

Huawei Hybrid-cooled GFM C&I Smart String ESS

Understand technicalities and channel into revenue stream



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Huawei: Leading provider of ICT infrastructure and smart devices



Vision and mission

Bring digital to every person, home and organization for a fully connected, intelligent world



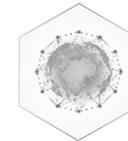
208,000
employees



54%
of employees work in R&D



170+
countries and regions



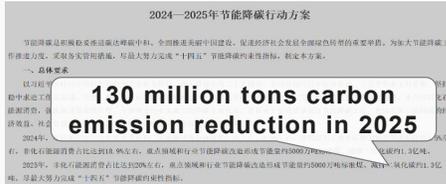
3 bn+
people served

Decarbonation, intelligence and electrification bring 3 key challenges to enterprises

Decarbonation

carbon control & carbon tax → green & new quality productive forces required

China: "2024-2025 Action Plan for Energy Conservation and Carbon Reduction"



EU: CBAM be taken effect in 2026, carbon tax raise the export cost of enterprises



EU: "Energy Performance of Building Directive", 0 carbon emission of buildings



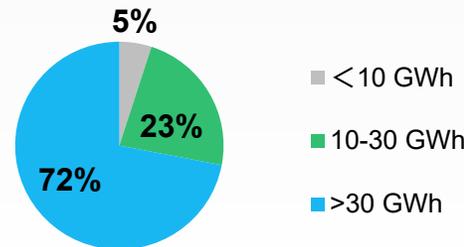
Intelligence

industries intelligent transformation → growth rate of electricity consumption exceeds 64% of GDP

Ubiquitous AI and intelligent transformation bring the growth rate of electricity consumption exceeds GDP by 64% 2024 YoY in China



Shenzhen 72% of medium and large manufacturing enterprises annual electricity consumption >30GWh



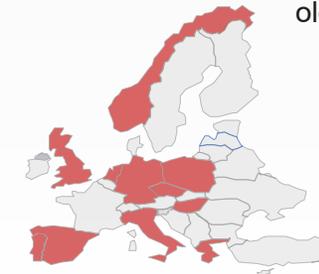
Electrification

more high-power equipment & aged grid → distributed grid congestion

Accelerating electrification increase the power demand. the global power demand for new EV will increase by 8X in the next six years



30% of Europe's distribution grids are over 40 years old



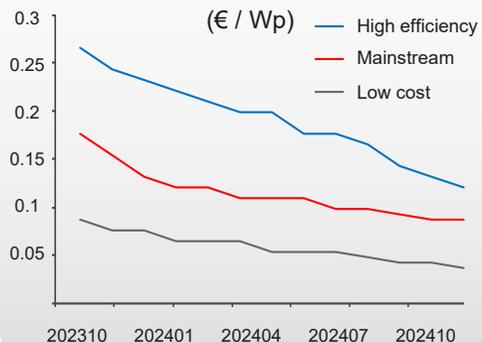
NL, IT, ES, DE, PT, PL, CZ, GR issued the grid capacity warning

Enterprises' green energy transformation is the only way towards success

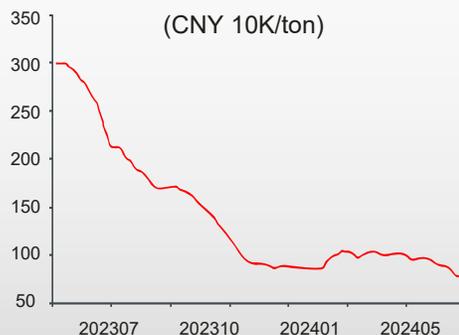
Four advantages accelerating enterprise green transformation and creating six business modes in typical industries

4 Factors Facilitate C&I PV+ESS Deployment

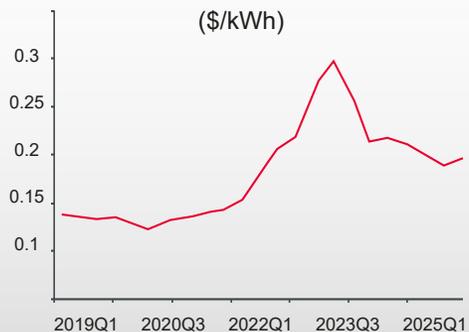
PV Module continuously decreased by 30%



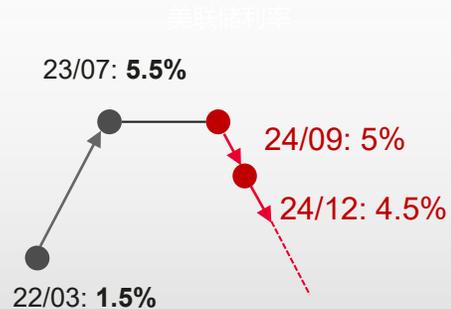
Lithium carbonate price dropped by 70%



Global C&I electricity price is steady upward



Investment driven by interest rate cut



China: high peak-valley tariff difference, EV charging explosive growth

- **Time of Use**
- **PBP: ~4 Years @Jiangsu hy-good semiconductor factory**
- **Grid Reinforce + Self-consumption**
- **PBP: ~4 Years @Shenzhen CNPC charge station**



EU: High electricity price, distributed grid congestion

- **Max. Self-consumption**
- **PBP: ~4 Years @Italy Baracilit concrete factory**
- **Grid Reinforce**
- **PBP: ~4 Years @NL Kronenburg campus**
- **Frequency Regulation**
- **PBP: ~1.8 Years @Sweden**



Asia Pacific, LATAM, Africa, ME: weak power grid, high oil price

- **Off-grid Application**
- **PBP: ~2 Years @Philippines islands**
- **Peak Shaving**
- **PBP: ~2 Years @Mexico hotels**
- **Max. Self-consumption**
- **PBP: ~6 Years @Thiland shopping mall**



Industry facing 3 key challenges: safety, reliability, and stable payoffs solution is urgently needed

Safety Challenges

- Fire or explosion, causing asset & personal loss
- 100+ safety accidents in 2023



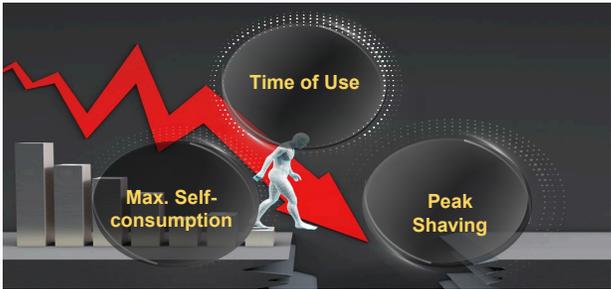
Quality challenges

- Low reliability, frequent faults
- Manufacturer delisted, no after-sales guarantee



Payoffs Challenges

- High manual O&M costs
- Fast performance attenuation Long-term benefits no guarantee



Safety



Proactive Safety

Proactive Safety, nip in the bud

Quality



Premium Quality

Ensure quality from product, mgmt., & culture

Benefit

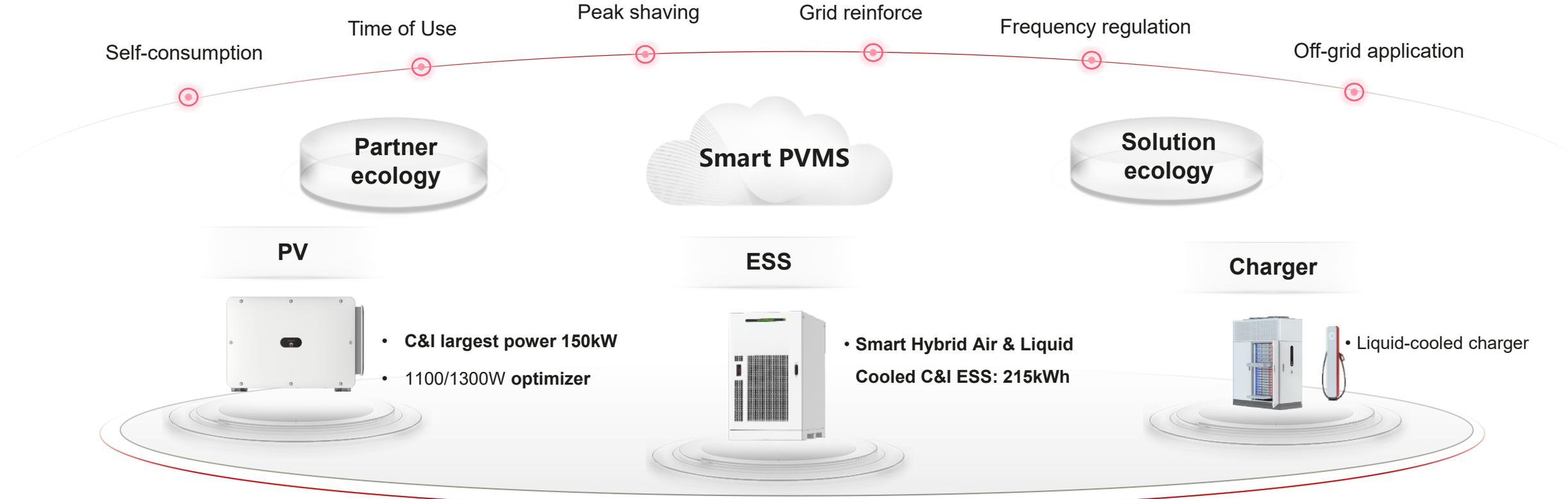


Higher Revenue

Lower O&M cost and Higher Revenue

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"One-Fits-All" Solution Empower Industrial Green Transition



