From Innovation to Implementation: Technological Progress and Economic Impacts in Renewable Energy & Energy Storage adoption

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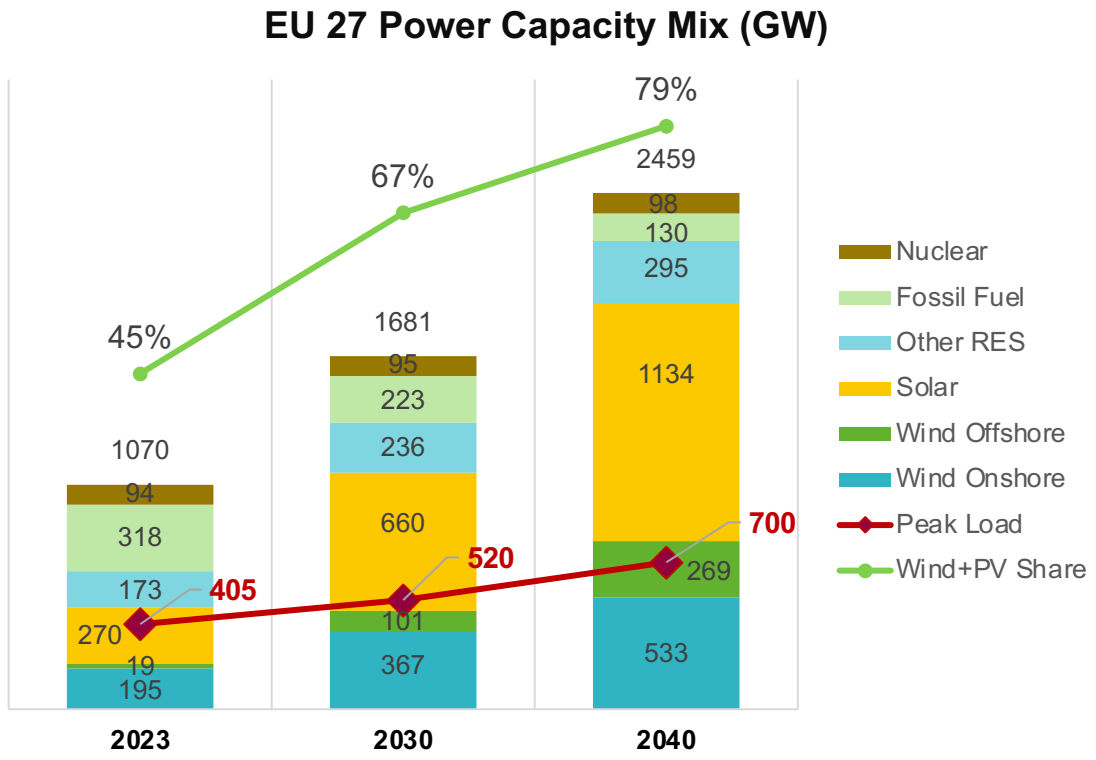
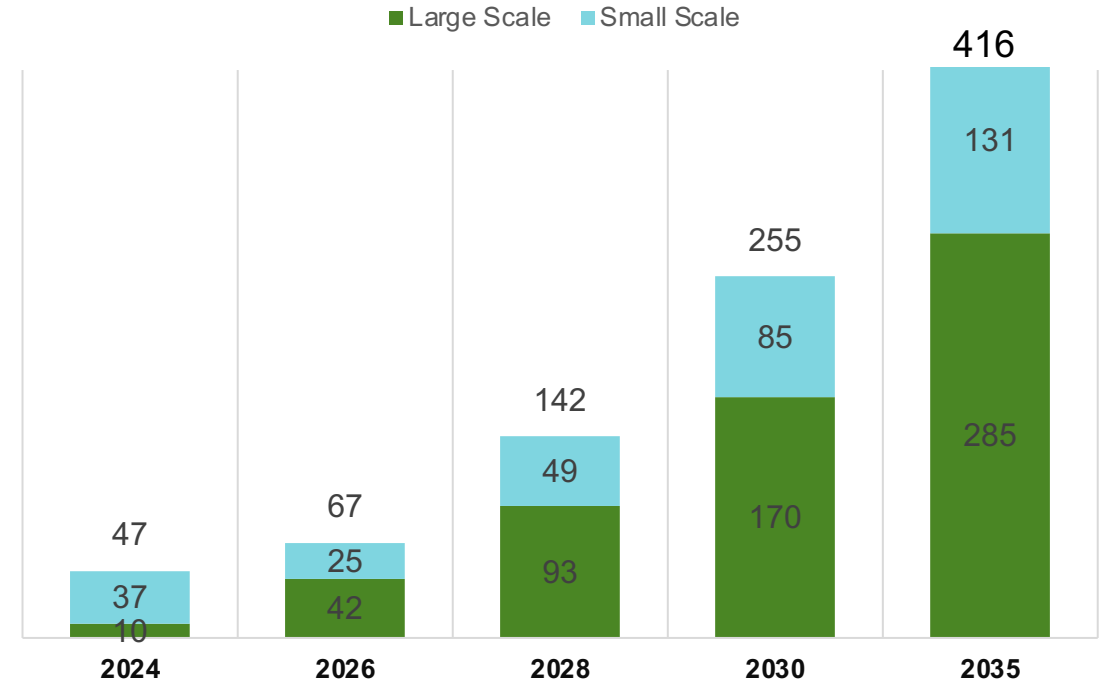
EU Power System's transformation: wind + Solar share is expected to reach 67% by 2030

