

FusionSolar Smart PV & ESS Solution

Grid Forming Experiences



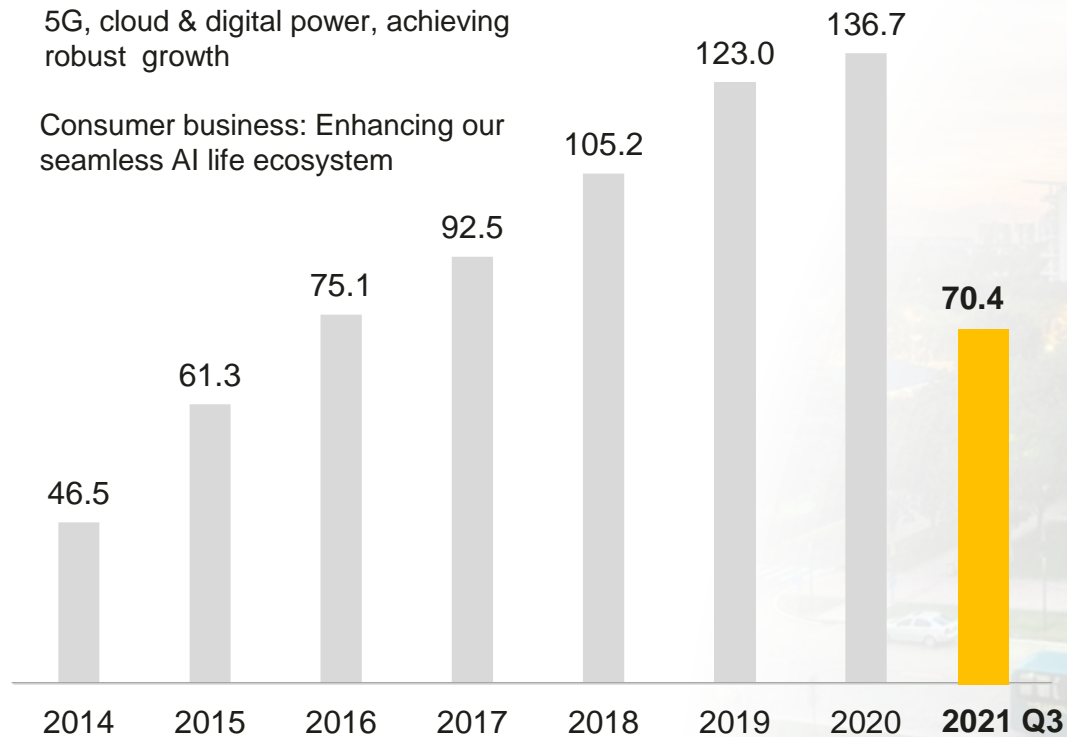
Go & cooperate with Fortune Global #44

Huawei: Most bankable partners for customers

Solid operations

Constantly creating value for customers

- 5G, cloud & digital power, achieving robust growth
- Consumer business: Enhancing our seamless AI life ecosystem



