FRANKLINWH

Quantifying Residential Backup Power **Reliability**

White Paper with Initiatives

Overview

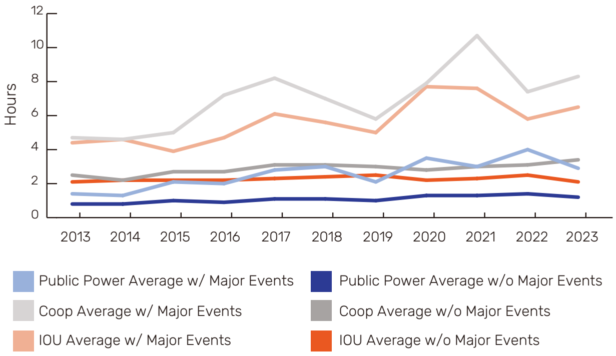
Power outages occur frequently across North America and they're lasting longer. Extreme weather events and aging electrical infrastructure have intensified threats to home safety and property. Traditional generators suffer from low backup takeover rates due to maintenance challenges, unreliable startup and other issues, while residential energy storage systems lack unified design and evaluation standards centered on backup power reliability, making it difficult for users to obtain stable and reliable power supply at critical moments.

FranklinWH draws upon the ANSI/TIA-942 Reliability Tier System to propose a Level I–IV quantification methods for residential energy storage, using "reliability" and "annual downtime" as unified metrics. The system ranges from entry-level 99.65% (approximately 30.6 hours/year) to the highest level of 99.9999999% (≤8.3 ms/year), creating a clear step-by-step progression. This framework is built upon each product's AC-coupling characteristics and reliability design, accommodating single-unit, parallel, multi-source integration, and fault-tolerant architectures across all domains, supplemented by measured failure rates of 0.30%[1] for validation. This helps transform the concept of "reliable power supply" into a quantifiable framework, providing clear reference methods for all parties and charting a path for industry-wide standardization.

Current Status and Challenges

Electricity is a critical safeguard for home, health, and property security. The growth of energy-intensive industries such as manufacturing and data centers has significantly increased demands for electricity while extreme weather events are coupled with aging electrical infrastructure, leading to frequent large-scale power outages. Trends show that U.S. residential power outage durations have increased: since 2013, average outage durations have fluctuated between approximately 3-8 hours, with significant increases in 2017, 2020, and 2021 due to extreme weather events. According to Energy Information Administration (EIA) statistics, the average residential power outage duration in 2023 was approximately 6.3 hours (including major events). In disaster-prone states, the duration is often longer. Typical examples include: Hurricane Beryl in 2024 caused 3 million households in Texas to lose power, with 1 million still awaiting restoration after three days; The 2021 cold snap left 4.5 million households in Texas without power; Hurricane Helene in 2024 affected 10 states, causing 2.8 million households to lose power; and spring storms in 2025 also left 700,000 households in the central and eastern regions without power. Improper handling of sudden power outages can cause irreversible damage to daily life and property security within hours. For example, spoilage of refrigerated medications, inconvenience for vulnerable populations, quality degradation or spoilage of fermentation materials in wine cellars, and reduced yields or withering of indoor plants.

[1] Source：DNV，2023.7–2024.11 FranklinWH System Market Report.



Source: Energy Information Administration Form EIA-861, 2023.
System average interruption duration index (SAIDI), IEEE standard, in hours.

Figure 1: Average duration of electric outages by utility type, 2013-2023

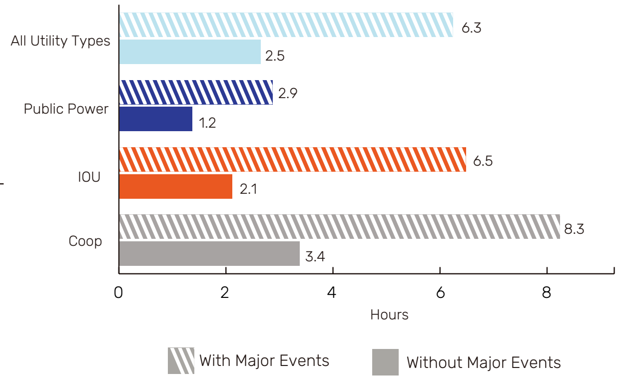


Figure 2: Average duration of electric outages by utility type, 2023

Many American households still rely on diesel or natural gas generators to cope with power outages, but their backup takeover rate is less than 60%[2] due to cold start failures, fuel shortages, or poor maintenance. Although the residential energy storage systems are considered as smarter, cleaner alternatives, but the industry lacks design and verification standards for backup power reliability. Many existing solutions face challenges such as switching delays or inconsistent output, highlighting the need for more unified reliability standards.

