IRENA INNOVATION WEEK 2025

Connecting the Dots:

Bridging Infrastructure Gaps for Renewable Powered Systems

Session organised in partnership with

国家电网
STATE GRID
中国电力科学研究院有限公司
CHINA ELECTRIC POWER RESEARCH INSTITUTE

11 June 2025 | 15:30-17:00

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Scene Setting

Francisco Gafaro

Team-Lead, Power Sector Transformation
IRENA

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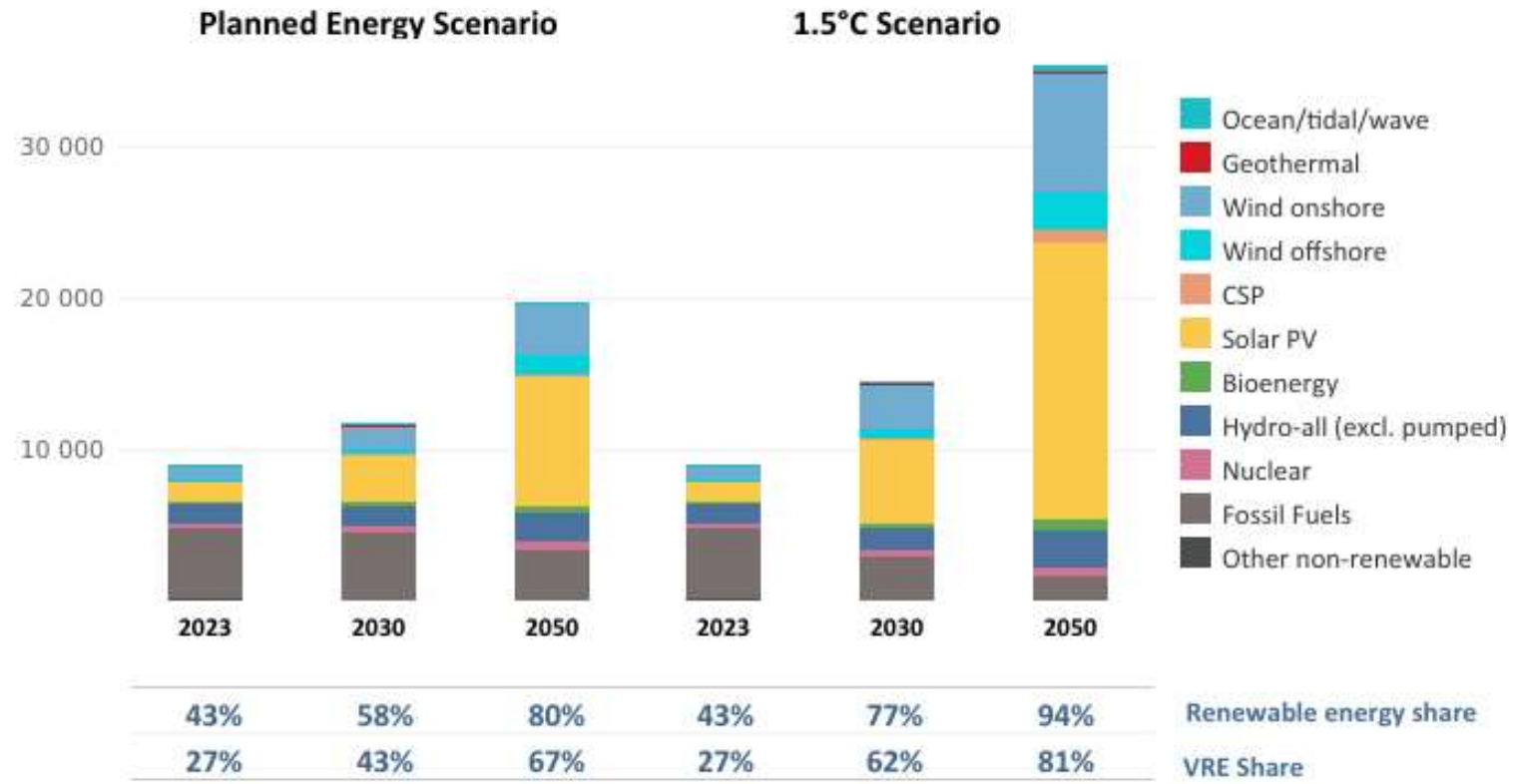
The transformation of the power system

