increased interest in solutions that are:

- affordable,
- quickly deployable,
- and scalable without long planning processes.

Plug-in PV fits well into this context. Systems can be purchased off-the-shelf, installed within hours, and begin reducing electricity bills immediately. While the financial savings per household are modest, they are tangible and visible, which further contributes to public acceptance.

Figure 2: Plug-in PV systems installed in Germany on balconies of multi-family houses

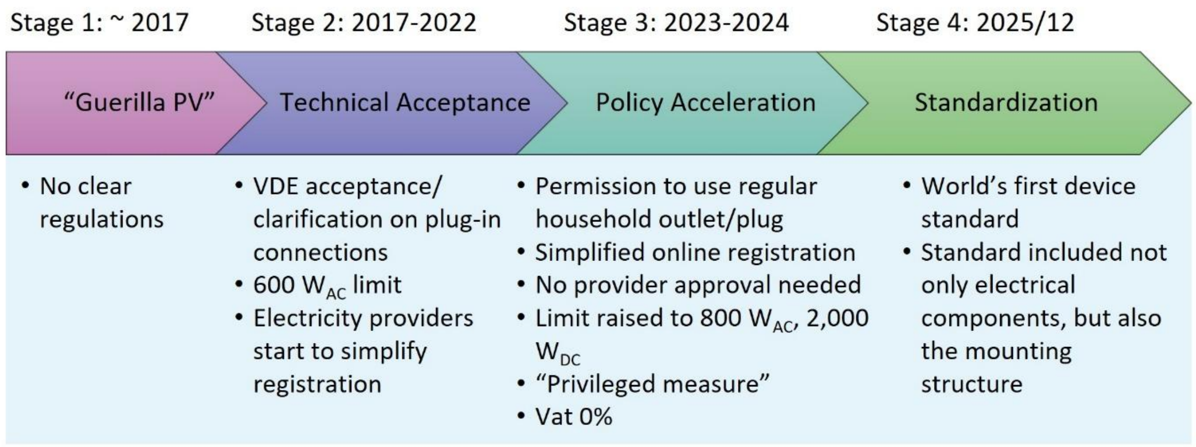
Source: Pictures taken by REI.

2. Regulatory framework and market development

2.1 History of plug-in PV in Germany and current regulatory framework

Germany’s plug-in PV boom is the result of gradual regulatory clarification, targeted policy reforms, and strong market dynamics that together transformed a former “grey-zone technology” into a mainstream consumer product. The regulatory evolution of plug-in PV in Germany can be understood as a gradual four-stage process, as shown in Figure 3.

Figure 3: Regulatory evolution of plug-in PV as a 4-stage process in Germany



Source: Created by REI.

Stage 1: “Guerilla PV” (Until 2017)

Plug-in photovoltaic systems did not begin as a government-supported policy instrument. Rather, they emerged from civil society. Until around 2017, plug-in PV existed in what was commonly described as a “grey zone” and the systems were often called “Guerilla PV[i].” Early adopters installed small balcony PV systems motivated by climate protection, energy autonomy, and technological curiosity. At that time, however, there was no dedicated regulatory category for such devices and the legal framework did not recognize their use via standard household sockets. Nevertheless, demand slowly increased, and public debate around the safety and legitimacy of plug-in PV intensified.

Stage 2: Technical acceptance (2017–2022)

A first turning point occurred in 2017, when the German technical standardization body VDE announced details on its intention to clarify the technical conditions under which small generators could be connected to household circuits. This clarification materialized in 2018 with the publication of two key standards: DIN VDE V 0100-551-1 (2018/05) [1], which addressed the connection of generating units to low-voltage installations, and VDE-AR-N 4105 (2018/11) [ii,2,3], which defined technical requirements for grid connection and anti-islanding protection of generators at the low-voltage level.

Together, these standards created a formal technical framework within which small plug-in PV systems could operate safely. During this phase, systems with a maximum inverter output of 600 W_{AC} became technically acceptable. However, connection via standard household plugs was not yet considered compliant; instead, the use of dedicated feed-in sockets was required.

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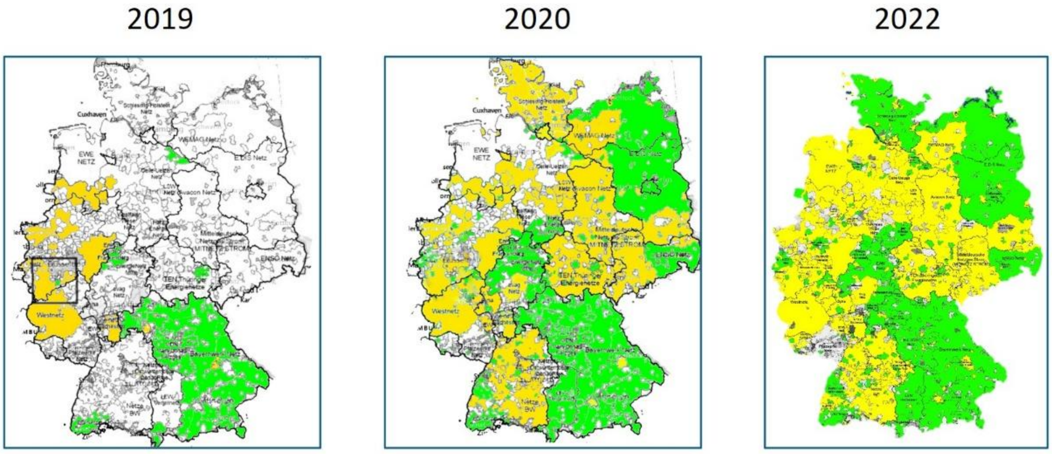
[i] The label reflects the metaphor of “guerilla” action (decentralized, bottom-up resistance) used to characterize early plug-in PV installations as a form of civic opposition to incumbent electricity providers.

[ii] Since then, a new version of VDE-AR-N 4105 has been published in March 2026.

A further practical step followed in July 2018, when the first grid operator[4] introduced a simplified registration procedure for plug-in PV systems. Other operators gradually adopted similar approaches in the following years. As illustrated in Figure 4, while some grid operators introduced their own registration forms, many others cooperated with a civil society platform[iii,5,6,7], which provided a standardized online notification process for plug-in PV systems. This marked the beginning of a gradual shift from purely technical clarification toward administrative facilitation.

Figure 4: Expansion of simplified registration procedures of grid operators 2019-2022. Yellow: grid-operator-specific simplified application forms; green: registration via a civil society online platform[iii].



Source: Created by REI based on graphics provided by the German Association for Plug-in Solar BVSS.[8]

Taken together, both stage 1 and stage 2 illustrate how individual engagement and civil society initiatives played a pivotal role in advancing plug-in PV from below.

Stage 3: Policy acceleration (2023–2024)

The decisive breakthrough occurred in the context of renewable energy reforms adopted between 2022 and 2024. Within a broader reform landscape, plug-in PV received explicit political support within this period and several key changes fundamentally altered the regulatory environment:

- Explicitly permits the usage of a standard household socket and plug
- Increase of inverter output limit from 600 W_{AC} to 800 W_{AC}
- Permission of up to 2,000 W_{DC} module capacity
- Nationwide registration via the Federal Network Agencies' Market Master Data Register (MaStR), using a simplified online form (details in Appendix C)
- No prior approval from or additional registration at the grid operator required
- Temporary use of existing non-bidirectional meters (until replacement with bidirectional meters)
- VAT exemption like other PV systems (0% instead of 19%)
- Increased tenant rights concerning plug-in PV

This reform changed the system fundamentally: Plug-in PV was no longer treated as a cautiously tolerated nice technology, but as a standard consumer energy product.

[iii] The platform refers to MachDeinenStrom.de, an initiative launched in 2018 to facilitate information about plug-in PV systems. The platform was developed in the context of the start-up EmpowerSource and played an important role in promoting standardized, low-threshold registration procedures. Its initiators later became leading figures in the German Plug-in Solar Association (Bundesverband Steckersolar, BVSS), which has since continued advocacy efforts for plug-in PV and small-scale storage.

A particularly significant development concerns tenant rights. From 2024 onward, plug-in PV was classified as a “privileged measure”[iv,9] under civil law. This means that landlords can no longer refuse installation without justified reasons, such as structural risks or monument protection concerns. While practical implementation may still involve negotiation, the legal shift substantially strengthened the position of tenants and residents in multi-family housing. This clarification was crucial for market expansion. Plug-in PV is particularly relevant in urban areas and apartment buildings, where traditional rooftop systems are often not an option for individual households.

Stage 4: Standardization (2025)

The final step in the regulatory maturation process was the introduction of the world’s first dedicated plug-in PV product standard: DIN VDE V 0126-95[10], which entered into force in December 2025. Until then, plug-in systems were regulated through a combination of general inverter standards, grid codes, and electrical installation rules. The new norm consolidated and specified requirements specifically for plug-in PV systems as complete consumer products. It defines electrical safety requirements, mechanical stability criteria (including wind and snow load considerations), touch protection standards for plug connections, and testing procedures for the entire system rather than individual components.

By shifting responsibility for structural and electrical validation more clearly to manufacturers, the standard also increased legal certainty for consumers, landlords, and insurers.

Next stage: plug-in storage solutions

With the rapid growth of plug-in PV, manufacturers increasingly began offering combined systems consisting of plug-in devices combined with storage systems (typically 1–3 kWh). These systems aim to increase self-consumption rates, store excess midday generation, and improve flexibility at household level.

However, the regulatory and technical framework for plug-in batteries remains less clearly defined than for plug-in PV systems themselves:

- The 2025 specific plug-in PV product standard DIN VDE V 0126-95 applies to plug-in PV devices but does not include integrated battery systems.
- In many cases, batteries require additional registration steps beyond the simplified MaStR registration used for plug-in PV.
- Economic benefits are limited compared to the PV system alone, especially at small system sizes.

In recent statements, the German Association for Plug-in Solar BVSS calls for a clearer and more enabling regulatory environment for small batteries systems[11], including simplified registration, better integration into market-based flexibility mechanisms, and the reduction of administrative barriers. In its response to the Federal Network Agency’s MiSpeL[v,12] procedure[13], the association also addresses the market and grid integration of small storage systems and warns against overly complex smart-meter requirements that could hinder decentralized participation.

[iv] In German tenancy and condominium law, a “privileged measure” (privilegierte Maßnahme) refers to certain modernization or energy-related modifications that landlords or condominium associations may not refuse without compelling justification. Examples include the installation of charging infrastructure for electric vehicles, measures improving accessibility (e.g., barrier-free access), burglary protection, and high-speed telecommunications connections. Since 2024, plug-in PV systems have been included in this category.

[v] MiSpeL stands for “Marktintegration von Speichern und Ladepunkten” (Market Integration of Storage and Charging Points). It is a regulatory procedure initiated by the Federal Network Agency BNetzA in 2025 designed to create a market-oriented framework for energy storage systems and charging points under the Renewable Energy Act (EEG). The goal is to enable more flexible participation of batteries and hybrid systems in the electricity market by defining options for how stored and grid electricity are accounted for in market and subsidy contexts.