The industry urgently needs reliability-focused evaluation methods and verification mechanisms. Right now, customers don't have a quantitative basis to guide their purchasing decisions, and there's no guarantee that systems will work reliably once installed. To address these issues, proven reliability standards from data centers should be adopted for residential energy storage systems, constructing a more rigorous assessment framework that offers clear guidance for future industry standardization.

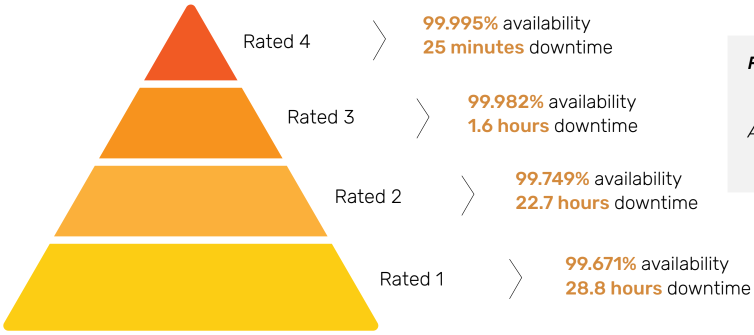
Why Use Reliability Standards for Data Centers?

More Authoritative, More Widely Applied, Quantifiable

The ANSI/TIA-942 Telecommunications Infrastructure Standard for Data Centers is developed by the Telecommunications Industry Association (TIA) and recognized by the American National Standards Institute (ANSI). It has been widely adopted globally, covering critical industries such as cloud services, finance, and healthcare. Its indicator system is based on rigorous standards, forming a mature and quantifiable methodology. By borrowing from this authoritative approach, FranklinWH achieves quantified and transparent assessment of residential energy storage backup power reliability through two major indicators: "Reliability" and "Downtime".

[2] Source：Based on Weibull function modeling and industry annual MTBF data, the estimated takeover success rate for traditional home generators during critical moments is approximately 60%.

This not only helps users precisely match critical loads with product capabilities, avoiding over- or under-configuration, but also enables them to clearly predict power supply coverage and duration during outages, obtaining robust and reliable power protection at critical moments.



Formula:

$$Availability = \frac{TotalTime - Downtime}{TotalTime} = 1 - \frac{Downtime}{TotalTime}$$

Downtime: Evaluates the total accumulated time during which the system is unavailable due to component replacement or maintenance caused by failures.
Availability: The proportion of time a system remains in normal operational condition within a specified period.

Figure 3: ANSI/TIA-942 Telecommunications Infrastructure Standard for Data Centers

FranklinWH Products Align with UPS Architecture Design for Data Centers

In terms of operating modes, UPS systems are online, while FranklinWH's residential energy storage systems are on standby. The only difference is that residential energy storage systems require relay switching during on-grid/off-grid mode transitions. To enhance reliability, FranklinWH uses time-tested relays, the ones the American power industry has relied on for over 40 years, combined with proprietary timing control technology[3], achieving precise switching, zero-crossing switching, and zero-load engagement, effectively reducing impact and malfunction risks. The overall reliability approaches UPS levels. Meanwhile, the AC-coupled architecture supports multi-source integration with design concepts highly consistent with UPS redundancy design.

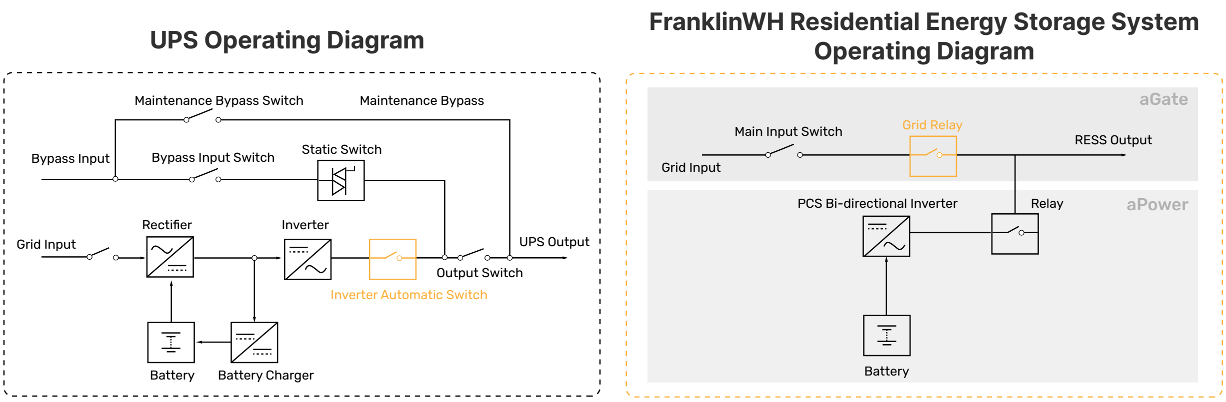


Figure 4: Comparing FranklinWH and UPS Systems

[3] Source: FranklinWH Patent US12107428B2, method for seamless switching between off-grid and grid-connected and household energy storage system.