Electricity Generation and Capacity

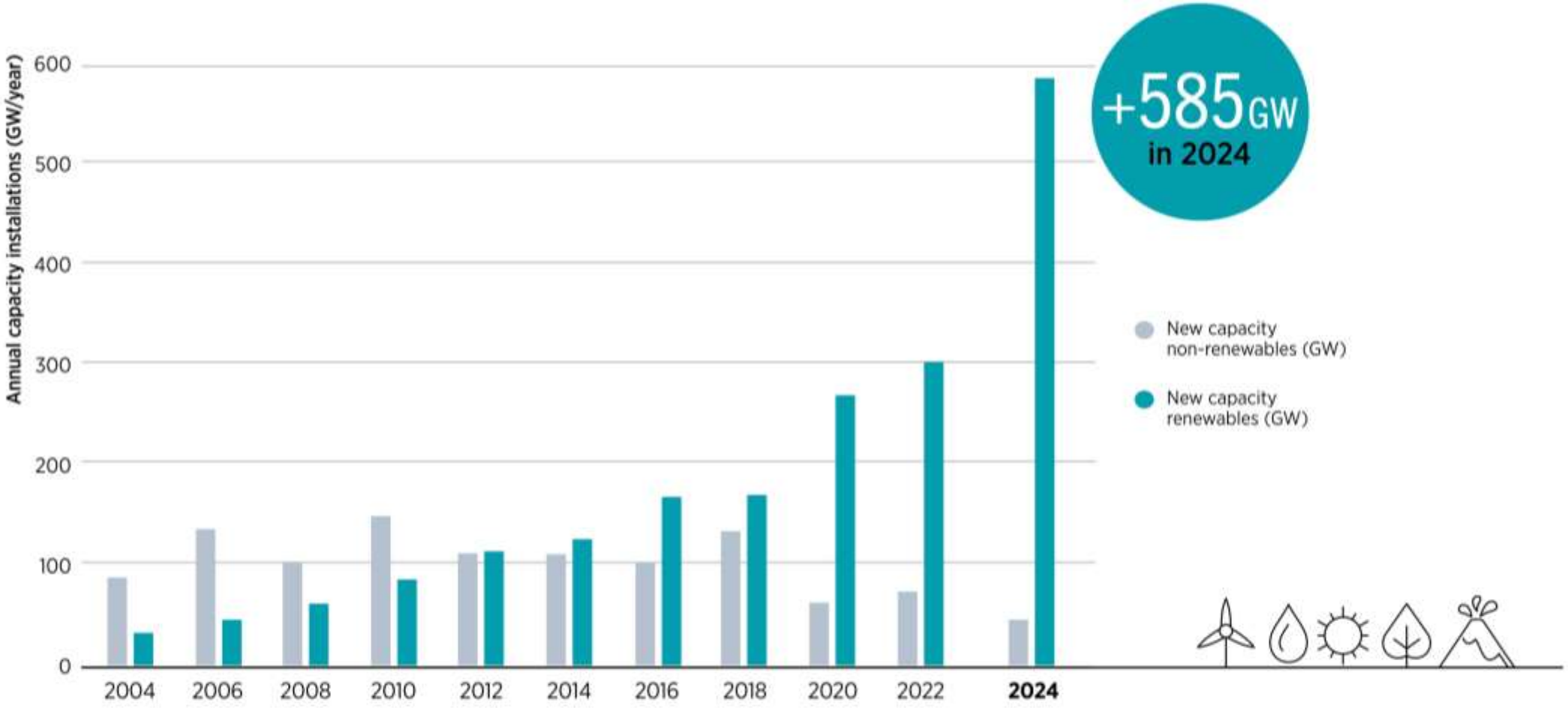
Show by
Electricity Capacity (GW)



Source: IRENA (2024), World Energy Transitions Outlook 2024: 1.5°C Pathway, International Renewable Energy Agency, Abu Dhabi.
https://www.irena.org/Publications/2024/Nov/World-Energy-Transitions-Outlook-2024