Wind + Solar Share of generation Capacity is expected to reach 67% by 2030



- Generation capacity is expected to increase from 1070 GW to 1681GW by 2030
- Onshore wind is expected to increase from 195GW to 367GW by 2030
- Offshore wind is expected to increase from 19GW to 101GW by 2030
- Solar is expected to increase from 270GW to 660GW by 2030

BESS is expected to reach 255 GWh by 2030

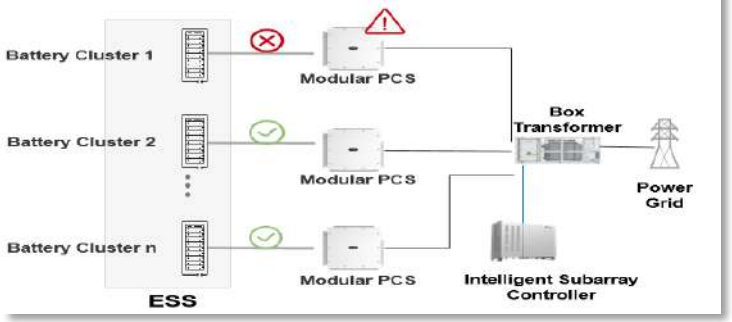


- By the end of 2024, BESS in EU reached estimated 47 GWh
- System needs an estimated 255 GWh to maintain stability

Source: ENTSO-e TYNDP 2024

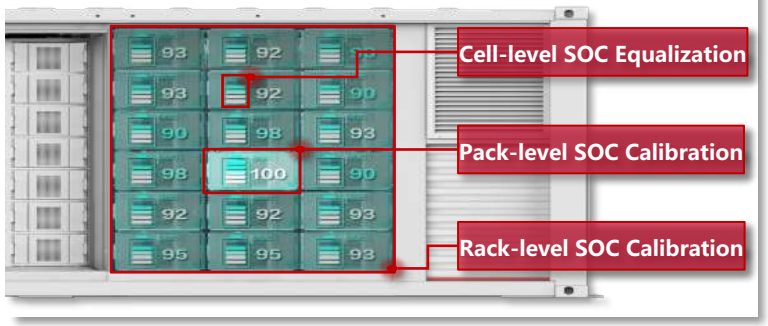
Technological advancement in Battery Energy Storage Systems (BESS)

High availability string Architecture



- ✓ Reduces the loss unit from the sub-array level to the cluster level after a single device failure.
- ✓ Enhances the overall availability of the system, enabling timely response to grid demands.
- ✓ If a single PCS fails, the power loss is limited to one battery cluster, and the availability of the energy storage system remains >99%.