Recent regulatory developments indicate a shift towards simplification. Updated provisions under the grid connection rule VDE-AR-N 4105[14] published in March 2026 introduce a simplified registration procedure also for small-scale systems combining plug-in PV and storage.

In this sense, the upcoming "battery stage" can also be understood as a continuation of the broader plug-in movement: a shift from enabling simple generation to enabling distributed flexibility in citizens' hands.

Why the 800 W inverter output limit?

In addition to the technical safety perspective (refer to section 4.2) , the maximum inverter output of 800 W (AC) used in the German framework for plug-in PV systems is closely related to European electricity market regulation.

A key reference point is the EU Network Code on Requirements for Grid Connection of Generators (RfG Regulation (EU) 2016/631),[15] which was developed by ENTSO-E (the European Network of Transmission System Operators for Electricity), adopted in 2016, and fully implemented in 2019. The regulation defines technical requirements for grid-connected generators and introduces several categories based on connection voltage and capacity. The smallest category, Type A, applies only to units with a capacity of 800 W or more. As a result, generation devices below 800 W fall outside the scope of the RfG regulation, meaning that no harmonized EU-wide grid-connection requirements exist for such very small generators. This structure effectively creates a practical threshold at around 800 W, below which EU member states can establish simplified national rules for devices such as plug-in PV systems.

Even though such devices fall outside the scope of EU grid-connection regulation, the European Union has expressed support for the deployment of small plug-in solar systems as a way to broaden citizen participation in the energy transition. Directive (EU) 2024/1711[16] on improving the Union's electricity market design calls for reducing administrative and technical barriers for small renewable installations and states in Article 15a(9) that Member States may promote plug-in mini-solar systems of up to 800 W capacity.

Table 1: Summary of current German regulations concerning plug-in PV

System Size	Maximum 800 W_{AC} inverter output and up to 2,000 W_{DC} module capacity[vi]
Connection	Direct connection to a standard household socket (Schuko) is permitted
Installation	Self-installation is allowed
Registration	Only online registration in the Market Master Data Register (MaStR) No prior approval by the grid operator necessary
Metering	Existing meters may be used temporarily; grid operators replace them with bidirectional meters where required
Safety requirements	(Refer to details in section 4)
Tax treatments	VAT reduced to 0%
Legal status in rental housing	Classified as a privileged measure; landlords cannot refuse installation without justified reason
Battery storage	The regulatory framework for integrated batteries is still under consideration, and additional registration or technical requirements may apply.

Source: Created by REI.

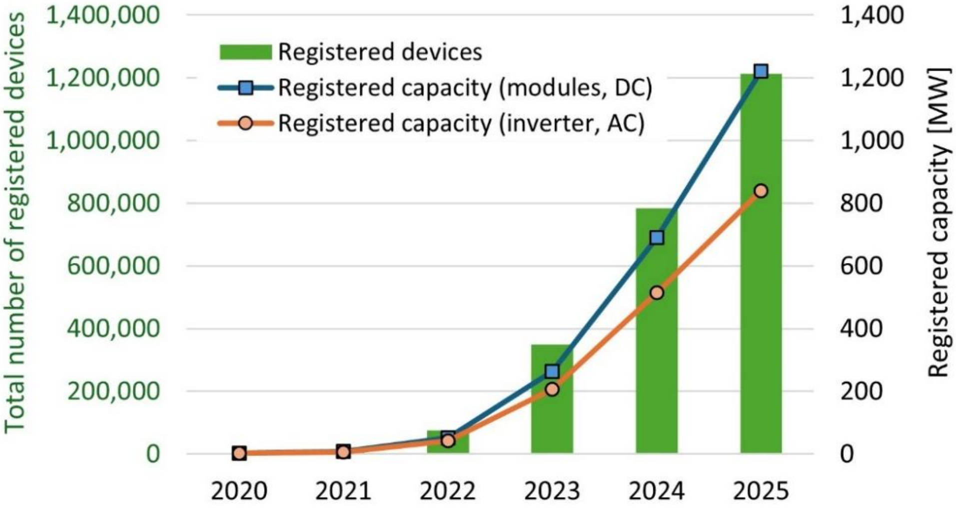
[vi] In March 2026 a new version of the grid-connection standard VDE-AR-N-4105 was released. The revised version of VDE-AR-N 4105 also introduces provisions under which higher-capacity systems (up to 7 kW) may, in principle, be connected via plug-based solutions. However, such systems require formal registration and coordination with the distribution system operator and therefore do not fall under the simplified plug-in PV category discussed in this report.

2.2 Market development of plug-in PV in Germany

Regulatory simplification and market growth reinforced each other: as rules became clearer and more accessible, adoption accelerated.

Figure 5 illustrates the rapid market development of plug-in PV systems in Germany over the past five years. While installations remained marginal until around 2021, the market has since expanded sharply. This reflects a transition from an early niche market to mass adoption, driven by falling equipment costs, rising electricity prices, and the regulatory simplifications mentioned in the previous section. By 2025, the number of registered systems has exceeded 1.2 million units, with cumulative module capacity reaching around 1.2 GW_{DC} and cumulative inverter output capacity more than $0.8GW_{AC}$. The divergence between DC and AC capacity reflects the regulatory framework, under which inverter output is capped at 800 W_{AC} while module capacity may be significantly higher.

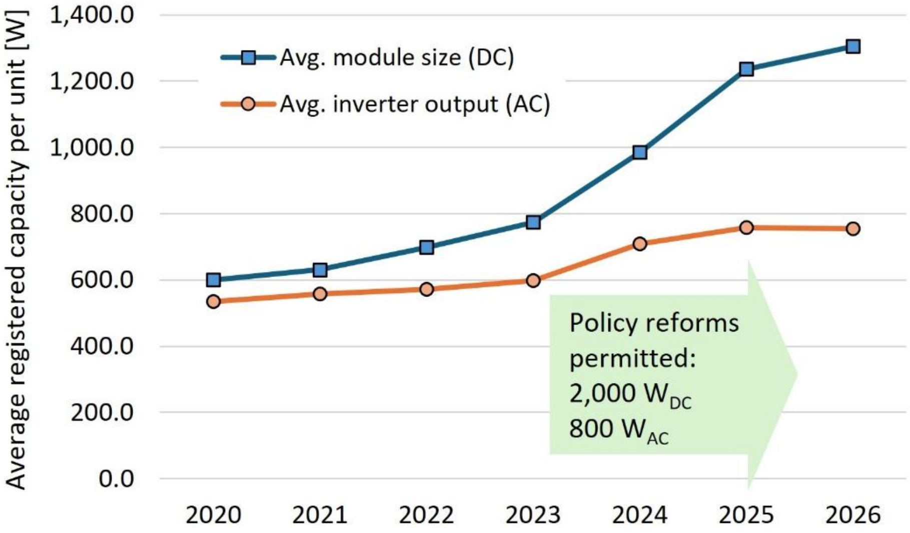
Figure 5: Number of registered plug-in PV devices and their cumulative capacity 2020-2025



Source: Created by REI based on MaStR (accessed 2026/02/09).[17]

Figure 6 shows how these regulatory adjustments directly shaped system configurations. Until 2022, both average module capacity and inverter output per unit increased only gradually, reflecting the former 600 W_{AC} on inverter output and unclear module capacities. A clear structural break appears from 2023 onward, following the reforms introduced under Solar Package I. The maximum inverter output was raised to 800 W_{AC} and the permissible module capacity expanded to up to 2,000 W_{DC}. This change is clearly visible in the sharp increase in average registered DC capacity per unit, accompanied by a more moderate rise in average inverter output toward the new 800 W_{AC} limit. The trend toward larger module capacities reflects user optimization: higher DC capacity improves energy yield under partial shading, suboptimal orientation, and seasonal variation, while the inverter continues to limit peak feed-in.

Figure 6: Average registered DC capacity (modules) and AC output (inverter) for each year

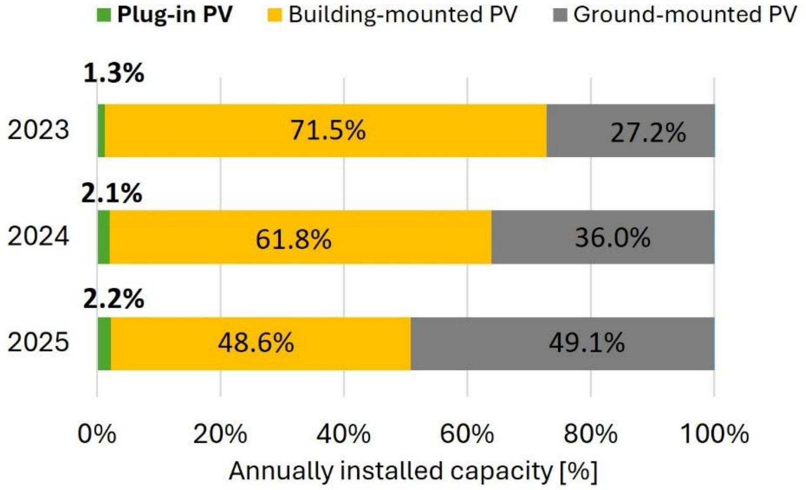


Source: Created by REI based on MaStR (accessed 2026/02/09).[18]

Although plug-in PV represents a relatively small share of total annual PV installations in Germany, its contribution is still remarkable and has increased steadily. As shown in Figure 7, plug-in PV accounted for approximately 2.2% of total newly installed PV capacity (AC) in 2025. When measured in DC terms (module capacity), the corresponding shares are even higher at 1.4% (2023), 2.5% (2024), and 3.1% (2025).

While still modest compared to building-mounted and ground-mounted installations, these figures illustrate the growing structural relevance of plug-in PV within the broader PV market.

Figure 7: Annual PV installation capacity by segment (AC, 2023–2025)



Source: Created by REI based on MaStR (accessed 2026/02/09).[19]

Number of households having plug-in installed and the number of unregistered systems

It should be noted that the figures shown above are based exclusively on officially registered plug-in PV systems. In practice, a non-negligible number of systems are installed without registration, particularly during earlier market phases and periods of regulatory uncertainty. Estimates therefore suggest that the actual number of installed plug-in PV systems in Germany is significantly higher than registration data alone indicate.

The precise number of unregistered systems remains uncertain. A representative study by HTW Berlin conducted in 2022[20] found that more than half of all plug-in PV systems at the time were not registered. More recent surveys[21,22] indicate that around 4–5% of households in Germany had a plug-in PV system installed in 2025. Assuming approximately 41 million households, this corresponds to roughly 1.6–2.0 million systems, or about 30–100% more installations than reflected in official registration data. Other sources report even higher penetration levels[23], suggesting that up to 9% of households may already be equipped with plug-in PV systems. This would correspond to approximately 3.7 million installed systems, or roughly three to four times the number of registered systems.

While these estimates vary, they consistently indicate that the real-world diffusion of plug-in PV is broader and more dynamic than suggested by registration statistics alone.

2.3 Costs and payback time

Plug-in PV systems in Germany are widely available through multiple sales channels. This broad distribution has contributed to price competition and rapid market diffusion.