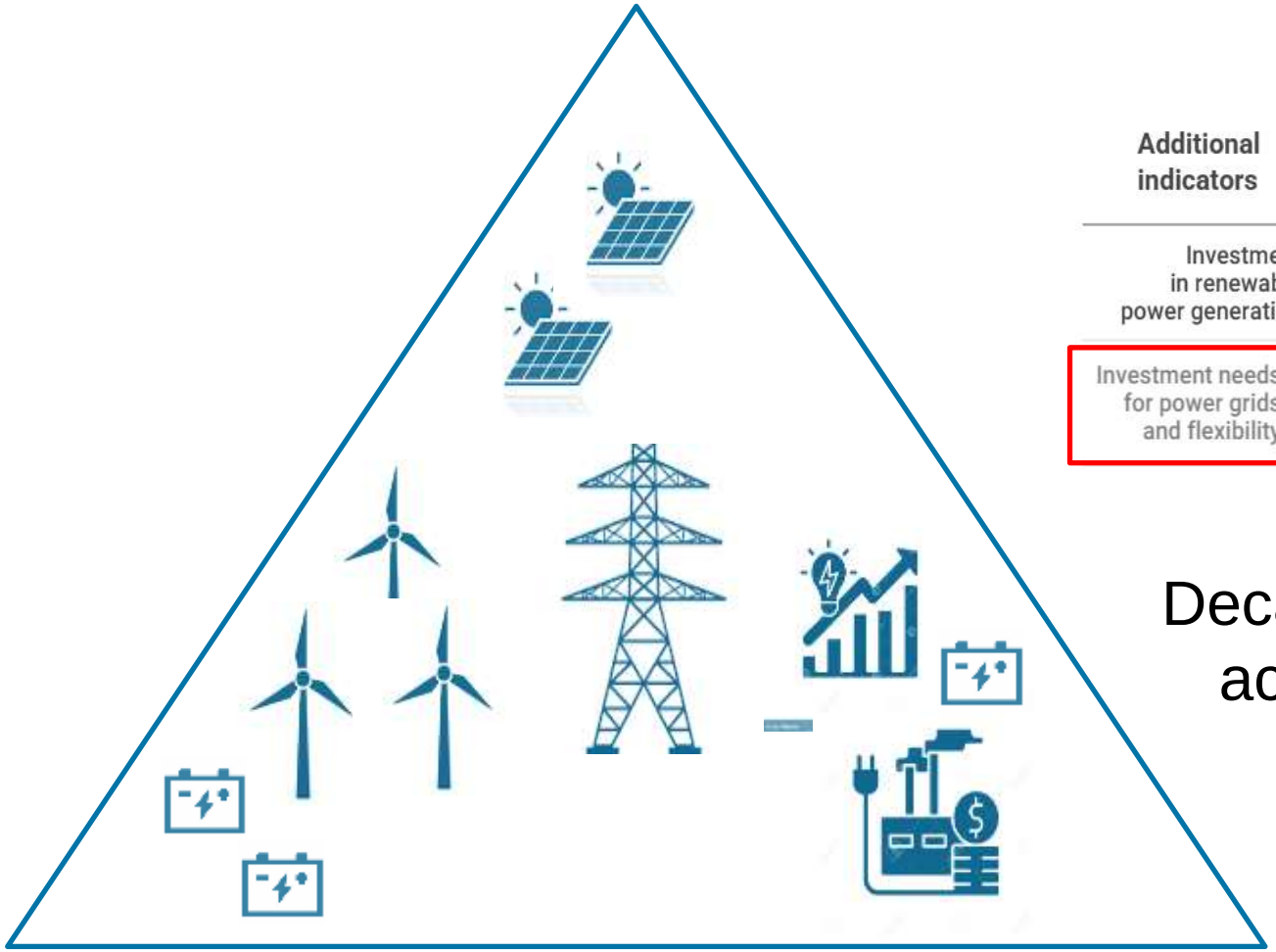
Last update: 07 January, 2024

The transformation is on its way



The transformation needs enabling infrastructure

Sustainable



Reliable

Affordable

Additional indicators	FINANCE AND INVESTMENT		
	2023	2024-2030 (1.5°C Scenario)	On track
Investment in renewable power generation	570 USD billion/yr	1 550 USD billion/yr	
Investment needs for power grids and flexibility	368 USD billion/yr	720 USD billion/yr	

Decarbonizing the power sector requires accelerating the development of grid infrastructure

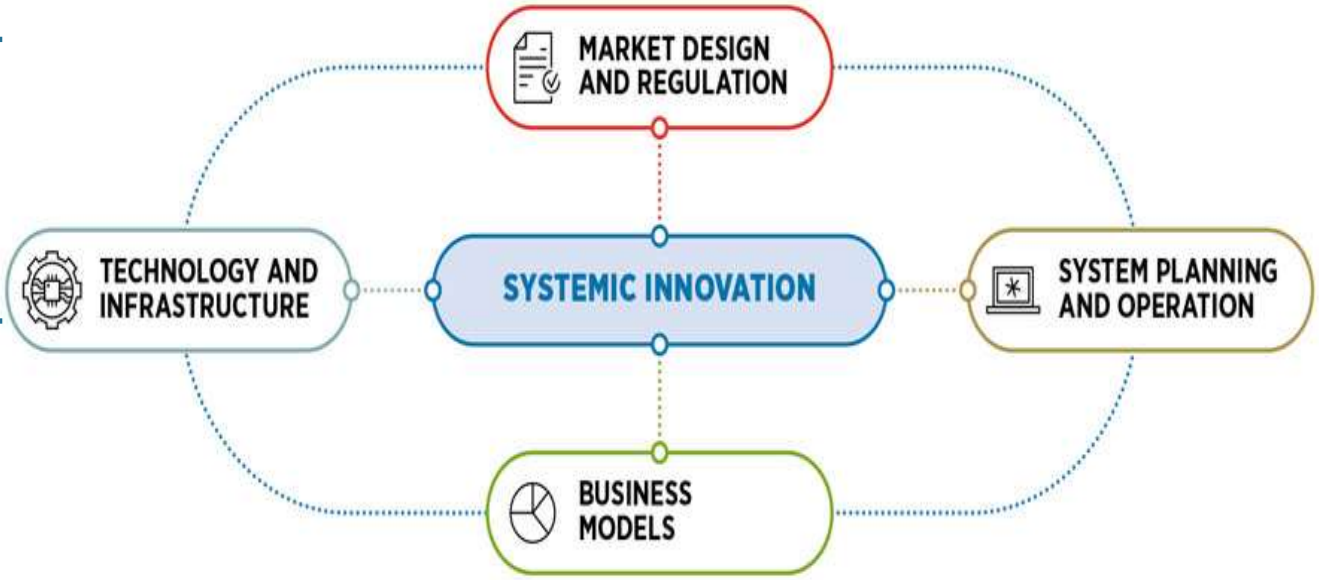
Innovative Solutions to Accelerate the Transformation

Infrastructure for the transformation has a double challenge: The scale is significant and traditional approaches often struggle to keep pace with evolving needs

Anticipatory investments

Co-location

Non-wire solutions



Some of our work

IRENA
International Renewable Energy Agency

Innovation

Flexibility

Energy Planning

IRENA FlexTool

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Scene Setting

Uroš Salobir

Director, Strategic Innovation Department
ENTSO-E Research and Development Committee

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Bridging Infrastructure Gaps for Renewable Powered Systems

Uroš Salobir, ELES & Chairman of RDIC at ENTSO-E

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Reliable Sustainable Connected