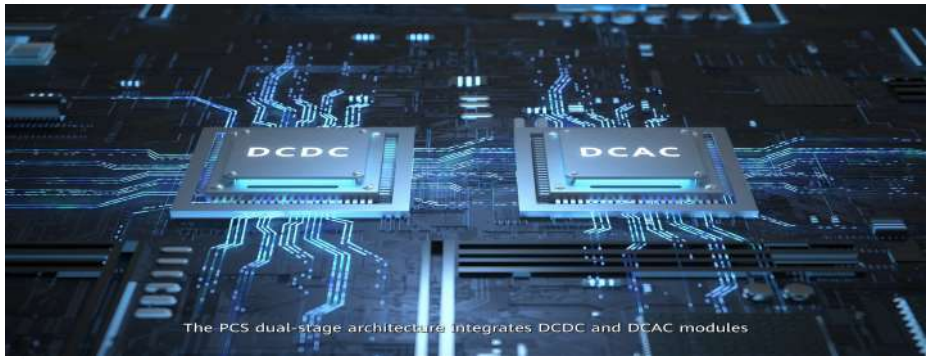
Pack & Rack level optimization

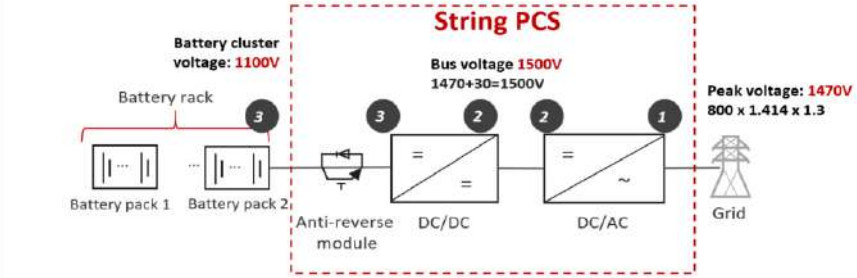


Pack & Rack level efficiency increase by 1.7% and 7.2% respectively

- ✓ Eliminates serial mismatch, Individually control charge performance of each pack.
- ✓ No risk of external short circuit. Faulty pack is isolated actively.
- ✓ Rack-level Optimization ensures all racks are simultaneously charged & discharged.
- ✓ Adjusts Bus side voltage of each rack and minimize bias current to less than 1%.

DC/DC + DC/AC dual-stage architecture





- ✓ Based on PCS OVRT adaptive algorithm, the bus voltage is dynamically adjusted during OVRT to ensure stable active power output.
- ✓ The battery voltage remains the same during OVRT, avoiding back feed of energy on the grid side.
- ✓ Ensures constant active power output.

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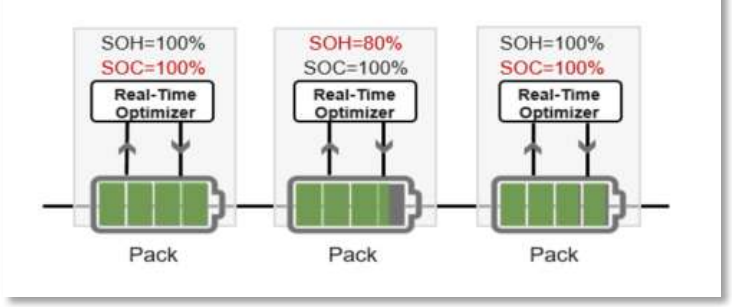
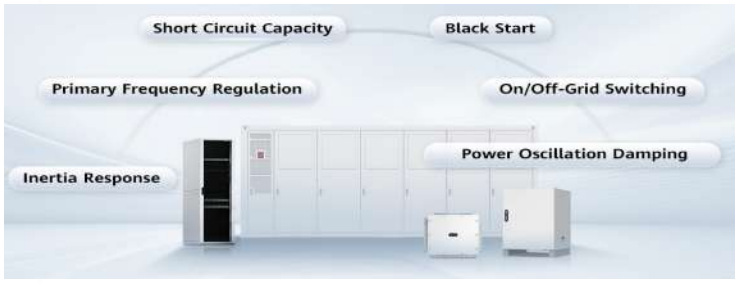
Technological advancement in Battery Energy Storage Systems (BESS)

