Southern Alliance for Clean Energy

POLICY AND SAFETY ANALYSIS

DISPROPORTIONATE REGULATION OF RESIDENTIAL PLUG-IN SOLAR

A comparative risk analysis of plug-in solar units with certified microinverters vs. portable gas or diesel generators for lineworker safety

Southern Alliance for Clean Energy (SACE)
By Dr. Stephen A. Smith and Amanda Arthur

V.7 | June 2026

EXECUTIVE SUMMARY

This white paper examines the scientific and regulatory basis for the differential treatment of residential plug-in solar photovoltaic (PIPV) units and portable gas/diesel generators with respect to lineworker safety. Drawing on documented fatality records from the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH), peer-reviewed electrical injury science, utility industry safety publications, applicable federal inverter safety standards, a U.S. Department of Energy (DOE) funded national laboratory barrier analysis, and the emerging bipartisan legislative consensus in multiple states, this analysis reaches the following central conclusions:

- **A DOE-funded Lawrence Berkeley National Laboratory study (2025) systematically catalogued the technical, interconnection, and regulatory barriers** to plug-in solar adoption in the United States, confirming that interconnection requirements—not technical safety limitations—are the primary barrier to deployment [1].
- **Anti-islanding protection mandated for inverters by UL 1741 (Clause 9.3) and IEEE 1547-2018 provides automatic disconnection within 2 seconds when grid power fails**—a protection that portable generators entirely lack. This protection operates independently of homeowner knowledge, behavior, or compliance. In practice, modern microinverters used in plug-in solar systems disconnect well within this 2-second ceiling: international standards already require shutdown times as fast as 0.2 seconds, and most microinverters on the market today disengage in under one second, significantly outperforming the UL 1741 standard [2], [3].
- **Peer-reviewed risk quantification studies place the annual probability of lineworker electric shock from residential solar islanding at less than one in one billion per year** under worst-case scenarios. An International Energy Agency study concluded this risk is three orders of magnitude lower than the baseline electrical hazards already present in utility operations. The study is often cited as evidence that anti-islanding protections built into PV inverters limit risk [4], [5].
- **Documented lineworker fatalities from backfeed are attributable exclusively to portable generators.** OSHA and NIOSH case records confirm multiple deaths, and the specific kill mechanism—transformer voltage step-up from sustained generator backfeed—has been directly observed and documented in the field [6], [7], [8], [9].
- **No lineworker has ever been killed or injured by backfeed from a UL 1741-certified grid-tied solar inverter.** The utility industry's own trade safety publication, *Incident Prevention*, confirms this record explicitly, stating that certified inverters have been "virtually 100 percent reliable" with no known lineworker injuries from inverter-failure-associated backfeed [10].
- **Bipartisan legislative momentum to exempt plug-in solar from utility interconnection requirements is accelerating.** Utah enacted HB 340 unanimously in March 2025, becoming the first state to adopt plug-in solar legislation [11]. Virginia's General Assembly passed SB 250/HB 395 with overwhelming bipartisan support in March 2026 [12]. As of June 1, 2026, 35 states and Washington, D.C. have introduced plug-in solar

legislation, including nine states that have passed legislation: Colorado, Connecticut, Maine, Maryland, New Hampshire, New York, Utah, Vermont, and Virginia [13].

- **Policy recommendations:**
  (1) A risk-tiered interconnection framework based on system size and certification status:
    (1a) **Sub-420W with UL 1741-certified microinverters**: exempt from all interconnection requirements, utility agreements, fees, and inspections. At 420 watts, a plug-in solar system produces no more than 3.5 amps at 120 volts—the same safety buffer used in Germany for 800W systems on 230V circuits—which eliminates any breaker-masking risk on standard 15- or 20-amp household circuits, even in worst-case wiring configuration.
    (1b) **420W–2,400W with UL 1741-certified microinverters**: system registration with the utility; no physical inspection required. Systems in this range remain within the rated capacity of standard 20-amp household circuits but may require breaker-masking protections (such as a UL 3141-certified Power Control System, a panel-installed circuit-monitoring device, or installation on a dedicated circuit) depending on the wiring configuration.
    (1c) **Over 2,400W, or any system without UL 1741-certified microinverters**: may warrant more robust interconnection review consistent with current rules.
  (2) **Equivalent regulatory treatment of portable generators** if lineworker safety is asserted as the basis for solar interconnection requirements.
  (3) **Evidence-based regulatory review** by state public utility commissions, including evaluation of whether external disconnect switch requirements remain justified for certified systems.
  (4) **Transparency in rulemaking**, requiring utilities to provide specific, technically documented safety justifications for any plug-in solar interconnection requirements.

The core finding: Plug-in solar—the technology with zero documented lineworker deaths—faces heavier regulation than the technology with confirmed fatalities. This regulatory inversion demands correction.

A critical clarification: This paper does not argue that plug-in solar presents zero theoretical risk to lineworkers. Any source of electrical energy connected to a distribution system has the potential, however remote, to contribute to hazardous conditions. The evidence demonstrates that:

(1) UL 1741-certified inverters provide automatic, hardware-based protections that reduce the practical risk to levels indistinguishable from zero;

(2) portable generators lack any equivalent automatic protection and have a confirmed lethal track record; and

(3) the current regulatory framework imposes greater burdens on the technology with superior safety performance, an inversion that cannot be justified on safety grounds.

1. BACKGROUND: THE REGULATORY DISPARITY

KEY DEFINITIONS: BACKFEEDING VS. SHARING

Throughout this paper, the term **backfeeding** refers specifically to the flow of electric power from a residence back onto the utility distribution grid **during a grid outage**, when utility workers may be performing maintenance or repair on lines they expect to be de-energized. This is the condition that creates a lineworker safety hazard: power flowing onto a line that is assumed to be dead. The backfeed risk is determined by whether a generation source can sustain energization of the distribution line through the service transformer during an outage, and whether the source disconnects automatically when grid power is lost.

When a grid-tied solar system sends excess power back to the utility while the grid is operating normally, in our definition, that is not backfeeding in the safety-relevant sense used in this paper. In normal grid operation, the grid sets the voltage and frequency, and any power exported by a residential system flows onto an energized, regulated network where lineworkers are already protected by standard live-line procedures. SACE refers to this normal-operation power export as **sharing**.

Sharing is distinct from **net metering** or other utility compensation arrangements. A homeowner who has a contractual agreement with their utility to receive credit or payment for exported power is participating in a formal interconnection program, not simply sharing. This paper's use of the term sharing refers specifically to the incidental export of power by a grid-tied solar system that is not in a contractual relationship with the utility to receive compensation for that power. The safety analysis in this paper addresses only the outage-condition backfeed scenario, which is the basis for lineworker safety concerns about distributed generation.

Note on certification references: Throughout this paper, references to "UL 1741" denote the technical standard itself—not exclusively products bearing the UL mark. Any product certified to UL 1741 by an OSHA-recognized Nationally Recognized Testing Laboratory (NRTL), including Intertek (ETL), CSA Group, TÜV Rheinland, and others, meets the same safety requirements. Unless otherwise noted, "UL 1741-certified" should be read as "certified to UL 1741 by any recognized NRTL" (see Section 6.3).

1.1 HOW PORTABLE GENERATORS ARE REGULATED

Portable gas and diesel generators are sold freely at hardware and home improvement stores across the United States without any pre-purchase utility notification, permit requirement, or interconnection agreement. A homeowner may purchase a generator of any wattage—commonly 2,000 to 7,500 watts for residential use—and operate it with minimal regulatory oversight. The principal safety requirement governing residential generator use is that the unit must not be connected to household wiring without an approved transfer switch or other approved interconnection equipment, per the National Electrical Code (NEC) Article 702.5(A) (NFPA 70-2023, Chapter 7). Article 702 specifically requires transfer equipment to prevent simultaneous connection of the utility service and the standby source—a provision designed to prevent hazardous backfeed conditions that could energize utility lines during outages and to protect lineworkers from backfeed [14].

However, enforcement of this requirement is largely reactive—violations are investigated only after an incident occurs, and many homeowners routinely bypass transfer switches using direct-plug "suicide cords." A "suicide cord" (also called a backfeed cord or cheater cord) is a power cord with male prongs on both ends, used to connect a portable generator directly to a wall outlet—bypassing the transfer switch required by the NEC—and thereby energizing the entire household circuit and potentially the distribution line.

Critically, NEC Article 702 contains no requirement for automatic anti-islanding protection equivalent to what UL 1741 mandates for solar inverters. Generator safety depends on correct installation and user compliance with transfer equipment requirements [14].