Efficient Power & High Quality Power

One-Fits-All

Proactive Safety

Premium Quality

Higher Revenue

Easy Design

Easy Purchase

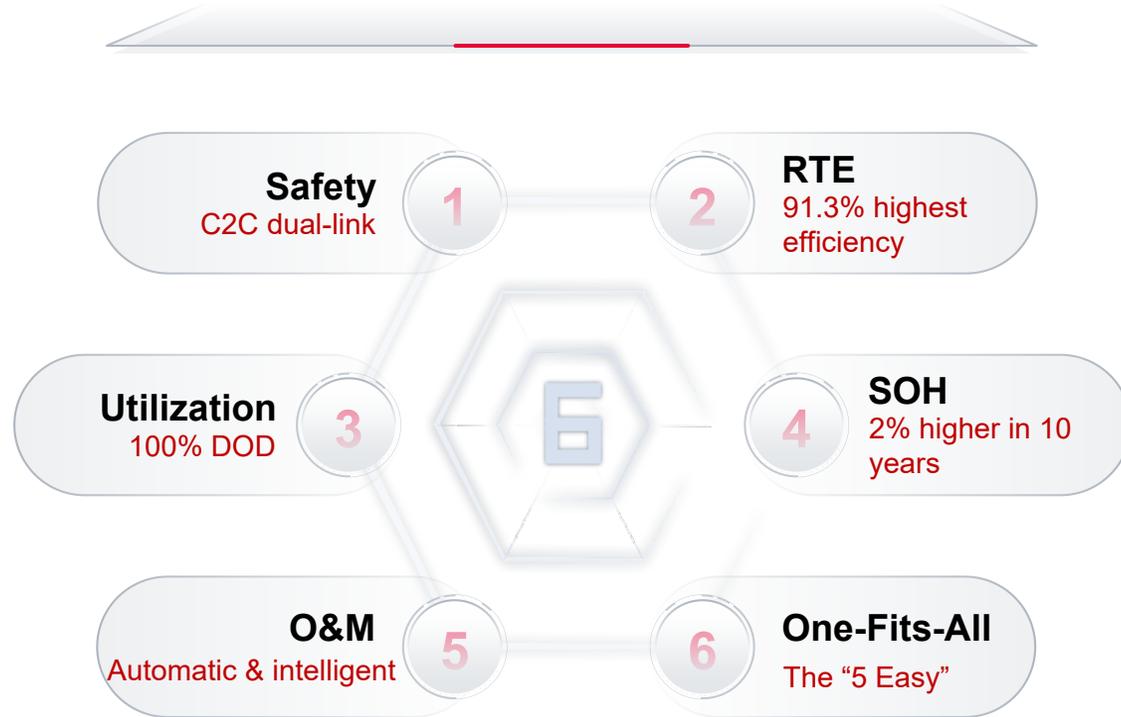
Easy Installation

Easy Commission

Easy O&M

To Create Value For Customers, Discern Their Needs First

How to choose ESS



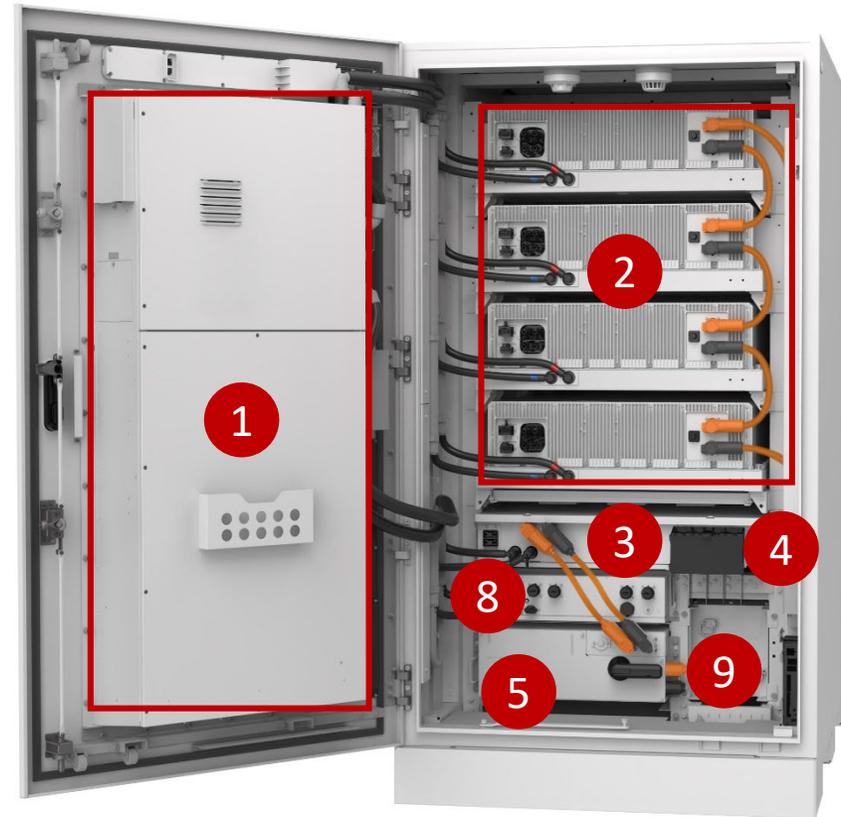
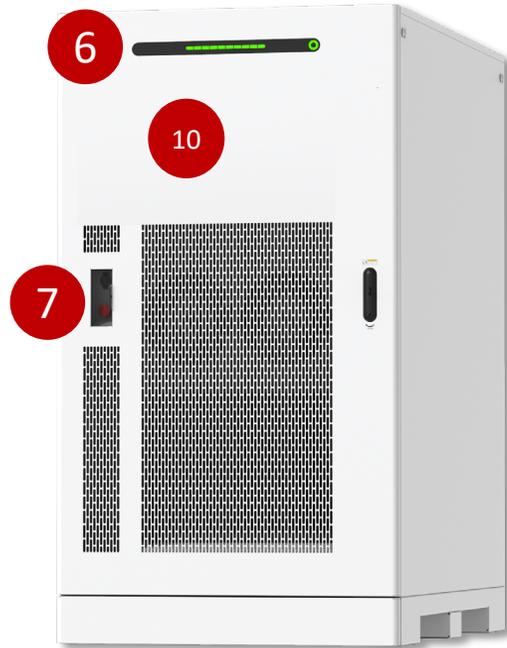
World's First Smart Hybrid Cooled C&I ESS

LUNA2000-215kWh



Bring Proactive Safety, Ultra Quality, and Higher Revenue to Customers

Huawei LUNA2000-215-S10 main building blocks



1: LTMS

2: Battery pack (including pack optimizer 2.0)

3: Smart PCS

4: AC output port

5: RCM

6: Fire alarm horn/strobe & Running status display

7: Emergency stop switch

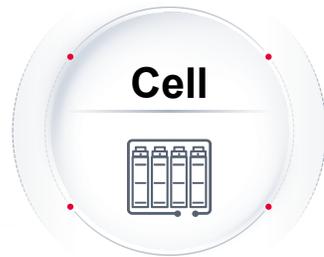
8: DCDC (optional, based on capacity, type and region)

9: Pack-level TRSD (optional, for China region)

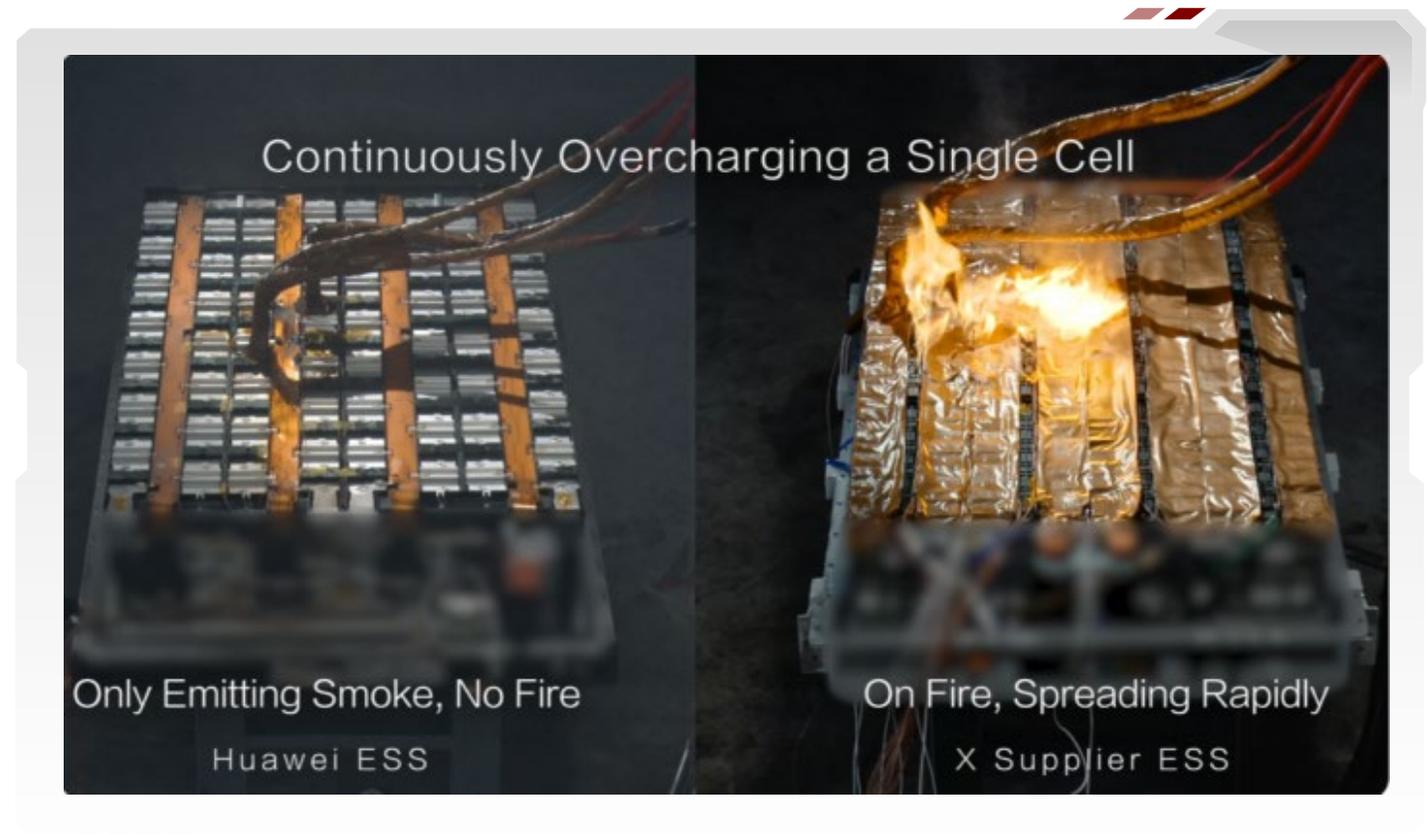
10: Document paste area (including warning information and document QR codes)