Active SoC Calibration



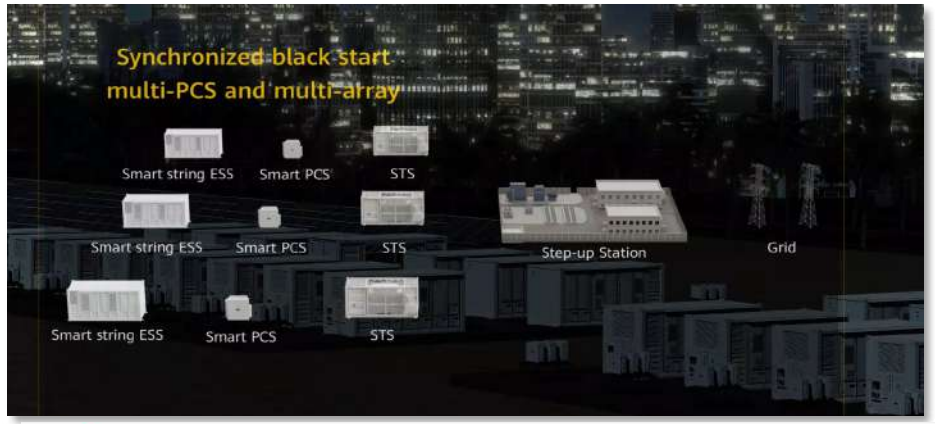
- ✓ High precision voltage and current sampling, Sampling accuracy ±3mV、±0.1A
- ✓ Dedicated battery management Integrated chip, higher computing power.
- ✓ Self-learning algorithm, High-precision battery modelling & parameter identification.
- ✓ Reducng SoC error to <3%, Increased discharged capacity > 2%.

Grid Forming



- ✓ Voltage stability: 10ms response time, 1~3 times reactive current support for 10s
- ✓ Frequency stability : 5ms response time, 3-20s inertia time constant for the equivalent MOI
- ✓ Phase angle stability: 0.1-100Hz wide-frequency oscillation suppression.
- ✓ Power station-level grid forming

Black start across Full SCR/SOC range



- ✓ Support 1- 40 Full Range SCR (weakest grid to strong grid).
- ✓ The system can operate stably across the entire SoC spectrum (0–100%).
- ✓ Minutes level synchronized black start.
- ✓ Black start load rate 70%.

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DC Safety technical enhancements in PV inverters

