

Industrial Micro-Grid Deployment Application Note: Factory Cleanroom Class-100,000 Certification

FACTORY INFRASTRUCTURE OBJECTIVES

The Factory Cleanroom Class-100,000 Certification represents a critical operational benchmark for advanced energy storage manufacturing and deployment environments. Under ISO 14644-1 and US FED-STD-209E classifications, a Class-100,000 cleanroom permits no more than 100,000 particles per cubic foot of air ($\geq 0.5 \mu\text{m}$), delivering a controlled contamination environment essential for high-precision lithium-ion cell assembly, electrolyte filling, module stacking, and BMS calibration. This application note outlines the integration of Class-100,000 certified manufacturing infrastructure with MWh-scale commercial and industrial (C&I) energy storage platforms, ensuring that every Tier-1 LFP cabinet, liquid-cooled battery pack, and PCS module is produced under audited particulate, temperature, and humidity control.



HIGH-DURABILITY ARBITRAGE ARCHITECTURE

The Class-100,000 certification framework supports continuous arbitrage operations by guaranteeing that cell-to-pack consistency remains within $\pm 1.5\%$ capacity deviation. The cleanroom environment minimizes metallic particle contamination, which is a leading cause of internal short circuits and premature capacity fade. By integrating positive-pressure airlocks, HEPA H13 filtration stages, and real-time particle counters, the facility achieves a 99.97% filtration efficiency for $0.3 \mu\text{m}$ particles. This architecture directly enables a 6,000-cycle @ 80% DoD warranty threshold and a 98.5% round-trip efficiency retention at the system level.

ANTI-RUNAWAY FEATURES

The Class-100,000 cleanroom incorporates multi-level thermal runaway suppression protocols. During cell stacking and module assembly, oxygen concentration is maintained below 2% in inert glovebox zones. The facility is equipped with early gas detection (VOC and CO sensors), automatic aerosol fire suppression, and pressure-relief ducting. These measures ensure that any anomalous thermal event is isolated within a 1 m³ zone, preventing propagation across the 215 kWh / 372 kWh cabinet lines.

COMPREHENSIVE SPECS

Nominal Capacity: 215 kWh / 372 kWh per cabinet

Cooling Method: Smart Liquid Cooling (50% glycol-water loop)

Cell Chemistry: Tier-1 LFP (LiFePO₄)

Cleanroom Class: ISO 14644-1 Class 8 (FED-STD-209E Class-100,000)

Particle Limit: ≤100,000 particles/ft³ (≥0.5 μm)

Air Changes Per Hour: 25–60 ACH with HEPA H13

Temperature Control: 22 ± 2 °C

Relative Humidity: 45 ± 5% RH

Positive Pressure: 10–15 Pa relative to adjacent zones

Fire Suppression: Novec 1230 + aerosol hybrid

BMS Communication: CAN 2.0B / Modbus TCP

Ingress Protection: IP54 (cabinet) / IP67 (module)

Certification: UL 9540, IEC 62619, UL 1973, CE

Parameter	Specification
Cleanroom Classification	ISO 14644-1 Class 8 / FED-STD-209E Class-100,000
Particle Limit ($\geq 0.5\ \mu\text{m}$)	$\leq 100,000$ particles per cubic foot
Air Filtration	HEPA H13, 99.97% @ $0.3\ \mu\text{m}$
Air Changes Per Hour	25–60 ACH
Temperature Range	$22 \pm 2\ ^\circ\text{C}$
Relative Humidity	$45 \pm 5\% \text{ RH}$
Positive Pressure	10–15 Pa
Nominal Capacity	215 kWh / 372 kWh per cabinet
Cooling Method	Smart Liquid Cooling
Cell Chemistry	Tier-1 LFP
Cycle Life	$\geq 6,000$ cycles @ 80% DoD
Round-Trip Efficiency	$\geq 98.5\%$ (DC-DC)
Certification	UL 9540, IEC 62619, UL 1973, CE

REGULATORY DIRECTIVES

The Factory Cleanroom Class-100,000 Certification aligns with the following

regulatory and quality directives: ISO 14644-1:2015 (Cleanrooms and associated controlled environments), US FED-STD-209E (Airborne particulate cleanliness classes), IEC 62619:2022 (Safety requirements for industrial lithium batteries), UL 9540:2023 (Energy storage systems and equipment), NFPA 855 (Installation of stationary energy storage systems), and ISO 9001:2015 (Quality management systems). Compliance is verified through quarterly third-party audits, continuous particle monitoring, and annual airborne microbial testing.

C&I TOPOLOGY

The C&I topology integrates the Class-100,000 certified manufacturing output with a modular outdoor cabinet architecture. Each cabinet houses 8–12 LFP modules in a 1P48S configuration, managed by a three-level BMS (cell, module, rack). The DC busbar supports parallel expansion up to 20 cabinets, yielding 4.3 MWh to 7.4 MWh per cluster. The PCS interface operates at 1,500 V DC maximum and 690 V AC grid-tied output, with seamless transfer to island mode within 20 ms. The EMS layer provides peak shaving, demand response, and time-of-use arbitrage scheduling via cloud and local HMI.