Safety Comparison Test: **Even More Excellent than the Excellent**

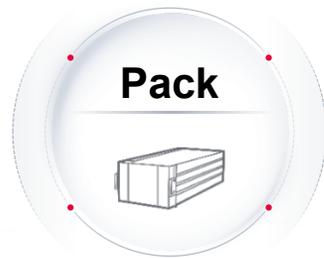
Single-Cell Overcharging Test



Heat insulation pad
cell non-diffusion

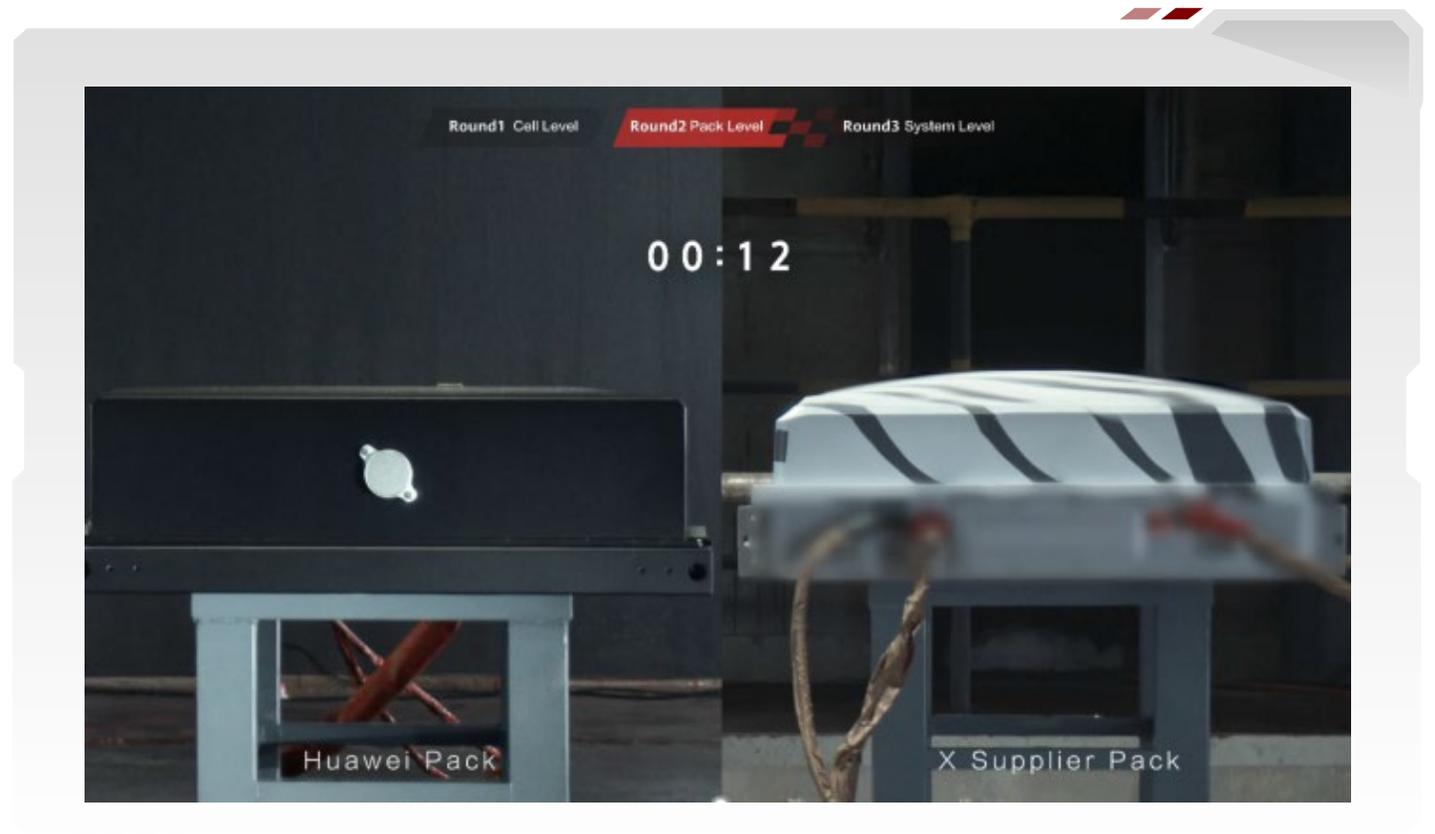


Safety Comparison Test: **Even More Excellent than the Excellent**



**Positive pressure
oxygen barrier
pack no fire**

Multi-Cells Overcharging Test



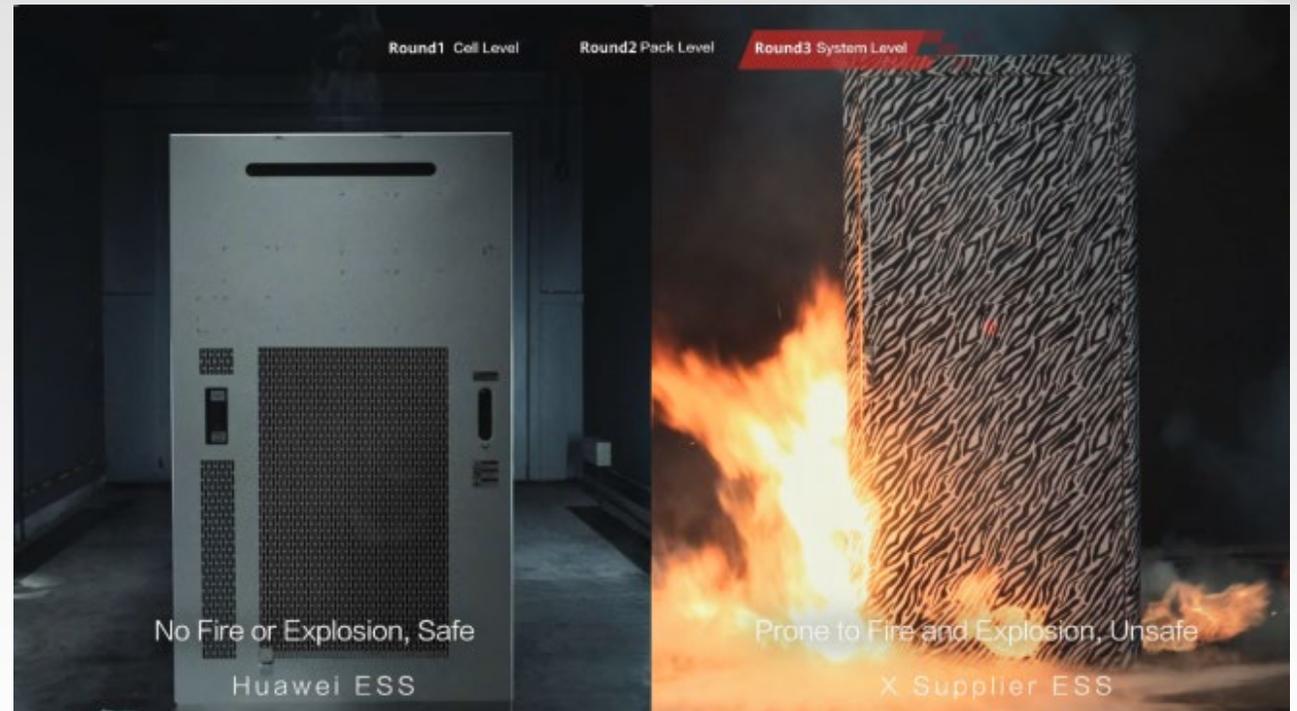
Safety Comparison Test: **Even More Excellent than the Excellent**