How to Quantify Backup Power Reliability

FranklinWH Level I Backup Power Reliability Implementation Path

Data center R1 uses a UPS single-phase power supply to ensure basic business continuity. FranklinWH's Level I single-unit system applies this same approach to residential energy storage. Both systems use the same power supply architecture, delivering entry-level reliability with basic configuration.

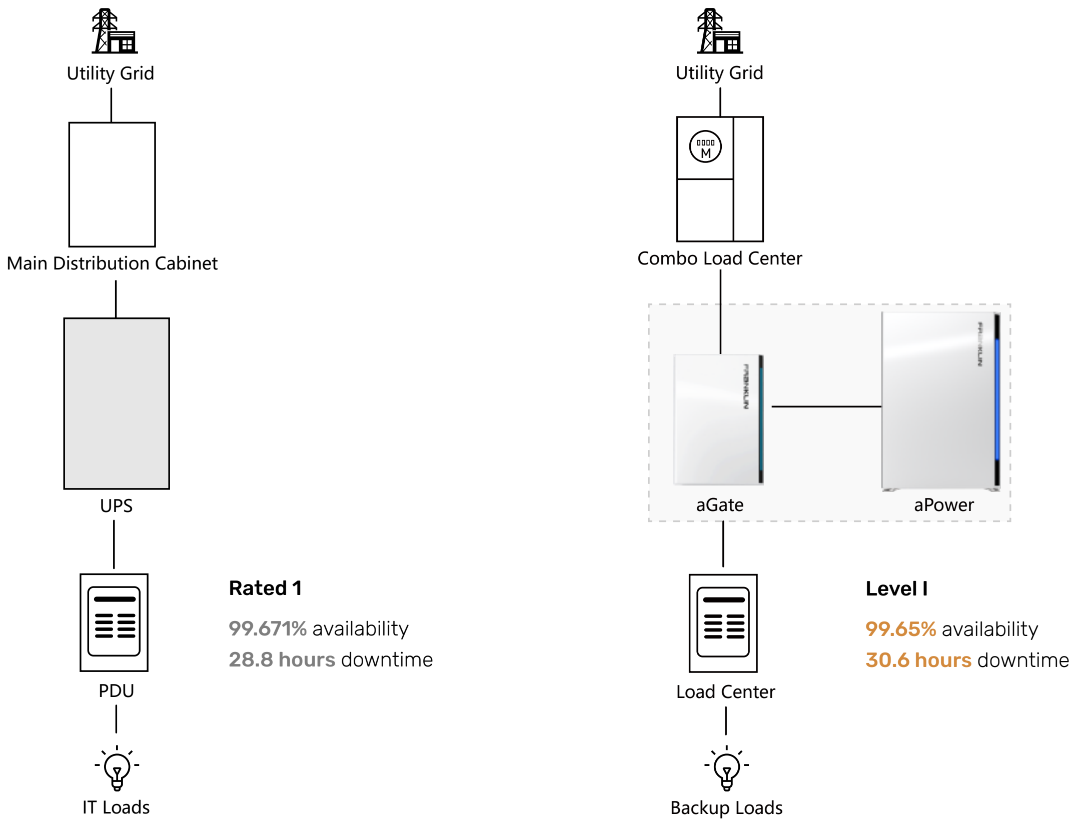


Figure 5: Comparing Data Center UPS and FranklinWH Single-Phase Systems

Key Technologies

- **Redundant auxiliary source design:** When the main power source is abnormal, the FranklinWH system controller can rely on auxiliary sources for continuous power supply, ensuring uninterrupted control, communications, and data upload, improving system safety and manageability.

- **Adaptive power allocation management:** Optimizes output characteristics, balance system protection and short-term overload requirements.

- **Wide-frequency adaptive damping control:** Significant wide-frequency vibration suppression capability, effectively eliminating low-frequency vibration and resonance; optimized dynamic performance improves anti-interference capability and system stability; adaptive control enhances current sharing and voltage sharing, ensuring long-term stable system operation.

