# Configurations for Simple, Safe, Ready-to-Go Plug-In Solar

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## 1. Executive Summary

The objective of this assessment is to identify the simplest, least-cost approach to safely connect up to 1,600 watts ("W") of plug-in balcony ("plug-in") solar in U.S. apartments and homes as of June 2026. An estimated four million plug-in solar systems are in operation in Germany with no reported safety incidents to date.

Presumptively, for the purposes of this assessment, the plug-in solar is connected to an outdoor 120 volt receptacle with an amperage rating of 15 amps or more. There are two primary safety concerns to supplying 1,600 W of plug-in solar power to the outdoor receptable: (1) the Ground Fault Circuit Interrupter ("GFCI") does not work properly with reverse power flow into the GFCI, and (2) the receptable is not on a dedicated circuit or at the terminus of a shared circuit, creating the possibility that sections of the circuit could exceed their amperage rating and overheat. As of January 2026, Underwriter Laboratories ("UL") has initiated a certification process for plug-in solar systems to address these issues.[1]

Outdoor receptacles have been required to utilize GFCIs since the 1970s to minimize the potential for electric shock. GFCIs are not specifically designed to accommodate bidirectional power flow. However, a number of GFCI makes/models do accommodate bidirectional power with no operational issues, per initial UL evaluation. In the short term, the plug-in system owner should confirm that GFCI make/model at the outlet to be used has no operational issues with bidirectional flow by consulting the UL list of approved GFCIs. In the mid-term, all GFCI manufacturers should be required to produce GFCIs that are compatible with bidirectional flow.

Many, but not all, outdoor receptacles are on dedicated circuits. The National Electric Code ("NEC") encourages placing outdoor receptacles on dedicated circuits but does not require it. For that reason, it is not uncommon for an outdoor receptacle to be on a shared circuit (a circuit with multiple receptacles). The outdoor receptacle may or may not be at the end of the shared circuit. There is the potential for sections of a shared circuit to overload if plug-in solar feeds into the shared circuit between the breaker and downstream loads.

The outdoor receptable can readily be checked, by an electrician or by an experienced homeowner/apartment dweller, to determine if it is at the end of a shared circuit. If only two wires are present, the receptacle is (1) either at the end of a dedicated circuit, or (2) at

[1] UL Solutions press release, *UL Solutions Debuts Testing and Certification Framework for Safer Plug-In Solar Across the United States*, January 8, 2026: https://www.ul.com/news/ul-solutions-debuts-testing-and-certification-framework-safer-plug-solar-across-united-states.

the end of a shared circuit. In either case, the plug-in solar system can feed in power up to the full amperage rating of the circuit.

Battery storage is a common option for plug-in solar systems. A battery would be incorporated into the plug-in system if the outdoor outlet is somewhere in the middle of a shared circuit, and therefore breaker masking would be a potential safety issue. The battery would serve as the reservoir for excess solar production beyond the level that might lead to circuit overheating due to breaker masking.

## 2. Background

Plug-in solar has been widely adopted in Germany and in other European countries. An estimated four million German households have balcony solar.[2] Germany and other European countries have passed laws to facilitate the deployment of plug-in solar. A major impetus for the German action was the Ukraine war and constrained supplies of Russian gas.[3] These laws address two issues in particular that can block plug-in solar: (1) safety concerns and (2) utility company or apartment owner-imposed hurdles and prohibitions.