No. 44 on Fortune Global 500



197,000 employees



170+ countries and regions



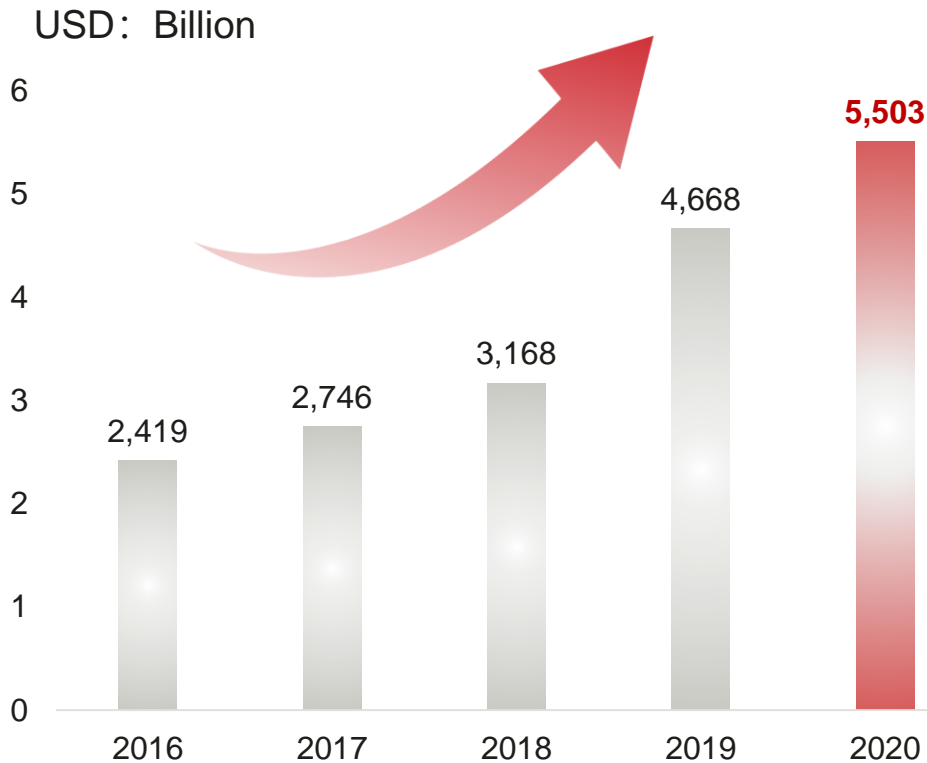
53.4% R&D employees



No. 3 in R&D investment

Digital Power: Constant & high-speed growth, worldwide recognition

Huawei Digital Power sales revenue



Huawei Digital Power serves 1/3 of the world's population across more than 170 countries and regions

Smart PV



No. 1 in the global market for six consecutive years Source 1

200GW smart PV plants

Data center facility



Prefabricated modular data center solution:
No. 1 in the global market for six years.
Smart module: No. 1 in the Chinese market for seven years Source 2

Site power



No. 1 for eight years since 2013, serving **170+** countries and regions Source 3

mPower



The world's first x-in-1 ePowertrain DriveOne

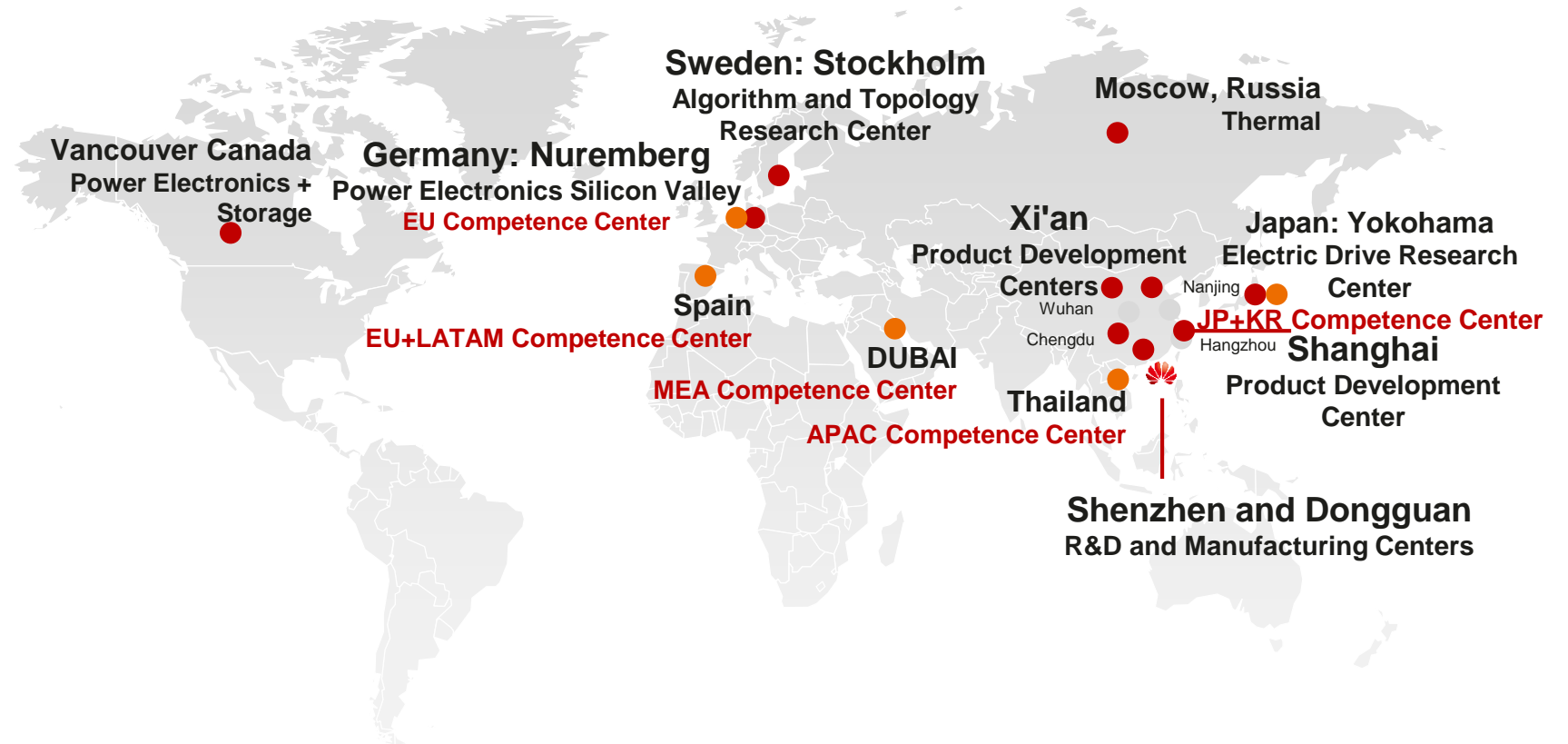
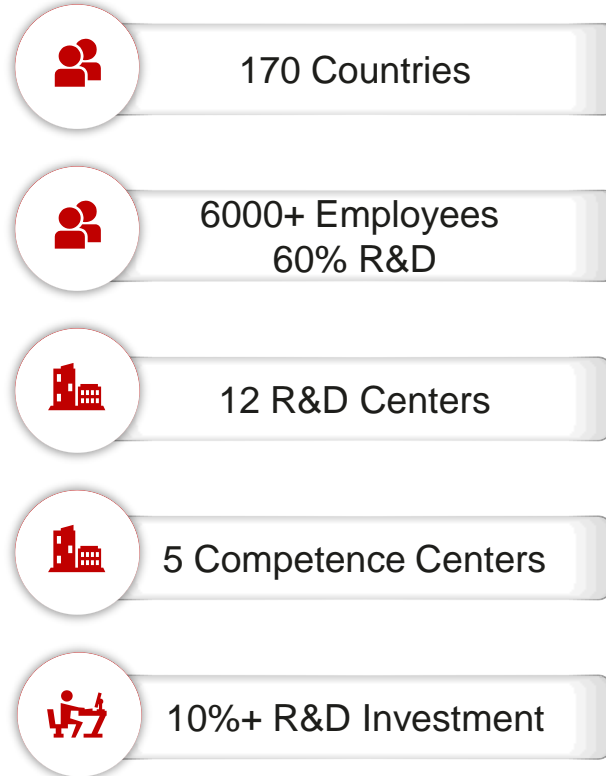
Embedded power