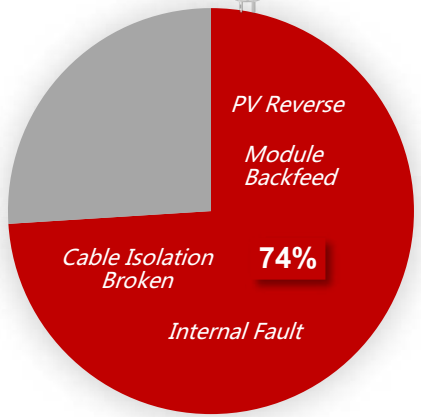
74% failure from DC side

DC cable breakage

DC disconnector fault

MC4 burned out

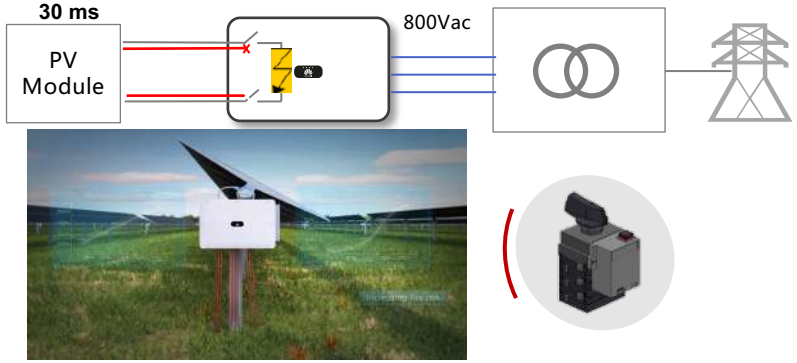
DC Capacitor damage



*Source : Statistics based on Huawei 300GW operation data

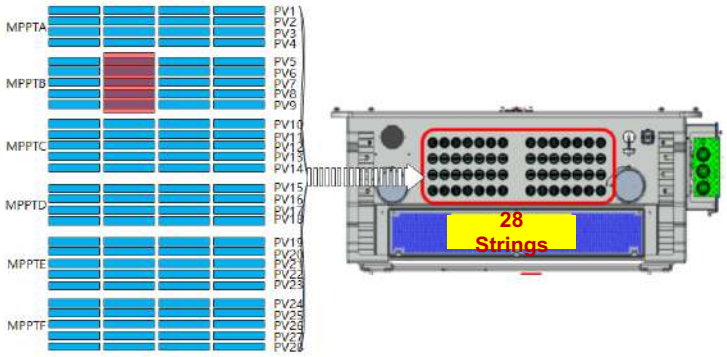
Smart String Level Disconnector (SSLD)

- Active DC-side safety device built into Huawei's string inverters and smart PV controllers.
- Inverter can sense the fault type through the DSP controller and automatically disconnect the switch based on the tolerance of the PV module.
- Detects string level DC faults like reverse polarity, back flow, short circuits.
- Short-term withstand current (1s) - 700 A, Mechanical tripping time - < 30 ms



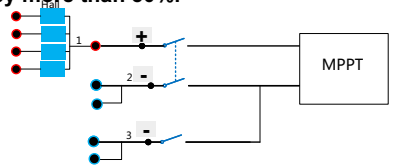
MPPT-Level insulation detection

- Measures the DC-to-ground insulation resistance for each individual MPPT.
- Inverter can pinpoint the faulty string to a specific MPPT with 6 times higher troubleshooting accuracy.
- Generates alarm and isolate or block the affected MPPT when insulation falls below safe thresholds.
- Fault localization, reduces troubleshooting effort and downtime.

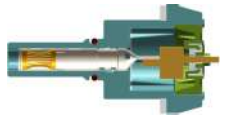


Smart Connector Level Disconnector (SCLD)

- Safety feature for proactive identification of faults in PV connectors and string inputs. Millisecond-level disconnection can be implemented to avoid fault expansion.
- Monitors abnormal conditions such as loose or damaged MC4, partial disconnections, reverse connections or arching.
- The number of cables is reduced by more than 50%.



4 strings per MPPT : 3 cables



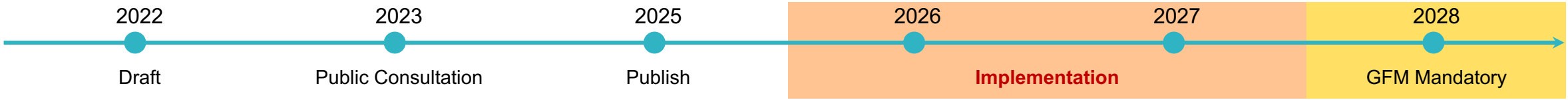
Smart Self Cleaning fan (SSCF)

- This is an integrated component of the inverter.
- The fan reverses its rotation based on temperature, dust, sunlight exposure and other conditions to actively remove dust, which is crucial for the inverter's performance and longevity.
- Improve efficiency and significantly reduces the need for manual cleaning and maintenance, lowering overall operating costs.

GFM is emerging as an essential requirement in European grids

RfG2.0 will likely be published in 2025, and GFM requirements will be implanted in member states by 2028