Internal & External Ignition Test

System



**Directional smoke
exhaust system**
system no explosion



Beyond Industry Standard, Global 1st C&I ESS Safety Prime Certification

Huawei vs Industry

★ **100kN** crushing, no fire
50kN

Needle penetrates cell no fire
Not penetrated

1.0 meter drop test no fire, no liquid leakage
Only no fire

1mΩ internal short circuit test
5mΩ



No Thermal runaway

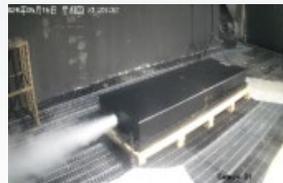
Huawei vs Industry

★ **Thermal runaway** ignition no fire, no explosion
No

72h salted water immersion no fire, no explosion
No

Electrolyte leakage test for insulation layer
No

1-50mΩ short circuit test
1/30mΩ



No Pack fire

Huawei vs Industry

★ **Ignition no explosion**
No

Coolant leakage test
No

Multi-points electrolyte leakage test
Single Point

PCS hydrogen explosion test
No



No system explosion

Huawei vs Industry

★ **Top explosion venting test**
No, or back side explosion venting

★ **AC/DC/Aux. RCD test**
Only DC RCD

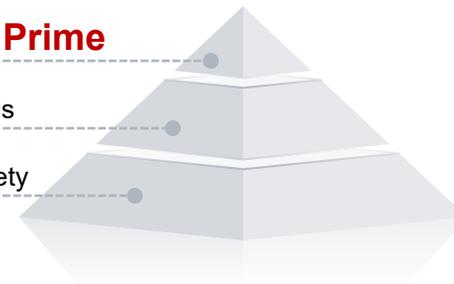


Release on top

★ Safety Prime

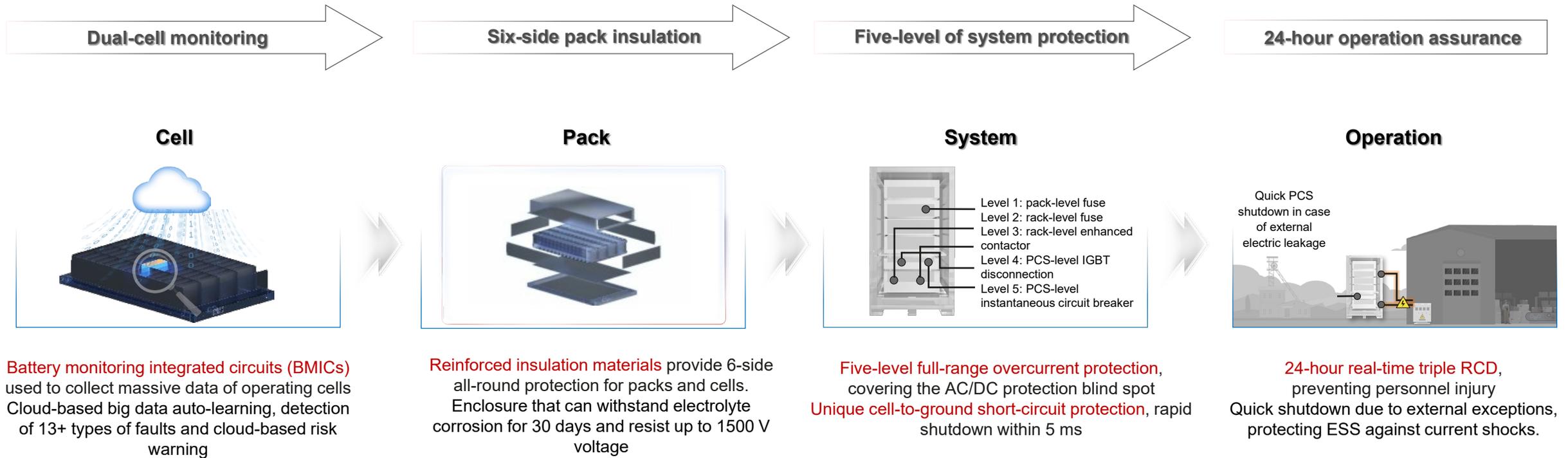
Safety Plus

Basic Safety



1st C&I BESS Safety Certification

C2C Electrical-link Safety: Short-circuit Prevention and Isolation

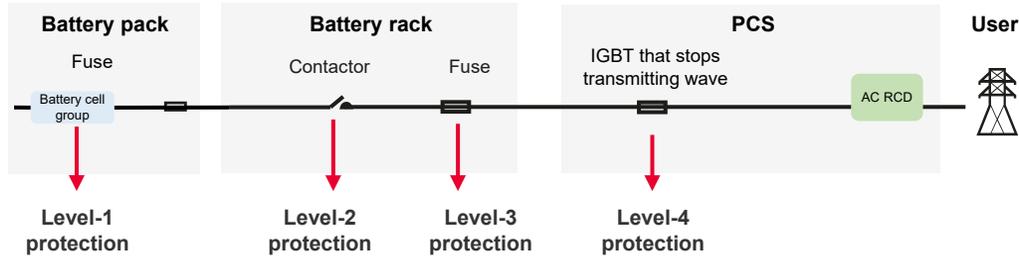


Electrical link short-circuits are major source of ESS safety risks

If a short-circuit occurs in any link of cells, battery packs, internal bus circuits, or external circuits on the consumption side, it may result in personal injury or device damage and cell short-circuit, **possibly causing thermal runaway of the thermal link.**

Five-level Full-Range Overcurrent Protection, Covering the 1200-1600 A Protection Blind Spot

Traditional solution: Poor protection capability with insufficient levels of disconnection



Protection blind spots

Protection blind spot exists between 1200 A and 1600 A. When external short-circuit resistance is 0.4–0.6 ohms (The external short-circuit resistance is generally 0.1–1 ohms) or in some cases, the system is unprotected.

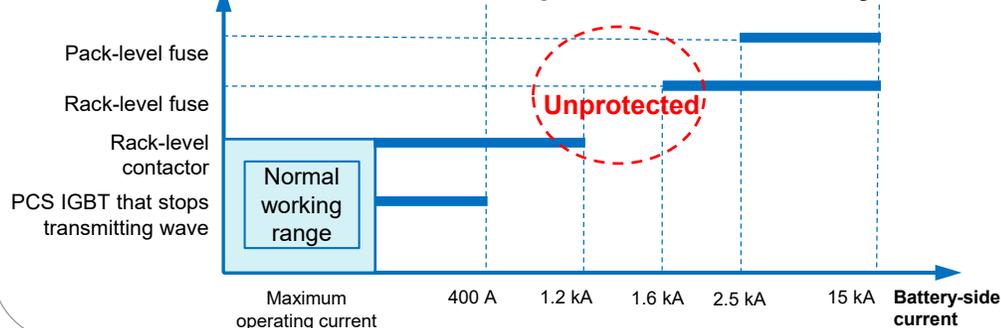
Long shutdown duration

Conventional fuses make response within seconds, which cannot protect the system from short-circuit against the ground. (If the busbar/blue film of cells is damaged or the cell shell is short-circuited to the ground, a fire may occur within tens of milliseconds.)

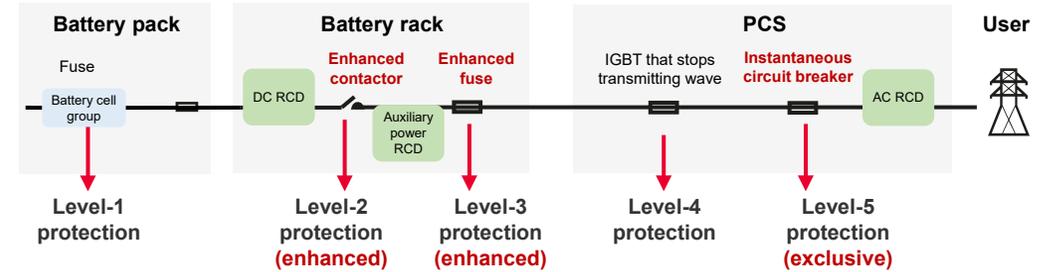
Insufficient detection items

Only short-circuit current leakage detection between the positive and negative buses are performed without detecting cell-to-ground short-circuit and current leakage and current leakage on the auxiliary power side, which may cause personal injury and other safety risks.

Protection blind spot in conventional systems



Huawei's solution: Enhanced protection capability with five-level full-range overcurrent protection



No protection blind spots

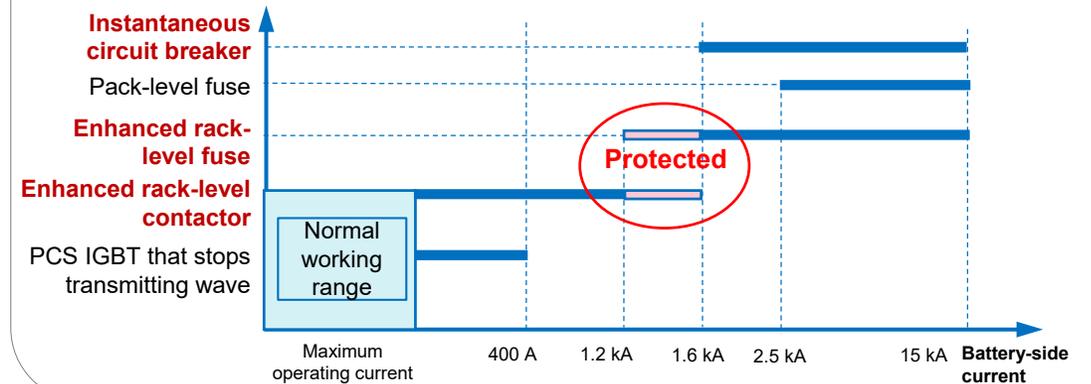
Contactors and fuses enhance the protection capability, covering the protection blind spot between 1200 A and 1600 A in conventional systems.

Rapid shutdown within milliseconds

Unique millisecond-level cell-to-ground short-circuit protection, rapid shutdown within 5 ms through the instantaneous circuit breaker.

Full-range detection

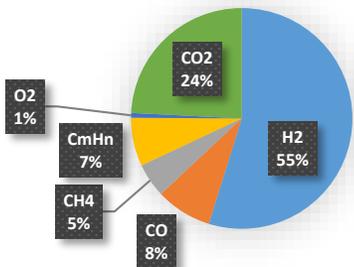
Only short-circuit current leakage detection between the positive and negative buses are performed without detecting cell-to-ground short-circuit and current leakage and current leakage on the auxiliary power side.



VS

Unique Design of Pack-Level Directional Gas Exhaust Eliminates Combustion and Explosion Conditions to Prevent Thermal Runaway from Spreading

Conventional: Combustion and explosion risks due to combustible gases in case of cell thermal runaway



A large amount of combustible gases, such as CO and H₂, will be generated if cell thermal runaway occurs.

Conventional solution

- No protection:** If cell thermal runaway occurs in a pack, combustible gases will be continuously generated. Combustion will occur if the gases come in contact with oxygen at a high temperature.
- Pressure relief valves designed for packs only:** Combustible gases are **discharged in the cabinet**. Combustion will occur if the gas concentration inside the cabinet reaches the explosion limit.
- Cabinet-level gas exhaust:** Thermal runaway will spread if combustible gases cannot be quickly exhausted out of the cabinet.



If cell thermal runaway occurs in an energy storage plant, combustible gases will accumulate, causing combustion and explosion inside the cabinet.

Combustion risk

Combustion will occur if combustible gases come in contact with electrical flames and oxygen.

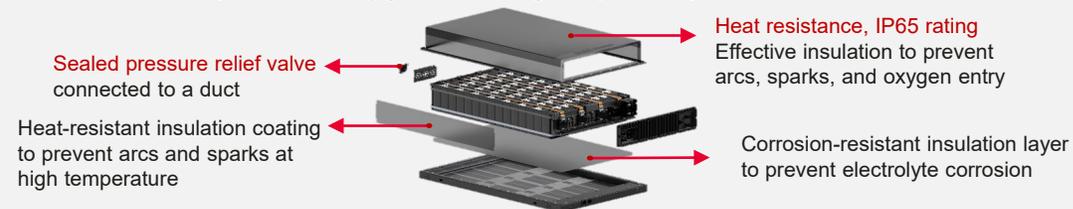
Explosion risk

If combustible gases are not exhausted out of the cabinet in time, they will accumulate and cause explosion.

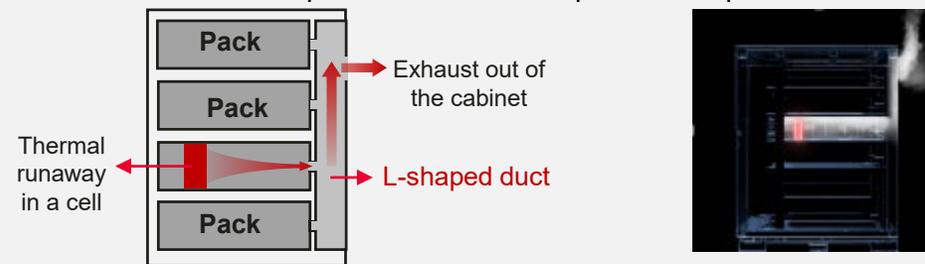
Pack-level directional gas exhaust to prevent combustion and explosion

Patented directional gas exhaust design: If combustible gases are continuously generated due to thermal runaway of cells in a pack, the IP65-rated heat-resistant enclosure with positive pressure oxygen blocking design and the L-shaped duct prevent oxygen from entering the pack and exhaust the combustible gases out of the cabinet to prevent combustion and explosion.