Systems can typically be purchased through:

- **Specialized plug-in PV companies**, primarily operating via online shops and offering complete certified sets including mounting systems, documentation, and often monitoring software.
- **Traditional hardware stores and home improvement retailers.**
- **Discount supermarket chains**, which periodically offer low-cost plug-in PV sets as promotional products.

Specialized suppliers generally provide more comprehensive documentation, a wider range of mounting options, and in some cases consultation services tailored to individual installation situations. Discount retailers, by contrast, compete primarily on price rather than customization. Despite this limited service, their market entry has played an important role in normalizing plug-in PV as an everyday consumer product. The market structure resembles a hybrid between consumer electronics retail and distributed energy technology, with relatively low entry barriers for buyers.

Typical system costs

A standard 800W plug-in PV set (usually consisting of two crystalline silicon PV modules with combined 800-960 W_{DC} output, $800W_{AC}$ microinverter, cable, and mounting system) currently costs approximately €300–600. Higher prices might exist for:

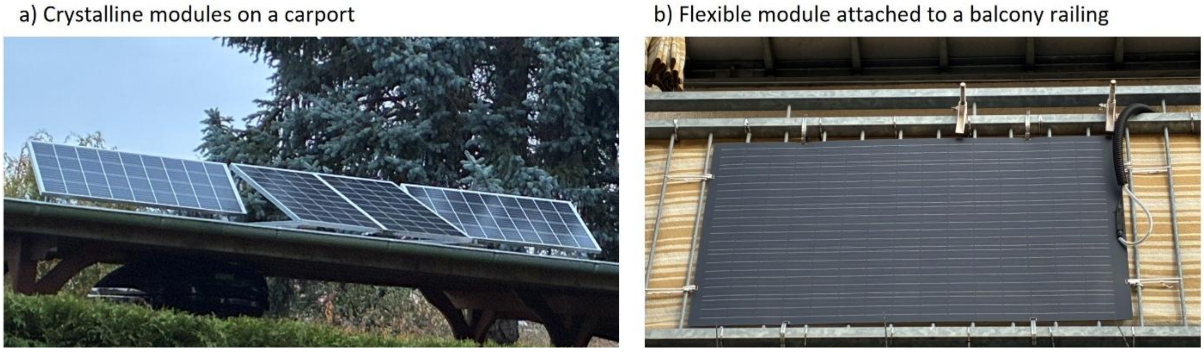
- Flexible modules
- Aesthetic or customized mounting systems
- Integrated monitoring software
- Battery add-ons

Prices have declined significantly since 2022 due to:

- Global module price reductions
- Increased competition
- VAT reduction to 0% for PV equipment (EEG2023)
- Economies of scale

Professional installation is generally not required, although some suppliers offer optional installation services at additional cost. Other optional costs might be photo-checking to confirm safe installation or consultation services.

Figure 8: (a) A standard crystalline PV module and (b) a flexible module (both silicon)



a) Crystalline modules on a carport

b) Flexible module attached to a balcony railing

Source: Pictures taken by REI.

Payback time

The economic viability of plug-in PV depends primarily on:

- Annual generation
- Self-consumption rate
- Electricity price

Higher self-consumption rates, favorable installation orientation, or higher electricity prices shorten the payback time. Conversely, poor installation conditions extend it.

Under normal conditions, 800 $W_{AC/DC}$ systems typically have a:

- Annual generation: approx. 600–900 kWh (depending on orientation and shading)
- Self-consumption rate: often 30–70% in households without battery
- Electricity prices (recent years): approx. €0.30–0.45/kWh

The payback period under above assumptions is generally less than 5 years.

For example, for a €400 system with 800 kWh annual electricity production and a 50% self-consumption rate, annual savings would be €140, assuming an electricity price of €0.35/kWh. That would mean a payback period of less than 3 years. Given that module lifetimes exceed 25 years and microinverters typically last 15–20 years or more, the system generates substantial net savings after amortization.

To support purchasing decisions online simulation tools of payback times exist.[24] These allow households to estimate expected generation, self-consumption rates, and amortization periods based on location, orientation, electricity price, and consumption patterns. Such tools contribute to transparency and informed consumer decisions.

Cost characteristics compared to rooftop PV

Compared to conventional rooftop systems, plug-in PV requires:

- Lower upfront investment
- No or little structural or electrical modification of the building
- Minimal administrative burden

While total generation remains limited by design, plug-in PV allows households to “test” solar energy with relatively low financial risk.

2.4 Merits of plug-in PV

1. Low financial entry barrier

Plug-in PV represents the most affordable form of grid-connected solar generation currently available. The price level fundamentally changes the nature of photovoltaic adoption. While rooftop PV systems usually require investments in the range of thousands of Euros and involve professional installation, plug-in PV is marketed and perceived as a consumer product. The relatively small investment lowers financial risk and enables participation without loans, installer contracts, or complex planning decisions.

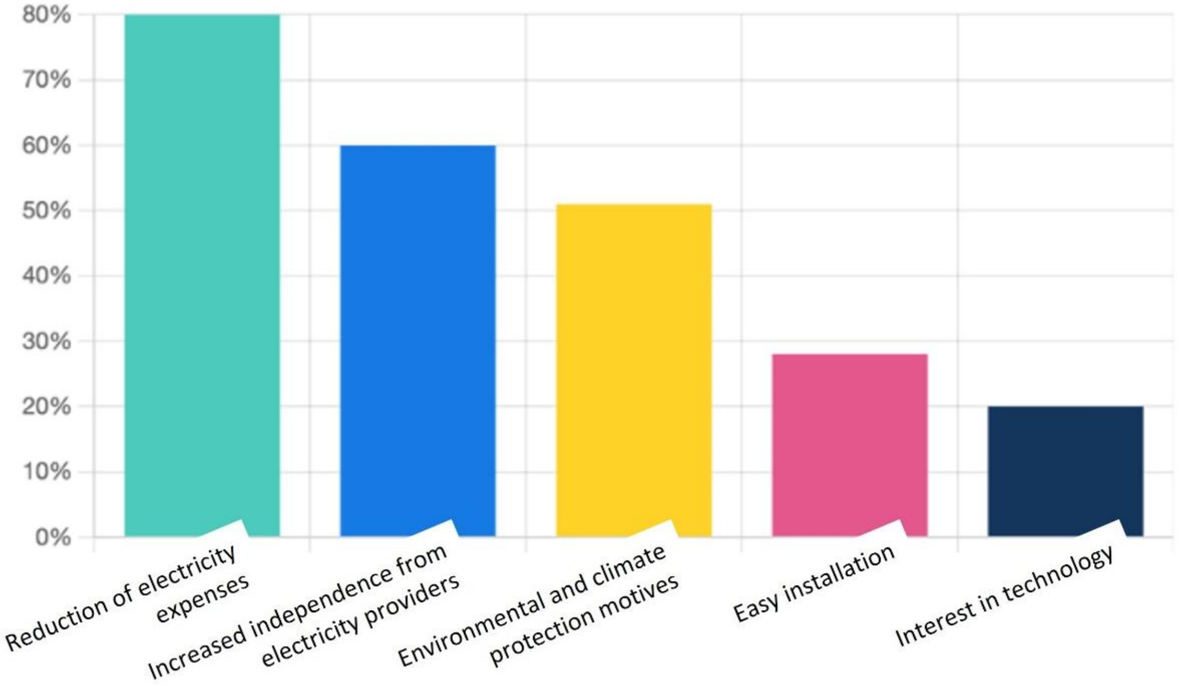
Since 2023, all PV systems, including plug-in PV, have been exempt from VAT in Germany, reducing purchase costs by 19%. In addition, some municipalities offer local subsidies[25]. Although modest in absolute terms, such incentives significantly improve economic attractiveness due to the already low investment threshold.

2. Electricity bill reduction and payback time

Electricity bill reduction is mentioned as the number one reason for installing plug-in PV, as can be seen in the questionnaire results presented in Figure 9. Plug-in PV systems are designed primarily for direct self-consumption. The generated electricity flows directly into the household circuit and reduces electricity purchased from the grid. As outlined in section 2.3, typical payback periods are below five years under average conditions. After amortization, the system generates net savings over its remaining lifetime.

Unlike larger rooftop systems, plug-in PV is not optimized for maximizing feed-in revenue. Its economic logic is based on simplicity: low upfront cost, minimal installation effort, no prior grid approval, and immediate reduction of household electricity expenditure.

Figure 9: Main motivations for purchasing plug-in PV systems (customer survey of a major German plug-in PV provider, 2024)



Source: Translated by REI based on YUMA.[26]

3. Accessibility and portability

One of the most significant merits of plug-in PV is its accessibility. It enables participation by tenants, residents of multi-family buildings, and households without roof ownership. All those are groups traditionally excluded from solar deployment.

Because plug-in systems are not permanently integrated into the building structure, they can be removed and taken along when moving. This portability reduces long-term commitment and investment risk, making the technology particularly attractive for mobile or younger households.

In this sense, plug-in PV lowers not only financial barriers, but also structural barriers to participate in renewable energy generation.

4. Social and behavioral effects

Beyond direct financial savings, plug-in PV has broader societal implications. Observations in Germany indicate that many users develop increased awareness of their electricity consumption after installing a system. In some cases, plug-in PV serves as a "gateway technology": households begin with a small balcony system and later invest in larger rooftop installations.

The German Environment Agency emphasizes that the primary significance of plug-in PV lies not in its absolute contribution to national capacity, but in its role in strengthening social acceptance and citizen engagement in the energy transition.[27] By enabling visible and tangible participation, plug-in PV transforms the energy transition from an abstract policy objective into a personal experience.

5. Independence and decentralized generation

The survey results shown in Figure 9 indicate that the primary motivation for purchasing plug-in PV is the reduction of electricity bills. However, "independence" and a desire for greater control over energy supply rank is the next most important motivation.

Plug-in PV produces electricity at the point of consumption, reinforcing the principle of decentralized generation. Although still grid-connected, the system enhances users' perception of autonomy by self-generation, particularly in times of energy price volatility or geopolitical uncertainty.

6. Contribution to digitalization and system awareness

While plug-in PV might not be system-relevant in terms of national generation capacity, it interacts positively with broader energy system developments. In households equipped with traditional Ferraris meters (mechanical rotating disk meters), reverse electricity flow may cause the meter to run backwards. In such cases, the meter must be replaced, typically by a modern digital meter or smart meter, to ensure accurate measurement and regulatory compliance. The responsible grid operator is informed of the installation through registration in the Market Master Data Register (MaStR) and arranges the meter replacement where necessary. This replacement is the responsibility of the grid operator and generally carried out without additional cost to the user.

As a result, plug-in PV installations can accelerate the replacement of outdated metering infrastructure. In this way, small-scale distributed generation contributes indirectly to Germany's broader smart meter rollout, grid digitalization efforts, and demand-side transparency.