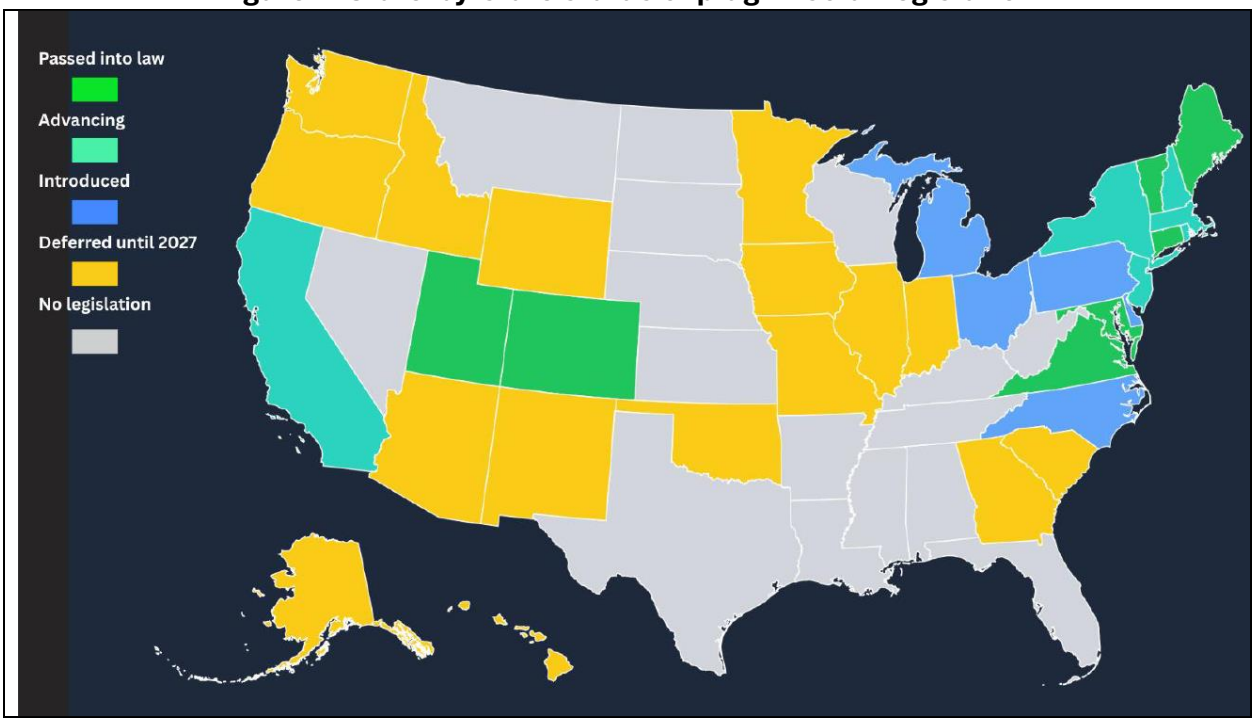
Germany specified a maximum wattage 800 W that can be input into an electric outlet from the plug-in PV panels.[4] The purpose of the wattage limit is to address potential safety concerns with the capacity of typical residential electric circuits.[5] German rules exempt these small PV systems from utility company interconnection requirements applicable to larger customer-sited solar arrays.

Seven US states have enacted plug-in solar legislation as of June 2026.[6] Many other states have introduced plug-in solar legislation, as shown in Figure 1.[7] State legislation generally includes a requirement that plug-in solar systems must be UL certified. UL has initiated a

[2] Solar Power Europe, *Plug-In Solar PV*, March 2025, p. 6. There are approximately 4 million plug-in solar systems in Germany. Approximately 1 million systems are registered with German federal energy market data regulator.
[3] Reuters, *Germany gives apartment-dwellers legal right to solar power*, July 5, 2024: https://www.reuters.com/world/europe/germany-gives-apartment-dwellers-legal-right-solar-power-2024-07-05/.
[4] European residential circuits operate at 240 volts. German utilities determined that plug-in solar inflows of up to 800 W would not result in excessive overheating of a residential circuit regardless of where on the circuit the solar power inflow occurred.
[5] Gerber, Daniel L. et al (2025) "Barriers to Balcony Solar and Plug-In Distributed Energy Resources in the United States", *Energies*, 18, 2132; MDPI April 2025, p. 7. German residential voltage is 240 v. US residential systems operate at half that voltage, 120 v. As a result, the equivalent presumptive US power inflow with "no breaker masking safety issues" would be 400 W.
[6] Clean Energy States Alliance, *What States Need to Know About Plug-In Solar*, June 2026, p. 15: https://www.cesa.org/resource-library/resource/plug-in-solar/.
[7] Ibid, Figure 8, p. 15.

certification process for plug-in solar systems to address these issues.[8] UL certification procedures are primarily focused on two issues: (1) the ability of the GFCI to safely accommodate bidirectional flow, and (2) the potential for the plug-in solar, depending on its point of connection to a branched (multiple outlet) circuit, to cause the circuit to overheat. These two issues are discussed in the following sections of this assessment.