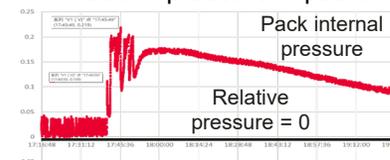
Positive pressure oxygen blocking for packs: prevents combustion



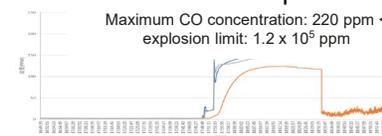
L-shaped directional duct: prevents explosion



Positive pressure in packs



The gas concentration inside the cabinet is far lower than the explosion limit.



1

Business Insight

2

Huawei C&I ESS Solution Safety Principles

3

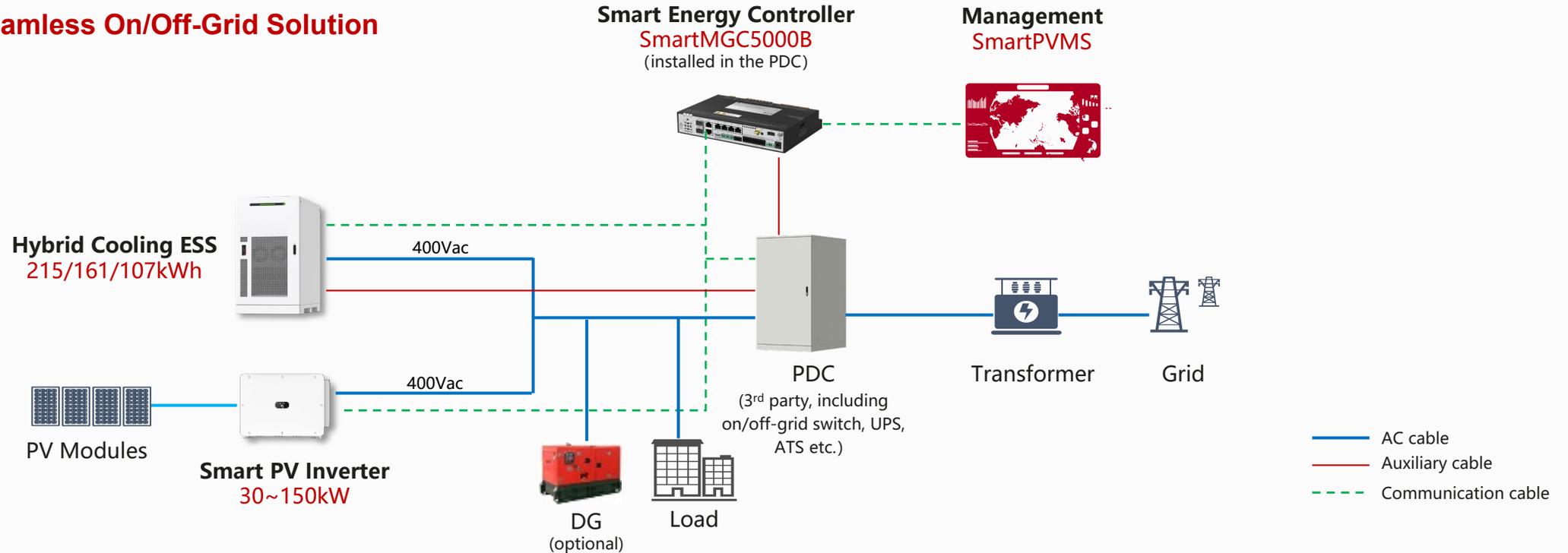
Huawei C&I ESS Feature and Revenue Stream

4

C&I Success Cases

C&I On/off-Grid Solution, Safe, Economical, and Seamless During Power Outages

Low-voltage Seamless On/Off-Grid Solution



Proactive Safety

- **C2C Dual-link Safety**
- **Electrical Circuit:** Cell 13+ Fault Warning; Pack Six-Sided Insulation to Prevent Arcing; ms-Level Shutdown to Prevent Short Circuits; Triple RCD for Leakage Protection
- **Thermal Link:** The battery cell is thermally insulated to prevent heat spread, positive pressure blocks oxygen to prevent ignition, directional smoke exhaust avoids combustion and explosion, and top venting ensures no harm to personnel.

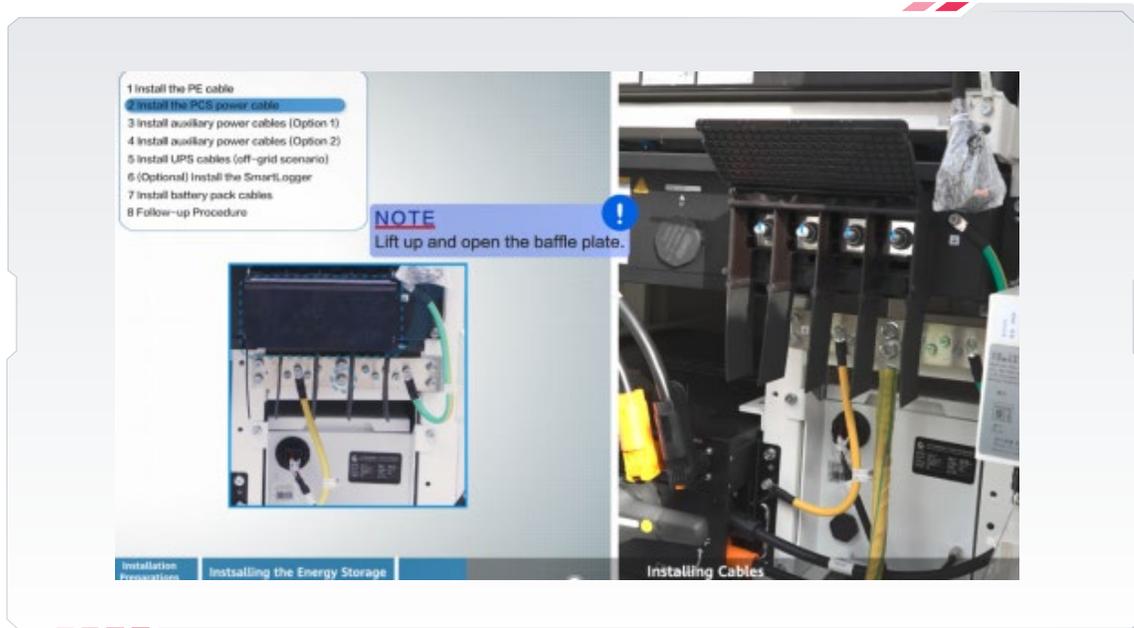
Higher Profitability

- **More Discharge:** Pioneering hybrid cooling, maximum RTE of 91.3%; Pack-level Optimization 2.0, 2% More Discharge Over Lifecycle
- **Intelligent Scheduling:** Load Shedding Intelligent Backup Power, Increasing Revenue by 6%
- **Lower CAPEX:** Pioneering the "5-in-1" smart energy controller, reducing third-party equipment investment by \$5,000.
- **Lower OPEX:** Pack-level SOC automatic calibration, 10 years without liquid replacement; APP-based simplified setup, no computer required, five steps in <5 minutes.

High-quality and Reliable Power Supply

- **Stable Power Supply:** 20ms (fast switch) or 60ms (general switch) seamless switching; minute-level multi-machine synchronous black start.
- **Enhanced Load Capacity:** Pioneering a three-phase four-wire five-arm PCS, it supports three-phase imbalance without a transformer and offers a maximum short-term overcurrent capability of 1.3 times.
- **Superior Power Quality:** Intelligent harmonic suppression ensures off-grid THDu $\leq 2\%$; intelligent circulating current suppression supports up to 20 units in parallel.

One Fits All: 2 Hours Quick Installation and Commissioning



Installation &
 Commissioning Video



Installation & Commissioning Steps

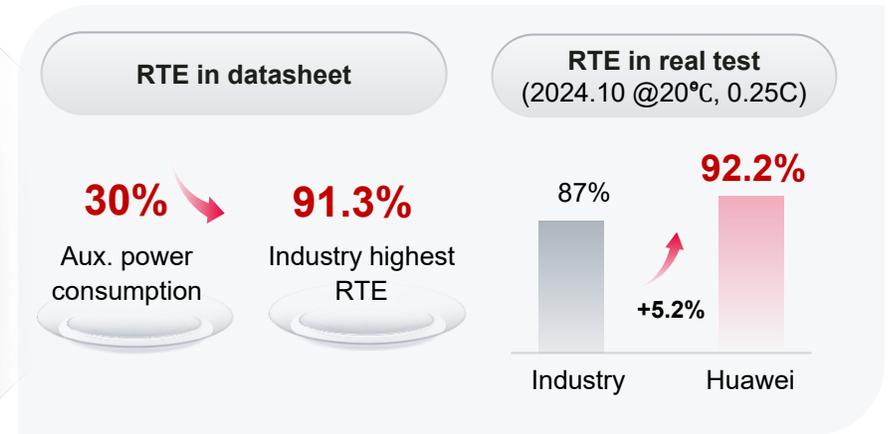
- | | | |
|-------|--------------------------------|---------|
| Step1 | Install Cabinet | ~60 min |
| Step2 | Connect AC Cables | ~25 min |
| Step3 | Install SmartLogger | ~10 min |
| Step4 | Network Configuration | ~10 min |
| Step5 | ESS Working Mode Configuration | ~15 min |

Thanks to 5.2% Higher RTE, Revenue Improved by \$4K/100kWh in a Decade

ESS efficiency related factors



POC result, 5.2P higher RTE than industry



POC Report @ Zhejiang ESS project

RTE 92.2%, DoD 100%, battery cell temp. difference <1.5°C

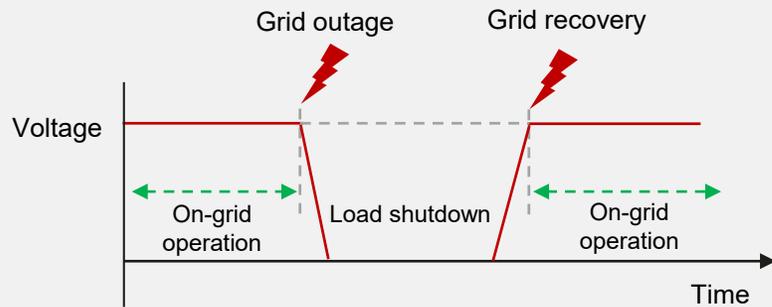
第 6 章 结论与总结

储能系统综合循环效率，放电深度会影响系统可用度，投资收益，系统的温控措施会影响电芯的衰减和使用寿命，通过本次测试，华为风液智冷储能系统 RTE 效率最高到 92.2%，长期运行的综合循环效率超 90%，放电深度 DOD 到 100%，pack 间温差 不超过 1.5°C，综合表现优异。