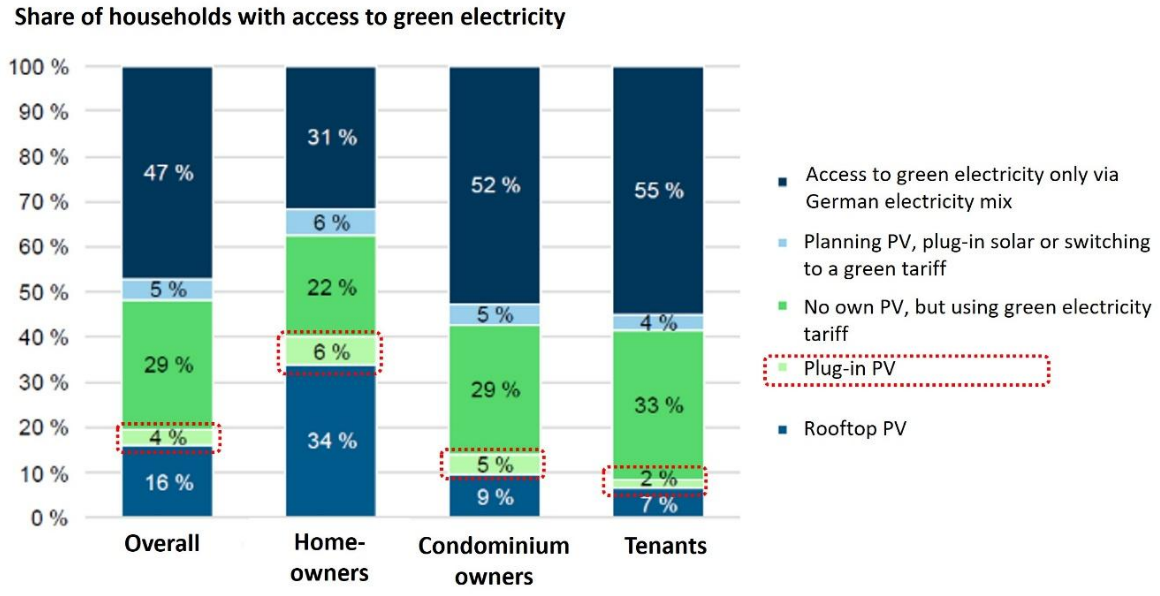
3. Plug-in PV in multi-family housing

A key regulatory development in 2024 was the classification of plug-in PV systems as a "privileged measure" under law.[vii,28,29] This means that landlords may not reject installation requests without justified reason, such as legitimate safety concerns or historic building protection. Sometimes called "the right to plug-in PV", this measure greatly strengthened the ability of apartment dwellers to obtain plug-in PV devices. It is important to note, this classification does not eliminate the requirement to obtain permission. In most cases, tenants and apartment owners must still inform and receive approval from the landlord or homeowners' association.

The regulatory shift reframes the question from "whether" installation is permitted to "under which conditions" it may be carried out. Structural, safety and aesthetic considerations must be reasonable, proportionate, and technically justified. When installed by tenants, plug-in PV systems remain their property and may be removed upon relocation. In such cases, the original condition of the building element (e.g., balcony) must be restored after removal.

Precise statistics for apartment buildings are limited, and it is hard to say how many plug-in PV devices exist in multi-family housings. According to a representative study[30], 2% of tenant households and 5% of condominium owners report owning plug-in PV systems. This is shown in Figure 10. However, as discussed in section 2.2, it is likely that more systems exist.

Figure 10: Share of plug-in PV systems overall, in single-family homes and in multi-family homes



The category "Rooftop PV system" also includes households that additionally use a plug-in solar, a green electricity tariff, or both.
The category "Plug-in PV" also includes households that additionally have a green electricity tariff.

Source: Translated by REI based on a study by KfW.[31]

While technically simple, installation in apartment buildings involves specific challenges, which explains why installation numbers lack behind those of single-family homes:

1. Balcony availability and suitability

- Not all apartments have a suitable balcony (no balcony, north-facing balcony, etc.)
- Shading issues due to surrounding buildings in cities

[vii] According to the German Civil Code BGB §554 and the German Condominium Act WEG §20.

- Wind exposure, particularly on higher floors

2. Electrical access

- Outdoor sockets might not be available, solutions might include:
    - Flat window feed-through cables (this solution is not recommended by official institutions, particularly for windows that are often used)
    - Installation of a dedicated outdoor outlet (increases costs)

3. Housing associations/landlords may require aesthetic conditions to be fulfilled, for example:

- Usage of specific mounting systems or sizes
- Defined tilt angles (e.g., max. 30°)
- Limitations on installation locations

4. Social coordination

- Preventing disputes among residents (e.g., glaring problem)
- Clarifying liability responsibilities

The new plug-in device standard (details in Appendix B), that was released in December 2025, is expected to increase the number of plug-in PV systems in multi-family buildings by reducing uncertainty. It clearly assigns responsibility for mechanical safety, structural verification, and system documentation to manufacturers and reduces the burden of individual tenants to prove system safety.

Figure 11: Plug-in PV in a large apartment building, Germany

Source: Pictures taken by REI.

Plug-in PV projects

For many landlords, housing companies, and condominium associations, plug-in PV is a new and unfamiliar technology. As non-technical actors, they often have concerns regarding structural safety, electrical risks, liability, appearance, and administrative effort. Often, they also do not know how to respond to tenant inquiries.

Some entities initiated pilot projects to reduce this uncertainty and to:

- gain practical experience,
- assess technical feasibility in real buildings,
- clarify safety and integration questions, and
- to increase the attractiveness of their properties.

The following section presents two examples: Möckernkiez in Berlin and a large-scale project in the federal state of Thuringia.

A. Möckernkiez (Berlin)

Möckernkiez[32] is a cooperative housing project located in Berlin. The complex consists of 14 buildings with 471 apartments and around 900 residents. The project follows a self-managed cooperative model, in which residents are members and collectively shape housing decisions.

Plug-in PV systems were introduced on a voluntary basis. Installation was tenant-financed, but subject to coordinated design rules to maintain façade consistency. To avoid visual fragmentation, one standardized mounting solution and one designated provider were used. Approximately 15–20% of households in Möckernkiez installed plug-in PV systems, which is a comparatively high share.

The project demonstrates that plug-in PV can achieve high acceptance in community-oriented housing environments when uncertainty is removed and rules are defined.

Figure 12: Plug-in PV in Möckernkiez, Berlin, Germany

Source: Pictures taken by REI.

B. State-led pilot projects in Thuringia

The federal state of Thuringia initiated a coordinated pilot program in 5 different cities (Sömmerda, Erfurt, Illmenau, Mühlhausen, and Gera) of the state in 2023/2024. The total project funding was €530,00[33] and all five projects shared the following characteristics:

- 80% of total investment costs were covered by the state.
- 20% were financed by the respective housing cooperatives.
- The plug-in PV systems are owned by the housing cooperative, not the tenants.
- Tenants may use the generated electricity free of charge within their apartments.

This arrangement creates a mutual benefit:

- For housing companies: increased attractiveness of the building and innovation profile, gaining information on plug-in PV and its usage.
- For tenants: reduced electricity costs without investment.

Unlike typical tenant-installed plug-in systems, these pilot projects did not use standard Schuko connections. As the systems were not intended to be removed by tenants, fixed electrical connections were installed. For this reason and to install dedicated measurement systems to collect performance data, installations were performed by professionals.

The following will introduce three of those projects in more detail.

Erfurt – Focus on data and performance analysis

The Erfurt project placed particular emphasis on performance monitoring and data evaluation. The primary objective was to generate empirical data and better understand real-world performance in multi-family settings.

One key finding was that electricity yields differed significantly between floors. For example, first-floor and fifth-floor apartments showed output differences of 30–50%, likely due to shading effects, especially during winter months with low solar angles. Additionally, a clear difference in usage rate could be seen between tenants who actively adjusted their electricity usage to accommodate daytime electricity and those who did not.

Figure 13: Plug-in PV pilot project in Erfurt, Germany

Source: Pictures taken by REI.

Sömmerda – Focus on architectural integration

In Sömmerda, plug-in PV was integrated into the building's architectural concept. Semi-transparent modules were installed at a 40° angle, serving not only electricity generation but also as shading elements for the balconies below during summer months. An architect was involved in the design process to ensure visual coherence and functional integration.

This project demonstrates how plug-in PV can be incorporated into passive-energy house designs and façade concepts rather than treated as an add-on technology.

Figure 14: Plug-in PV pilot project in Sömmerda, Germany

Source: Pictures taken by REI.

Gera – High-rise application

The Gera project focused on implementing plug-in PV in a high-rise building[viii]. For such buildings, additional safety requirements apply, including:

- Structural verification,
- Enhanced fire safety standards,
- Restrictions on module mounting angles (often vertical installation only).

As a result, the project involved higher technical and regulatory complexity. The emphasis was on testing feasibility under high-rise conditions and achieving a uniform façade design. The Gera case illustrates that plug-in PV can be implemented even in high-rise buildings, provided that additional safety requirements are addressed.

[viii] Under German building regulations (MBO § 2 (4)), a high-rise building is defined as a building in which at least one occupied floor is located more than 22 meters above ground level.

Figure 15: Plug-in PV pilot project in Gera, Germany

Source: Pictures taken by REI.

4. Ensuring safety and system compatibility

The safety of plug-in devices depends not only on technical standards, but also on proper installation and responsible use. According to the German Environment Agency (UBA)[34] and the German Consumer Advice Center,[35] the following principles should be observed:

- Usage of certified equipment (conformity with applicable VDE standards, CE marking)
- Connection of the system directly to a fixed wall socket without the use extension cords or multi-socket adapters
- Only one plug-in PV device per electricity meter
- Usage of secure mechanical mounting, especially on balconies exposed to strong wind or snow loads
- Proper cable routing without mechanical stress
- Registration of the system via the official online registry (MaStR)

In addition:

- For older buildings or uncertain wiring conditions, consultation with a qualified electrician is recommended, although professional installation is generally not required for compliant systems.
- In multi-family housing, additional considerations include landlord communication and ensuring that modules do not obstruct escape routes or significantly alter building appearance.

Despite the rapid market growth in Germany, **consumer protection agencies**[36] **and insurance providers report**[37,38] **no known cases of property damage or personal injury caused by compliant plug-in PV systems**. Insurers generally treat these small systems as standard household electrical devices that are covered under existing household or liability insurance policies.

Based on real-world experience, plug-in PV systems are therefore considered safe, provided that: certified products are used, installation guidelines are followed, and systems are operated within defined technical limits.

The following looks at the specific safety dimensions in closer detail.

4.1 Protection against electric shock

Because plug-in PV systems are connected via a household socket, protection against electric shock is a central safety requirement. German regulation addresses this through inverter design, plug requirements, and compatibility with household protection devices.

Rapid shutdown and residual voltage limitations

All plug-in PV inverters must comply with safety regulations and include automatic grid monitoring. Most importantly, the inverter shuts down and therefore stops electricity feed-in:

- in case of power outage,
- if voltage or frequency leave the permitted range,
- or after unplugging.

The inverter shutdown must occur within ≤ 0.2 seconds. After unplugging, internal capacitors must discharge so that residual voltage falls below 34 V within 1 second.[ix] This ensures that no hazardous voltage remains at accessible contacts.