Introduction to ENTSO-E

500.000 km of transmission lines

520 million citizens

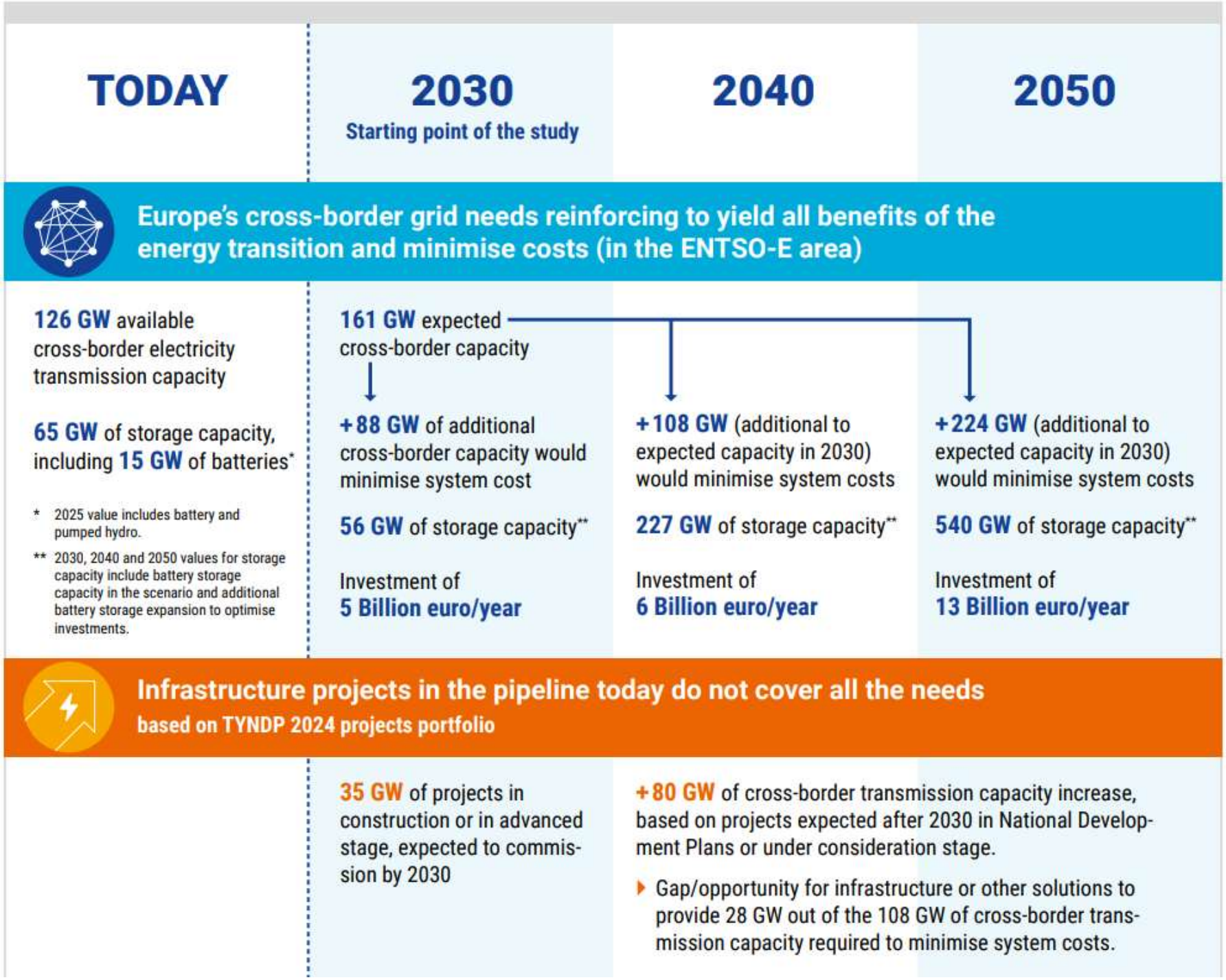
- ENTSO-E, established in **2009,** represents **40 TSOs from 36 countries**
- Represents TSOs at the European level.
- Helps TSOs implement and monitor common rules and EU legislation.
- Enhances cooperation among members