675+ Million PCS delivered

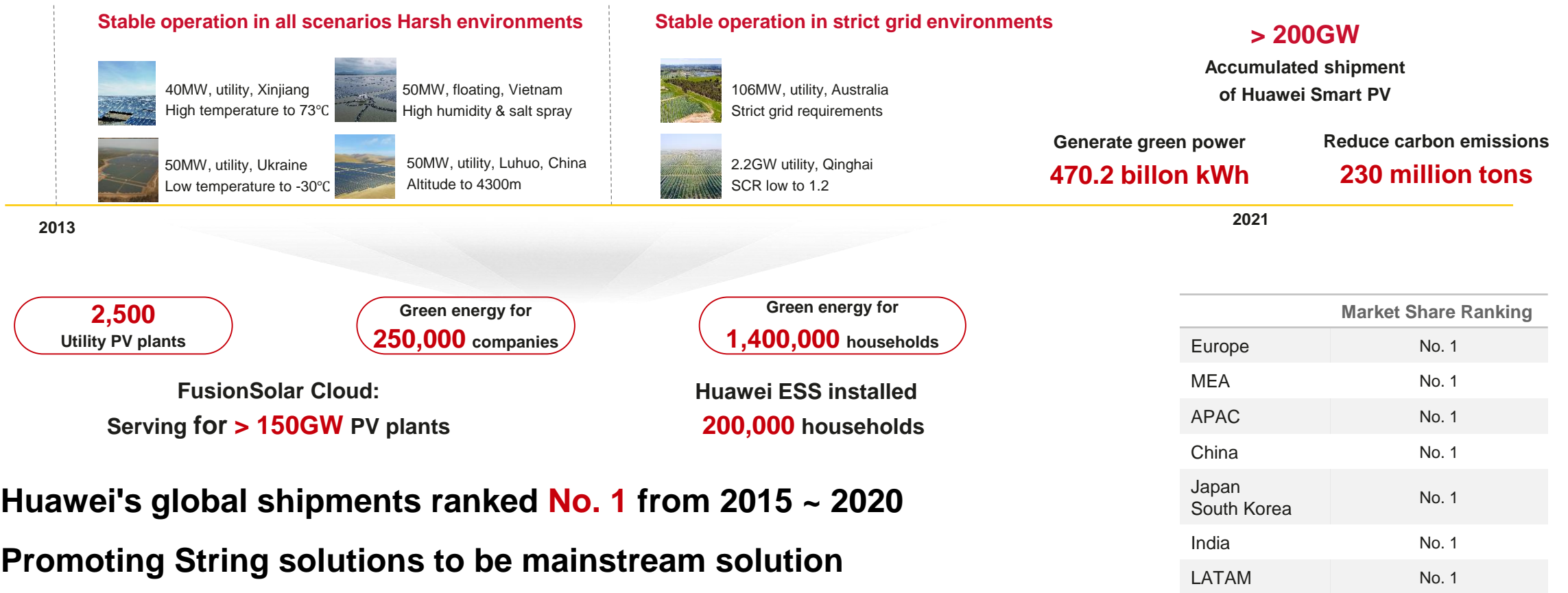
Source 1: IHS Markit
Source 2: Omdia
Source 3: Frost & Sullivan