Safety measures at the plug

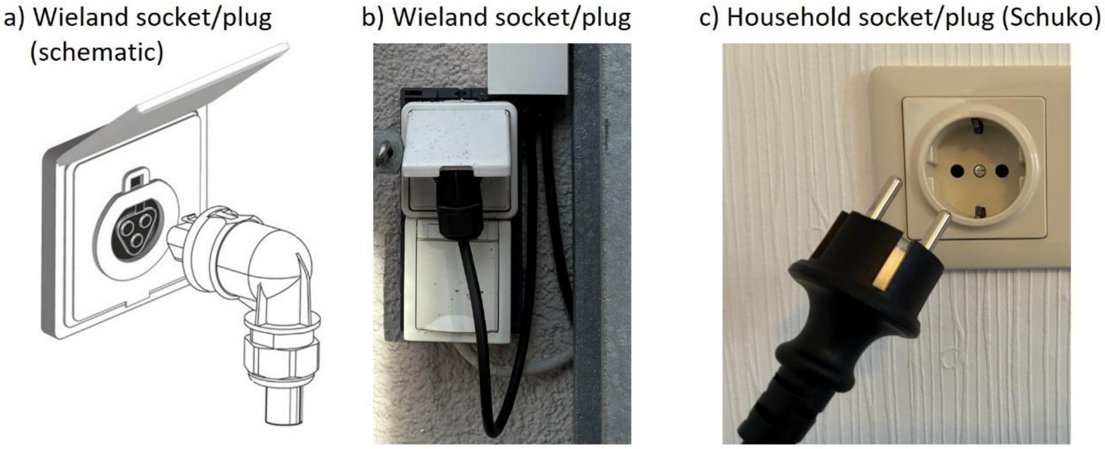
Historically, a special feed-in plug/socket[x] (e.g., Wieland) was required, as shown in Figure 16a-b.

Such plugs:

- have recessed contacts with no touchable metal pins,
- are mechanically secured and cannot be accidentally unplugged,
- are typically installed by a qualified electrician.

Because no energized parts can be touched and the connection is fixed (meaning it cannot be removed accidentally, only by using a screwdriver), the risk of electric shock is technically minimized. However, this solution has disadvantages, mainly because the socket type is not commonly available in households, and installation requires a qualified electrician. That increases costs and reduces accessibility.

Figure 16: Dedicated Wieland socket/plug and regular household Schuko socket/plug


a) Wieland socket/plug (schematic)
b) Wieland socket/plug
c) Household socket/plug (Schuko)

Source: a) Schematic taken from Wieland Electric[39], b) and c) are pictures taken by REI.

[ix] Required through DIN VDE V 0126-95 (plug-in PV device standard) and VDE-AR-N 4105 (an inverter safety norm in low-voltage installations).

[x] Required through the norms DIN VDE V 0100-551-1 (norm for low-voltage installations) and DIN VDE V 0628-1 (norm for electricity generation device connections).

Hence, in practice, most plug-in PV systems are connected via standard Schuko (Type F) household plugs, as shown in Figure 16c. Basic shock safety is ensured through the inverter's shut-down specifications mentioned earlier. As a result, even though Schuko plugs have exposed metal pins, they are not energized under normal unplugged conditions.

As a secondary measure of protection, the 2025 German product standard (see Appendix B for details) further specifies that, when using standard Schuko household plugs, additional touch-protection concepts may be implemented. These include: 1) even faster inverter-shutdown upon unplugging (≤ 0.1 s), and/or 2) dedicated plug designs with movable covers or integrated safety switches.

Thus, modern standard Schuko-based systems achieve a comparable safety level to dedicated feed-in plugs.

Compatibility with household protection devices

German household circuits are typically protected by residual current devices (RCDs, also known as FI switches). An RCD continuously compares the current flowing through the phase conductor (L) and the neutral conductor (N). If a difference occurs, indicating current leakage, the device disconnects the circuit within milliseconds. The functionality of an RCD is independent of the direction of current flow. Therefore, the presence of a plug-in PV system does not prevent correct RCD operation and plug-in PV inverters must be designed so that they do not impair the protective function of standard household RCDs. Manufacturers are required to specify in the documentation which RCD types are compatible with the device.

4.2 Protection of household circuits (circuit overload)

One of the most frequently discussed concerns regarding plug-in PV systems is the potential overloading of existing household wiring. The question arises because the system feeds electricity into a circuit that was originally designed only for consumption.

Theoretical worst-case scenario

In a typical German household:

- socket circuits are protected by a 16 A circuit breaker,
- plug-in PV systems are limited to 800 W_{AC}, corresponding to approx. 3.5 A at 230 V.

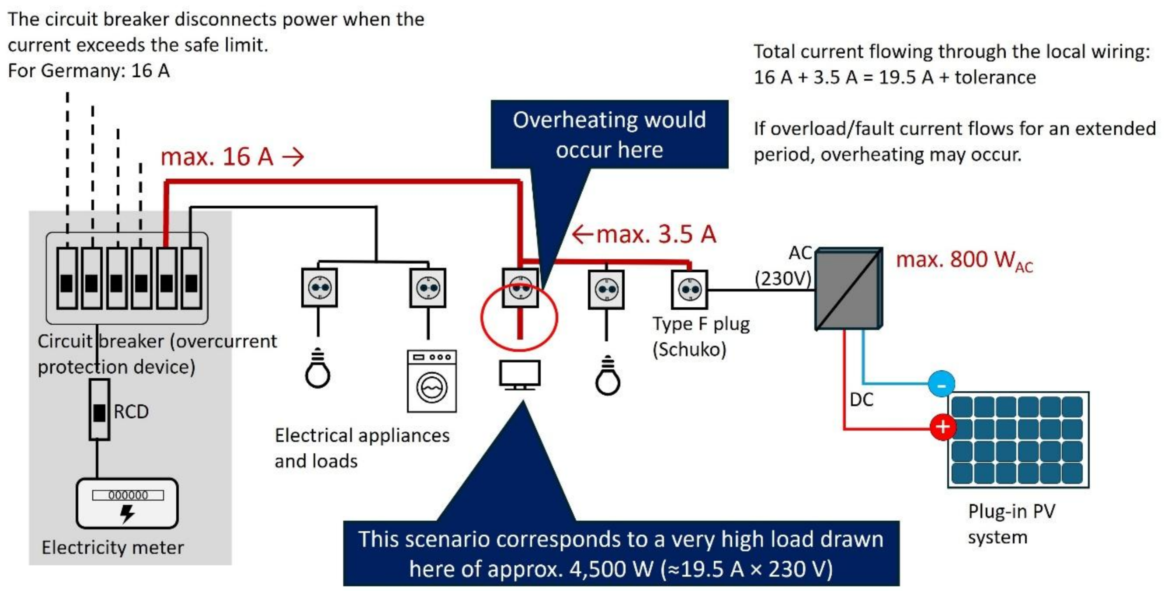
In a purely theoretical scenario, the following could occur:

- A load draws the maximum permitted 16 A from the grid, without the circuit breaker tripping.
- Simultaneously, the plug-in PV system feeds in the maximum 3.5 A behind the breakers.
- The local wiring downstream of the breaker could temporarily carry over 19.5 A.

In such a case, the circuit breaker would not trip immediately, since it measures the current flowing from the distribution board, not the locally added PV current. This current overload could potentially cause overheating in the wires and connections that carry the maximum load.

This theoretical scenario forms the basis of the overload discussion.

Figure 17: Schematic view of a circuit overload scenario



Source: Created by REI.

Practical risk assessment

Several factors significantly reduce the practical relevance of this worst-case assumption:

1. **Output limitation:** The inverter output is limited to 800 W_{AC} (≈3.5 A) and cannot be increased by the user.
2. **Load coincidence:** Simultaneous continuous maximum grid draw and maximum PV feed-in is extremely unlikely. Especially since high-load appliances such as stoves are on separate circuits. If due to some fault a higher electrical load occurs, the breaker would trip. So this worst-case

scenario can only occur when the load is exactly at the maximum threshold and inverter output is also at maximum at the same time, drawing a total load of approximately 4,500 W.

3. **Thermal tolerance of wiring:** Standard wiring in residential installations has short-term thermal tolerance above nominal 16 A without immediate damage. Even if a worst-case scenario as above occurs, it is unlikely to occur for a prolonged period of time.

4. **Empirical testing:** A federally funded research project supported under the German WIPANO programme[40] (2020–2023, funded by the Federal Ministry for Economic Affairs and Climate Action) was conducted, among others, by Fraunhofer ISE, DKE (German Commission for Electrical, Electronic & Information Technologies within DIN and VDE), and the German Solar Energy Society (DGS). It systematically investigated potential overload risks in household circuits caused by plug-in PV systems.[41] The project included:

    1. field measurements in older residential buildings; testing of installations from the 1950s to 1980s (including old aluminum and copper wiring),
    2. controlled laboratory experiments,
    3. and accompanying simulation analyses.

    Worst-case conditions were intentionally created:

    - application of a 25.8 A test current over prolonged periods, exceeding the nominal 16A circuit rating by a large margin,
    - thermally unfavorable cable positioning (including reduced heat dissipation scenarios),
    - and exposure periods of up to 1.5 hours under sustained high load.

    Temperature measurements (including thermal imaging) were performed directly at socket connections. Junction boxes, and within wall cavities.

    Key findings

    - Measured temperature increases remained within acceptable safety margins.
    - No systematic critical overheating was observed, despite sustained 25.8 A test currents.
    - No fire risk attributable to plug-in PV systems was identified, even in aged installations.

Figure 18: Empirical overload testing of aged residential wiring and worst-case conditions

(a) Temperature measurement at socket wiring under sustained 25.8 A test current.
(b) Open junction box and distribution panel of the tested 1950s residential installation.

(c) Laboratory setup, with cables embedded between Styrofoam insulation boards to trap heat under worst-case conditions.

Source: Created by REI, based on the project report published by DKE[42] for (a) and (b); and on PI Photovoltaik-Institut Berlin AG's test report on plug-in PV safety in household installations[43], which were earlier experimental investigations related to and referenced in the project, for (c).

Additionally, installation guidelines recommend:

- only one plug-in PV per circuit,
- direct wall socket connection (no extension cords),
- consultation with an electrician if the installation is uncertain or worries exist.

As a conclusion, it can be said that while a theoretical overload scenario can be constructed mathematically, empirical evidence and technical limitations indicate that:

- the additional current contribution (≈3.5 A) is small relative to standard circuit ratings,
- simultaneous worst-case loading for a prolonged period of time is highly improbable,
- and large-scale field testing has not revealed systematic fire risks.

Under compliant installation and within the defined $800W_{AC}$ limit, the overload risk of household circuits is considered technically unlikely.

4.3 Anti-islanding protection (grid protection)

Plug-in PV systems are grid-connected generation devices. Therefore, they must ensure that electricity is not fed into the grid when the public supply is unavailable or unstable. This requirement is addressed through mandatory anti-islanding protection.

All plug-in PV inverters in Germany must comply with the grid connection standard VDE-AR-N 4105[44] (the German technical rule governing the connection of generation systems to the low-voltage distribution network).

The inverter actively continuously monitors:

- grid voltage,
- grid frequency,
- and grid impedance conditions.