**Figure 1. State-by-state status of plug-in solar legislation**




## 3. GFCI Safety Issue and Resolution

Many of the millions of plug-in solar systems in Germany are plugged-in to outdoor receptacles. The GFCI receptable in Germany is known as a Residual Current Detector ("RCD"}. No incidents have been reported in Germany related to issues with RCD functionality in managing bidirectional power flow from plug-in solar systems.[9]

Since the 1970s, all new construction outdoor receptables in the US have been required to be "Ground Fault Circuit Interrupter – GFCI" receptables, to minimize the potential for exposure to electrical shock. Most US GFCIs informally tested by Underwriters Laboratory (UL) in 2025 for bidirectional flow issues functioned properly when evaluated. The results of this informal UL testing was summarized by Gerber et al as follows:[10]

[8] UL Solutions press release, *UL Solutions Debuts Testing and Certification Framework for Safer Plug-In Solar Across the United States*, January 8, 2026: https://www.ul.com/news/ul-solutions-debuts-testing-and-certification-framew,ork-safer-plug-solar-across-united-states.
[9] A. Hu, "Balcony solar is all the rage in Germany. Why not in the US?", Canary Media, May 1, 2025.
[10] Gerber et al, 2025, p. 8.

> None of today's GFCIs are officially rated for bidirectional power flow, nor is there an official UL testing procedure for bidirectional GFCIs. Our UL interviewee recently conducted a series of informal backfeed tests. While most of the GFCIs functioned properly, a few samples were reportedly damaged due to backfeed. There are no other reports on the effects of backfeeding a GFCI.

The informal UL GFCI assessment described in the Gerber paper indicates that, at a high level, most GFCIs have no performance issues with bidirectional flow. UL has also confirmed some GFCIs do meet the pertinent UL 943 performance specification for shut down speed.[11] In the short term, the plug-in solar system user could confirm that GFCI make/model at the outlet to be used has no operational issues with bidirectional flow by consulting the UL list of approved GFCIs.[12] If replacement is warranted, a typical GFCI receptacle costs in the range of $20 to $30.[13] In the longer-term, GFCI manufacturers should be required to produce GFCIs that are fully compatible with bidirectional flow.

Another concern raised by UL is residual power flow coming from the plug-in solar inverter after the GFCI has interrupted power flow, such that a user could be shocked by the slower shut down of the solar inverter.[14] However, UL does note that some plug-in solar inverters do shut down sufficiently fast to meet the current UL shut down duration specification. Again, UL could post a list of plug-in solar inverters that meet or exceed the UL 943 shut down speed requirement.

### 4. Breaker Masking Issue and Resolution

Breaker masking refers to a situation on a non-dedicated circuit where the current flow on the circuit exceeds the breaker rating without tripping the breaker. This would potentially result in the wires overheating.

Figure 2 is an example of how this situation could develop with plug-in solar. An excessive load is put on a residential circuit, shown by the red arrow. In the example, it is two 14 amp hairdryers at the end of a circuit rated at 20 amps. The combined demand of the hair dryers, 28 amps, would normally trip the 20 amp breaker.  protecting the line from overheating. However, the plug-in solar and battery system upstream from the hair dryer load reduces the load detected at the breaker. This prevents the breaker from tripping to protect the circuit from overload.

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[11] UL Solutions, *White Paper - Interactions of Plug-In PV with Protection of Existing Power Systems*, December 2025, p. 21: https://www.ul.com/insights/safety-considerations-plug-photovoltaic-pipv-systems.
[12] This would require that UL post a list of GFCIs that meet UL 943.
[13] Home Depot, webpage accessed June 27, 2026, 20 amp GFCI receptacle.
[14] UL Solutions, *White Paper - Interactions of Plug-In PV with Protection of Existing Power Systems*, December 2025, p. 21.