Digital Power Global Platforms: Leveraging the domain specific advantages globally to keep leading



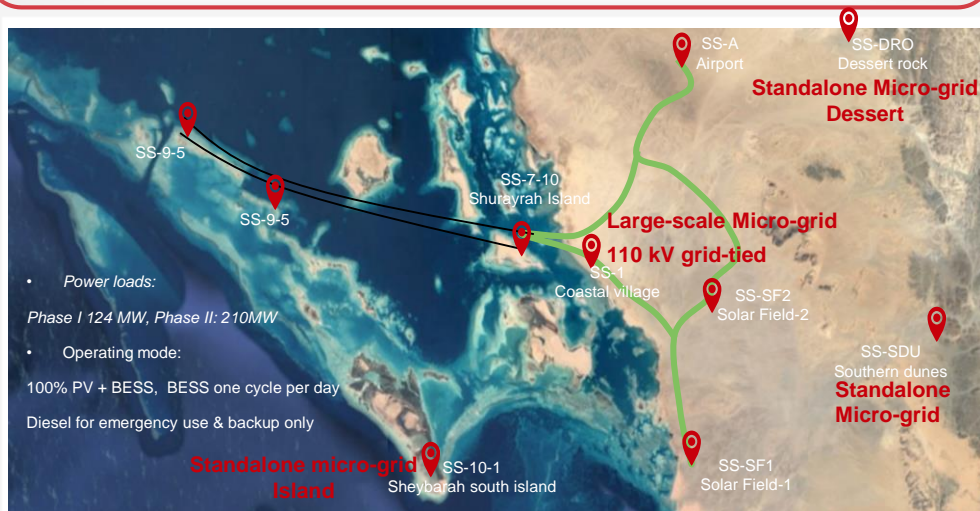
Huawei smart PV: Continuous innovation for PV scenarios

Unique string solution with accumulated shipment > 200GW



Huawei Smart PV support world's largest GW-level ESS project

Red Sea 1.3GWh, 100% Renewable Energy Micro-grid Project



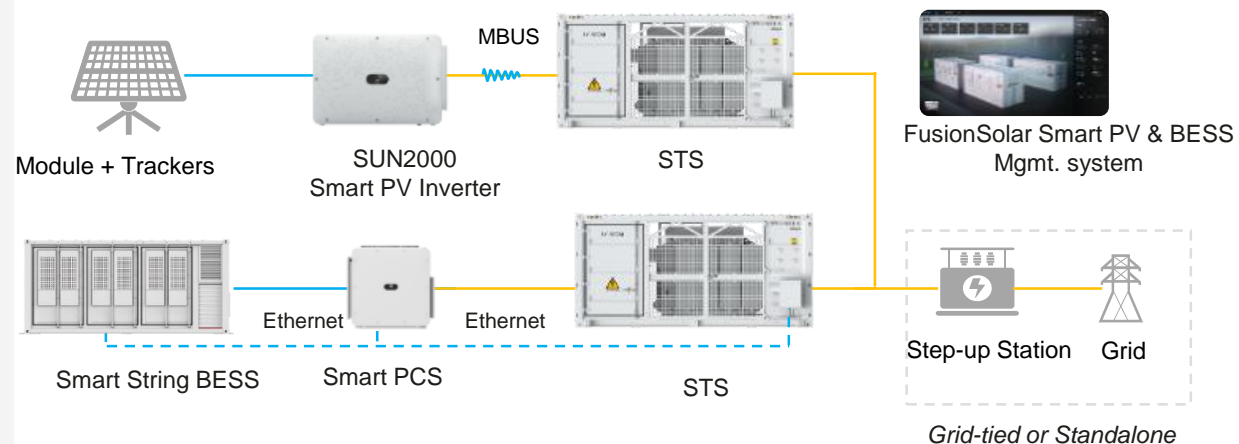
400MW PV + 1.3 GWh BESS

- 100% powered by renewable energy, weak grid environments, high requirements for grid stability
- Large-scale micro grid system, grid networking by 110 kV, requiring off-grid fault ride through
- High Temperature, High Humidity, High Salt Spray