If:

- the public grid fails (power outage),
- voltage or frequency leave the permitted tolerance range,
- or abnormal grid conditions are detected,

the inverter automatically disconnects from the grid within ≤ 0.2 seconds (200 ms).

This prevents so-called “islanding”, meaning unintentional continued energization of a de-energized grid section.

Anti-islanding protection serves three main purposes:

1. **Protection of grid maintenance personnel** During repair or maintenance work, grid sections must be safely de-energized. Automatic inverter shutdown ensures that no plug-in PV system can energize the line.

2. **Grid stability** Small decentralized generators must not operate independently in unstable voltage or frequency conditions.

3. **System integrity** The inverter may only reconnect after stable grid conditions are restored and verified.

From a grid-protection perspective, compliant plug-in PV systems behave like other small grid-connected generators and meet established safety requirements of the German low-voltage network.

4.4 Structural and mechanical safety

In addition to electrical safety, plug-in PV systems must meet structural and mechanical safety requirements. The systems are exposed to wind loads, snow loads, and weathering. Residential balconies in Germany are generally designed in accordance with building codes to withstand defined load requirements (e.g., live loads for occupancy and environmental loads). Under normal structural conditions, the additional weight of plug-in PV modules does not exceed these design limits.

Since December 2025, the world's first plug-in PV product standard[45] requires that:

- the complete mounting system provided in the plug-in PV set is structurally verified by a professional,
- permissible wind and snow loads are specified,
- maximum installation height above ground is defined,
- corrosion resistance and UV resistance are ensured,
- installation instructions clearly state allowed mounting configurations.

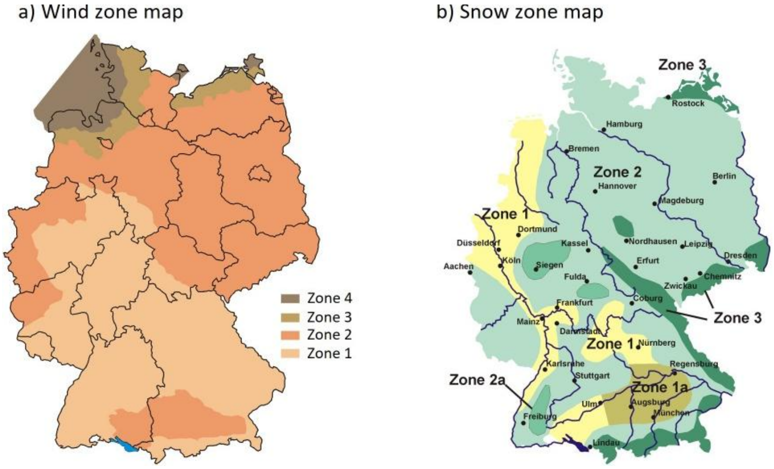
For the first time, structural verification of the mounting system is mandatory under a dedicated plug-in PV product norm. This shifts responsibility from the user to the manufacturer, who must provide technical proof of mechanical safety. Even before the publication of the device norm in December 2025, reputable plug-in PV manufacturers typically provided structural information and load specifications. The new standard now makes such documentation mandatory for all manufacturers.

For users, standard residential buildings generally do not require additional structural calculations when compliant mounting systems are used. However, if specific concerns or uncertainties arise, for example in the case of visibly aged or damaged balconies, professional assessment is advised. Some manufacturers also offer optional remote assessment services (e.g., review of photographs or installation parameters) for a modest fee. While not a substitute for formal structural evaluation where required, such services can provide additional reassurance in cases of uncertainty.

Wind and snow loads

Germany is divided into defined wind load zones and snow load zones under norm-based structural standards.[xi] Manufacturers must specify for which wind and snow load zones their mounting systems are approved and whether installation height limitations apply.

Figure 19: Maps of (a) wind load zones and (b) snow load zones in Germany. Higher zone numbers correspond to higher potential loads.



Source: Compiled by REI and translated, based on images by Störfix, CC BY 2.5, via Wikimedia Commons.[46]

[xi] According to DIN EN 1991-1-4 (wind) and DIN EN 1991-1-3 (snow).

Fire safety

Fire safety is addressed through both general building regulations and specific product requirements.

Key aspects include:

- PV modules must comply with applicable fire classification standards (commonly class B2 for standard PV modules[xii]; higher classes may apply in special buildings).
- Cables must be flame-retardant and suitable for outdoor use.
- Installation must not obstruct escape and rescue routes, which is particularly relevant for apartment balconies.

In practice, compliant plug-in PV systems do not introduce additional ignition sources beyond those typically associated with certified PV installations.

Special case: high-rise buildings

High-rise buildings (in Germany generally defined as buildings with at least one occupied floor above approximately 22 m, according to state building regulations) are subject to enhanced structural and fire safety requirements.

In such cases:

- additional structural calculations may be required,
- stricter fire protection requirements can apply (e.g., higher building material classifications depending on regional building codes, for example usage of class A2 fire classification),
- certain mounting configurations (e.g., tilted modules) may be restricted.

Because high-rise buildings are typically classified as special buildings under building law, installation may require closer coordination with property owners and, in some cases, local authorities. Pilot projects (e.g., in Gera section 3) demonstrated that plug-in PV systems can also be implemented in high-rise buildings. These projects showed technical feasibility, although installation costs were significantly higher compared to standard balcony installations.

[xii] In Germany, building material fire classifications are defined in DIN 4102 and DIN EN 13501-1 (Euroclass system). Class B2 denotes “normally flammable” materials and is common for standard framed PV modules (e.g., glass-foil constructions). Glass-glass modules often achieve improved fire performance and, depending on design and certification, may reach higher classifications such as A2 (“non-combustable”).

5. Concluding summary

Germany’s experience with plug-in PV demonstrates that small-scale distributed generation can be integrated safely and efficiently when regulatory clarity, technical standardization, and administrative simplicity are combined.

By defining clear size limits, permitting standard household plugs, eliminating prior grid approval, enabling tenant participation, and introducing a dedicated product standard, Germany transformed plug-in PV from a legal grey zone into an institutionalized and consumer-accessible technology.

The model highlights the importance of:

- Clear legal categorization,
- Standard-based risk management,
- Reduced bureaucracy,
- Rental housing access,
- Transparent manufacturer responsibility.

Although plug-in PV contributes only a limited share to total electricity generation, its societal and participatory effects are significant. It lowers barriers to renewable energy participation and broadens ownership of the energy transition.

The following appendices provide additional technical and procedural details.

Appendices

Appendix A: The German household electrical system

As is summarized in Figure 20, electricity enters residential buildings in Germany as a three-phase system:

- Three phase conductors: L1, L2, L3
- One neutral conductor: N
- One protective earth conductor: PE

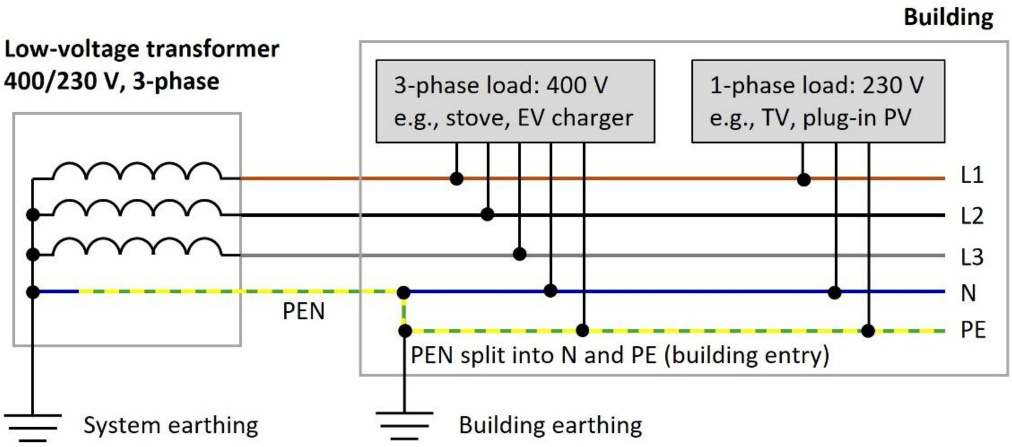
The voltage levels are:

- 230 V between any phase (L) and neutral (N), used for normal household sockets and appliances
- 400 V between two phases (L–L), used for high-power devices such as electric stoves or EV chargers

Large appliances such as stoves or EV chargers are often connected to all three phases (L1, L2, L3), which allows power to be distributed evenly across the grid. In a typical apartment, individual rooms and socket circuits are distributed across different phases (e.g., kitchen on L1, living room on L2, bedroom on L3).

Plug-in PV systems always connect single-phase (230 V), just like conventional household appliances.

Figure 20: Simplified German 400/230 V three-phase TN-C-S system



Source: Created by REI based on RP Energie Lexikon.[47]

Earthing system: TN-C-S

Germany uses a TN-C-S earthing system, which is commonly used in Germany and many other European countries. Internationally, several earthing arrangements exist, including TN, TT, and IT systems. In residential distribution networks, TN and TT systems are the most common.

The key difference between TN and TT systems lies in how protective earthing is provided. In TN systems, the protective earth (PE) is connected to the supply network and ultimately to the transformer earthing point. In TT systems, by contrast, the protective earth is connected to a local earth electrode at the building, independent of the network earthing.

The TN-C-S system in Germany works as follows:

1. From the distribution transformer to the building, neutral (N) and protective earth (PE) are combined into one conductor (PEN).
2. At the building connection point, the PEN conductor is split into separate N and PE conductors.
3. Inside the building:
    - N carries operating current
    - PE is used exclusively for protective earthing.

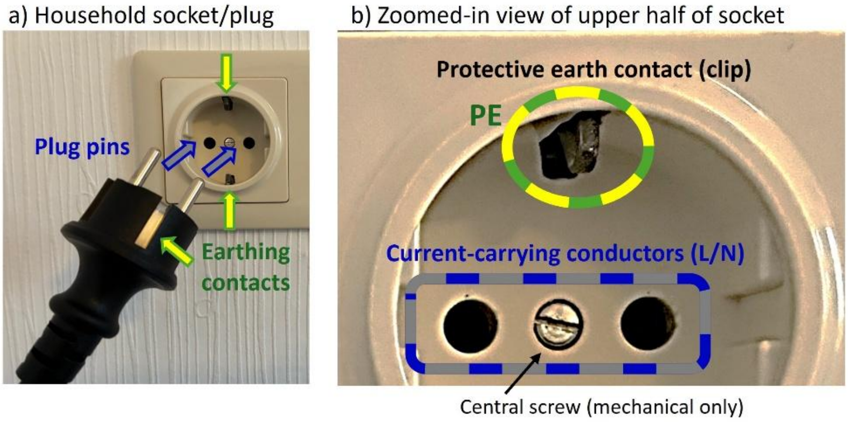
Household sockets and plugs in Germany

A standard socket for Germany is shown in Figure 21. Its main characteristics are:

- Rated for 230 V / 16 A
- Two side contacts provide protective earth (PE) at the top and bottom
- The protective earth contacts engage before the current-carrying conductors when plugging in and disengage last when unplugging.