The Electrical Safety Foundation International (ESFI), compiling U.S. Bureau of Labor Statistics and OSHA data from 2011 through 2023, reports an average of approximately 150 electrical fatalities per year across all industries; contact with or exposure to electricity remaining one of the leading causes of workplace fatalities in the United States [15].

Despite this record, the regulatory framework governing portable generator use at the residential level is characterized by minimal pre-installation oversight and limited utility involvement.

1.2 HOW PLUG-IN SOLAR IS REGULATED

In contrast, small plug-in solar photovoltaic (PIPV) units—including balcony-mounted panels, window units, and plug-in microinverter systems typically ranging from 200 to 2,400 watts—are subject to a substantially heavier regulatory environment in most U.S. jurisdictions. At the national code level, grid-interactive power sources such as rooftop and plug-in solar must comply with NEC Article 705, which governs electric power sources operating in parallel with the utility grid. Article 705.2 requires such equipment be listed and evaluated for safe interconnection, typically through certification to UL 1741, which mandates automatic anti-islanding protection that disconnects generation when grid power is lost—without requiring any action from the homeowner—preventing the re-energization of utility lines and protecting lineworkers during outages [14].

A 2025 DOE-funded study by Lawrence Berkeley National Laboratory (LBNL) systematically documented the regulatory barriers facing plug-in solar in the United States, finding that regulatory and interconnection requirements—not technical safety issues—represent the primary obstacle to deployment [1]. The report further notes that these requirements are often identical to those applied to multi-kilowatt rooftop PV systems, despite plug-in units typically producing only a few hundred watts.

In many utility territories in the U.S., connecting such a unit to a residential outlet or household circuit requires:

- A formal interconnection application to the serving utility
- Utility technical review, which may take weeks to months
- A signed interconnection agreement
- In some cases, an electrical inspection and permit
- In some cases, installation of an external disconnect switch
- Ongoing utility approval that can be denied, delayed, or conditioned without clear technical justification

This framework mirrors the requirements applied to large-scale rooftop solar systems of 5 to 20 kilowatts or more, despite the fact that a 400-watt plug-in unit produces roughly one-quarter the power of a single hair dryer on its lowest setting (a typical hair dryer draws 1,500 to 1,875 watts) and is a fraction of the wattage of gasoline or diesel generators sold without any such requirements. (It is worth noting that solar generation is a continuous load under NEC definitions, running for more than three hours, and therefore subject to the 80% derating rule under NEC Article 210. A 400-watt continuous solar load is well within this derated capacity on any standard 15- or 20-amp household circuit.)

1.3 THE REGULATORY QUESTION

The central question this paper addresses is whether the safety evidence supports this regulatory disparity. Specifically: **do sub-2,400-watt plug-in solar units with UL 1741-certified microinverters present a comparable or greater lineworker safety risk than portable generators of equivalent or greater wattage?**

As the evidence below demonstrates, the answer is clearly no.

2. ELECTRICAL INJURY SCIENCE: HOW ELECTRICITY KILLS

2.1 CURRENT DETERMINES INJURY

Understanding the relative risks of different power sources requires grounding the analysis in the basic physiology of electrical injury. Injury severity is determined by the amount of electrical current flowing through the body—measured in milliamps (mA)—not by the wattage of the source. The threshold values established by decades of research are shown in Table 1.

Table 1. Physiology of electrical injury. Source: NIOSH Publication No. 2009-113, "Electrical Safety: Safety and Health for Electrical Trades Student Manual," p. 7 [16].

Current Level	Physiological Effect
Below 1 mA	Generally not perceptible
1 mA	Faint tingle
5 mA	Mild shock; not painful but disturbing. Generally harmless
6–25 mA (women) 9–30 mA (men)	Painful shock; possible loss of muscle control ('let-go' threshold). Individual cannot let go, but can be thrown away from the circuit if extensor muscles are stimulated
50–150 mA	Extreme pain; breathing stops. Severe muscular contractions. Potentially fatal
1,000–4,300 mA	Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage; death likely.
10,000 mA	Severe burns, cardiac arrest; almost certainly fatal
15,000 mA	Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit

Important context: These thresholds apply to direct body contact with an energized conductor. In the lineworker safety scenario under discussion, the relevant question is not merely whether a source can theoretically produce dangerous current levels, but whether that current can be delivered through the distribution system—including transformer impedance, line losses, and load absorption—to a worker at a given point on the line. As explained in the following sections, this delivery pathway introduces substantial additional barriers that further reduce the already-minimal risk from small residential sources.

2.2 SOURCE IMPEDANCE AND THE LIMITS OF SMALL SOURCES

A 2022 National Renewable Energy Laboratory* (NREL) primer on IEEE 1547 islanding protection explains that sustained islanding requires a near-perfect balance between generation and load on the islanded section—an inherently unstable condition that inverter protection systems are specifically designed to detect and terminate. However, even without inverter protection, sustained islanding becomes increasingly unlikely as the generation source becomes smaller relative to the connected load, because small sources cannot maintain voltage and frequency stability across a typical distribution circuit [5].

Under ideal conditions, the maximum current available from a source can be approximated as Watts ÷ Volts. However, this theoretical maximum is never achieved in real-world fault conditions because distribution lines present substantial impedance to current flowing from a small residential source.

For small sources, the physical limits of power delivery further constrain the risk. A 400-watt source operating at 120 volts AC can deliver only about 3.5 amps under ideal conditions, and real distribution networks introduce substantial impedance through transformers, conductors, and connected loads. In addition, residential distribution transformers present significant impedance between the customer service and the primary distribution line, further limiting the ability of small sources to drive meaningful current back onto the utility system. These factors make sustained hazardous current flow from small sources extremely difficult to achieve in practice.

Typical residential distribution transformers are commonly rated between 15 and 50 kVA (kilovolt-amperes, a measure of transformer capacity), with 25-kVA and 50-kVA units widely used in utility distribution systems serving homes [17]. A 1,200–1,600-watt plug-in solar system (referring to inverter AC output, the actual power delivered to the grid) therefore represents only 2–6% of the transformer's capacity, further illustrating the limited ability of such small sources to drive sustained current onto a primary distribution line.

These physical constraints apply to plug-in solar generally, though they are most pronounced at the smallest system sizes. Even at 1,200–1,600 watts, a 120-volt source producing roughly 10–13 amps remains severely limited by transformer and line impedance, load mismatch, and voltage collapse under abnormal conditions.

2.3 THE TRANSFORMER STEP-UP MECHANISM: WHY WATTAGE TIER MATTERS

The critical danger mechanism in documented lineworker fatalities from generator backfeed is not direct 120-volt household current—it is the step-up transformation of that current through distribution transformers operating in reverse. A distribution transformer designed to step down 7,200 volts to 120 volts will, when energized from the secondary side by a sufficiently powerful generator, step that 120-volt source up to approximately 7,200 volts on the distribution line

* Note that NREL is now the National Laboratory of the Rockies (NLR). This paper uses the former name, NREL, for historical accuracy of the documents cited.

side. This mechanism is what creates the hazardous condition for lineworkers. The Polk County, Florida incident described in Section 4.1 documents precisely this mechanism: a homeowner's generator energized the distribution transformer in reverse, stepping 120 volts up to distribution-level voltage and seriously injuring an apprentice lineman [7]. Distribution transformers are not isolation devices; when energized from the secondary side they behave according to the same voltage ratio as in normal operation.

The key threshold is whether the backfeed source can sustain sufficient voltage and current under load to maintain energization through the transformer and the connected distribution circuit. Very small sources cannot maintain this condition. A 400-watt plug-in solar unit has extremely limited power available to energize the transformer and supply connected loads, and voltage quickly collapses when even modest loads are present on the circuit. By contrast, multi-kilowatt gasoline or diesel generators commonly used during outages can supply significantly greater power and can sustain transformer energization and load simultaneously. Indiana Electric Cooperatives and Middle Tennessee Electric have both issued public safety advisories warning specifically about the dangers of generator backfeed through distribution transformers, confirming that the utility industry itself recognizes generators as the primary backfeed hazard [18], [19].

It is worth distinguishing between plug-in solar systems in the 1,200–2,400-watt range discussed in this paper and the multi-kilowatt generators referenced above. While both may technically be described as "multi-kilowatt," a 2,400-watt plug-in solar system with UL 1741-certified anti-islanding protection is fundamentally different from a 3,000–5,000-watt portable generator with no automatic disconnection capability. The anti-islanding protection ensures that even at the upper end of the plug-in solar range, the system will cease energizing the circuit within 2 seconds of grid failure—a protection generators entirely lack.

The additional solar safety factor: An additional safety layer applies to solar generation. Even before these physical limitations come into play, a UL 1741-certified inverter will detect the loss of grid voltage and automatically disconnect from the circuit. The physical limits of low-wattage sources and automatic anti-islanding protection therefore operate as independent, redundant safety layers—either one alone substantially reduces the hazard. Portable generators provide neither automatic disconnection nor inverter-based anti-islanding protection.