-----报告结束-----

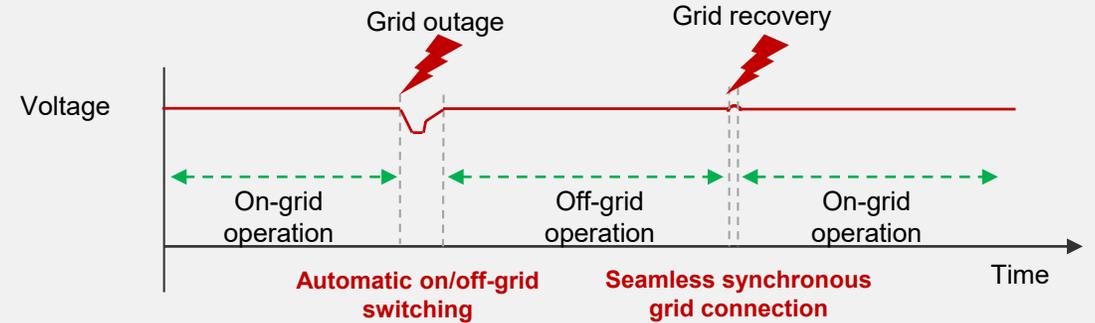
Quick On-grid and Off-grid Switching to Ensure Uninterrupted Power Supply

Frequent power outages causing losses due to production interruption

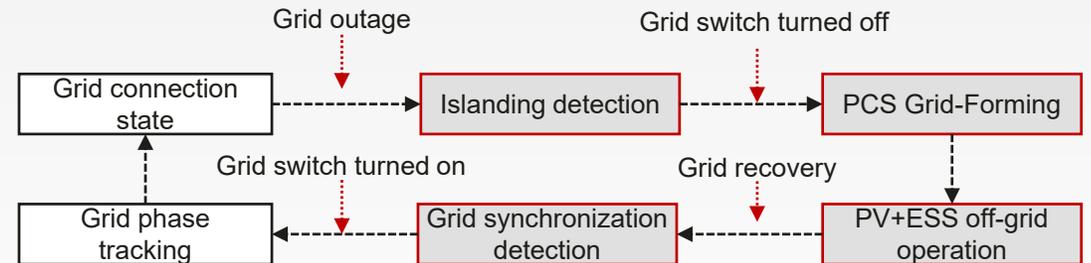


The loss caused by power outages in factories reaches **CNY190,000 per time.**
@ Jiangsu Centuray Factory

Quick on/off-grid switching ensuring uninterrupted power supply to loads



Grid forming + running control, PV+ESS automatic switching



< 20ms

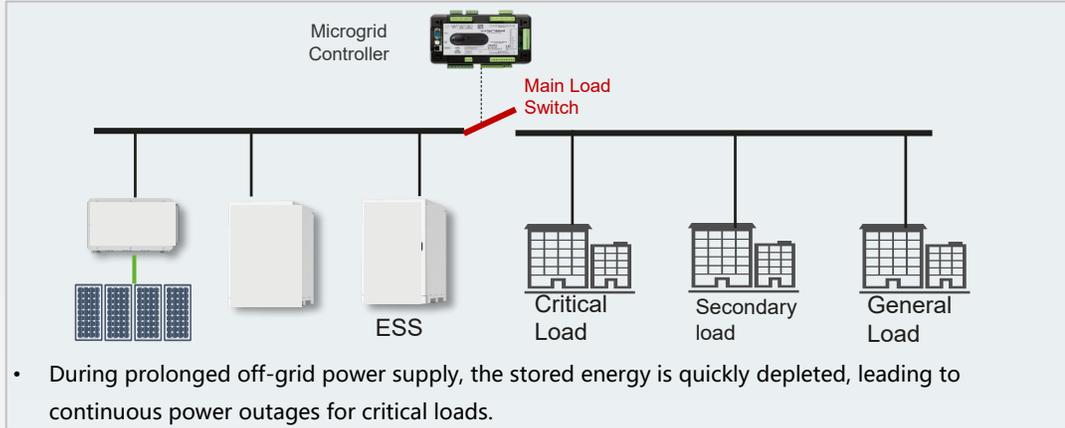
- Online PQ-to-VSG seamless switching <20 ms*.
- Normal PQ-to-VSG switching, 3 seconds for a single ESS and 10 seconds for multiple ESSs.

* Seamless switching available in 2025Q4, 3rd part fast switch is required.

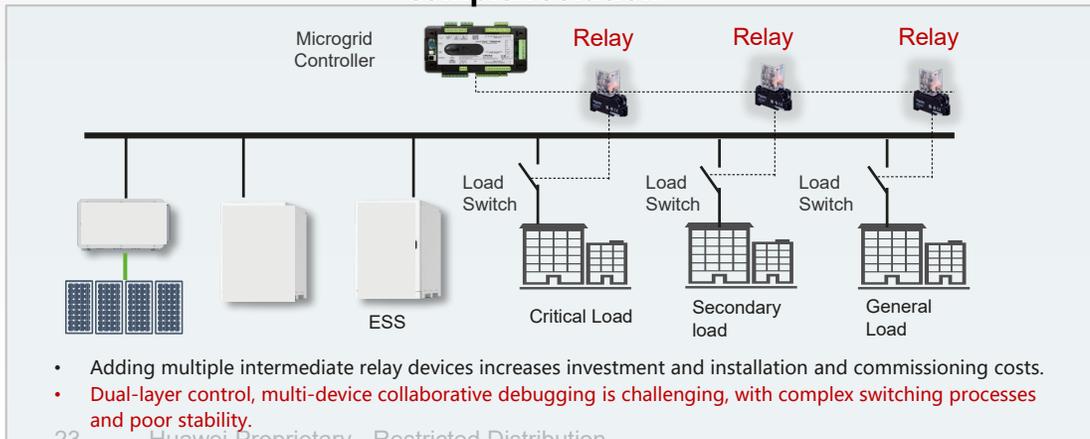
Hierarchical Load Management: Off-grid Three-level Load Management to Extend Power Supply Duration for Critical Loads

Traditional: Load no hierarchical control or intermediate relay control

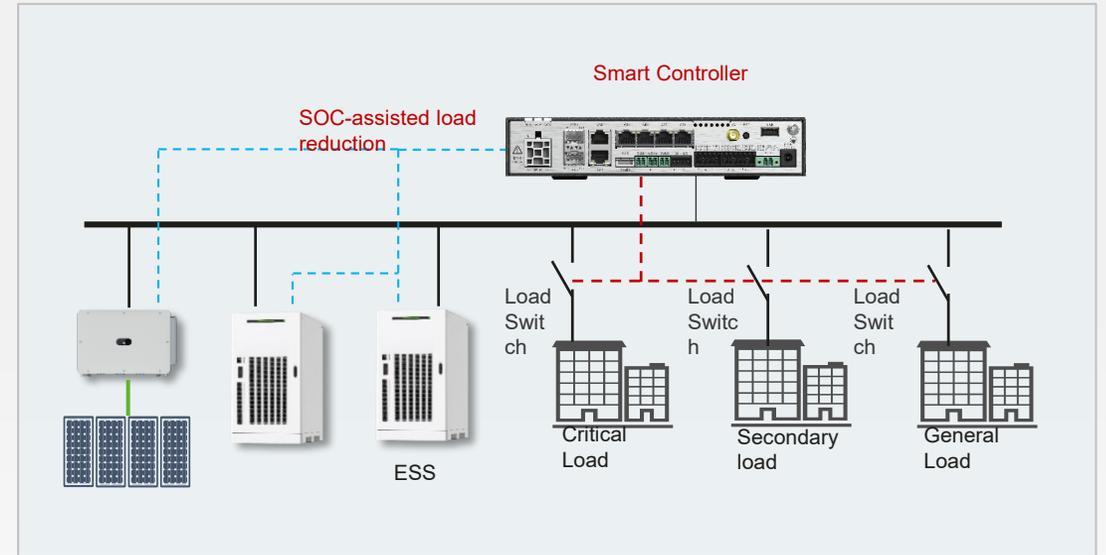
No hierarchical control, short backup power time for critical loads.



Intermediate Relay Load Control: Increased third-party integration, complex solution



Huawei: Hierarchical Load Management, Minimalist, Flexible, and Reliable



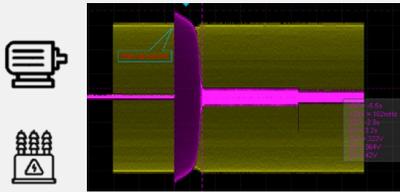
- Based on the SOC status of energy storage, it flexibly manages power disconnection and reconnection under different loads to ensure critical power supply.
- Supports a maximum of three-level load management, eliminating intermediate relays and reducing costs.
- Single-layer control architecture, simple installation and debugging, high control stability
- By controlling the power consumption of secondary/general loads, the grid load is optimized to avoid issues such as overload and voltage instability.

Scheduled for release in Q4 2025, the technical specifications and constraint requirements are detailed in the Solution User Manual.

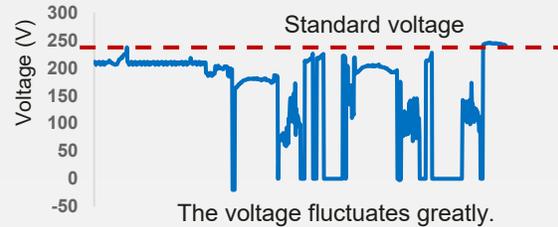
Grid Forming for Fast Fault Ride-Through, Enhancing Resilience Power Supply

Inrush current during load connection, causing power grid disturbance and system breakdown

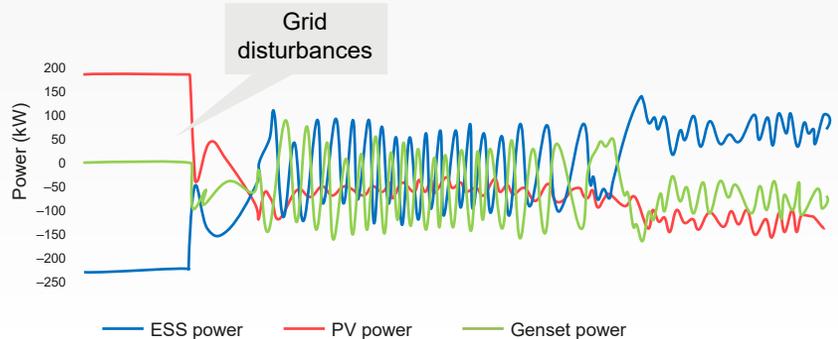
- **Inrush current:** When a load is suddenly connected, inrush current several times the normal level is generated. As a result, the voltage frequency is unstable and the power grid is severely disturbed. **A higher load leads to a larger inrush current.**



The connection of the asynchronous motor/transformer causes inrush current.