Both Type C (without protective earth contacts) and Type F (with protective earth contacts) plugs can be inserted into this socket. However, for plug-in PV systems, only Type F plugs (commonly referred to as "Schuko" plugs[xiii]) are permitted. Plug-in PV systems therefore use the same socket type as everyday household appliances such as washing machines or refrigerators.

Figure 21: German household socket and Schuko plug (Type F) with protective earth contacts



a) Household socket/plug

b) Zoomed-in view of upper half of socket

Source: Created by REI. Photos taken by REI.

Further protective devices

In addition to the earthing system, German residential installations are equipped with protective devices located in the distribution board. Socket circuits are typically protected by 16 A circuit breakers, which disconnect the circuit in the event of overload or short circuit.

Residual current devices (RCDs) are mandatory in residential buildings. They continuously monitor the difference between the current flowing in the phase conductor (L) and the neutral conductor (N). If an imbalance occurs, the RCD disconnects the circuit within milliseconds. RCDs provide protection against electric shock, insulation faults, and leakage currents. In older installations, one or two RCDs may protect larger sections of the household, whereas newer installations typically use multiple RCDs to provide more selective and localized protection. Because RCDs in Germany operate by detecting current imbalance rather than current direction, they function independently of the direction of power flow. Plug-in PV devices are designed not to impair the proper functioning of RCDs.

[xiii] "Schuko" is derived from the German word Schutzkontakt (literally "protective contact"), referring to the protective earth connection integrated into the plug and socket design.

Appendix B: Summary of the plug-in PV device standard DIN VDE V 0126-95 (2025-12)

Purpose and scope of the standard

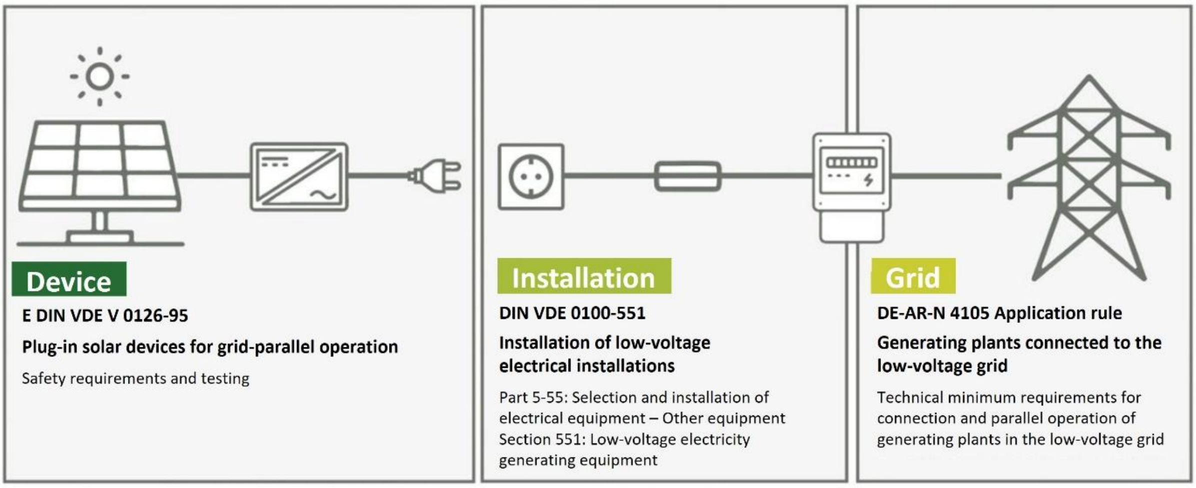
DIN VDE V 0126-95[48], published in December 2025, is the world's first dedicated product standard for plug-in PV devices. It defines safety requirements and test methods for complete plug-in PV systems intended for connection to household electrical circuits via a plug. The standard was developed in response to the rapid market growth of plug-in PV in Germany and the absence of a holistic product-level regulation covering electrical safety, mechanical safety, installation conditions, and user documentation in a single framework.

Importantly, DIN VDE V 0126-95 is a product standard for manufacturers, not an installation or grid-connection rule. Its main contribution is not enabling plug-in PV in principle, but defining how it can be manufactured, tested, and marketed safely. DIN VDE V 0126-95 does not replace existing standards but integrates them at the product level. Important related standards and regulations are:

- VDE-AR-N 4105: grid connection and inverter safety.
- DIN VDE 0100 series: household electrical installations.
    - in particular, DIN VDE V 0100-551-1: low-voltage generating installations
- EU product safety and EMC directives: CE conformity.

Together, these create a coherent framework in which plug-in PV devices are treated as safe consumer energy devices, rather than ad-hoc electrical installations as shown in Figure 22.

Figure 22: Framework of most relevant German norms for plug-in PV installations.



Source: Translated by REI based on DGS.[49]

Definition of a plug-in PV device

The standard defines a *plug-in PV device* as a consumer-ready system consisting of at least:

- one or more PV modules,
- a grid-connected micro-inverter,
- connection cables,
- an AC plug,
- and an included or specified mounting system,

that is designed to be connected to a low-voltage household.

A key conceptual shift introduced by the standard is that the complete system is assessed as a single device, rather than as independent components.

DIN VDE V 0126-95 distinguishes three system configurations, each with specific test and documentation requirements:

- **Compact systems**: PV module(s) and the micro-inverter form an integrated unit. All required DC electrical connections between the module(s) and the inverter are pre-assembled by the manufacturer and are not intended to be modified by the user.
- **Two-component systems:** PV module(s) and the micro-inverter are separated. The DC electrical connections between the PV module(s) and the inverter are made by the end user, strictly in accordance with the manufacturer's installation instructions and using the specified connection components**.**
- **Multi-component systems**: The Plug-in PV device consists of multiple PV modules and/or multiple micro-inverters that are electrically interconnected and operated together as one functional device. All DC interconnections are performed by the end user according to the manufacturer's specified system configuration and installation instructions.

Electrical performance limits

The standard confirms and technically specifies the power limits established in German legislation:

- Maximum AC output: **800 W_{AC}** (approximately 3.5 A at 230 V), not adjustable by the user.
- DC module capacity:
    - **Up to 960 W_{DC}** (800 W_{AC} + 20%) when connected via a standard household plug (Schuko). This reflects a safety margin intended for non-professional installation and typical existing household wiring conditions. This value (DC/AC ratio 1.2) reflects a common PV practice. It is often called "DC oversizing."
    - **Up to 2,000 W_{DC}** when a dedicated feed-in plug and socket system[xiv] is used. These systems are typically installed by a qualified electrician.
    - **Up to 2,000 W_{DC}** may be permitted in the future even when using a standard household plug, provided that additional technical measures for current limitations or end-circuit monitoring are implemented. For this purpose, alternative technical solutions may be developed in a future revision of the plug-in PV device standard DIN VDE V 0126-95.

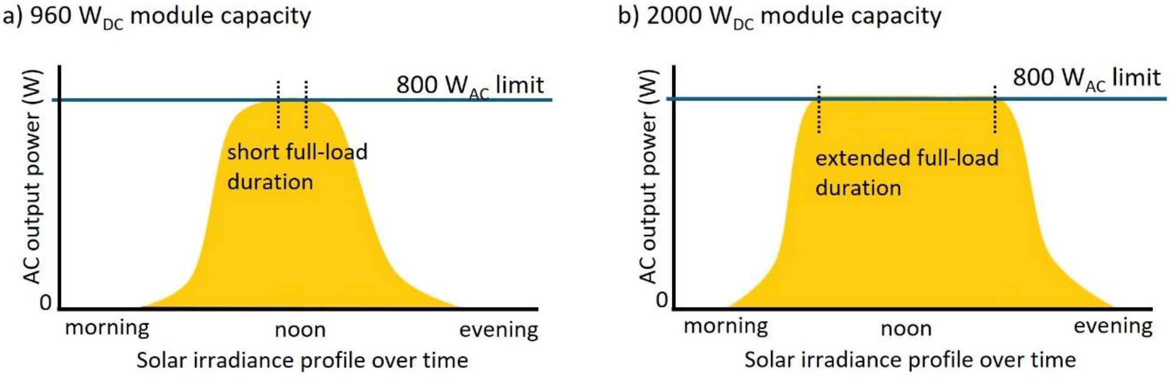
The standardization committee justified this lower DC limit for installations using a standard household plug for several reasons:

- Plug-in PV systems can be installed in unknown and potentially older electrical installations, where wiring quality and connection conditions cannot be verified.
- The degree of DC oversizing influences the duration of full AC output periods: With 960 W_{DC}, the inverter will reach the 800 W_{AC} limit only during limited peak irradiance periods (e.g., around noon under optimal summer conditions), hence only for a short duration.
- With 2,000 W_{DC}, full 800 W_{AC} output would occur more frequently and for longer periods, increasing cumulative thermal stress in downstream wiring and connection points.

This logic is schematically illustrated in Figure 23. The reduced DC limit for Schuko-based systems therefore serves as a precautionary measure in view of heterogeneous building stock and non-professional installation. As discussed in section 4.2, the WIPANO research project confirmed safety under worst-case conditions , including irradiation periods of up to approximately 1.5 hours at full load. This DC limit of 960 W_{DC} makes sure longer exposure times than those are not reached.

[xiv] According to DIN VDE 0618-1.

Figure 23: Effect of DC module capacity on the duration of maximum inverter output (800W_{AC})



Source: Created by REI based on Balkon.Solar e.V. .[50]

Plug and touch protection (compare to section 4.1)

Because plug-in PV devices are usually connected via accessible plugs, protection against electric shock is a central element of the standard.

For use with standard household Schuko plugs, the device must ensure that:

- no hazardous voltage is present on accessible contacts when unplugged,
- power conversion stops immediately when the plug is removed (shutdown within 0.1s),[xv]
- residual voltage is reduced to a safe level within a defined short time (< 34V within 1s).

The standard also describes another way for touch protection: the usage of special designed Schuko plugs for household sockets. This way, the user can still use their regular household sockets, whereas the maker provides additional safety features for touch protection. An example of a plug with additional touch protection can be seen in Figure 24. In this figure, touch protection is provided through movable covers. Touch protection could also be reached, for example, via a switch within the plug, that disengages when the plug is removed from an outlet.

Figure 24: Additional touch protection through movable covers over the plug pins

Source: Created by REI based on (a) DIN VDE V 0126-95 and (b) Solar RRL publication[51]*/Seplugs.*[52]

[xv] This is done via the inverter, which is defined through VDE-AR-N 4105. However, the device standard described in this section requires a faster shutdown time than defined in VDE-AR-N 4105 (which asks for <0.2s shutdown time), when using a standard Schuko plug. When using a modified Schuko plug with touch protection or a designated feed-in system, an inverter shutdown time of <0.2s is acceptable.

Grid and electrical safety requirements (compare to section 4.3)

Plug-in PV devices must comply with established grid-connection safety rules via the integrated micro-inverter, in particular compliance with VDE-AR-N 4105 for low-voltage grid connection. Each inverter must be tested for compliance individually by a qualified professional.[xvi]

In addition, the standard requires:

- compatibility with common household residual current devices (RCDs),
- limitation of residual voltages after disconnection (e.g. rapid discharge of capacitors),
- compliance with EMC (electromagnetic compatibility) requirements for residential and commercial environments.