3. WATTAGE-TIERED RISK ANALYSIS

For the lineworker backfeed hazard that is the subject of this analysis, the primary safety variable is protection architecture—specifically, whether automatic anti-islanding disconnection is present. Wattage is a secondary variable that determines the scale of the potential hazard only in the absence of that protection. (A separate, non-backfeed consideration—branch-circuit overcurrent, or "breaker masking"—does scale with wattage and is addressed through circuit sizing and overcurrent protection, discussed in Section 3.4.) The safety implications of backfeed depend strongly on source wattage because available current increases directly with power output. Table 2 examines actual lineworker risk across the wattage range relevant to residential plug-in solar and portable generators, integrating source impedance limitations, the transformer step-up mechanism, and the presence or absence of automatic safety protections. Generator risk assessments are informed by NIOSH fatality documentation [6] and utility industry safety warnings [18], [19]. Solar risk assessments are informed by the International Energy Agency (IEA) Photovoltaic Power Systems Programme (PVPS) IEA-PVPS risk analysis [4] and the NREL islanding protection primer [5].

Table 2. Wattage-tiered risk comparison of plug-in solar vs. portable gas or diesel generators [4], [5], [6], [18], [19].

Wattage	Max Current at 120V	Gas or Diesel Generator Risk and Anti-Islanding	Plug-in Solar Risk (UL 1741-Certified) and Anti-Islanding
400W	3.5A	Theoretical only. No anti-islanding protection	Negligible—source collapses + anti-islanding auto shutdown active
800W	6.7A	Very low. No anti-islanding protection	Negligible—impedance limits + anti-islanding auto shutdown active
1,200W	10A	Low-moderate without protection. No anti-islanding protection	Very low—anti-islanding auto shutdown prevents sustained energization
2,000W	16.7A	Real and documented. No anti-islanding protection	Very low—anti-islanding auto shutdown prevents sustained energization
2,400W	20A	Real and documented. No anti-islanding protection	Very low—anti-islanding auto shutdown prevents sustained energization
3,000W–5,000W	25–42A	Documented fatalities. No anti-islanding protection	Plug-in solar is typically <2,400W. Anti-islanding auto shutdown prevents sustained energization

Utility distribution protection systems are designed to detect and interrupt large fault currents on distribution feeders, typically far above normal load levels. By comparison, even a 1,600-watt plug-in solar system can supply only about 13 amps at 120 volts, two to three orders of magnitude smaller than the currents associated with distribution faults. In addition, inverter-based distributed energy resources certified under IEEE 1547 and UL 1741 are required to cease energizing the circuit under abnormal grid conditions, further limiting their ability to sustain hazardous conditions [3].

3.1 MULTIPLE PLUG-IN SOLAR UNITS ON A SINGLE DISTRIBUTION CIRCUIT

A natural question arises when considering the deployment of multiple plug-in solar units within a neighborhood or building: could the aggregate generation from many small systems create an islanding risk that individual systems do not? The technical evidence indicates that this concern is addressed by existing standards. Each UL 1741-certified microinverter operates its anti-islanding detection independently. A 2016 NREL study tested multiple inverters from different manufacturers simultaneously deployed on the same simulated distribution feeder. In 244 multi-inverter tests, the maximum run-on time observed was 632 milliseconds—well within the 2-second IEEE 1547 requirement [5].

The NREL primer on islanding further notes that while the speed of anti-islanding detection could theoretically decrease as the number of inverters increases, run-on times in all cases tested remained within the 2-second limit [5]. Moreover, sustained islanding requires a near-perfect balance between total generation and total load—a condition that becomes increasingly unlikely on a typical residential distribution circuit with diverse loads. In practice, even a building with 20 apartments each running 800-watt plug-in solar systems would collectively produce only 16 kW—a fraction of the 25–50 kVA capacity of the distribution transformer serving those units.

Germany's experience supports this: with over a million plug-in solar units deployed, no safety incidents attributable to aggregated systems have been reported [1].

A 2024 study by the Berlin University of Applied Sciences (HTW Berlin) found that plug-in solar systems may actually improve fire safety in residential electrical installations [20]. Because plug-in solar reduces the net load on building wiring, the study concluded that the number of electrical fires in German homes could decrease slightly with widespread adoption. Even under worst-case assumptions, the study found no statistically significant increase in fire risk [20].

3.2 SAFE HARBOR: SUB-420W PLUG-IN SOLAR

At 420 watts, maximum theoretical current delivery at 120V is 3.5 amps—well within the safety buffer of a standard 15-amp household circuit, and equivalent to the margin that Germany's regulatory framework applies to 800-watt systems on its 230V/16-amp circuits. The combination of source impedance limitations and the automatic anti-islanding shutdown required by UL 1741 makes meaningful sustained fault current delivery to a lineworker at the distribution level physically implausible in practice. A UL-certified microinverter at this wattage will disconnect from the circuit within 2 seconds per UL 1741 Clause 9.3—and in many modern implementations within milliseconds—well before a lineworker could physically approach a downed conductor [2], [3].

3.3 PLUG-IN SOLAR AT 420W–1,200W

Given the limited available current, distribution system impedance, and the automatic cease-to-energize requirement of UL 1741-certified inverters, the practical risk to lineworkers from a sub-1,200-watt plug-in solar unit is, for all practical regulatory purposes, functionally negligible. This is the wattage tier addressed by Utah's law governing plug-in solar, HB 340 (1,200W cap) and Virginia's SB 250/HB 395 (1,200W cap), both of which exempt these systems from utility interconnection requirements [11], [12].

3.4 PLUG-IN SOLAR AT 1,200W–2,400W

As source wattage increases toward 2,400 watts, the theoretical current availability (up to 20 amps at 120V) begins to approach levels that could be dangerous if delivered efficiently and sustained. However, UL 1741-certified microinverters continue to provide automatic islanding protection at all wattages, making the practical risk for solar at this level comparable to the sub-1,200-watt range. The anti-islanding protection does not become less effective as wattage increases—it remains mandatory and automatic regardless of system size [2].

While anti-islanding protection remains equally effective across all wattages, systems above 420 watts do introduce a separate consideration: breaker masking. On a shared branch circuit, a plug-in solar system producing more than 3.5 amps can offset load current as seen by the circuit breaker, potentially allowing total current on a section of wiring to exceed the breaker's rating without tripping it. This is not an islanding or lineworker safety issue—it is an overcurrent protection issue addressed by pairing the system with a UL 3141-certified Power Control System, a panel-installed circuit-monitoring device, or installation on a dedicated circuit. The need for these additional protections is the basis for the notification requirement in the 420–2,400W policy tier (see Section 9).

Acknowledging the higher-wattage context: At 2,400 watts, a source without anti-islanding protection would present a meaningful hazard. This is precisely why UL 1741 certification is critical at this tier, and why this paper's policy recommendations distinguish between sub-1,200W systems (which should require no notification or interconnection process) and 1,200–2,400W systems (which should require notification but no interconnection process).

3.5 PORTABLE GENERATORS AT THE SAME WATTAGE TIERS

The risk profile of portable generators at identical wattage tiers is dramatically different. A 2,400-watt portable generator has no automatic anti-islanding protection—by design, generators are intended to provide power independently of the grid, which is precisely why they lack this safeguard. NEC Article 702 requires a transfer switch but imposes no automatic shutoff mechanism equivalent to UL 1741 [14]. When improperly connected without a transfer switch—a common occurrence documented extensively in OSHA records—the generator can sustain line energization as it continues running through a grid outage. At 3,000–5,000W, available current output (25–42A at 120V) is sufficient to energize a distribution transformer in reverse and sustain hazardous conditions that have directly caused documented worker fatalities [6], [7], [8], [9].

4. DOCUMENTED SAFETY RECORD: THE EVIDENCE

4.1 OSHA- AND NIOSH-DOCUMENTED LINEWORKER FATALITIES FROM GENERATOR BACKFEED

The NIOSH Fatality Assessment and Control Evaluation (FACE) program and OSHA incident reporting systems contain specific documented cases of lineworker deaths directly attributable to portable generator backfeed. The NIOSH comprehensive monograph, *Worker Deaths by Electrocution* (Publication No. 98-131, 1998), summarizes 224 FACE electrocution investigative reports and remains the most comprehensive federal compilation of occupational electrocution data. While the publication date is 1998, the OSHA Electric Power Generation, Transmission, and Distribution industry hazards page continues to reference it as an authoritative resource, and the incident patterns it documents—generator backfeed during storm restoration—remain current and recurring [6], [21].