Failed fault ride-through fails, the device shutdown for protection, and the power to the load disconnected



VS

Stronger resistance to inrush current impact and fault ride-through

- The **grid forming** technology improves the voltage and frequency support capability of the PCS to overcome the impact of inrush current and enhance the stability of the power system.



Grid forming



10%

Supports the connection of asynchronous motors.

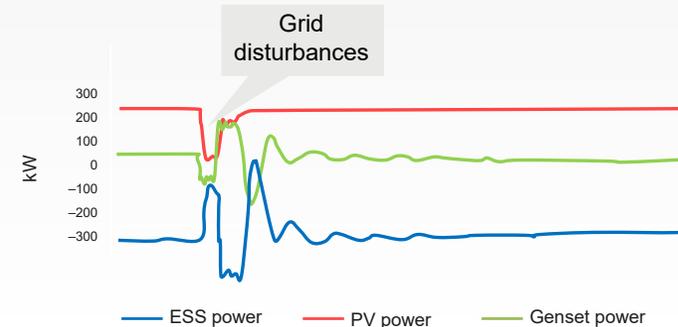


50%

Supports the connection of no-load transformers.

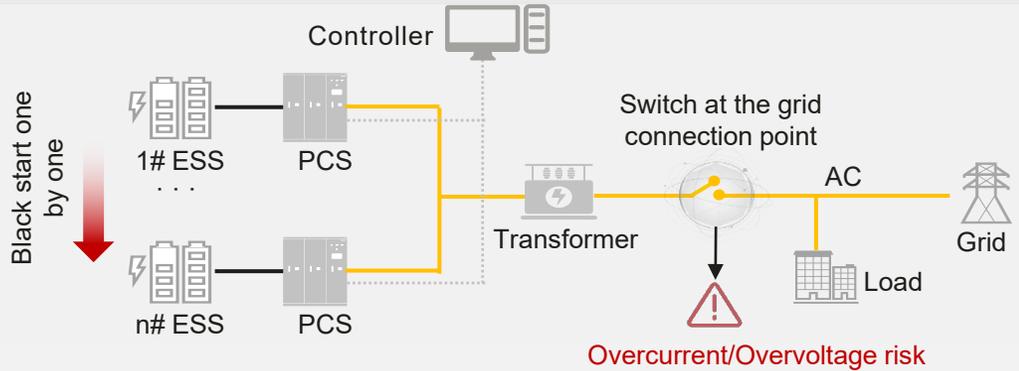
Connected capacity/PCS rated power

Fast fault ride-through, ensuring uninterrupted power supply to loads



Synchronous Black Start of 20 ESSs, Fast Power Supply Recovery Within 10 Minutes

Traditional: one-by-one black start, circulating current and time-consuming



Black start in turn

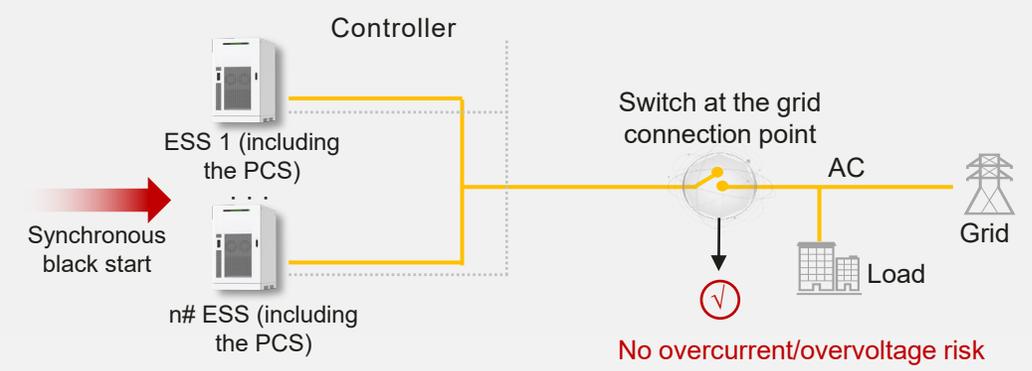
- **Time-consuming** power supply recovery in hours
- **High risk** due to the overcurrent and overvoltage at the grid connection point
- **Prone to faults**, requiring onsite manual operation in the case of failures

Internal circulating current is easily generated during the black start process of multiple devices connected in parallel.



A small voltage phase difference can cause circulating current and lead to the failure of black start.

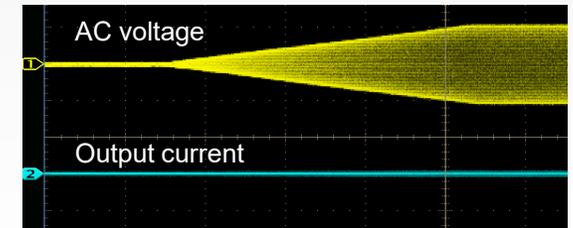
Huawei: Multi-device synchronous black start, no circulating current, and fast startup



Synchronous black start

- **Fast** power supply recovery in minutes
- **Low risk**, with no risk of overcurrent or overvoltage at the grid connection point
- **High reliability**, and good remote one-click experience

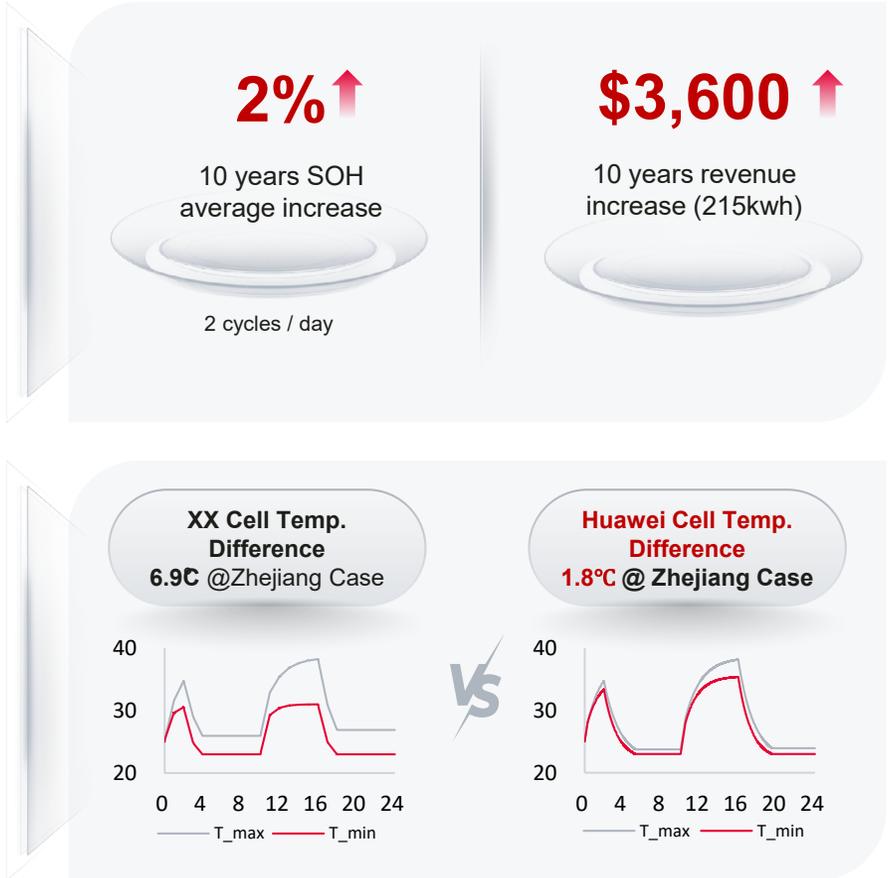
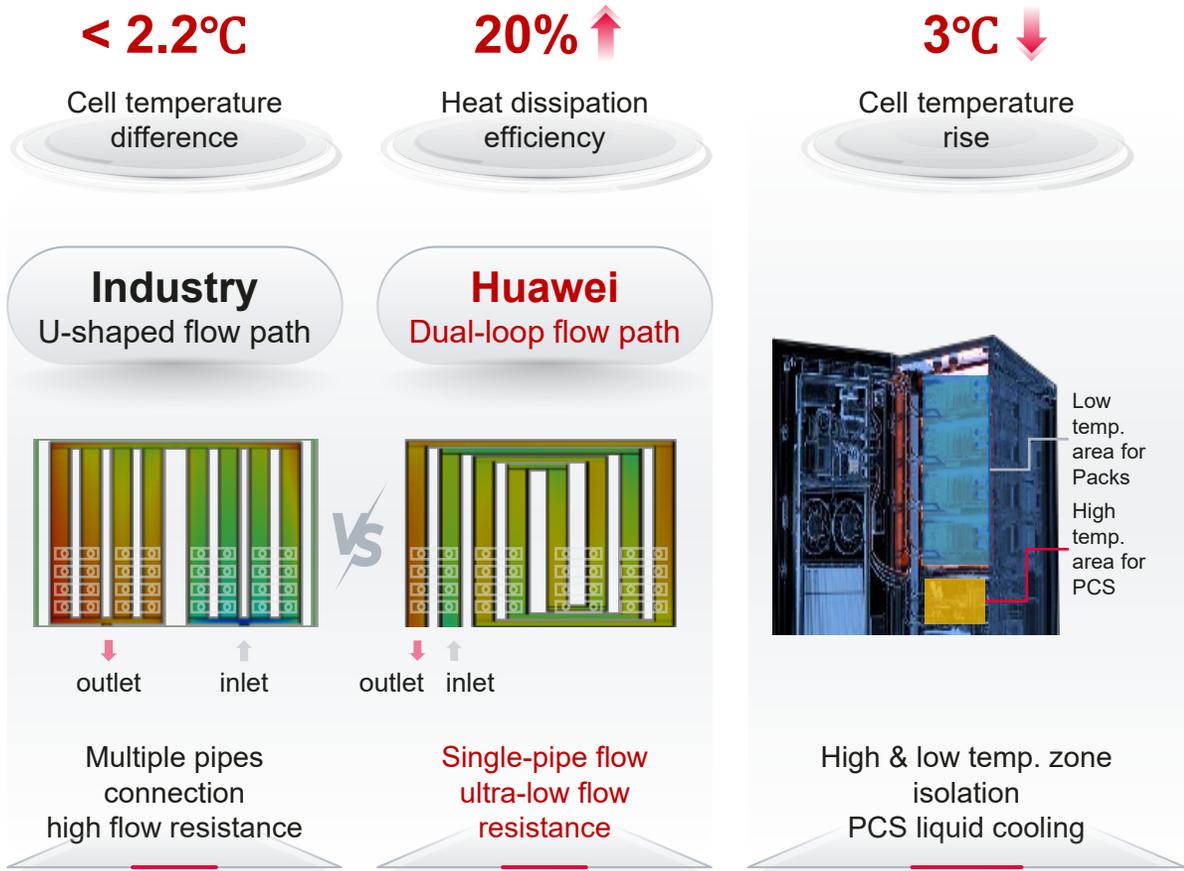
Soft start of multiple parallel PCSs
Synchronous voltage boosting of multiple parallel PCSs



The voltage phases are consistent, and there is no internal circulating current.