Security of **power system**

Optimal functioning and development of **electricity markets**

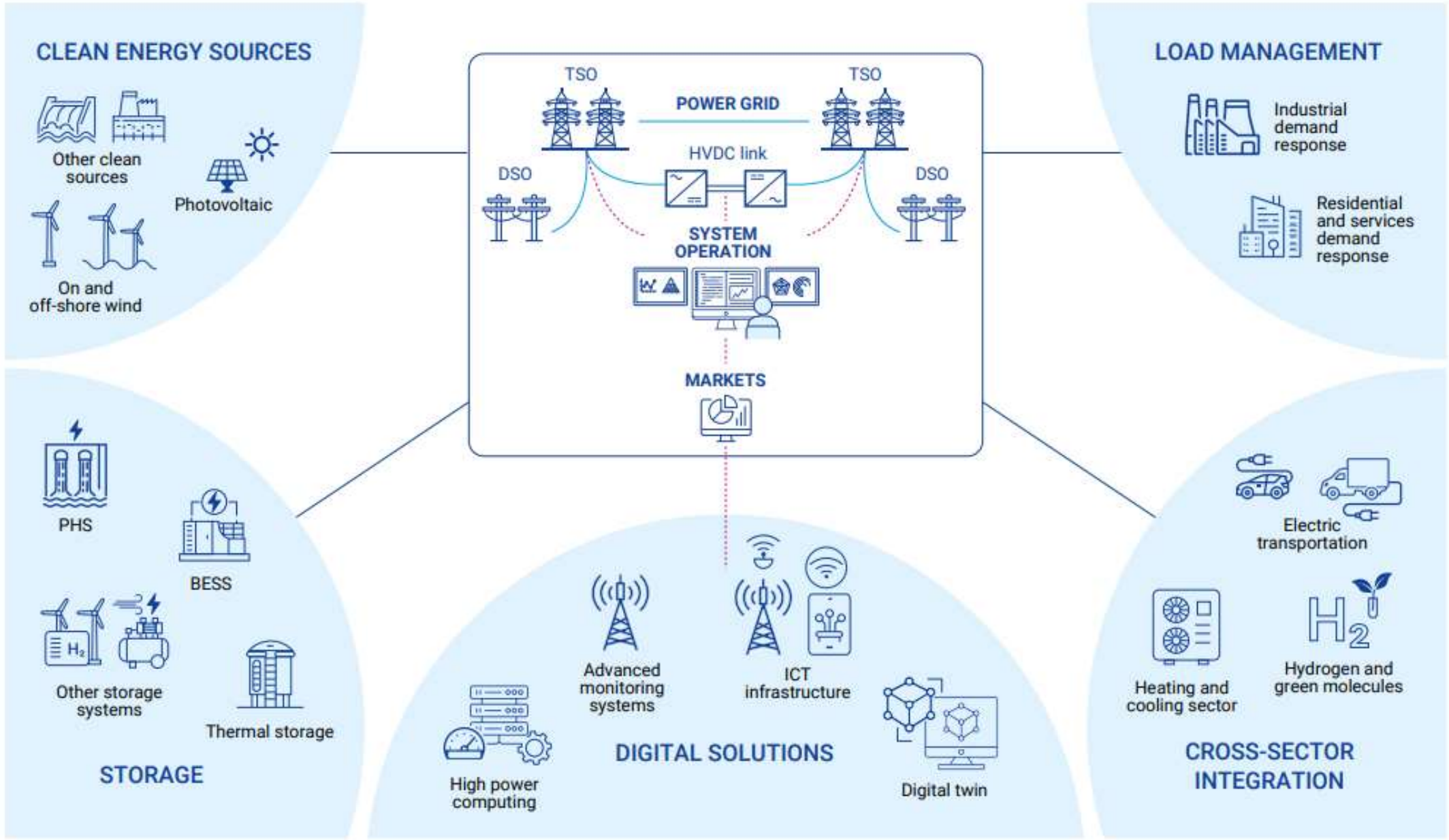
Climate-neutrality by 2050

TSO views on Infrastructure needs and gaps in EU



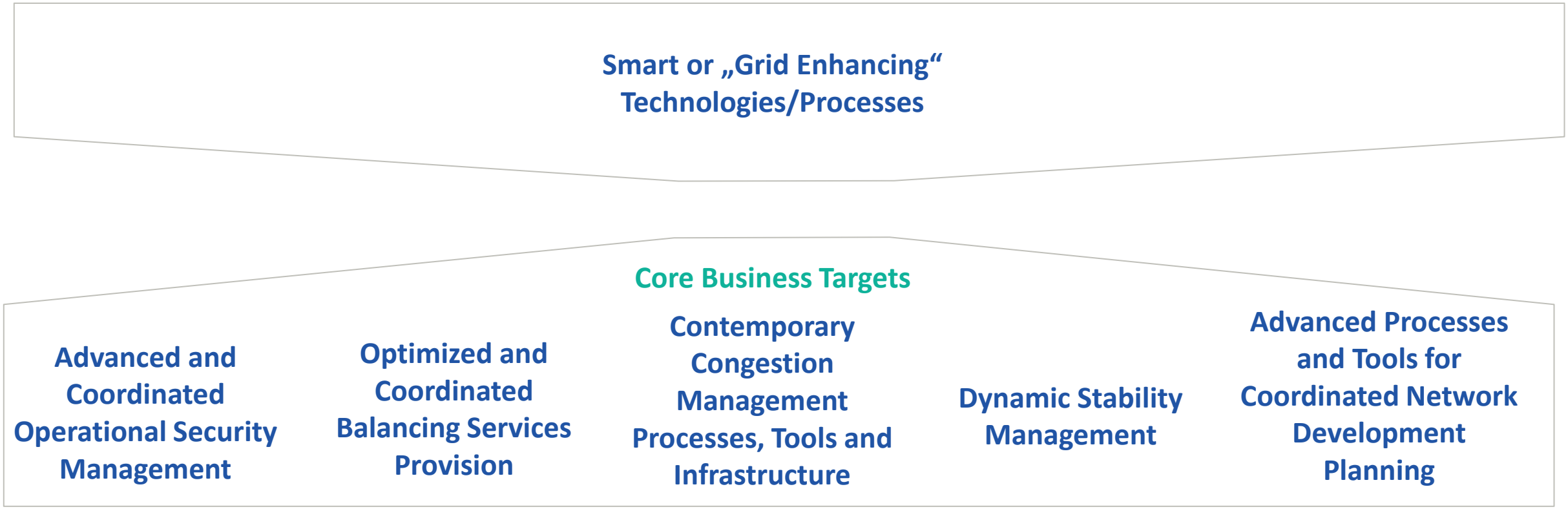
TSO Innovation beyond VRE and Storage……

The future power system is sustainable, flexible, digitalised and at the core of the European energy system of systems