NIOSH FACE Case 90-05: A lineman was electrocuted while attaching a 2,400-volt powerline to a pole-mounted insulator. The victim was assured by his supervisor that the line was de-energized. It had in fact been re-energized by a nearby portable generator [6].

NIOSH FACE Case 90-02: A leader of a tree-trimming crew was electrocuted during hurricane cleanup when he contacted a downed powerline he believed to be de-energized. Electric current from a portable generator operating at a nearby gas station had re-energized the powerline [6].

Polk County, Florida, 2009: An apprentice lineman was grasping a conductor while wearing leather gloves, repairing a line downed by a falling tree. When a homeowner whose house was served by the line started a generator, the electricity passed through the distribution transformer, stepping up from 120 volts to 7,200 volts—the full distribution voltage. The lineman survived with serious injuries [7].

Flomaton, Alabama: An electric lineman employed by Pike Electric, Inc. was killed when he came into contact with a power line energized by a generator that had been hooked up improperly. The worker was transported by LifeFlight to hospital where he was pronounced dead. Alabama authorities investigated the improper connection [8].

In each case, the energization occurred because a portable generator remained connected to household wiring during a grid outage, allowing current to flow backward through the distribution service transformer and re-energize the distribution line. These cases are representative, not exhaustive. Informal industry discussions also reflect this risk. In online forums used by electrical workers, lineworkers describe close calls and incidents involving generator backfeed during outage restoration, reinforcing the safety concerns documented in formal investigations [9].

The NIOSH FACE database contains additional cases involving generator-induced line energization across multiple states and weather events. The utility industry itself recognizes this pattern: Indiana Electric Cooperatives published a specific safety advisory titled “Generator Backfeed is Dangerous and Potentially Deadly,” and Middle Tennessee Electric’s “Beware of Backfeed” advisory specifically identifies improperly connected generators as the primary backfeed threat [18], [19].

4.2 DOCUMENTED LINEWORKER INJURIES FROM UL 1741-CERTIFIED SOLAR INVERTERS

The inverters for plug-in solar are certified to the same UL 1741 standard as inverters used for rooftop solar, which have been in use for decades and have an impeccable safety record.

> The documented number of lineworker fatalities or injuries caused by backfeed from a UL 1741-certified grid-tied solar inverter is: ZERO.

This conclusion is supported by statements from within the utility safety community itself. *Incident Prevention*, a trade publication written by and for electrical utility workers, states explicitly in its 2014 article on distributed generation (DG) safety by Mike Caro, CUSP*, that certified inverters protect lineworkers. “These inverters have been shown to be virtually 100 percent reliable. There has never been a known injury to a lineworker from backfeed onto a line from a DG facility associated with an inverter failure” [10].

This statement—from a publication whose entire editorial purpose is worker safety, not solar promotion—is perhaps the single most powerful piece of evidence in this analysis. The technology that utilities are subjecting to the heaviest regulatory scrutiny has never harmed a lineworker through the mechanism that scrutiny is designed to prevent.

A second *Incident Prevention* article from April 2024, “Solar Backfeed Safety on Distribution and Secondary Circuits,” reaffirms this framework. The article emphasizes that lineworkers must protect themselves from all potential backfeed sources, including improperly installed solar systems—that is, systems installed *without* UL-certified inverters. This distinction is critical: the safety concern is not with certified equipment performing as designed, but with non-certified or improperly installed equipment. The article further confirms that UL-labeled grid-tied inverters are required to shut off when grid power fails or AC frequency deviates, preventing the customer’s system from becoming an island [22].

This analysis has been reviewed by a former utility lineworker with direct field experience in both solar installation and the utility grid power lines. The reviewer confirmed that this paper accurately represents lineworker safety protocols and addresses all relevant ways that behind-the-meter generation systems affect linework. They noted that the fear of backfeed is a constant concern during storm restoration, and that in their own practice, lineworkers treated solar and

* Certified Utility Safety Professional

generator systems identically when mitigating hazards—making no operational distinction between the two. When they shared the paper's findings with colleagues still working as lineworkers, they were unaware that the regulatory standards for solar and generators differed so significantly and could not identify a safety-based rationale for the disparity.

4.3 QUANTIFIED RISK: THE IEA ISLANDING STUDY AND NREL CONFIRMATION

A formal risk analysis conducted under the International Energy Agency Photovoltaic Power Systems Programme (IEA-PVPS) applied standard fault-tree analysis techniques to the probability of lineworker injury from residential solar islanding. The study concluded that the annual risk of electric shock from islanding of PV systems under worst-case PV penetration scenarios is less than one in one billion [4].

Subsequent technical reviews, including a 2022 National Renewable Energy Laboratory (NREL) primer on IEEE 1547 islanding protection, cite this work as evidence that islanding risk from modern inverter-based PV systems is three orders of magnitude lower than the baseline electrical hazards already present in utility operations [5].

A companion IEA-PVPS study (Verhoeven, IEA-PVPS T5-07:2002), based on extensive real-world measurements over two years in a representative Dutch residential network, concluded that the probability of islanding itself is "virtually zero" [23].

A risk of less than one in one billion per person per year is, under any standard risk-tiering framework, effectively indistinguishable from zero. For comparison, the annual risk of being struck by lightning in the United States is approximately 1 in 1,000,000—roughly three orders of magnitude (1,000 times) greater than the upper-bound islanding risk from residential solar.

Taken together, the incident record, the operational experience of utilities, and formal probabilistic risk analyses all converge on the same conclusion: modern inverter-based residential solar systems present an extremely low islanding risk to lineworkers.

4.4 INTERNATIONAL SAFETY RECORD: THE EUROPEAN EXPERIENCE

The European experience with plug-in solar provides additional real-world confirmation of these safety conclusions. Germany, which has the most mature plug-in solar market in the world, had deployed over a million balcony solar (Balkonkraftwerk) units with no reported lineworker safety incidents aside from cases involving deliberate tampering [1]. Germany's regulatory framework permits systems up to 800 watts to be registered and connected without an electrician, a threshold established based on a 2016 Fraunhofer Institute report showing that 600 watts of backfeed was safe even under worst-case scenarios, later raised to 800 watts to align with European Network Code standards [1].

Other European countries permitting plug-in solar with registration or notification include the Netherlands, Belgium, Spain, Portugal, Switzerland, Austria, Italy, and several others [1]. The German Association of Fire Chiefs (AGBF) has stated that it is unaware of fire safety issues from balcony power plants and has confirmed that the systems are insulated and touch-safe. While the German electrical system (230V single-phase) differs from the U.S. system (120V split-phase), meaning safety thresholds do not translate directly, the fundamental conclusion—that certified plug-in solar microinverters with anti-islanding protection do not create meaningful lineworker safety risks—is consistent across both regulatory environments.

5. LINEWORKER PROTECTIVE PRACTICES AND THEIR IMPLICATIONS

5.1 STANDARD LINEWORKER SAFETY PROTOCOLS

Professional electrical lineworkers do not rely on the de-energization of lines as their sole protection. OSHA Standard 1910.269(m) requires employers to ensure that all sources of electric energy are identified and controlled through de-energization, isolation, or protective work practices before employees contact conductors [21]. Additionally, the National Rural Electric Cooperative Association (NRECA) and Federated Rural Electric Insurance Exchange (FREIE) identify several "life-saving rules" for field personnel in the Commitment to Zero Contacts initiative [24] including:

- Use rubber gloves and sleeves
- Apply proper insulating material or cover-up to adjacent conductors
- Use proper clearance procedures and Lockout/Tagout (LOTO)
- Test lines as de-energized and apply Personal Protective Grounds (PPGs) before contact.

5.2 PERSONAL PROTECTIVE GROUNDS: THE CRITICAL DEFENSE

Personal Protective Grounds (PPGs) are grounding cables attached to de-energized conductors before work begins, bonding the conductor to earth. If the line becomes energized from any source, the fault current routes to the ground rather than through the worker. PPGs are designed to carry momentary fault currents of tens of thousands of amps, allowing upstream protective devices to clear the fault before worker exposure occurs in accordance with American Society for Testing and Materials* (ASTM) F855 grounding equipment ratings [25]. Against a 400-watt plug-in solar source capable of delivering a maximum of 3.5 amps at 120 volts, a properly installed PPG represents an overwhelming margin of safety.

Critical context on PPGs and generators: The *Incident Prevention* article on distributed generation safety notes that generators may not trip standard protective devices when only the primary side is grounded due to transformer impedance. This means generators can present a backfeed hazard when only the primary side is grounded, because transformer impedance may limit fault current and prevent upstream protective devices from operating—lineworkers must also ground or isolate the secondary side to ensure generators cannot backfeed the line. This additional procedural burden exists specifically because generators lack automatic anti-islanding protection. Certified solar inverters, by contrast, have already disconnected before grounding procedures even begin [10].