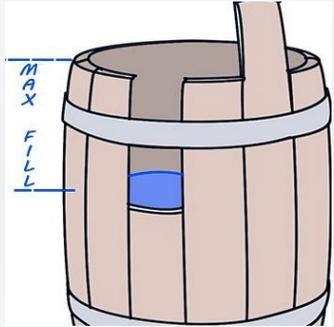
VS

Unique Heat Dissipation Design, 2% Higher SOH and Revenue Improved by \$1.7K/100kWh in 10y



Unique Pack Optimizer Realizes 100% DOD, Revenue Improved by \$1.5K/100kWh in a Decade

Cask Principle



Volume decided by shortest wood plate

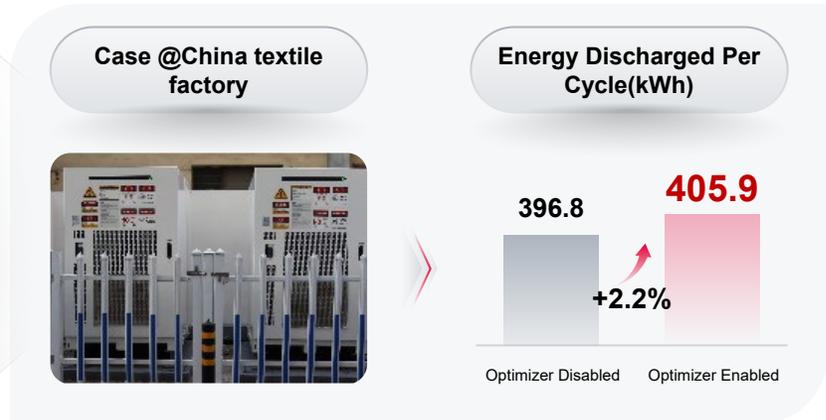
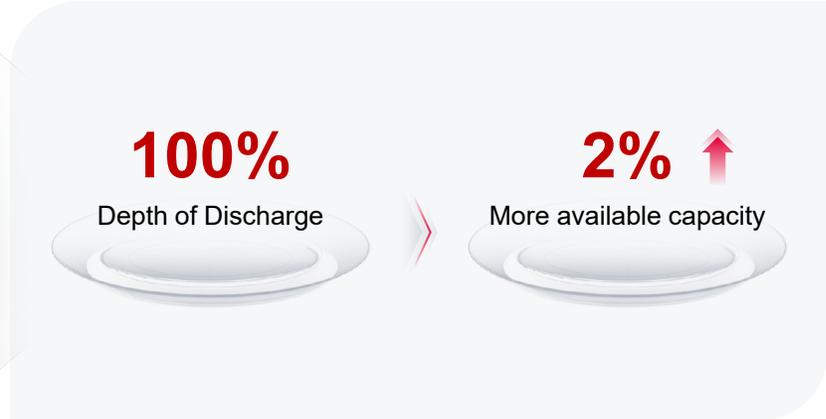
Optimizer : Eliminates Cask Effect, Maximizes Capacity

Industry: series link, cannot fully charge and discharge



VS

HW: pack optimizer, auto eliminate SOH, Fully charge and discharge



Reducing Costs and Improving Efficiency Throughout the Lifecycle to Cut the LCOS by 20%

$$\text{LCOS} \downarrow = \frac{\text{CAPEX (system, transportation, installation, and footprint)} \downarrow + \text{OPEX (commissioning, maintenance, and inspection)} \downarrow}{\text{Throughput (RTE, lifespan, and DOD)} \uparrow}$$

*LCOS: levelized cost of storage throughout the ESS lifecycle

Lower LCOS

More Energy

■ Actuarial Powering

- Optimal efficiency, maximum system round trip efficiency (RTE) $\geq 91.3\%$
- **Pack-level optimization 2.0**, real-time active balancing to improve the usable energy by **2%**
- **Phase-level control**, 100% three-phase unbalanced output

■ Hybrid Cooling

- Low consumption: **Thermal Router**, intelligent multi-mode switching, reducing energy consumption by **30%**
- Long life: triple cooling techniques for system performance life ≥ 15 years
- High reliability: automotive-grade liquid cooling system, full-range anti-condensation, failure rate reduced by **60%**

Lower CAPEX

- **Three-sided cabinet layout**, saving space and improving energy density per unit area by **8%**
- Transported with prefabricated components in a 20-foot standard container, reducing the transportation cost by **20%**.
- **No trenching or external auxiliary power cable**, reducing installation costs
- Transformerless in off-grid scenarios, reducing system investment by **5%**

Lower OPEX

- Pack-level automatic SOC calibration, free of site visits
- **No need to change the coolant for 10 years**, reducing labor costs and leakage risks

1

Business Insight

2

Huawei C&I ESS Solution Safety Principles

3

Huawei C&I ESS Feature and Revenue Stream

4

C&I Success Cases

Massive Applications of Huawei PV-ESS Around the World

Empower Industrial Transition to Prosumer with Green and Economical Energy



100 GW+

Cumulative shipment, No.1 global market share for 8 consecutive years



100,000+

Serving enterprises @ 2023



42 million tons

Reducing carbon emissions @ 2023



Rome Logistics Park

Reduce Electricity Cost and Carbon Emission for Medium & Large Sized C&I Scenario

2.4 MW PV modules deployed on rooftops and open spaces



Customer requirements

- Customer: Roma Logistics Park: High reliability, high power generation, cost reduction, and simplified O&M throughout the product lifecycle. Photovoltaic power plants operate safely under the provided sites. The logistics park can use green electricity stably and at a lower cost, and is committed to **energy green transformation**.
- **Logistics enterprises**, High demand for stable power supply
- Solve problems such as low manual O&M efficiency, power generation loss caused by frequent startup and shutdown of machines, and inverter explosion

Customer benefits

SUN2000-150K-MG0

The largest C&I power inverter



Smart PV controller

+



Smart PV cloud

- Annual power generation: **2.88 million kWh**
- **Reduce the BOS by 20%**, help the logistics park build a green benchmark in the industry, and improve the brand image.
- Simplified O&M, AFCI **450m** longer protection

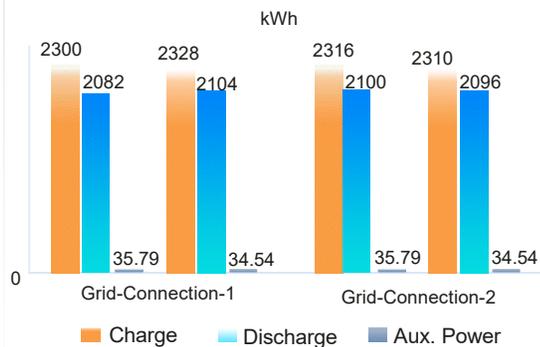
Semiconductor Factory in China: RTE 92.2% @20°C, Revenue Increased by \$500K

2.15MWh ESS in Semiconductor Factory

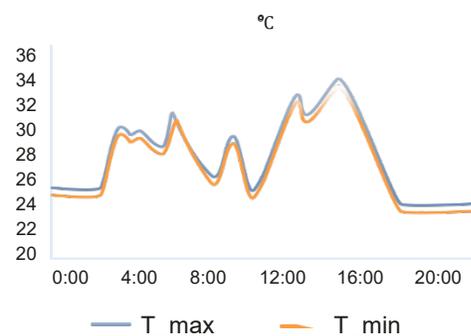


-  COD: Oct, 2024
-  PV: 1.2MW
-  ESS: 10*215kWh

ESS Test Data @2024.10



Cell temp. difference: 1.3°C



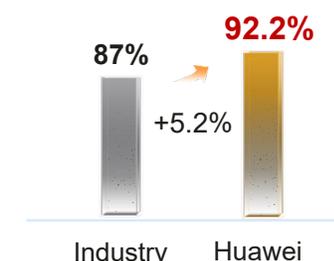
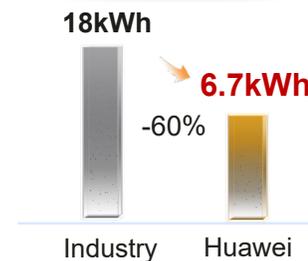
3.85GWh More Energy Available in Lifespan



@2 cycles per day

24h Aux. power consumption /ESS

RTE including Aux. power



@20°C, ~0.25P, 2 cycles per day

Baraclit Concrete Factory in Italy, Max. Self-consumption to Reduce Electricity Cost



Customer Challenges & Requirements

- Founded in 1946, Baraclit is a leader in the field of prefabricated concrete for industrial, commercial and logistics construction
- High energy demand to heat concrete for drying. Annual consumption is about **4.5GWh**, high electricity cost
- Sustainability strategy: reduce CO₂ by using solar energy for social responsibility

Customer Benefit

- Solution: **2.4 MW PV + 1 MWh ESS**
- Benefit 1: **Max. self-consumption** save electricity cost by **\$647k/year**
- Benefit 2: reduce carbon emission by 1460t/year, **carbon trading revenue** can reach **\$160k/year**
- Benefit 3: green power accounts for 42%, and "**green concrete**" making it more competitive
- Overall project ROI: **~4 years**

Thank you.