**Figure 2. Example of breaker masking resulting in overload of a 20 amp circuit** (from Gerber et al 2025)

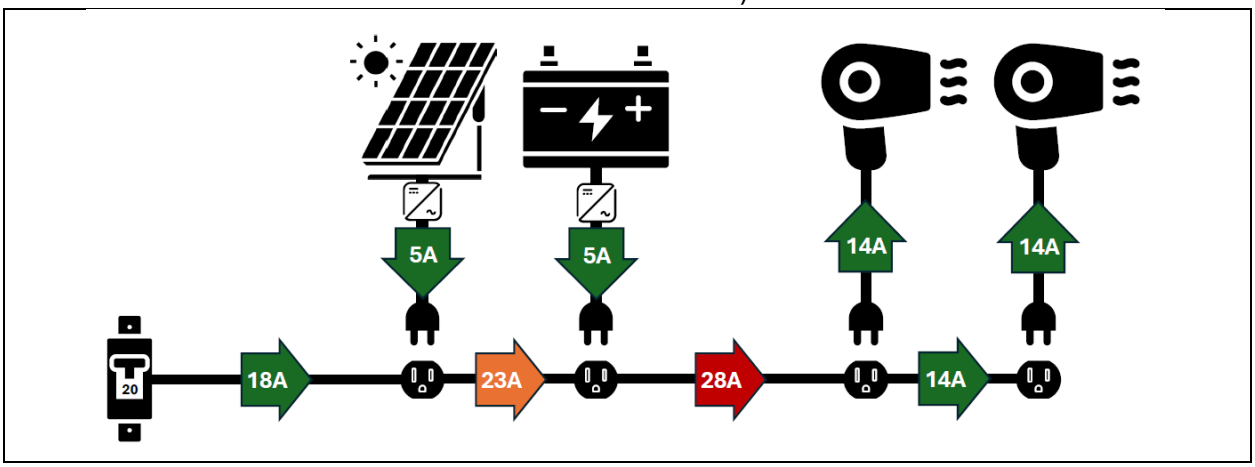
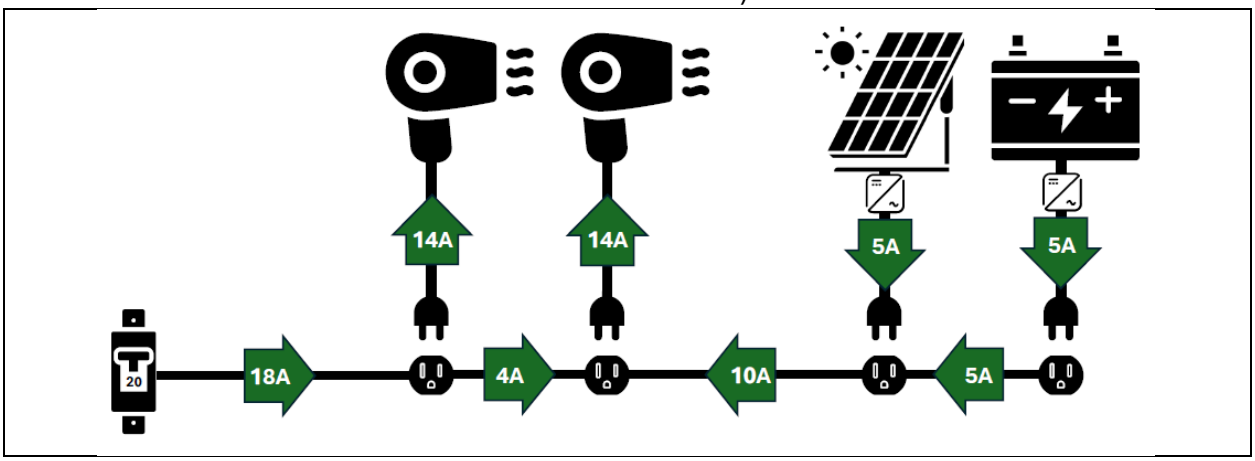



Figure 3 shows the location of the plug-in solar and battery at the end of the circuit. Gerber et al (2025) indicate plug-in solar at the end of a shared circuit should not present "breaker masking" issues, enabling plug-in solar to deliver up to 1,800 watts to the circuit.[15]