Modern lineworker safety relies on multiple independent protection layers—including testing, grounding, protective equipment, and system protection—so that no single failure mode should expose workers to hazardous voltage.

* Now ASTM International

5.3 LINEWORKER PERSPECTIVE ON RELATIVE RISK

The *Incident Prevention* articles provide the most authoritative professional perspective on this question. The 2014 article by Mike Caro, CUSP, makes clear that personal generators are "the most common type of DG [distributed generation] you will come into contact with in the field" and that backfeed from customer generators during storm work is "one of the primary safety concerns for lineworkers." The article does not identify certified solar inverters as a comparable concern—to the contrary, it notes their "virtually 100 percent" reliability [10].

The 2024 *Incident Prevention* article reinforces this by focusing its backfeed concern specifically on non-UL-certified installations and battery storage systems connected without proper anti-islanding protections—not on UL 1741-certified grid-tied inverters operating as designed [22].

This professional perspective matters: When the utility industry's own safety publications identify generators as the primary backfeed concern and affirm the reliability of certified solar inverters, the regulatory asymmetry becomes impossible to justify on worker safety grounds.

6. TECHNICAL STANDARDS: UL 1741 AND IEEE 1547

6.1 WHAT UL 1741 REQUIRES: THE BASE STANDARD AND ITS SUPPLEMENTS

UL 1741, the *Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources* (3rd Edition, 2021, updated March 10, 2026), is the primary U.S. safety certification standard for grid-tied solar inverters. In its current form, it is aligned with IEEE 1547-2018 and IEEE 1547.1-2020 and covers electrical safety, abnormal operation, and anti-islanding protection [2], [3].

The critical lineworker safety protection—automatic anti-islanding—is a requirement of the base UL 1741 standard. UL 1741 Clause 9.3 requires testing to verify that the inverter detects an island condition and ceases to energize the area electric power system within 2 seconds of island formation. This two-second disconnection requirement applies to all UL 1741-certified inverters regardless of supplement level [2], [3], [26].

Since 2017, two major supplements have been added to the UL 1741 standard. It is essential for policymakers to understand that these supplements add grid-management capabilities—they do not address deficiencies in the base standard's lineworker safety protections:

<u>UL 1741 (Base Standard):</u> Tests for electrical safety, fire hazards, abnormal operation, and anti-islanding protection. It requires the inverter to detect loss of grid conditions and cease energizing the area electric power system within two seconds. This requirement forms the foundational lineworker safety protection for inverter-based distributed generation. Every UL 1741-certified inverter—whether base, SA, or SB—must satisfy this anti-islanding requirement [2], [3], [26].

<u>UL 1741 Supplement A (SA), published 2016:</u> Adds "smart inverter" grid-support functions including voltage and frequency ride-through, volt-var control, and frequency-watt response. These functions allow inverters to remain connected during certain grid disturbances while supporting system stability. SA was developed in conjunction with California Rule 21 Phase 1 requirements. These are grid-management capabilities rather than additional lineworker safety protections—the base UL 1741 anti-islanding protection already addresses lineworker safety [2], [27].

<u>UL 1741 Supplement B (SB), published 2021 (3rd Edition):</u> Aligns advanced-function testing with IEEE 1547-2018 and IEEE 1547.1-2020. SB includes interoperability and communications testing using protocols such as IEEE 2030.5, SunSpec Modbus, or IEEE 1815 DNP3 (Distributed Network Protocol 3), enabling monitoring and control of distributed energy resources. SB became the certification pathway used in California Rule 21 for distributed energy resource (DER) compliance with IEEE 1547-2018. These capabilities support high-penetration DER grid management rather than adding new lineworker safety protections beyond the base anti-islanding requirement [2], [27], [28].

The key implication for this analysis: If a utility rejects a plug-in solar system certified to base UL 1741 solely because it lacks SA or SB certification, it is not making a lineworker safety argument—it is making a grid-management or interoperability argument. The anti-islanding protection that prevents lineworker injury from backfeed is identical across all three certification levels. Requiring SA or SB for a sub-1,200-watt plug-in system that will never provide grid services is regulatory overreach that uses technical standards language to accomplish what is functionally a barrier to entry.

IEEE 1547-2018, the *Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*, establishes the broader technical requirements for connecting distributed energy sources to the utility grid, including requirements for islanding detection and cease-to-energize behavior. UL 1741 provides the product certification testing framework used to verify inverter compliance with these requirements, while UL 1741 SB incorporates the additional interoperability and advanced-function testing associated with the IEEE 1547-2018 revision [2], [3], [28].

6.2 THE FUNDAMENTAL DIFFERENCE FROM GENERATORS

Unlike inverter-based distributed energy resources, portable generators are not subject to a mandatory automatic cease-to-energize requirement. Portable generators have no equivalent automatic safety feature at any certification level. NEC Article 702 requires transfer equipment to prevent simultaneous connection of utility service and standby power, but this is a manual or semi-automatic requirement that depends entirely on proper installation and use [14]. The entire generator safety framework depends on: (1) the homeowner knowing that a transfer switch is required, (2) the homeowner having purchased and installed one correctly, and (3) the homeowner using it properly under the stress of a power outage. All three conditions must be met. When any one fails—as documented repeatedly in OSHA records—the line can become energized [6].

For UL 1741-certified solar inverters, dependence upon resident adherence to these behavior-dependent mechanisms is not a factor in achieving safety. The safety mechanism is built into the hardware and operates independently of user knowledge, training, or stress-of-the-moment decision making. This represents a categorically superior safety architecture, not a merely equivalent one.

It is important to acknowledge that no manufactured product is immune to malfunction. A UL 1741-certified inverter could theoretically fail to disconnect properly, just as any safety-critical component in any industry can experience a failure. However, the certification testing process under UL 1741 Clause 9.3—which tests anti-islanding at 33%, 66%, and 100% of rated output power—is specifically designed to verify reliable disconnection under a range of operating conditions [26]. The absence of any documented lineworker injury from a certified inverter failure across decades of deployment constitutes strong empirical evidence that the certification testing regime is effective. By contrast, generator safety depends entirely on human compliance with transfer switch requirements—a far more failure-prone protection mechanism than hardware-based automatic disconnection.

6.3 NRTL EQUIVALENCY: THE STANDARD VS. THE TESTING LABORATORY

An additional barrier that some utilities have imposed is requiring that inverters be certified specifically by UL Solutions (UL), formerly Underwriters Laboratories, rather than accepting certification to the UL 1741 standard by any NRTL. This conflation of the *standard* (UL 1741) with the *testing laboratory* is unsupported by federal law and creates an unjustified barrier to entry.

The Occupational Safety and Health Administration (OSHA) operates the NRTL Program under Code of Federal Regulations (CFR) 29 CFR 1910.7. Multiple NRTLs are authorized to certify products to UL 1741, including Intertek (ETL mark), CSA Group, TÜV Rheinland, and MET Laboratories. OSHA's position on equivalency is unambiguous: "OSHA considers all NRTLs recognized under 29 CFR 1910.7 to be equivalent in their 'capability' to certify to the standards in their scope of recognition. OSHA does not dictate to manufacturers which NRTL they must use" [29].

The California Energy Commission—which oversees interconnection for the largest solar market in the nation—requires certification "from a NRTL whose OSHA Scope of Recognition includes UL 1741," explicitly accepting any OSHA-recognized NRTL rather than requiring UL specifically [28]. The International Association of Electrical Inspectors (IAEI) likewise lists multiple NRTLs as authorized for UL 1741 certification without distinguishing between them [30].

A utility that requires certification by UL specifically, rather than certification to UL 1741 by any OSHA-recognized NRTL, is imposing a requirement that has no basis in federal regulation, no basis in the safety standard itself, and no technical justification. This practice functions as an additional barrier to plug-in solar adoption that does not promote lineworker safety.

6.4 THE NON-CERTIFIED EQUIPMENT CAVEAT

Safety: DIY systems that are not certified do pose a major risk to lineworkers. Passing legislation that requires UL 1741 or equivalent NRTL certification is itself a critical safety measure, because it establishes a minimum safety standard that prevents the sale and installation of uncertified equipment—the only category of inverter-based distributed generation identified as a genuine backfeed concern. Such legislation will also lead to broader requirements for certification of units for sale in the U.S., further improving the safety baseline.

It is important to acknowledge—as the 2024 *Incident Prevention* article does—that non-UL-certified inverters, battery storage systems connected without proper anti-islanding protections, or do-it-yourself installations that bypass certification standards can present genuine backfeed hazards [22]. The LBNL barrier study notes that the NRTL label is considered far more credible than self-certification and that authorities having jurisdiction (AHJ) appropriately look for this certification [1].