The World's Largest 100% Renewable energy Micro-grid Project

Huawei Large-scale Micro-grid Solution

Grid Forming, Stable PV & BESS power supply, Lower LCOE

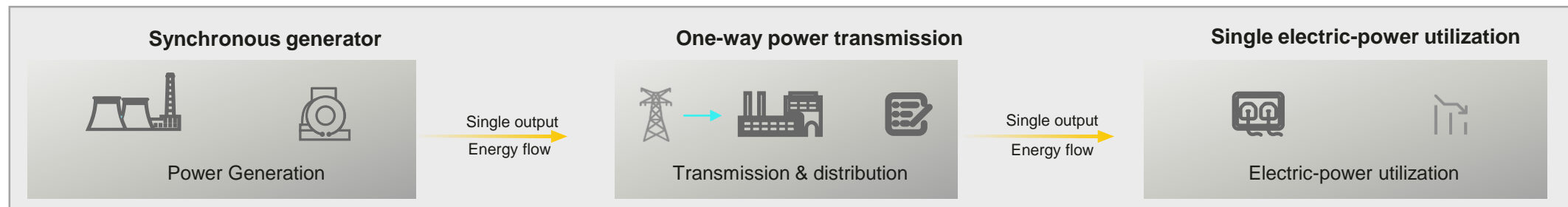


- Smart Grid Forming, higher grid-tied ability, passing grid simulation within 1 month
- Micro-grid fault ride through enables higher availability and higher revenue
- Online MV off-/on-grid change-over, higher system revenue
- 2:1 PV / BESS ratio, maximum reducing 50% BESS configurations

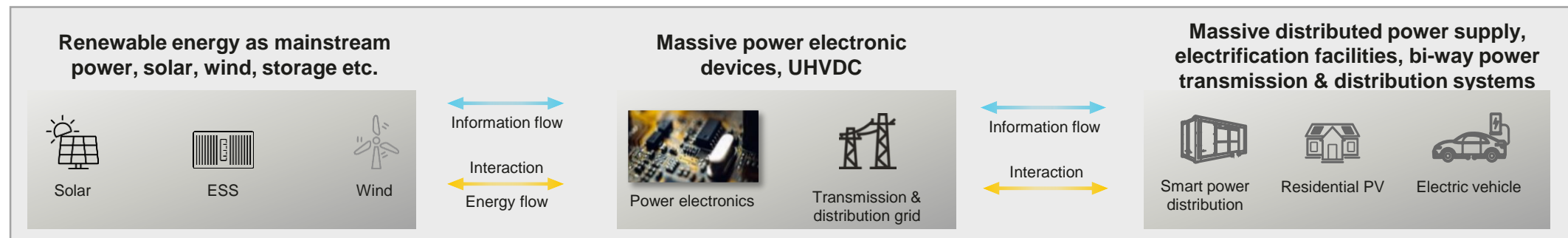
New power system bring new challenges to grid: high proportion of renewable energy, power electronic devices, distribution energy

Trends

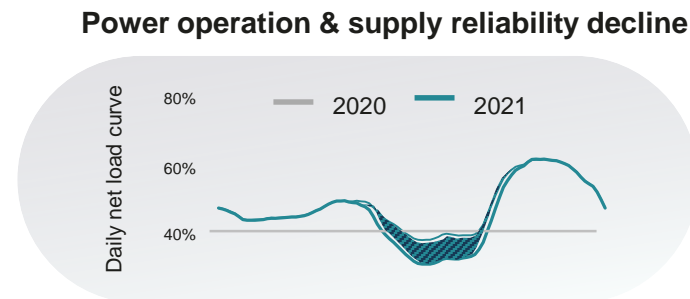
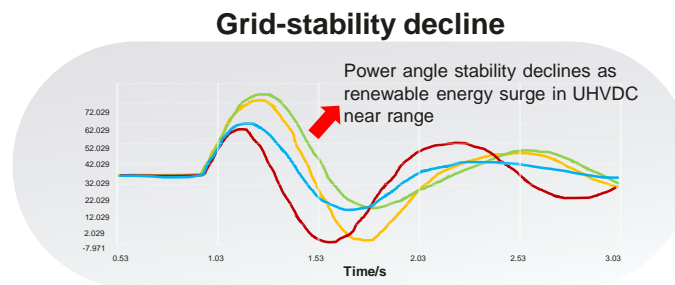
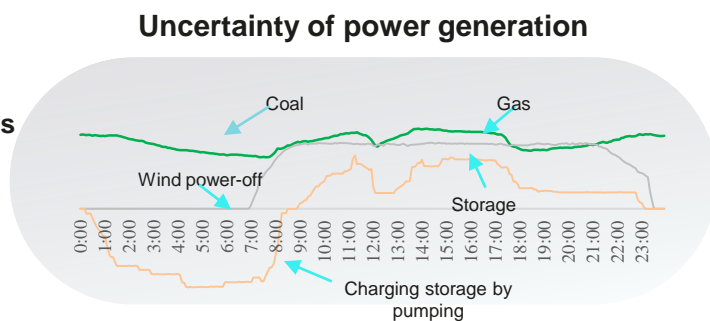
Traditional Power System



New Power System



Challenges



China: Multiple policy guidance and UHVDC power transmission, driving rapid development of PV renewable energy

#1 Large clean energy bases

During the 14th Five-Year Plan period, the construction of renewable energy bases will be promoted.