- **Software redundancy design:** When Energy Management System (EMS) software experiences anomalies, the Power Control System (PCS) can automatically take over critical control logic, ensuring the system can operate stably even when the core management layer fails, avoiding power interruption and ensuring continuous power supply to critical loads.

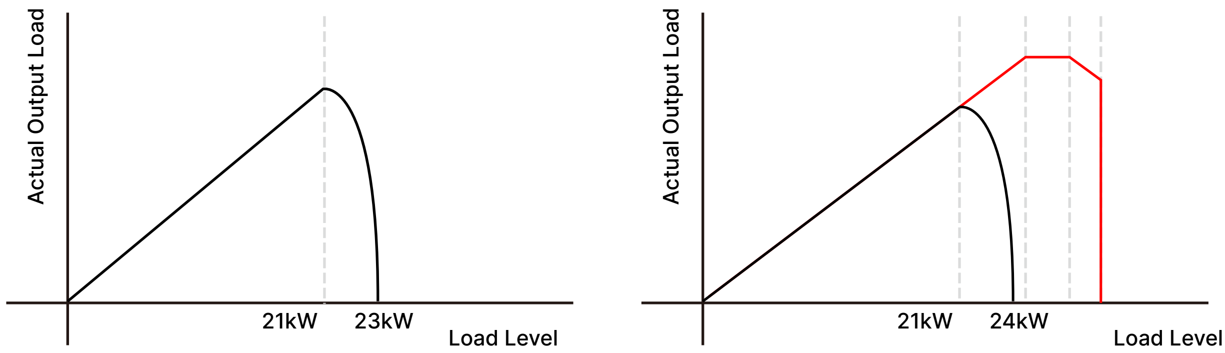


Figure 6: Traditional Solution Output Characteristics vs. FranklinWH Solution Output Characteristics

Reliability Design and Verification

Series system model failure rate (λ) analysis: The residential energy storage system consists of multiple critical functional modules, including BMS, PE modules, EMS modules, etc. Based on the reliability model of series systems, FranklinWH calculates the failure rate of each functional module within a 15-year lifecycle and reasonably allocates the overall reliability indicators of the system accordingly.

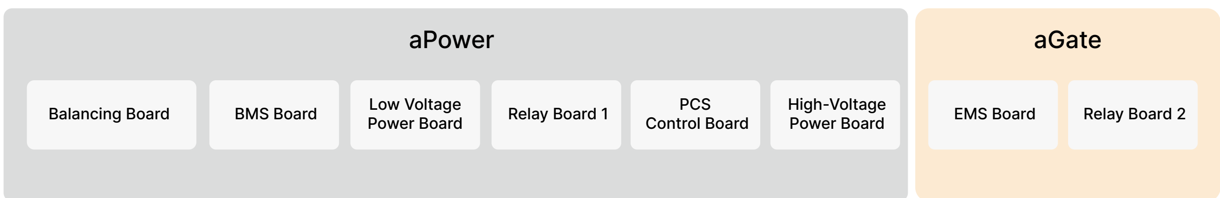


Figure 7: FranklinWH Series System Failure Rate Equivalent Model

Calculation formula： $R(t) = e^{-\lambda t}$

- R(t)：Reliability, representing the probability that the system/product can still work normally at time t, where t usually represents operating time
- λ：Failure Rate, reflecting the probability of system/product failure per unit time
- t：Observation time, i.e., the time point for evaluating reliability
- e：Natural constant (approximately 2.71828)

After calculation, $R_{aPower} = 99.8092\%;$ $R_{aGate} = 99.9985\%;$

Level I single-unit system annual reliability $R_{level\ I} = R_{aPower} \times R_{aGate} = 99.65\%;$

Corresponding Level I single-unit system annual $365 \times 24 \times (1 - R_{level\ I}) = 30.6h;$

FranklinWH's Level I architecture incorporates data center T1 basic power supply concepts, using inherent single-system reliability and fault tolerance to deliver entry-level uninterrupted protection for residential energy storage.

FranklinWH Level II Backup Power Reliability Implementation Path

Data center R2's limited redundancy architecture improves fault tolerance and reduces unplanned interruption risks by implementing redundant configuration of critical components, thereby improving infrastructure availability. FranklinWH's Level II architecture is the implementation of this approach. Compared to DC-coupled solutions, Level II can significantly reduce single point of failure impacts. Even when multiple devices are offline, remaining nodes can still provide stable power supply and support on-demand node additions to achieve balance between reliability and cost.