GFM compliance will gradually transition from a recommendation to an obligation



GFM requirements or market mechanism in GB, Germany, Italy, Spain, Finland

GB	• **Grid code:** G0137 was published in 2022; GFM capabilities will be mandatory for all PPMs that 50MW+ or connected to 110kV+ grid from 2025 • **Market mechanism:** Stability Market, procured 36GVA.s inertia service, include 2.2GWh BESS projects
Ireland	• **Market mechanism:** A second phase of Low Carbon Inertia Services procurement will commence in 2024 which may **allow for Grid Forming capability to provide the service**
Germany	• **Network codes：** VDE-AR-N 4105/4110/4120/4130 public consultation in 2024, will be published in 2026-2027 • **Market mechanism：** Inertia market from 2025, technology requirements published in 2024
Finland	• **Network code:** Specific Study Requirements for Grid Energy Storage Systems • **Network code SJV2024：** GFM capabilities will be mandatory for type D BESS (30MW+ or 110kV integration) from 2025.
Italy	• **Network codes:** Annex 79 was published in 2023, GFM capabilities is mandatory for high voltage and ultra high voltage connected BESS
Netherlands	• RWE with Tennet will build a 7.5MW/11MWh BESS with grid-forming inertia capabilities by the end of 2024 • On the supply of fast fault current by power park modules and electricity storage units by means of grid forming
Spain	• **Market mechanism:** subsidized projects in IDEA, GFM was a criteria
France	• RTE, is investing in innovation, including smart grids and the integration of technologies like GFM based IBR and BESS to support these changes.

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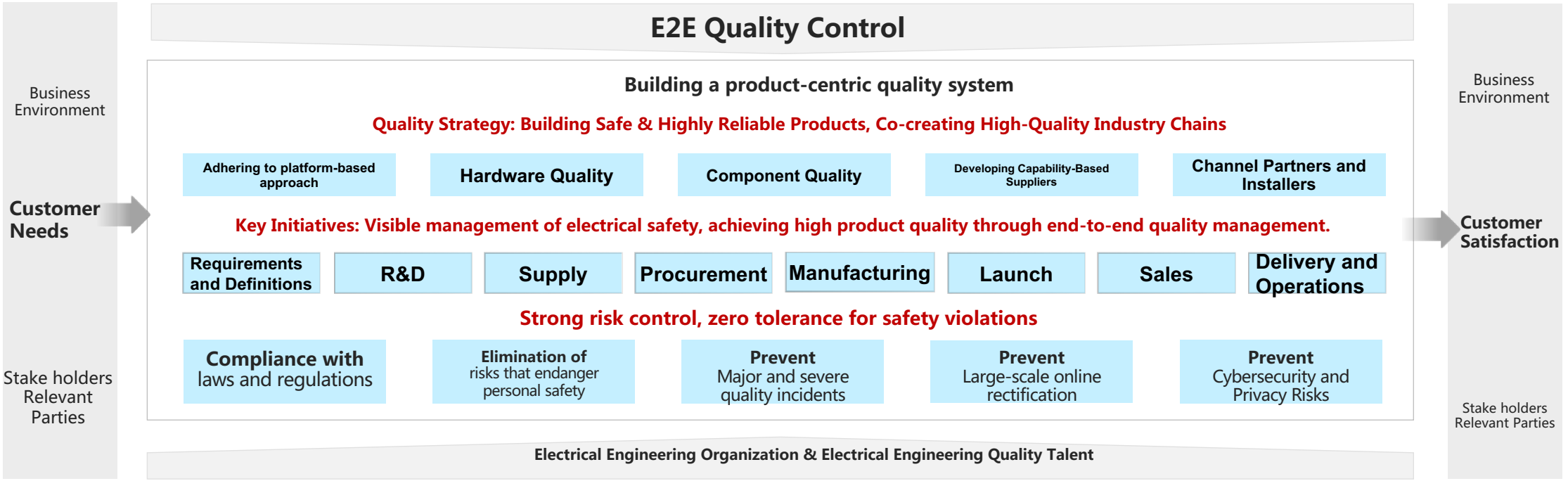
Product-centric safety & quality system for high-quality development.

Huawei regards quality, safety and reliability as the foundation of our existence and build a product-centric quality system, making quality the core competitiveness of digital energy.