9 large energy base

wind/solar/hydrogen/ESS

Songliao Base	Northern Hebei Base	Upper Huanghe River Base
Yellow River Jizhiwan Base	Upper Jinsha River Base	Yalong River Base
Hexi Corridor Base	Xinjiang Base	Lower Jinsha River Base

Integration of wind/water/fire/hydrogen/ESS

#3 ESS as mandatory

17 provinces explicitly require ESS mandatory or priority approval

Shandong	10% ESS storage as mandatory
Hunan	ESS capacity \geq 20%
Xinjiang	20% ESS capacity of PV plant capacity
Jiangsu, Hubei	ESS capacity \geq 10%

#2 PV construction in whole county



- ✓ Pilot project for PV construction in whole county
- ✓ Vigorously develop solar to revitalize rural areas
- ✓ Combine solar & buildings, reducing power loads & land demand

#4 Region (province, city, and district)/source network load storage

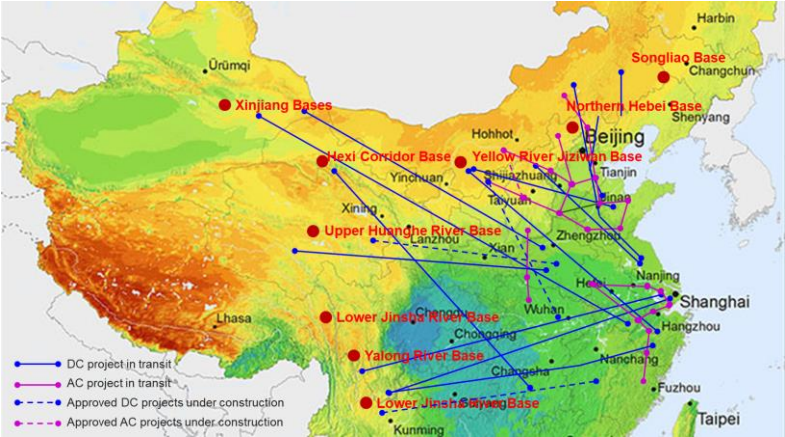
- Integration of source/load/net/storage
- Pluripotent complementarity
- Optimize & integrate local resource
- Proper configuration, optimized power ratio
- Exploit load-side regulation
- Coordinate power supply planning, design, construction and operation
- Local and nearby flexibility to stimulate market vitality



Shanxi Province Promotes the Integration of Power Source, Load and Storage and Multi-Energy Complementary Demonstration

UHVDC power transmission important power transmission channel

- In 2020, UHVDC lines transmit 531.8 billion kWh of electricity, of which 244.1 billion kWh of electricity from renewable energy sources, accounting for 45.9%.
- By the end of 13th Five-Year, State Grid has completed and put into operation 24 UHV projects in the "13th Party, 10th Party and 10th Party" projects, and approved and under construction 4 UHV projects in the "one Party, three direct Party" projects. UHV projects have been put into operation with a total line length of 35,583 km and a total transformation (conversion) capacity of 39,667 million kVA (kW), accounting for 5 percent of the country's electricity.



The diagram illustrates the power system architecture, showing a 220kV Substation Busbar connected to a 35kV Substation Busbar. The 220kV busbar is connected to a 1x180MVA Main Transformer, which has a Short Circuit Capacity of approximately 253MVA. The 35kV busbar is connected to two separate power distribution systems:

- Stage I Project 100MW (with central inverters):** This system is connected to the 35kV busbar and consists of two parallel branches. Each branch contains a 2.5MVA x 40 transformer connected to a Central Inverter.
- Stage II Project, 20MW (with Huawei):** This system is also connected to the 35kV busbar and consists of two parallel branches. Each branch contains a 2.5MVA x 40 transformer connected to a Huawei Sun2000 series inverter.

画面1: 220kV主变电路

System Normal

Plant normal

Phase shift and reduced voltage magnitude

Inverter failing LVRT and shut downs

Line-Line 2phase faults

[1]220kV电压_Ua 42.05718V

[2]220kV电压_Ub 41.20275V

[3]220kV电压_Uc 59.74766V

[4]220kV电压_3U0 0.56025V

[29]220kV主变... 1.53629A

[30]220kV主变... 1.39522A

[31]220kV主变... 1.36087A

[32]220kV主变... 0.24907A

- 35 out of 140 inverters shutdown and damaged.
- Whole plant shuts down for 2 weeks (3% yield loss) ..
- Replacement of control PCB of all inverters ... does not guarantee no recurring.

Detected the fault accurately and rode through the fault.