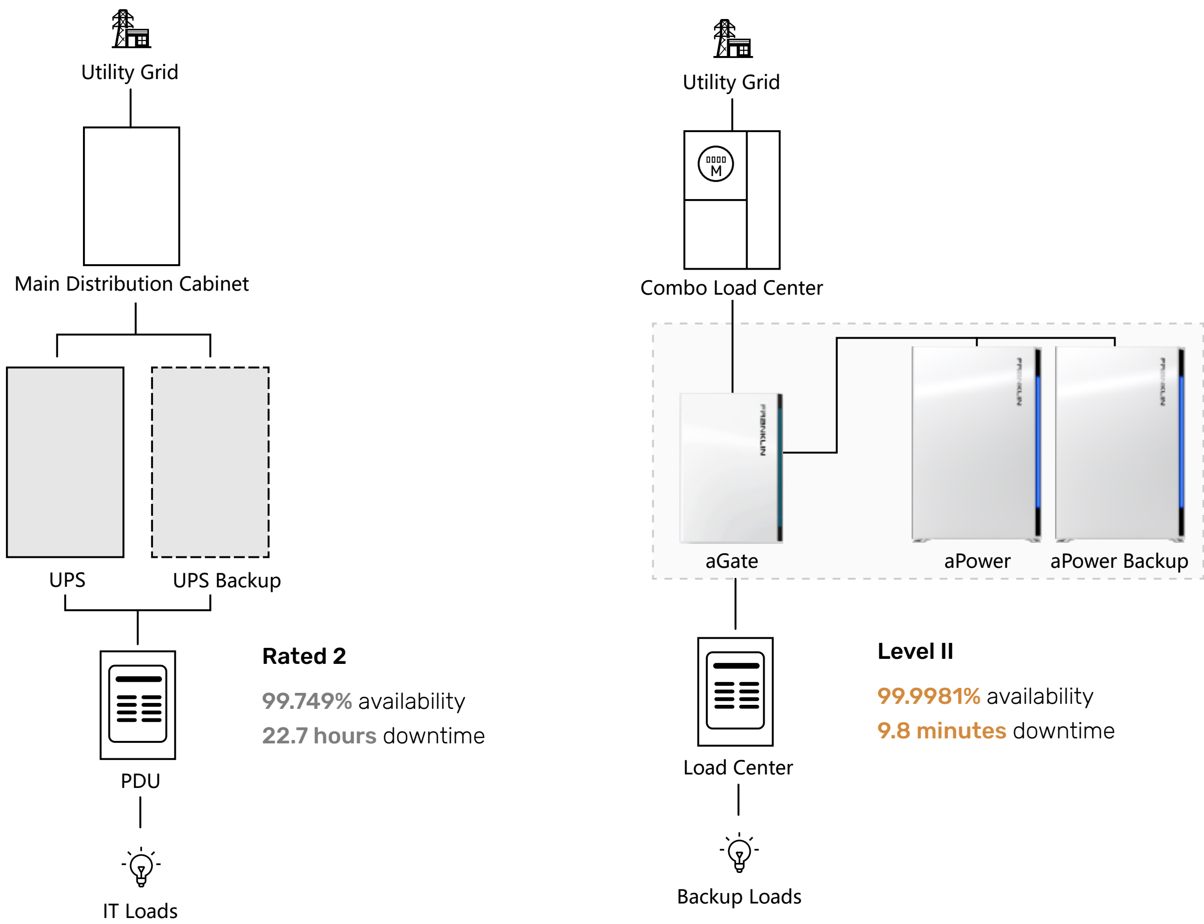


Figure 8: Data Center Rated 2 vs. Level II Redundant Architecture

Key Technologies

- **Multi-unit adaptive parallel control:** Supports parallel operation of up to 15 devices per controller, with excellent scalability.

- **Dynamic power balancing:** During multi-unit parallel operation, dynamic balanced power allocation is realized without relying on high-speed communication.

- **High-speed synchronous control architecture:** Achieves high integration of signal transmission at communication and control levels, greatly simplifying system **architecture, reducing hardware complexity, and ensuring stability and reliability during coordinated operation of multiple units.**

- **Dual-channel layered communications architecture:** Adopts high/low-speed CAN bus separation design, reasonably allocating communications channels according to data priority, achieving layered management of communication and control, significantly improving control instruction transmission efficiency and system response speed.

Reliability Design and Verification

$$R_{level\ II} = \left[1 - \left(1 - R_{aPower}\right)^2\right] \times R_{aGate} = 99.9981\%$$

Corresponding annual downtime ≤ 9.8 minutes

Through four key technologies that address multi-unit coordination stability issues, FranklinWH's Level II architecture provides highly reliable power supply protection for critical scenarios.