Leveraging TSO Innovation for Core Business Processes

TSOs expect Smart Grids and Grid enhancing technologies
will penetrate into their Core Business Processes (Qualitative vs Quantitative improvements)



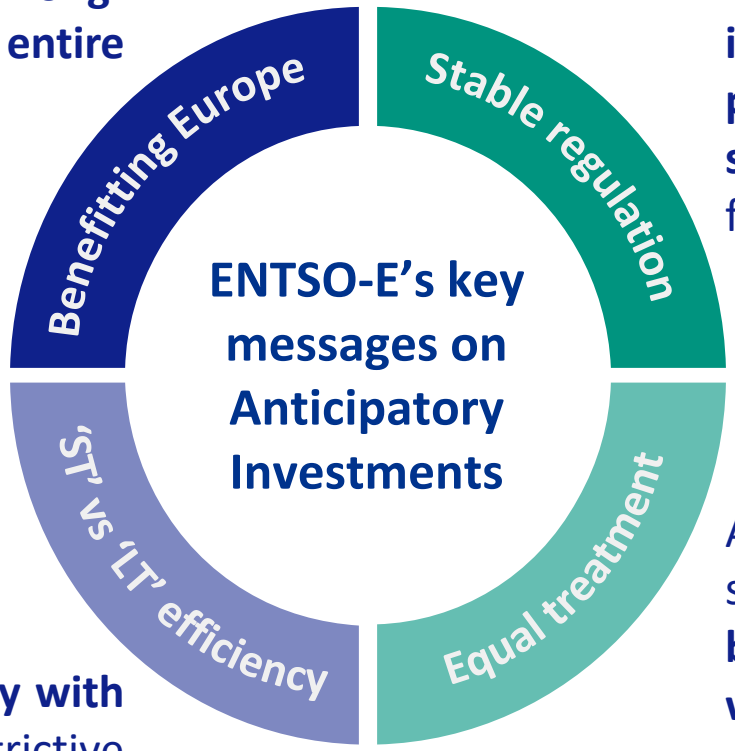
Planning vs Risk taking with the Anticipatory investments

Main messages

Investing in interconnections and other grid infrastructure, based on anticipated, long-term system needs, benefits the entire European industry and society.

While infrastructure costs in the short term will rise due to those investments, the socio-economic benefits are expected to outweigh the costs.

NRAs must balance short-term efficiency with long-term effectiveness. Overly restrictive approaches can be costlier than controlled anticipatory investments.

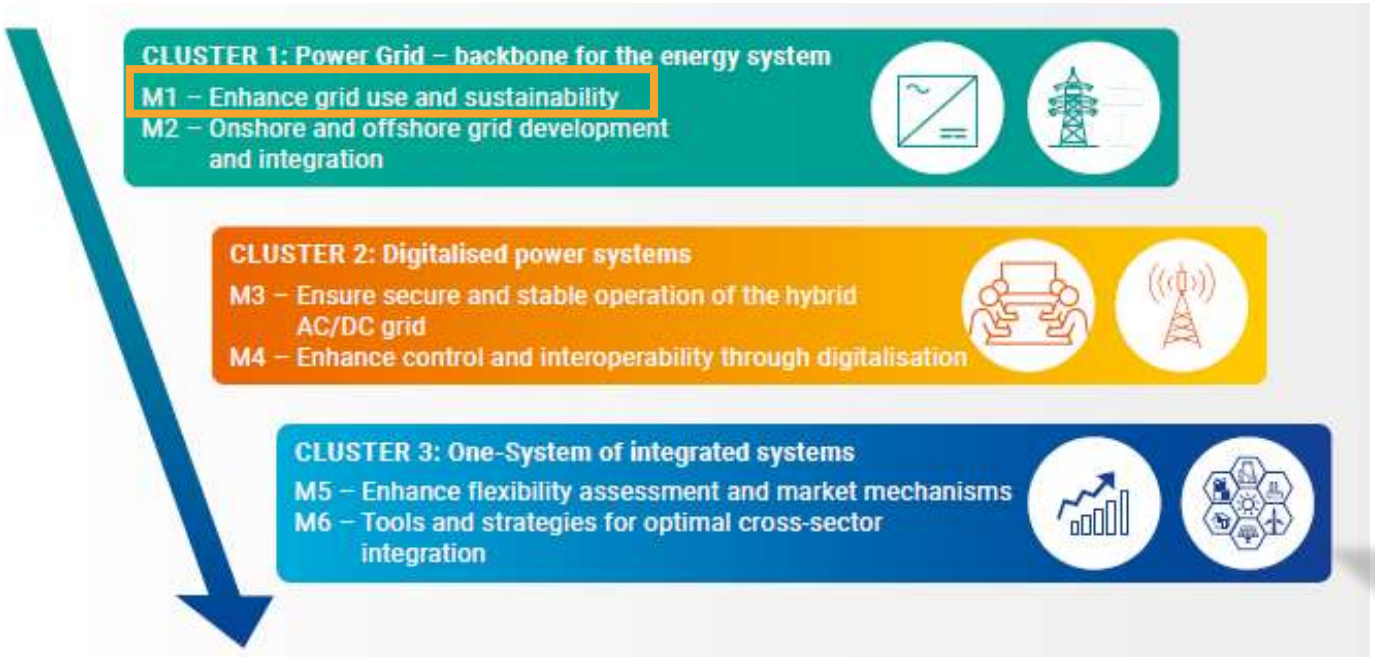


A stable regulatory framework is required to support anticipatory investments, as they have a long planning horizon and necessitate a substantial investment volume. National frameworks may need some adaptations.