This paper's analysis and policy recommendations apply specifically to systems equipped with UL 1741-certified microinverters. The distinction between certified and non-certified equipment illustrates why the regulatory gatekeeping mechanism should be product certification to UL 1741, not burdensome interconnection processes that add cost and delay without improving safety beyond what the certification already requires.

7. SIDE-BY-SIDE COMPARISON

Table 3. Comparison of plug-in solar and gas or diesel generators by safety factors [3], [5], [6], [8], [9], [10].

Safety Factor	Plug-in Solar (with UL 1741-certified microinverter)	Portable Generator (any wattage)
Anti-islanding protection	YES—automatic, mandatory per UL 1741 Clause 9.3 [3]	NO—NEC Art. 702 requires transfer switch only [6]
Shuts down when grid fails	YES—within 2 seconds (often milliseconds)	N/A—backup generator would not be running when connected to operational grid
Documented lineworker fatalities	ZERO—confirmed by *Incident Prevention* [10]	YES—multiple OSHA/NIOSH-documented [8]
Transformer step-up risk	None—shuts down before energizing	YES—documented 120V→7,200V [9]
Carbon monoxide hazard	None	Kills dozens of users annually
Safety depends on user behavior	NO—hardware-based, automatic	YES—transfer switch install & use required
Quantified annual risk (IEA)	Less than one in one billion per year [5]	Not quantified—multiple confirmed fatalities
Current regulatory burden	High—interconnection agreements, permits	Low—hardware store purchase, minimal oversight

8. LEGISLATIVE MOMENTUM: THE EMERGING BIPARTISAN CONSENSUS

The regulatory disparity documented in this paper is not merely a theoretical concern—it has become the focus of a rapidly growing bipartisan legislative movement across the United States.

8.1 UTAH: FIRST-IN-THE-NATION LEGISLATION

In March 2025, Utah Governor Spencer Cox signed HB 340 (Solar Power Amendments) into law, making Utah the first state in the nation to exempt plug-in solar from utility interconnection requirements. The bill passed unanimously through both chambers, with the Utah House 72-0 and the Senate 27-0. Sponsored by Republican Representative Raymond Ward, HB 340 defines a “portable solar generation device” as a movable PV system with a maximum power output of 1,200W that connects through a standard 120V outlet and includes anti-islanding protection. The law exempts these devices from interconnection applications and utility fees while requiring UL and NEC compliance [11].

8.2 VIRGINIA: SOUTHEASTERN BREAKTHROUGH

In March 2026, Virginia’s SB 250 and HB 395 passed the General Assembly with overwhelming bipartisan support, with final votes of 93-4 in the House and 29-11 in the Senate. Governor Abigail Spanberger signed the bill into law on April 22, 2026. The legislation allows portable solar devices up to 1,200W, prohibits utilities from imposing interconnection requirements or charging fees related to the devices, and prevents landlords with more than four rental units from prohibiting their use. Virginia’s passage is particularly significant as the first southeastern state to advance plug-in solar legislation [12].

8.3 NATIONAL MOVEMENT

As of June 2026, legislators in 35 states and Washington, D.C. have introduced plug-in solar legislation, including 9 states that have passed legislation (Table 4). This bipartisan momentum reflects a growing recognition that existing interconnection requirements for small-scale solar are disproportionate to the actual safety risk [13]. Most legislation caps plug-in solar systems at 1,200–1,600W, although some states’ proposed legislation accommodates 240-volt connections, higher wattage, and battery storage. Real-world AC output from these systems is lower than the DC panel rating due to conversion losses, panel orientation, and available sunlight—for example, an 800-watt DC system may deliver roughly 560–640 watts of AC power in practice.

Table 4. States that have introduced plug-in solar legislation as of June 1, 2026, and legislative status [13]

State	Status	State	Status
Alaska	*Deferred until 2027*	New Hampshire	*Passed*
Arizona	*Deferred until 2027*	New Jersey	*Passed one chamber*
California	*Passed one chamber*	New Mexico	*Deferred until 2027*
Colorado	*Passed*	New York	*Passed*
Connecticut	*Passed*	North Carolina	*Active*
Delaware	*Deferred until 2027*	Ohio	*Active*
Georgia	*Deferred until 2027*	Oklahoma	*Deferred until 2027*
Hawaii	*Deferred until 2027*	Oregon	*Deferred until 2027*
Idaho	*Deferred until 2027*	Pennsylvania	*Active*
Illinois	*Deferred until 2027*	Rhode Island	*Active*
Indiana	*Deferred until 2027*	South Carolina	*Deferred until 2027*
Iowa	*Deferred until 2027*	Utah	*Passed*
Maine	*Passed*	Vermont	*Passed*
Maryland	*Passed*	Virginia	*Passed*
Massachusetts	*Passed one chamber*	Washington	*Deferred until 2027*
Michigan	*Active*	Washington, D.C.	*Active*
Minnesota	*Passed one chamber*	Wyoming	*Deferred until 2027*
Missouri	*Deferred until 2027*		

Legend

Passed | Passed one chamber | Active | Deferred until 2027

8.4 DEVELOPING STANDARDS

The existing UL 1741 certification standard has served as the primary safety certification for grid-tied solar inverters for over two decades and has been the foundation for the safe deployment of millions of rooftop solar installations across the United States. Its anti-islanding protection requirement (Clause 9.3) applies identically to rooftop and plug-in solar inverters, and the safety record documented in this paper—zero lineworker injuries from certified inverter backfeed—reflects the effectiveness of UL 1741 across all deployment contexts. Multiple OSHA-recognized NRTLs are authorized to certify products to UL 1741, providing competitive certification pathways (see Section 6.3). The success of UL 1741 in protecting lineworker safety should not be overlooked while the newer UL 3700 framework develops.

UL Solutions released preliminary certification criteria (UL-3700) for plug-in PV systems in December 2025, establishing a pathway for product safety certification specifically designed for plug-in solar devices [31]. Lawrence Berkeley National Laboratory and GismoPower, with DOE Solar Energy Technologies Office funding, are actively collaborating on developing standards and resolving the technical barriers identified in the LBNL study [1].

However, UL 3700 remains in its early stages. Industry participants have characterized it as an Outline of Investigation rather than a fully developed standard—essentially a system-level framework that evaluates how all components of a plug-in solar system work together, in addition to existing component certifications such as UL 1741 for inverters [31]. Certification costs are expected to be substantial—potentially in the hundreds of thousands of dollars—creating a significant barrier to market entry for smaller manufacturers. As of May 2026, no products have yet received UL 3700 certification, and companies are unlikely to obtain certification until late 2026 at the earliest.

Policymakers should not condition plug-in solar deployment on UL 3700 availability when UL 1741 already provides the critical lineworker safety protection—anti-islanding—that is the focus of this paper. Legislation should reference “UL 1741 or equivalent NRTL certification” as the baseline safety requirement, with UL 3700 recognized as a complementary system-level standard as it matures.

9. POLICY RECOMMENDATIONS

Based on the evidence reviewed in this analysis, and informed by the legislative frameworks already enacted or advancing in multiple states, the Southern Alliance for Clean Energy recommends the following policy positions for state utility commissions, investor-owned utilities, cooperative governing boards, and municipal utility authorities in the southeastern United States:

9.1 RECOMMENDATION 1: RISK-TIERED INTERCONNECTION FRAMEWORK

Interconnection requirements should be explicitly tiered by wattage and by the presence or absence of certified anti-islanding protection, consistent with the approach taken by several states with signed legislation:

- **Sub-420 watts with UL 1741-certified microinverter:** No interconnection application, no utility agreement, no fees, and no inspection required—equivalent to the plug-and-play treatment of other appliances. Colorado enacted a similar exemption, set at a 391W threshold. At 420W, a plug-in solar system produces no more than 3.5A at 120V—the same safety buffer used in Germany for 800W systems on 230V circuits—which eliminates any breaker-masking risk on standard 15- or 20-amp household circuits, even in worst-case wiring configuration. No breaker-masking protection is required.
- **420–2,400 watts with UL 1741-certified microinverter:** System registration with the utility; no physical inspection requirement. Systems in this range remain within the rated capacity of standard 20-amp household circuits but may require breaker-masking protections (such as a UL 3141-certified Power Control System, a panel-installed circuit-monitoring device, or installation on a dedicated circuit) depending on the wiring configuration.
- **Over 2,400 watts, or any system without UL-certified microinverter:** May warrant a more robust interconnection review consistent with current rules.