FranklinWH Level III Backup Power Reliability Implementation Path

The essence of data center R3 architecture is to achieve concurrent maintenance through redundant core power distribution networks, thereby eliminating planned downtime impacts and ensuring business continuity. FranklinWH has implemented the same approach in the residential storage industry: adopting dual-source switching and concurrent maintenance design to achieve long-term operation during grid failures, corresponding to high availability goals and uninterrupted maintenance windows (planned maintenance does not affect power supply). Therefore, FranklinWH's Level III architecture meets the same reliability standards as data center R3.

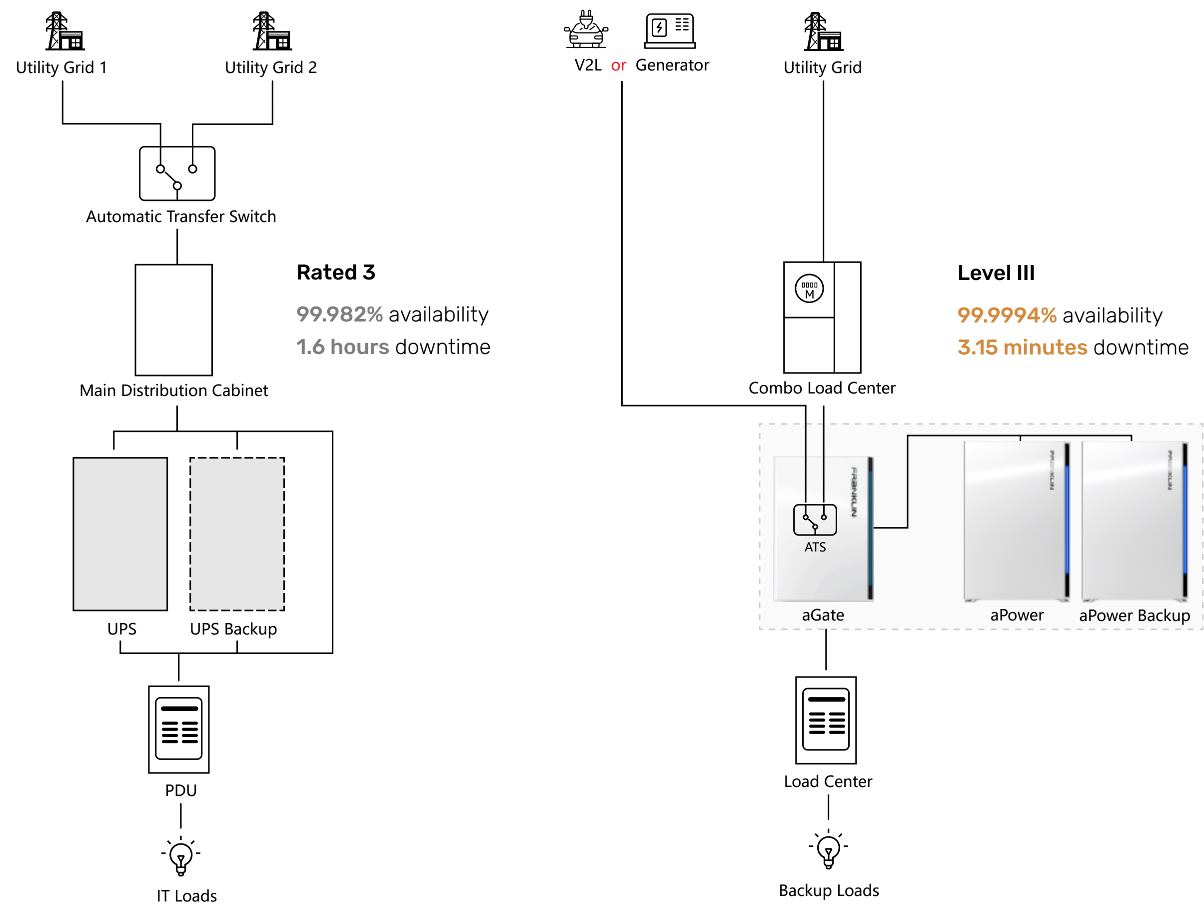


Figure 9: Data Center Rated 3 vs. Level III Multi-Source Architecture

Key Technologies

- Redundant Power Distribution Network Design: Uses two independent power paths. When one path needs maintenance, the other automatically handles the full electrical load, keeping power running without interruption.