**Figure 3. Placement of plug-in solar at end of the circuit avoids breaker masking** (from Gerber et al 2025)



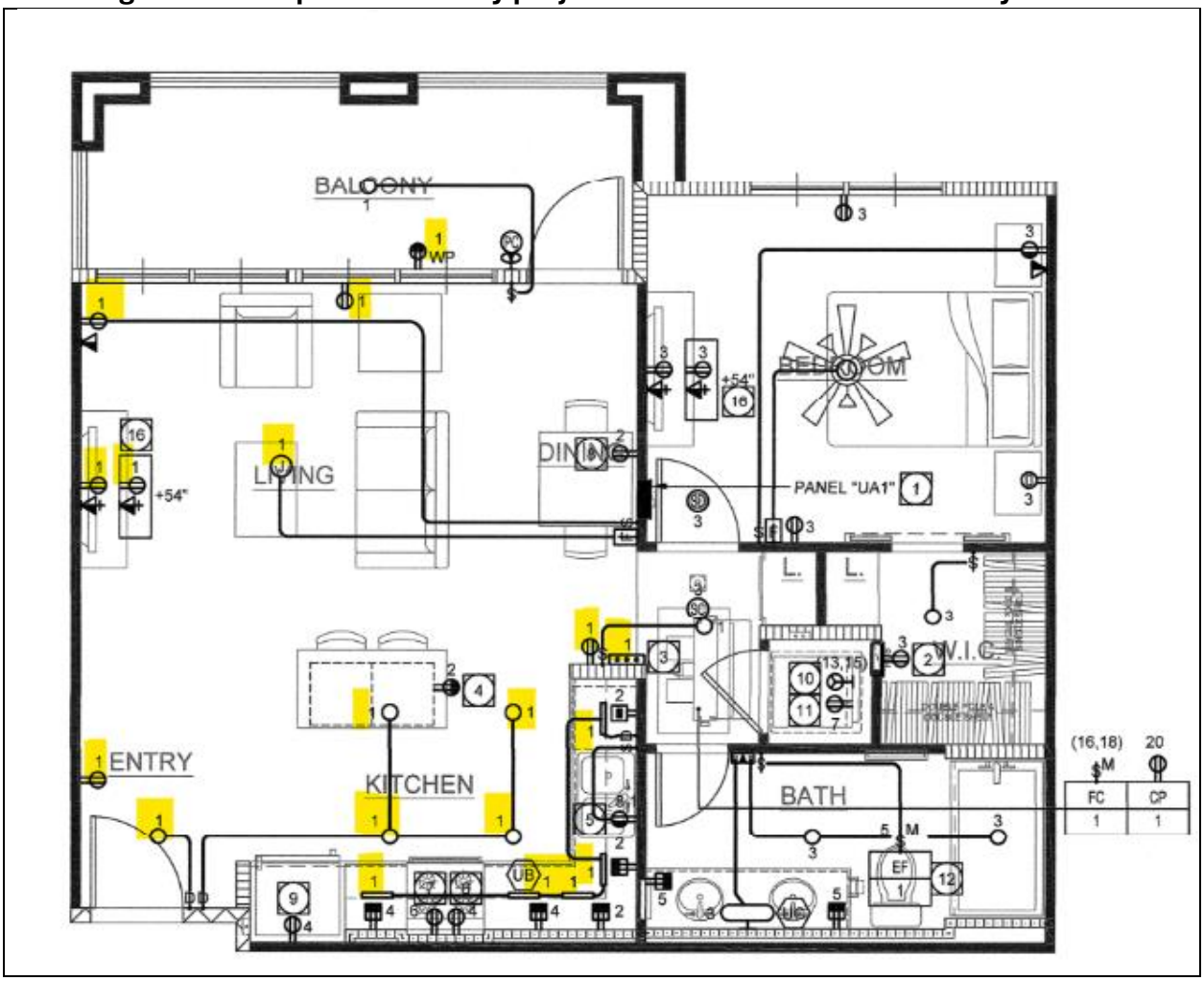

The breaker masking examples in Figures 2 and 3 assume a circuit rating of 20 amps. The typical 120 v residential US electrical outlet has a breaker rating of 15 amps, equivalent to 1,800 watts. As a result, a circuit would have to have a higher rating than the standard 15 amps to accommodate a plug-in solar system greater than 1,800 watts in capacity.

[15] Gerber et al (2025) pp. 7-8: ". . . plug-in DERs at the end of a circuit may be safe. However, we cannot expect occupants to have knowledge of their home's internal wiring . . . Many argue that proper positioning of the solar breaker can prevent masking of the main breaker, safely allowing for more solar capacity. However, code-making officials established the 120% rule [800 W maximum in Germany] as a catch-all: even electricians are not expected to understand breaker masking when adding solar circuits."

## 5. Identifying Location of Outdoor Outlet on A Circuit

The NEC does not require that outdoor receptacles be served by a dedicated circuit. Most plans may identify the circuit number the outdoor receptacle is on, but do not provide wiring diagrams for individual branch circuits. Figure 4 shows an electrical floor plan for a representative multifamily project in development. The weatherproof outdoor receptacle located on the balcony is highlighted in yellow, as are the other receptacles and lighting fixtures on the same circuit. A field investigation is the only way to make a definitive determination regarding whether the outdoor receptacle is at the end of the circuit.