The National Electrical Code (NEC) already establishes the safe capacity limits for residential circuits. A standard 20-amp household circuit at 120 volts has a total capacity of 2,400W. The NEC's 80% derating rule for continuous loads (1,920W on a 20A circuit; 1,440W on a 15A circuit) applies specifically to loads "expected to continue for 3 hours or more" under NEC Article 100 [14]. Plug-in solar units do not meet this definition in practice: even a 2,400W system reaches its rated output only briefly around solar noon under ideal conditions. As a result, the 80% derating does not bind plug-in solar at its rated wattage, and the full 2,400W capacity of a 20A circuit can be safely utilized when paired with appropriate breaker-masking protections such as a UL3141-certified Power Control System, a panel-installed circuit-monitoring device, or when plugged onto a dedicated circuit. Legislation that caps plug-in solar at 1,200 watts is therefore substantially more restrictive than what the NEC itself requires for safety. For households seeking higher capacities, hiring a licensed electrician to install a dedicated circuit or upgrade to a 240-volt outlet—typically costing a few hundred dollars—provides a pathway under existing NEC and UL frameworks. Restricting all plug-in solar to 1,200 watts without offering a pathway for higher capacities through proper electrical work may unnecessarily limit solar deployment.

The NEC also does not impose a household level cap on the number of plug-in solar systems a homeowner may install. Each system must independently meet branch circuit and overcurrent protection requirements under NEC Articles 210 and 240, but a homeowner who installs multiple dedicated circuits—for example, two separate 20-amp circuits each serving a 2,000W system—is operating entirely within the framework the NEC already provides. Service-panel-level capacity provisions under NEC Article 705 may apply to the combined system size, particularly for installations approaching the service entrance rating [14]. Legislation that caps households at one system per service address is therefore more restrictive than existing electrical code requirements and unnecessarily limits the deployment of a technology that households are otherwise free to install.

9.2 RECOMMENDATION 2: EQUIVALENT GENERATOR STANDARDS

If utilities or any other organization assert lineworker safety as a basis for solar interconnection requirements, the same regulatory logic must be applied consistently to portable generators. NEC Article 702 requires transfer switches but imposes no automatic anti-islanding protection and no utility notification or approval process [14]. Any utility requiring a solar interconnection agreement for sub-2,400-watt systems should be required to demonstrate why portable generators at equivalent or greater wattage do not trigger equivalent requirements.

9.3 RECOMMENDATION 3: EVIDENCE-BASED REGULATORY REVIEW

State public utility commissions may initiate a formal review of residential distributed generation interconnection rules, with specific direction to assess whether current requirements for sub-2,400-watt plug-in solar systems are proportionate to documented safety risks. This review should incorporate: OSHA and NIOSH fatality data [6]; UL 1741 [2] and IEEE 1547-2018 certification requirements [3]; the IEA-PVPS islanding risk quantification study [4]; the LBNL barrier analysis [1]; and legislative frameworks enacted.

As part of this review, commissions should specifically evaluate whether requirements for external disconnect switches remain justified for systems equipped with UL 1741-certified or equivalent NRTL-certified inverters. The evidence reviewed in this paper demonstrates that certified inverters provide automatic disconnection within 2 seconds of grid failure—a hardware-based protection that renders an external manual disconnect switch redundant for lineworker safety purposes. Removing external disconnect switch requirements from interconnection tariffs for certified systems would eliminate an unnecessary cost and installation barrier without compromising safety.

More broadly, the safety of plug-in solar—like the safety of any household appliance—is established and continuously updated by independent certification bodies (UL, ETL, and other NRTLs), by the National Electrical Code and by IEEE standards. These bodies have the technical expertise, the testing infrastructure, and the institutional incentives to set safety requirements that reflect current engineering knowledge. Legislation works best when it respects this division of labor: certification and code bodies establish what is safe, and legislation establishes the administrative pathway by which homeowners can use safe, certified products on their own property without unnecessary regulatory burden.

9.4 RECOMMENDATION 4: TRANSPARENCY IN RULEMAKING

Any utility seeking to impose or maintain interconnection requirements on plug-in solar systems should be required to provide specific, verifiable, technically-documented safety justifications—not generic safety language—and to address directly the differential regulatory treatment of generators with equivalent or greater power output and no automatic safety protections.

CONCLUSION

The evidence is unambiguous. Portable gas and diesel generators have a documented, confirmed record of causing lineworker fatalities through the specific mechanism—transformer-stepped backfeed onto distribution lines assumed to be de-energized—that utility interconnection rules are designed to prevent. Plug-in solar units with UL 1741-certified microinverters have never caused a lineworker injury through this or any other mechanism, a record confirmed by the utility safety industry's own publications, by peer-reviewed risk quantification studies conducted under the International Energy Agency and reviewed by the U.S. National Renewable Energy Laboratory, and by a DOE-funded barrier analysis from Lawrence Berkeley National Laboratory.

The anti-islanding protection built into certified solar inverters is automatic, hardware-based, and independent of user behavior—making it categorically superior to the transfer switch requirements applied to generators, which depend entirely on homeowner knowledge, installation, and behavior under stress.

This paper has been careful to acknowledge that no electrical source is entirely without theoretical risk, and that non-certified or malfunctioning certified equipment can present genuine hazards. But the regulatory question is not whether risk is theoretically conceivable—it is whether the level of risk justifies the level of regulation imposed. By every available metric—documented fatalities, peer-reviewed risk quantification, industry safety publications, DOE-funded national laboratory research, and the bipartisan legislative consensus now emerging across the country—the answer for UL 1741-certified plug-in solar under 2,400 watts is clearly no.

No scientifically credible safety rationale supports the current regulatory environment in which a 400-watt plug-in solar unit with a certified microinverter faces heavier regulatory scrutiny than a 5,000-watt gasoline generator. The asymmetry does not reflect safety evidence, and should be corrected through risk-tiered, evidence-based regulatory reform.

Finally, plug-in solar is not inherently limited to 120-volt systems. Dedicated 240-volt circuit configurations supporting significantly higher output are technically feasible under existing NEC and UL frameworks. The case for their equitable regulation falls outside the scope of this analysis, which addresses 120-volt systems, and will be addressed in a forthcoming SACE whitepaper.

ACKNOWLEDGEMENTS

We would like to thank the following individuals for their review and feedback on this paper: Achim Ginsberg-Klemmt (GismoPower); Erika Ginsberg-Klemmt (GismoPower); Mark Leidlein (Solar120); Nathan Phelps (Vote Solar); Stephan Scherer (CraftStrom Solar); Cora Stryker (Bright Saver); Dan Terpstra, Ph.D.; and Eric Wigginton (Efficient Power & Light, LLC). We also thank several additional reviewers who wished to remain anonymous.

ACRONYMS

AC	Alternating Current
AGBF	German Association of Fire Chiefs
ASTM	American Society for Testing and Materials (now ASTM International)
CFOI	Census of Fatal Occupational Injuries
CFR	Code of Federal Regulations
CSA	Canadian Standards Association (now CSA Group)
CUSP	Certified Utility Safety Professional
DC	Direct Current
DER	Distributed Energy Resource
DG	Distributed Generation
DHHS	Department of Health and Human Services
DOE	Department of Energy
ESFI	Electrical Safety Foundation International
FACE	Fatality Assessment and Control Evaluation
FREIE	Federated Rural Electric Insurance Exchange
HTW	Hochschule für Technik und Wirtschaft (HTW Berlin)
IAEI	International Association of Electrical Inspectors
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
KTL	Korea Testing Laboratory
LBNL	Lawrence Berkeley National Laboratory
LOTO	Lockout/Tagout
NEC	National Electrical Code
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NLR	National Laboratory of the Rockies
NRECA	National Rural Electric Cooperative Association
NREL	National Renewable Energy Laboratory (now NLR)
NRTL	Nationally Recognized Testing Laboratory
OSHA	Occupational Safety and Health Administration
OSHRC	Occupational Safety and Health Review Commission
PIPV	Plug-in Photovoltaic
PV	Photovoltaic
PVPS	Photovoltaic Power Systems Programme
PPGs	Personal Protective Grounds
SA	Supplement A (UL 1741)
SACE	Southern Alliance for Clean Energy
SB	Supplement B (UL 1741)
UL	UL Solutions (formerly Underwriters Laboratories)

CITATIONS AND SOURCES

[1] Gerber, Daniel L.; Ginsberg-Klemmt, Achim; et al. "Barriers to Balcony Solar and Plug-In Distributed Energy Resources in the United States." *Energies* 2025, 18(8), 2132. Funded by Lawrence Berkeley National Laboratory (LBNL) and U.S. DOE. https://doi.org/10.3390/en18082132