Mechanical and structural safety (compare to section 4.4)

For the first time, a plug-in PV standard explicitly includes mechanical and structural safety requirements, particularly for mounting systems. The mounting systems need to be tested according to the norm specifications, and those tests need to be performed by a qualified engineer. PV modules also need to be safety tested according to international standards.[xvii]

This requirement shifts responsibility for structural safety from the user to the manufacturer and provides an objective basis for safety assessment, especially relevant in rental and multi-apartment buildings.

Environmental and durability requirements

All outdoor-exposed components must demonstrate:

- adequate ingress protection (e.g., IP ratings) to protect against dust and particles,
- resistance to UV radiation and weathering,
- corrosion resistance, including prevention of galvanic corrosion,
- compliance with fire safety classifications commonly applied to PV modules.

Documentation and user information

The standard places strong emphasis on clear, consumer-oriented documentation, which means that regular people with no technical knowledge can use the device safely. Manufacturers must provide:

- installation instructions understandable (in German) without specialist knowledge,
- clear specification of permitted installation configurations,
- explicit limits (output, height, wind and snow load applicability),
- information on compatible household protection devices.

All documentation must be consistent with the tested system configuration.

[xvi] According to the international standard IEC 62109.

[xvii] According to the international standard IEC 61730.

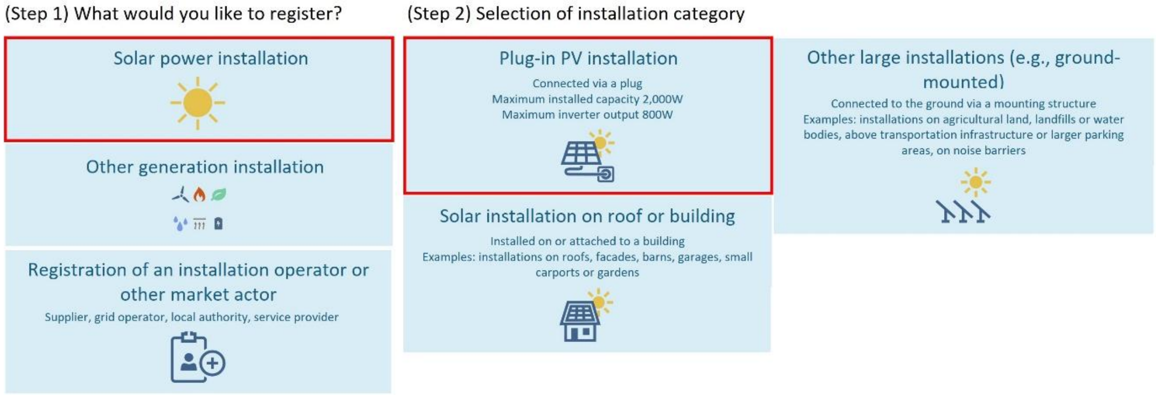
Appendix C: Online registration in the Market Master Data Register (MaStR)

In Germany, plug-in PV systems do not require prior approval from the grid operator. Instead, users must register the system online in the Market Master Data Register (Marktstammdatenregister, MaStR). Registration is completed via: https://www.marktstammdatenregister.de/MaStR.

The MaStR is a nationwide database operated by the Federal Network Agency BNetzA and serves as the central registry for electricity and gas generation assets in Germany. All electricity generation systems must be registered in this system.

For plug-in PV systems, a simplified registration category exists as shown in Figure 25. Since plug-in systems are registered by non-professionals, additional explanation pages and videos are accessible on the site.

Figure 25: MaStR interface with simplified icons for user-friendly registration



Source: Created by REI and translated based on MaStR interface screenshots.

After selecting "Plug-in PV installation" in Step 2 of the registration (Figure 25), the user needs to create an account and then enter the following information:

- Name of the installation
- Date of commissioning
- Installation address and geographic location
- Number of modules
- Total installed module capacity
- Maximum inverter output
- Meter number
- Information on whether a battery storage system is installed

No technical drawings, certificates, or electrician confirmations must be uploaded.

After registration, the information is automatically transmitted to the responsible grid operator. A separate grid connection application is not required. If necessary, the grid operator replaces an old mechanical electricity meter with a bidirectional or smart meter to properly record potential reverse power flows.

Registration in the MaStR is mandatory under German energy law, but the procedure is fully digital and typically takes only a few minutes. No prior approval, technical review, or waiting period is involved. This low administrative threshold is widely considered an important factor contributing to the rapid market growth of plug-in PV systems in Germany.

References

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[1] VDE Standard “DIN VDE V 0100-551-1 VDE V 0100-551-1:2018-05“, released 2018/05

[2] VDE Standard “VDE-AR-N 4105 Anwendungsregel:2018-11“, released 2018/11

[3] VDE Standard “VDE-AR-N 4105 Anwendungsregel:2026-03“, released 2026/03

[4] PV magazine, article, “Bonn-Netz macht Anmeldung von Photovoltaik-Balkonmodulen möglich“, released 2018/10/04

[5] Online platform, HP, “MachDeinenStrom.de”, accessed 2026/02/17

[6] EmpowerSource, HP, “Empowersource.de”, accessed 2026/02/17

[7] Plug-in PV Association, HP, “Bundesverband Steckersolar BVSS”, accessed 2026/02/17

[8] BVSS presentation by Christian Ofenheusle, “Das Balkonkraftwerk- Technik, Markt und Perspektiven”, obtained 2025/11/10

[9] Anwalt.de, HP article, “Privilegierte Bauvorhaben nach dem WEG“, accessed 2026/02/17

[10] VDE Standard ”DIN VDE V 0126-95 VDE V 0126-95:2025-12”, released 2015/12

[11] BVSS, press release, “Verbände-Bündnis warnt: Smart-Meter-Desaster und mangelhafter Rechtsrahmen für Energy Sharing und Kleinspeicher bremsen Energiewende in Bürgerhand aus“, accessed 2026/02/17

[12] BNetzA, article, “Festlegung zur Marktintegration von Speichern und Ladepunkten (MiSpeL)“, accessed 2026/02/17

[13] BVSS, press release, “Stellungnahme zum Festlegungsverfahren zur Marktintegration von Speichern und Ladepunkten (MiSpeL) der Bundesnetzagentur“, accessed 2026/02/17

[14] VDE Standard “VDE-AR-N 4105 Anwendungsregel:2026-03“, released 2026/03

[15] Commission Regulation (EU) 2016/631: “Establishing a Network Code on Requirements for Grid Connection of Generators “, accessed 2026/03/13

[16] EU Directive 2024/1711: “Improving the Union’s electricity market design”, accessed 2026/03/13

[17] MaStR, HP, “Marktstammdatenregister” accessed 2026/02/09

[18] MaStR, HP, “Marktstammdatenregister” accessed 2026/02/09

[19] MaStR, HP, “Marktstammdatenregister” accessed 2026/02/09

[20] HTW Berlin, report, “Nutzung von Stecker-Solargeräten 2022“, released 2022/05

[21] KfW, report, “KfW Energiewendebarometer 2025“, released 2025/10

[22] YUMA x Statista, study, “Exklusive Studie zum Balkonkraftwerk-Markt”, released 2025/10/03

[23] BVSS, article based on a study, “Auswertung Marktstammdatenregister 2025”, page accessed 2025/02/09

[24] HTW Berlin, Forschungsgruppe Solarspeichersysteme, “Stecker-Solar-Simulator”, accessed 2026/03/03

[25] SmartGridsBW, HP, “Förderprogramme für Stecker-Solaranlagen”, accessed 2026/03/03

[26] YUMA x Statista, study, “Exklusive Studie zum Balkonkraftwerk-Markt”, released 2025/10/03

[27] UBA, HP, “Steckersolargeräte (Balkonkraftwerke)”, released 2025/10/08

[28] Ministry of Justice and Consumer Protection “Bürgerliches Gesetzbuch BGB §554”, accessed 2026/02/17

[29] Ministry of Justice and Consumer Protection “Wohnungseigentumsgesetz WEG §20”, accessed 2026/02/17

[30] KfW, report, “KfW Energiewendebarometer 2025“, released 2025/10

[31] KfW, report, “KfW Energiewendebarometer 2025“, released 2025/10

[32] Möckernkiez, homepage, “Möckernkiez”, accessed 2026/02/17

[33] Süddeutsche Zeitung, news article, “Pilotprojekt: Balkonkraftwerke für mehr Mieter in Thüringen”, released 2024/01/15

[34] UBA, HP, “Steckersolargeräte reduzieren eigene Stromkosten – auch für Mieter*innen“, released 2025/06/02

[35] Verbraucherzentrale, article, “Steckersolar: Solarstrom vom Balkon direkt in die Steckdose“, released 2025/12/02

[36] Verein für Konsumenteninformation, “Balkonkraftwerk Österreich: Solaranlage zum Einstecken“, released 2025-07-01

[37] MachDeinenStrom.de, HP, “Mini-Solar News: Versicherungen Keine Schadensfälle bekannt“, accessed 2026/03/13

[38] Süddeutsche Zeitung, news article, “ Neues Balkonkraftwerk – Zeit, die Hausratversicherung zu prüfen“, released 2025/02/23

[39] Wieland electric, “Mit Wieland-Stecker zum sicheren Balkonkraftwerk“, accessed 2026/02/18

[40] DKE, homepage, “WIPANO”, accessed 2026/03/03

[41] DKE, report, “SteckerSolar: Entwicklung einer Produktnorm für PV-Geräte mit Stecker-Anschluss”, released 2024/12/04

---

[42] DKE, report, “SteckerSolar: Entwicklung einer Produktnorm für PV-Geräte mit Stecker-Anschluss”, released 2024/12/04

[43] PI Photovoltaik-Institut Berlin AG, report, “Untersuchung der Beeinflussung der Schutzkonzepte von Stromkreisen durch Stecker-Solar-Geräte “, released 2017/05/20

[44] VDE Standard “VDE-AR-N 4105 Anwendungsregel:2026-03“, released 2026/03

[45] VDE standard, “DIN VDE V 0126-95 VDE V 0126-95:2025-12 Steckersolargeräte für Netzparallelbetrieb”, published 2025/12

[46] Wikimedia Commons licence by Störfix, CC BY 2.5, for wind zones, and snow zones, accessed 2026/03/03

[47] RP Energie Lexikon, “Das TN-C-S-System“, accessed 2026/03/02

[48] VDE standard, “DIN VDE V 0126-95 VDE V 0126-95:2025-12 Steckersolargeräte für Netzparallelbetrieb”, published 2025/12

[49] DGS pvplug.de, HP article, “VDE-Normen für Steckersolargeräte”, accessed 2026/03/10

[50] Balkon.Solar e.V., HP article, “Neue Steckersolar Norm”, accessed 2026/03/02

[51] Solar RRL, Volume: 9, Issue: 22, “Assessment of Personal Safety Concerns of Plug and Play Photovoltaic Inverters using a Black Box Approach and Laboratory Measurements”, published 2025/10/14

[52] SEplugs, HP, “Neue Studie bestätigt: Der seplugs SEP-Stecker bietet höchsten Personenschutz bei Balkonkraftwerken”, accessed 2026/03/02

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