**Figure 4. Example multifamily project – outlets on same circuit in yellow[16]**




Despite not being a NEC requirement, patio or balcony outdoor outlets are often on dedicated circuits.[17] The rationale for this is that outdoor outlets often are used to provide

[16] O. Herrera, Building Official, Community Development, City of Solana Beach, email communication to B. Powers, Powers Engineering, May 15, 2026.

[17] "Dedicated circuit" means the outdoor outlet is the only receptable on the circuit and has its own dedicated breaker.

power to electric-driven tools that may have the potential to trip the breaker. Putting the outdoor receptable on a dedicated circuit avoids the possibility of disabling shared outlets inside the house that are on the same circuit.

Outdoor outlets on branched circuits, meaning circuits with multiple outlets, are often at the end of the circuit. An outdoor outlet at the end of a circuit is readily identifiable by having only two wires (hot and neutral) connecting to the receptacle. An example of such an outdoor patio outlet is shown in Figure 5.

**Figure 5. Outdoor patio outlet with 2-wire "end of circuit" termination**

The field inspection procedure for physically verifying whether an outdoor patio outlet is simple and quick.

### 6. Options if Outdoor Receptacle Is Not at End of Shared Circuit

The primary options for situations where breaker masking may present a potential safety issue are to incorporate (1) battery storage with the plug-in solar system, and (2) a sensor that limits power flow to 400 W (or whatever wattage level that is determined to create no safety issues) and directs "excess" solar production to battery storage. Some plug-in solar companies, like Craftstrom, offer plug-in solar systems that approximate these requirements.[18]

[18] Craftstrom, *How It Works*, webpage accessed June 28, 2026: https://craftstrom.com/how-it-works/.

Alternatively, a sensor that can detect the real-time maximum power flow anywhere on the branched circuit that the plug-in solar system feeds into, and adjusts the plug-in solar output to not exceed the rating of the circuit, would enable the plug-in solar user to plug in without concern for the location of the outlet on the circuit. The industry is actively developing these types of sensors.[19]

## 7. Conclusion

Four million plug-in solar systems are in operation in Germany with no reported safety issues. Many US states have passed plug-in solar legislation or have introduced it. Clearly, technical parameters can be set that assure safety and enable rapid deployment of plug-in solar based on the European experience. UL is currently evaluating potential requirements for plug-in solar systems. This assessment reviews the two principal safety issues, GFCI function and breaker masking, and the potential near-term actions that UL could take to facilitate plug-in solar adoption while at the same time assuring user safety.

## 8. Primary References

Clean Energy States Alliance, *What States Need to Know About Plug-In Solar*, June 2026, p. 15: https://www.cesa.org/resource-library/resource/plug-in-solar/.

Avanza Energy, *1 Million Balcony Solar Panels, Zero Incidents, and the Utilities Fighting to Stop Them*, April 26, 2026: https://avanzaenergy.substack.com/p/1-million-balcony-solar-panels-zero.

UL Solutions, *White Paper - Interactions of Plug-In PV with Protection of Existing Power Systems*, December 2025: https://www.ul.com/insights/safety-considerations-plug-photovoltaic-pipv-systems.

Gerber, Daniel L. et al (2025) "Barriers to Balcony Solar and Plug-In Distributed Energy Resources in the United States", *Energies*, 18, 2132; MDPI April 2025.

Hu, Akielly (2025) "Balcony solar is all the rage in Germany. Why not in the US?", Canary Media, May 1, 2025.

[19] Gerber, Daniel L. et al (2025), *Energies*, 18, 2132; MDPI April 2025, p. 8. "The interviewees mentioned several potential technical solutions for breaker masking. The plug-in solar/storage company developed a smart outlet that disconnects attached DERs upon detecting a breaker-masking event. It precisely measures wall voltage and can detect voltage droop due to downstream loading. The German industry consultant mentioned two other solutions currently being explored in Germany. One uses a smart metering circuit breaker that communicates with the plug-in DERs. The DERs will curtail power if the sum of the metered and generated power exceeds the circuit's rating. This approach could allow up to 1800 W of generation on a lightly used 120 V, 15 A circuit."

Reuters, *Germany gives apartment-dwellers legal right to solar power*, July 5, 2024: https://www.reuters.com/world/europe/germany-gives-apartment-dwellers-legal-right-solar-power-2024-07-05/.