[2] UL Solutions. *UL 1741: Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources* (3rd Edition, 2021; updated March 10, 2026). Clause 9.3 mandates anti-islanding testing with 2-second disconnection requirement. https://www.shopulstandards.com/ProductDetail.aspx?productId=UL1741

[3] Institute of Electrical and Electronics Engineers (IEEE) Standards Association. *IEEE Std 1547-2018: Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*. April 6, 2018. Establishes technical interconnection requirements including anti-islanding protection. https://standards.ieee.org/ieee/1547/5915/

[4] Cullen, Neil; Thornycroft, Jim; and Collinson, Alan. *Risk Analysis of Islanding of Photovoltaic Power Systems Within Low Voltage Distribution Networks*. International Energy Agency Photovoltaic Power Systems Programme (IEA-PVPS), Report T5-08:2002. March 2002. Formal fault-tree analysis concluding islanding shock risk is less than one in one billion per year. https://iea-pvps.org/key-topics/risk-analysis-of-islanding-of-photovoltaic-power-systems-within-low-voltage-distribution-networks-2002/

[5] Narang, David; Gonzalez, Sigifredo; and Ingram, Michael. *A Primer on the Unintentional Islanding Protection Requirement in IEEE Std 1547-2018*. National Renewable Energy Laboratory, NREL/TP-5D00-77782. April 2022. Cites IEA-PVPS risk findings. https://docs.nrel.gov/docs/fy22osti/77782.pdf

[6] National Institute for Occupational Safety and Health (NIOSH). *Worker Deaths by Electrocution: A Summary of NIOSH Surveillance and Investigative Findings*. Department of Health and Human Services (DHHS) Publication No. 98-131. May 1998. Contains 224 FACE electrocution investigative reports including Cases 90-02 and 90-05 (generator backfeed fatalities). https://www.cdc.gov/niosh/docs/98-131/

[7] Rossetter, Shelley. *Improperly Connected Generators Put Emergency Workers at Risk*. The Ledger. October 2, 2009. https://www.theledger.com/story/news/2009/10/03/improperly-connected-generators-put-emergency-workers-at-risk/26213670007/

[8] U.S. Occupational Safety and Health Review Commission (OSHRC). *OSHRC Docket No. 06-0166: Secretary of Labor, Complainant v. Pike Electric, Inc., Respondent.* February 5, 2007. https://www.oshrc.gov/wp-content/uploads/06-0166.pdf

[9] "Backfed Generator Kills Lineman." *Homesteading Today*, September 2009. Linemen discuss their close calls and firsthand eyewitness accounts of hazardous events related to generators. https://www.homesteadingtoday.com/threads/back-fed-generator-kills-line-man.226280/

[10] Caro, Mike, CUSP. “Distributed Generation Safety for Lineworkers.” *Incident Prevention*, July 15, 2014. https://incident-prevention.com/blog/distributed-generation-safety-for-lineworkers/

[11] Utah State Legislature. HB 340: Solar Power Amendments. https://le.utah.gov/~2025/bills/static/HB0340.html

[12] Virginia General Assembly. SB 250 / HB 395. Signed into law, April 2026. https://lis.virginia.gov/bill-details/20261/HB395

[13] “States with Plug-in Solar Legislation.” Bright Saver, June 1, 2026. Reports 35 states and DC with introduced plug-in solar legislation as of June 2026. https://www.brightsaver.org/publicly-filed-states

[14] National Fire Protection Association (NFPA). *NFPA 70: National Electrical Code* (2023). Articles 702 (Optional Standby Systems) and 705 (Interconnected Electric Power Production Sources). https://www.nfpa.org/codes-and-standards/nfpa-70-standard-development/70

[15] Electrical Safety Foundation International (ESFI). *Workplace Electrical Fatalities: 2011–2023*. Compiled from U.S. Bureau of Labor Statistics Census of Fatal Occupational Injuries (CFOI) and U.S. Department of Labor Occupational Safety and Health Administration (OSHA) 170 reports. Data shows an average of approximately 150 workplace electrical fatalities per year. https://www.esfi.org/electrical-fatalities-in-the-workplace-2011-2023/

[16] National Institute for Occupational Safety and Health (NIOSH). *Electrical Safety: Safety and Health for Electrical Trades Student Manual*. DHHS Publication No. 2009-113. April 2009. https://www.cdc.gov/niosh/docs/2009-113/

[17] Short, T. A. *Electric Power Distribution Handbook*. CRC Press, 2004. ISBN 978-0849317910.

[18] Indiana Electric Cooperatives. “Generator Backfeed is Dangerous and Potentially Deadly.” May 31, 2014. https://www.indianaec.org/2014/05/31/generator-backfeed-dangerous-potentially-deadly/

[19] Middle Tennessee Electric. “Beware of Backfeed.” Utility acknowledgment that generators are the primary source of dangerous backfeed incidents. https://mte.com/beware-backfeed

[20] Bergner, J. *Brief Report: Plug-In Solar Panel 800W*. Berlin University of Applied Sciences (HTW Berlin), February 2025. https://solar.htw-berlin.de/publikationen/kurzbericht-steckersolar-800-w/.

[21] Occupational Safety and Health Administration (OSHA). *Electric Power Generation, Transmission, and Distribution: Industry Hazards*. References NIOSH FACE reports, OSHA 1910.269, and electrical safety standards. https://www.osha.gov/power-generation/industry-hazards

[22] Mabe, Jerone. “Solar Backfeed Safety on Distribution and Secondary Circuits.” *Incident Prevention*, April 14, 2024. https://incident-prevention.com/blog/solar-backfeed-safety-on-distribution-and-secondary-circuits/

[23] Verhoeven, Bas. *Probability of Islanding in Utility Networks Due to Grid-Connected Photovoltaic Power Systems*. International Energy Agency Photovoltaic Power Systems Programme (IEA-PVPS), Report T5-07:2002. September 2002. https://iea-pvps.org/key-topics/probability-of-islanding-in-utility-networks-due-to-grid-connected-photovoltaic-power-systems-2002/

[24] National Rural Electric Cooperative Association (NRECA) and Federated Rural Electric Insurance Exchange (FREIE). *Commitment to Zero Contacts: Implementation Guide for Field Personnel*. https://www.cooperative.com/programs-services/safety-resap/commitment-to-zero/

[25] ASTM International. *ASTM F855-20: Standard Specifications for Temporary Protective Grounds to Be Used on De-Energized Electric Power Lines and Equipment.* February 28, 2023. https://store.astm.org/f0855-20.html

[26] MET Laboratories (Eurofins). "UL 1741: The Standard for Anti-Islanding Protection." August 3, 2023. Describes Clause 9.3 anti-islanding test procedure: 2-second disconnection requirement, tested at 33%, 66%, and 100% rated output power. https://metlabs.com/product-safety/ul-1741-safety-testing-of-inverters-includes-anti-islanding-requirement/

[27] Solar Builder Magazine. "Smart PV Inverter Overview: IEEE 1547-2018 and UL 1741 Explained." Technical Bulletin, March 6, 2023. Details UL 1741 base standard, Supplement A (SA), and Supplement B (SB) testing requirements and their relationship to IEEE 1547-2018 grid-support functions. https://solarbuildermag.com/inverters/smart-pv-inverter-overview-ieee-1547-2018-and-ul-1741-explained/

[28] California Energy Commission. "Changes to the Inverter and Energy Storage System Lists: UL 1741 3rd Edition Inclusive of Supplement SB." Requires certification "from a NRTL whose OSHA Scope of Recognition includes UL 1741"—explicitly accepting any OSHA-recognized NRTL. https://www.energy.ca.gov/sites/default/files/2022-03/Addition_of_UL_1741_3rd_Ed_Supplement_SB_to_the_Solar_Equipment_Lists_ADA.pdf

[29] Occupational Safety and Health Administration (OSHA). *Nationally Recognized Testing Laboratory (NRTL) Program, 29 CFR 1910.7*. OSHA states: "OSHA considers all NRTLs recognized under 29 CFR 1910.7 to be equivalent in their 'capability' to certify to the standards in their scope of recognition. OSHA does not dictate to manufacturers which NRTL they must use." https://www.osha.gov/nationally-recognized-testing-laboratory-program

[30] International Association of Electrical Inspectors (IAEI). "The NEC, Standards, OSHA, NRTLs, and Beyond." November 2021. Lists Intertek (ETL), CSA Group, MET Laboratories, and TÜV Rheinland as OSHA-recognized NRTLs for UL 1741, confirming federal equivalency of all recognized testing laboratories. https://iaeimagazine.org/columns/photovoltaic/the-nec-standards-osha-nrtls-and-beyond/

[31] UL Solutions. *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

Southern Alliance for Clean Energy (SACE)

cleanenergy.org