Quality Leadership and Culture | **Strictly follow processes and continuously improve.** | **Digital System (Measurement Platform)**

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Quality control, safety, stability & reliability of cells

Entire process with full transparency (1000+ checklists), namely white-box management

Safety Test

External short circuit
Overcharging
Forced discharge
Vibration
Extrusion
Nail penetration
Heat abuse
Fall……

Cell Performance Test

Capacity test
Energy efficiency test
Insulation test
Cycling test
Self-discharge
Temperature rise
Storage test
Expansion force
……

White-box Test

Lithium Plating Disassembling test
Cathode SEM/XRD
Anode SEM/XRD
Electrolyte GC

Dimensional Testing

Cell thickness
Cell Width
Cell Height
Pole spacing
Creepage distance
…

470+ Number of tests

B-sample Certification Tests: 240+

C-sample Certification Tests: 230+

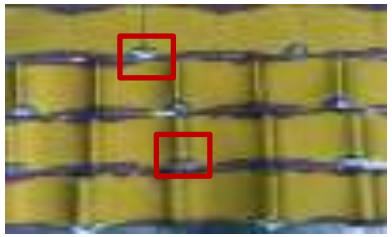
Comprehensive tests from cell design to cell process stability

short circuit Test

1mΩ- Simulates the real cell internal resistance

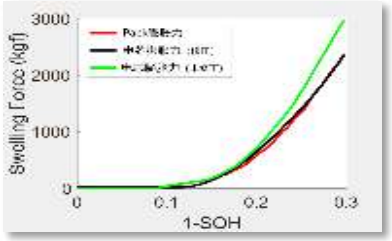
lithium precipitation Test

Charge/discharge cells Lithium evolution is not generated



Expansion/ Swelling Test

Simulate the running conditions and expansion force of the cell in pack



Drop Test

No fire, no explosion, and no liquid leakage during 1.0 m drop

Puncture Test

The needle **penetrates** the cell, and there is no thermal runaway phenomenon.

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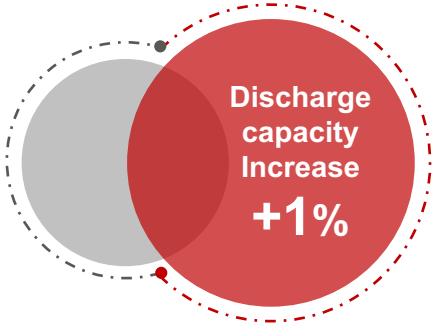
Enhanced safety, reliability, efficiency, and AI based intelligent BMS reduce LCOS

Smart String Grid-Forming Energy Storage Solution

LCOS reduced by 5 %~ 8%

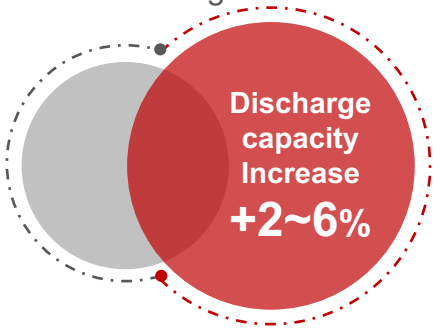
***Higher availability**

Additional revenue of 2M US$



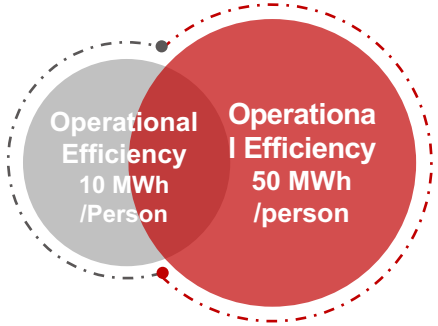
***Higher Returns**

Additional Earnings of 4M~12M US$



***Enhance operational efficiency**

Save OPEX 1.5~2.8M US$



Traditional Energy Storage Solution

Smart String Grid-Forming ESS 2.0

***Based on a 100MWh Battery Energy Storage System**
1 charge/discharge cycle per day, electricity price: 0.10 US$/kWh

* LCOS: Levelized Cost of Storage

$$\downarrow \text{LCOS} = \text{Safety Factors (4-Ply Safety)} \propto \text{System Availability (Modular/String Design)} * \frac{\text{CAPEX (RTE/DoD/Optimizer, etc.)} \downarrow + \text{OPEX (Automatic SOC Calibration/Simplified Maintenance, etc.)} \downarrow}{\text{Total Lifecycle Energy Discharge (RTE/Constant Power/Package Optimizer)} \uparrow}$$