Anticipatory investments should be supported by the regulatory frameworks by **being treated like any other investments with regulatory provisions managing the risk of underutilization of assets**. TSOs should not be exposed to ex-post financial penalties for anticipatory investments.

Effective communication TSOs <> regulators (Roadmap 2024-2034)

Innovation Needs and Priorities



The uptake of smart and grid-ehnancing technologies has been well acknowledged in ENTSO-E Roadmaps and is a continuous challenge – both technical and financial – to identify the right framework that can support effective implementations

Effective communication TSOs <> vendors with DSO/TSO technopedia

- Enhanced asset management tools
- Dynamic line rating (DLR)
- Enhanced Wind Forecasting
- Digital Fault Recorder
- Artificial Intelligence and Digital Twins
- Cloud and Edge Computing
- Distributed Ledger Technology/Blockchain
- Synchronous Compensators and series of compensators
- ….

- DSO- and TSO-relevant technologies:
  - Dynamic line rating (DLR)
  - AC power transformers (with tap charger)
  - Asset management, tools, and procedures
  - Digital twins
  - High-temperature superconductor (HTS) cables
  - Voltage source converters
  - Digital fault recorders
  - Circuit breakers - AC
  - Static synchronous series compensators
  - Software-defined security

Applications on the technologies can be submitted via the DSO/TSO Technopedia website available **here**.

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Uroš Salobir, ELES & Chairman of RDIC at ENTSO-E

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Scene Setting

Huang Yuehui

Senior Expert, Department of Renewable Energy
China Electric Power Research Institute (CEPRI)

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Research and Practice of Renewable Energy in China

HUANG Yuehui

China Electric Power Research Institute (CEPRI)

Jun 2025

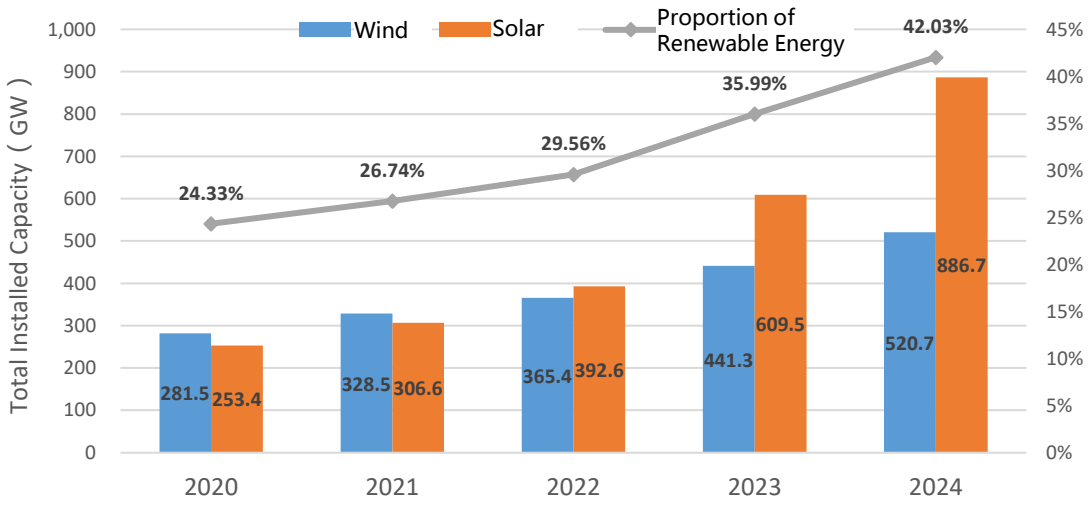
1 Development Status

2 Relevant Research & Practices

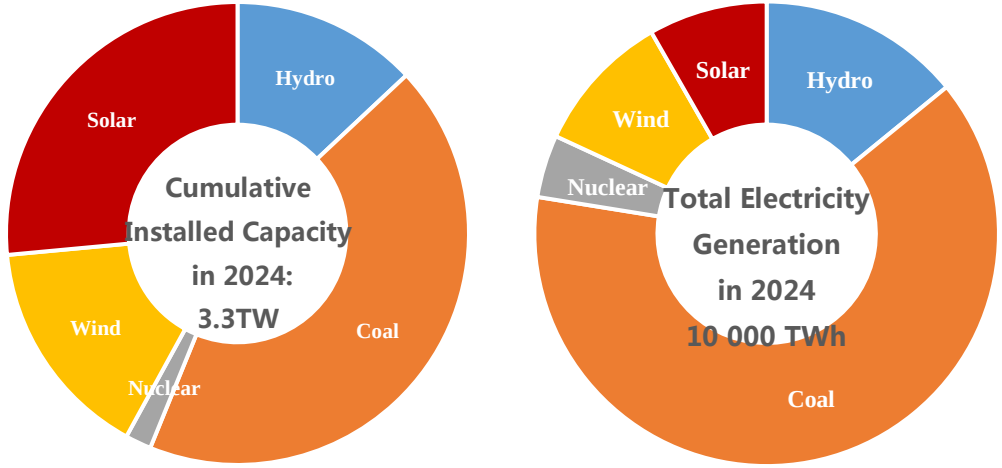
3 Summary

01 Development status

- By the end of 2024, the total installed capacity of RE reached **1.4 TW**(0.52 TW from wind and 0.89 TW from PV) in China, accounting for **42%** of its total installation capacity and over **40%** of the global total RE capacity.
- In 2024, RE generation in China achieved 1830 TWh, accounting for roughly **18.2%** of its total electricity production.