Summary Analysis result DSP Log 5min Log Wave Log

Row: 0 Content:

LVRT Event Detection

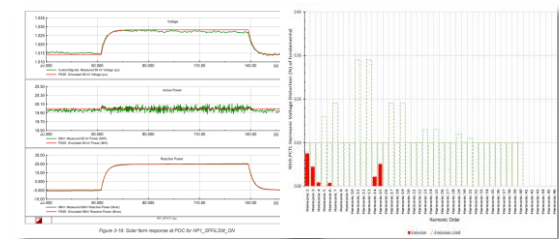
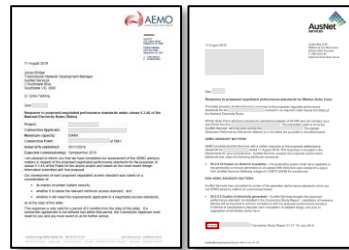
Negative sequence voltage

	File	Pre	Time	ID	LVRT	HVRT	Grid_AB	Grid_BC	Grid_CA	Grid_PosSeq	Grid_NegSeq	Id_Ref	Iq_Ref
▶ 0	A	0...	2020/4/4 9:38:54	INV_VRT_INFO_LOG_VRT	1	0	5062	5042	5047	3343	627	1128	65352



Success Case: Huawei Smart PV Fully Compliance with World's Strictest Grid Code

Huawei Smart PV: Unique string solution fully compliance with Australian new strict grid code



**New Grid Code
Launched in Australia**

GPS Simulation

**R1 Simulation &
Construction**

**R2 Testing &
Commissioning**

2019.02

2019.08

2020

2021.04~08

New Australian grid code

Fully compliance with new code

Successfully pass strict model audits

300+ onsite tests, **100%** fully grid-connected

➤ Strictest grid code for HVRT/LVRT

➤ First approval letters compliance with new code within half year

➤ Fully compliance with new Australian dynamic models
➤ SCR low to 1.5

➤ Onsite results fully overlay with simulation
➤ Superior power quality: $THD_u < 0.37\%$
➤ Better communication: 40 ms instruction cycles and < 10 ms time delay

ESS functions as a reservoir/regulator in the power system, supporting high-proportion development of renewable energy



国家发展改革委关于
进一步完善抽水蓄能价格形成机制的意见

发改价格〔2021〕633号

- Establish mechanism for recovery of capacity tariffs into transmission and distribution tariffs. The capacity electricity fee corresponding to ESS capacity electricity price approved by gov. shall be paid by grid enterprises, and shall be included in the provincial transmission and distribution price for recovery.

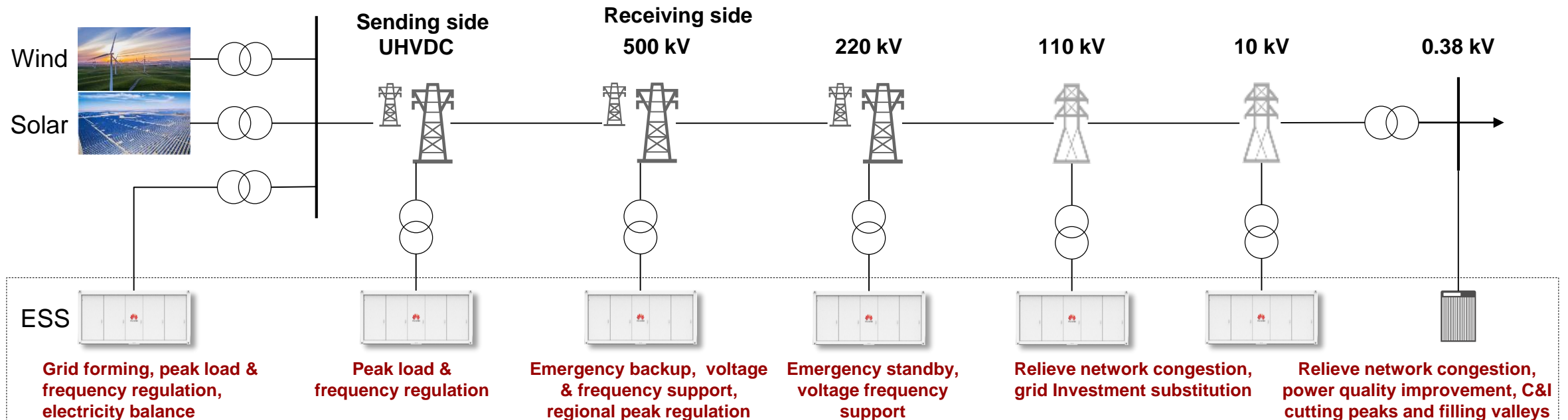
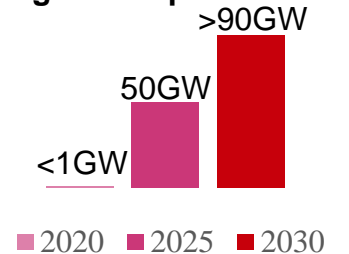


国家发展改革委 国家能源局关于加快推动
新型储能发展的指导意见

发改能源规〔2021〕1051号

- Establish a capacity price mechanism for independent energy storage power stations on the grid side, and explore how to incorporate the cost and benefit of alternative ESS facilities into transmission and distribution price recovery.