- Optimized generator management system: The aGate supports smooth generator integration and intelligent switching, while the aPower reduces cold start failure and overheating occurrence rates by over 60% through compatibility algorithms (automatic warm-up, self-inspection). The system intelligently adjusts power to maintain efficient operation, which is expected to extend generator life by approximately 30%.

Reliability Design and Verification

$$R_{level\ III} = 1 - \left(1 - R_{Generator} \times R_{aGate}\right) \times \left(1 - R_{level\ II}\right) = 99.9994\%$$

Corresponding annual downtime: 3.15 minutes/year

According to industry data, $R_{Generator} = 66.46\%$ [4]

FranklinWH's Level III architecture, through dual-path independent configuration of power distribution networks combined with intelligent generator management technology, helps improve system stability and contributes to long-term reliability, building a solid foundation for home backup power reliability.

FranklinWH Level IV Backup Power Reliability Implementation Path

Data center R4 architecture builds fault-tolerant systems using physically-isolated redundancy across all domains, with automatic failover that can withstand any failure of single path/component. This achieves zero business interruptions and meets the highest continuity standards. FranklinWH Level IV takes the same approach: it uses two physically-isolated power paths, dual aGates, and PSL (PowerSync Link) synchronization technology. Through precise coordination, the backup system can seamlessly take over with undetectable switching, ensuring truly uninterrupted power from a technical perspective.

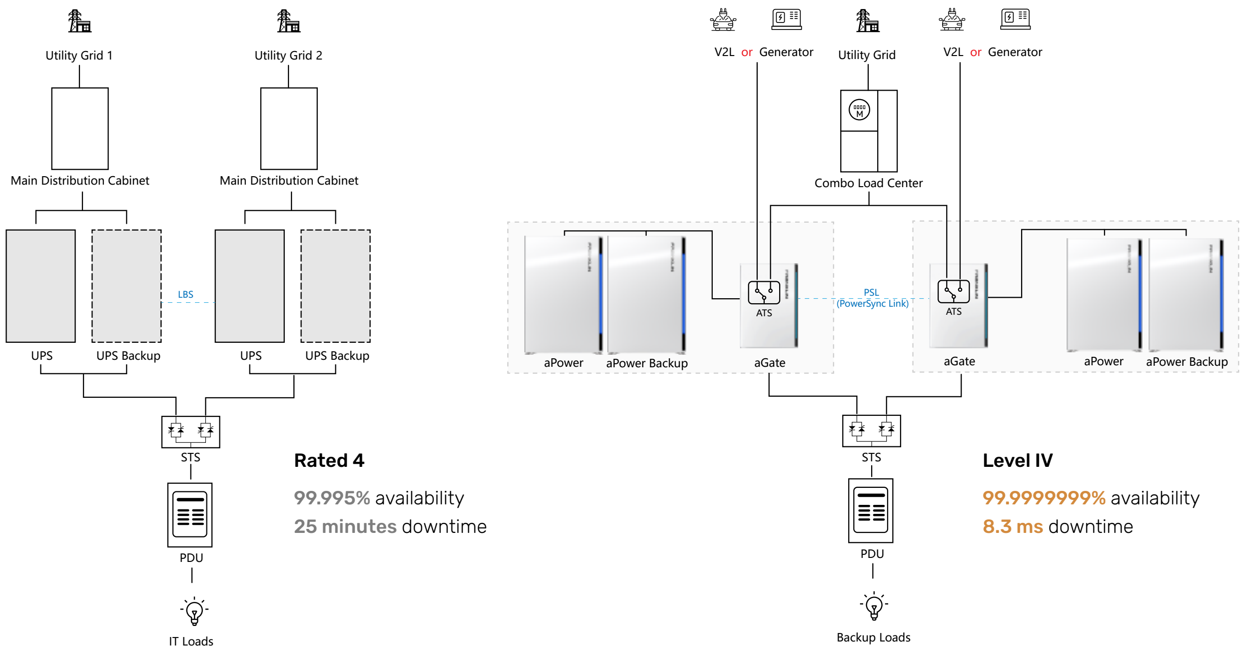


Figure 10: Data Center Rated 4 vs. Level IV Multi-Source + Redundant Architecture

Key Technologies

PowerSync Link (PSL) is the core technology for FranklinWH Level IV, synchronizing all inverter outputs to ensure consistent output frequency and phase.

- **Failover (redundancy protection):** When equipment fails, the PSL coordinates operational equipment to seamlessly take over, ensuring effective N+1 redundancy while maintaining continuous power to loads.

- **Hybrid input compatibility (overcoming single-source constraints):** Compatible with different bypass power sources such as diesel generators and multiple grid circuits, maintaining synchronization despite frequency variations. Also supports bypass and inverters from different transformers (such as dual grids + generator).