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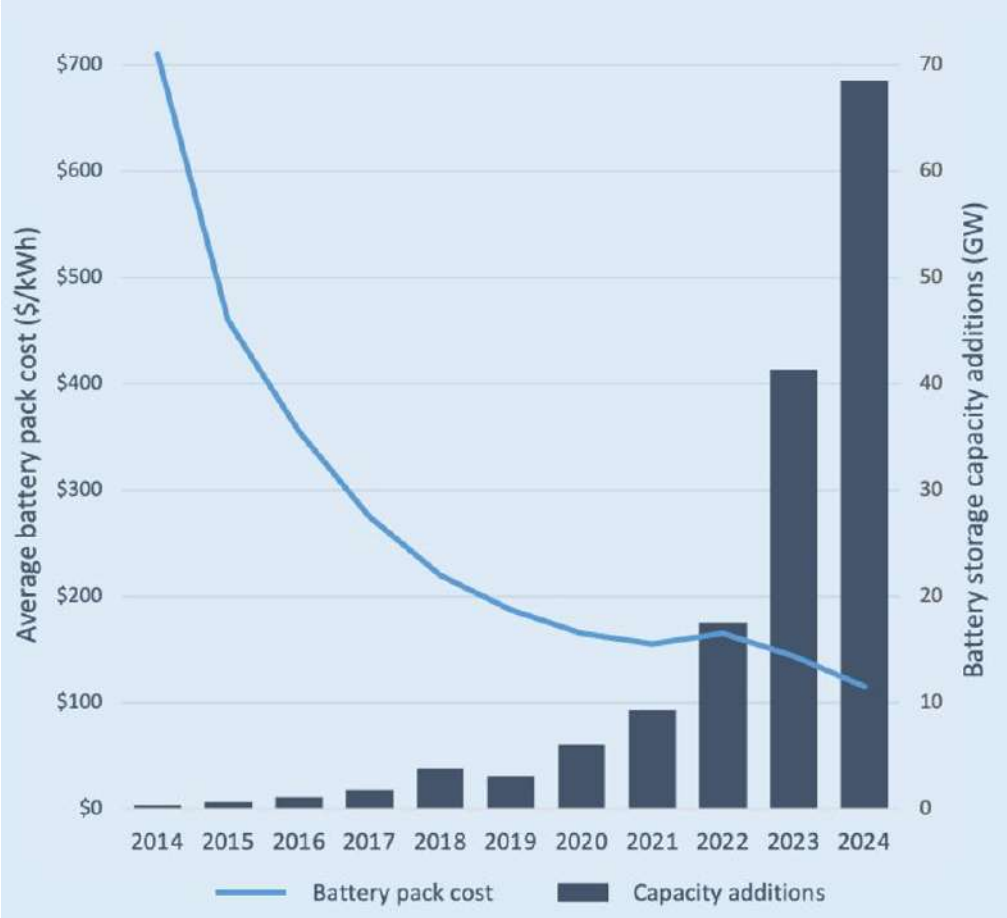
Impact of BESS & Renewables costs on adoption in global market



BESS cost in US$/KWh & BESS capacity addition (Source: BNEF, IEA, Ember Global Electricity Review 2025)

Renewable energy technologies have experienced spectacular cost declines since 2010 (Source: IRENA: Renewable power generation costs in 2024)

Both solar PV and battery storage have seen dramatic cost reductions since 2010, thanks to technological innovation, large-scale production, and more efficient supply chains.

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Digital Power: Your Best Partner for a Better, Greener Future

Thank You

By March 2024, Huawei Digital Power has helped customers

generate green power	save power	reduce carbon emissions	equivalent to planting
1,110.6 billion kWh	**53.18 billion** kWh	**553 million** tons	**755 million** trees

Conversion note:

Note 1: Conversion coefficient of electricity carbon emissions – 1 kWh electricity is equivalent to 475 g CO_2 (global average). Source: IEA Global Energy & CO_2 Status Report 2018

Note 2: Lifetime CO_2 absorption of trees (equivalent number of planted trees) – A tree absorbs 18.3 kg of CO_2 a year, and each tree has a 40-year lifespan. Source: Open data of the North Carolina State University website