Planned ESS capacity by 2
giant grid companies



From simple series and parallel connection of batteries to smart string architecture, building safe & reliable ESS architecture

Traditional energy storage solution: low available capacity and high safety risks

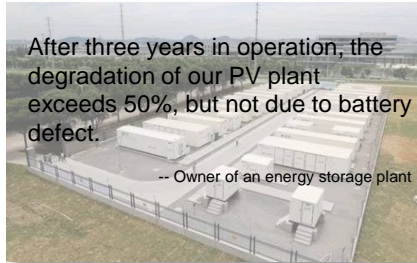
Low available capacity

Insufficient production from renewable energy

Battery mismatch in series and parallel connection

Large temperature differences

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High degradation of a plant in Anhui



Fire in an energy storage plant in Beijing

Battery system defect

Lack of insulation detection protection

External short circuit

Cross current between racks

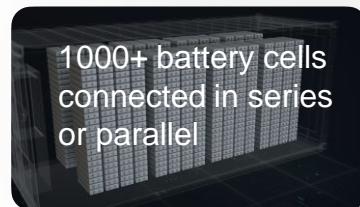
Inappropriate fire control

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High safety risks

Unstable operation of power plants

Battery



1000+ battery cells connected in series or parallel

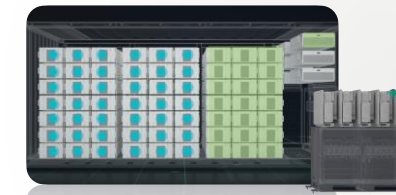


- 1000+ battery cells connected in series and parallel, centralized charging and discharging
- Reactive protection
- Centralized PCS
- Centralized cooling



ESS

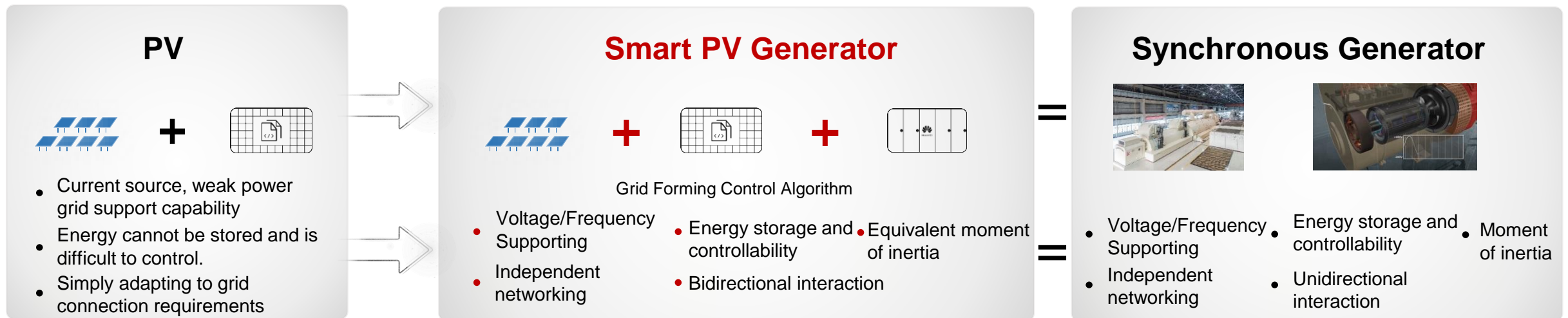
Integrated system supported by electrochemical, heat dissipation, power electronics, and digital technologies



Cloud management

- Multi-level charge and discharge optimization
- Proactive warning, zero fire or explosion risk
- Modular PCS
- Distributed cooling

Grid Forming: Enabling PV voltage source attributes and align grid-tied features with synchronous generators



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

By Nov. 2021, Digital Power has helped customers

generate green power

save power

reduce carbon emissions

equivalent to planting

470.2 billion kWh **14.4 billion kWh** **230 million tons** **310 million trees**



Conversion note:

Note 1: Conversion coefficient of electricity carbon emissions – 1 kWh electricity is equivalent to 475 g CO₂ (global average).
Source: IEA Global Energy & CO₂ Status Report 2018

Note 2: Lifetime CO₂ absorption of trees (equivalent number of planted trees) – A tree absorbs 18.3 kg of CO₂ a year, and each tree has a 40-year lifespan.
Source: Open data of the North Carolina State University website