- **Phase synchronization (avoiding circulation):** Unified clock locks phase/frequency, avoiding circulation impact and module damage.

Reliability Design and Verification

$$R_{level\ IV} = 1 - \left(1 - R_{level\ III}\right)^2 = 99.9999999\%$$

Corresponding annual downtime $<$ 8.3ms/year.

The Level IV, based on dual physically-isolated redundant power distribution networks across all domains, along with dual aGates and PSL synchronization technology, practically guarantees "zero-interruption" home backup power.

Extremely Low Failure Rate

FranklinWH offers a tiered power supply and distribution solution system, progressing from Level I's basic configuration through Level II's power redundancy and Level III's dual power sources (i.e., energy storage and generator), to Level IV's dual-layer (gateway and power) fault-tolerant architecture. In real-world applications, multiple users reported that their FranklinWH Systems continued powering their homes during Hurricane Ian (2022), Hurricane Beryl (2024), and Hurricane Helene (2024), despite severe flooding and widespread grid outages, fully demonstrating the system's reliability. One elderly resident in Florida recalled that, after Hurricane Ian, floodwaters not only cut off all access to the outside world but also surged into his home. Yet, the FranklinWH battery system continued to operate reliably after the flood waters receded. Its steady blue indicator light became his most dependable source of reassurance, providing safety and peace of mind until normal conditions were restored.

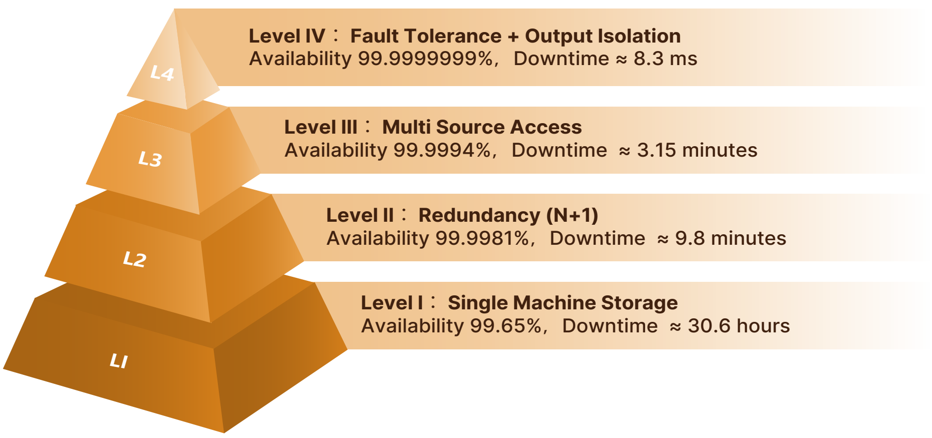
Additionally, field data from DNV reports (July 2023 - November 2024) shows that FranklinWH residential energy storage systems have only a 0.30% failure rate in real-world environments. This measured performance data, combined with the tiered architecture design, provides quantifiable reliability evidence to support informed decision-making and comparative evaluations across different application scenarios.

Proposed Initiatives for Industry, Installers, and Homeowners

FranklinWH encourages all stakeholders to collaborate on promoting the establishment of a unified reliability grading system for the residential energy storage industry. Standards bodies should incorporate residential backup power reliability into formal standards, develop clear grading specifications and evaluation methods, and provide a unified benchmark for the industry. Installers, by referencing the reliability grading system during system design and deployment, provide professional guidance to ensure systems are configured properly and reliably. Homeowners should consider their actual needs and make rational choices for storage solutions that match their power usage scenarios. Through these collaborative efforts, the industry can collectively advance toward a more systematic, standardized, and highly reliable development path.

Summary

As the energy transition accelerates, residential energy storage systems have long lacked unified, quantifiable evaluation standards, leading to competition focused on low prices and simplistic metrics. To address this gap, FranklinWH has adapted core concepts from ANSI/TIA-942 standards in data center telecommunications and infrastructure to develop a tiered home backup power reliability quantification method (Level I-IV), using annual Reliability and Downtime as key metrics. This quantification method provides users and product designers with quantifiable and transparent reliability references. As a result, customers no longer need to rely on parameter speculation, but instead make intuitive and rational assessments of product reliability based on clear classification and verifiable data, thereby achieving more transparent, comparable, and verifiable informed choices.



Moving forward, FranklinWH calls for industry-wide collaboration to establish reliability as a common language with quantified performance levels, driving the industry toward a safer, more efficient, and sustainable future.

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