China's Renewable Energy Development (2020-2024)

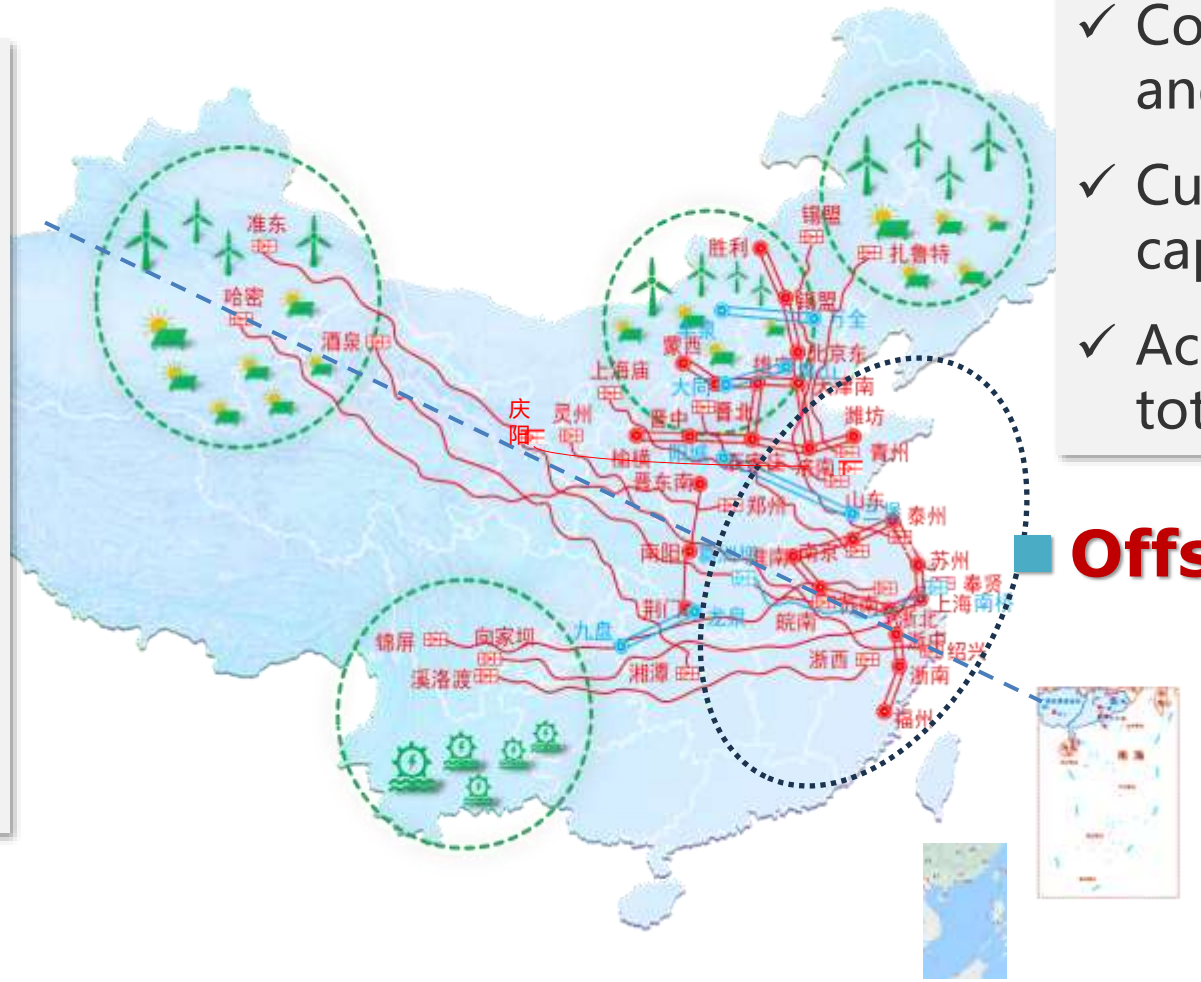


China's Installed Capacity Structure and Electricity Generation

——Data source: National Energy Administration, National Bureau of Statistics

Large-scale RE bases

- ✓ Large RE bases(≥10GW)
- ✓ Concentrated in Northwest, North China, and Northeast China
- ✓ Transmitted over long distances to load centers through UHV AC (1000kV) or UHV DC(±800kV)



Distributed PV

- ✓ Concentrated in the central and eastern regions
- ✓ Cumulative installed capacity aroud 370GW
- ✓ Accounting for 42% of the total PV capacity

Offshore wind power

- ✓ Along southeastern coastline
- ✓ Cumulative installed capacity around 45GW

To achieve cross-regional power balance and to reduce reserve generators

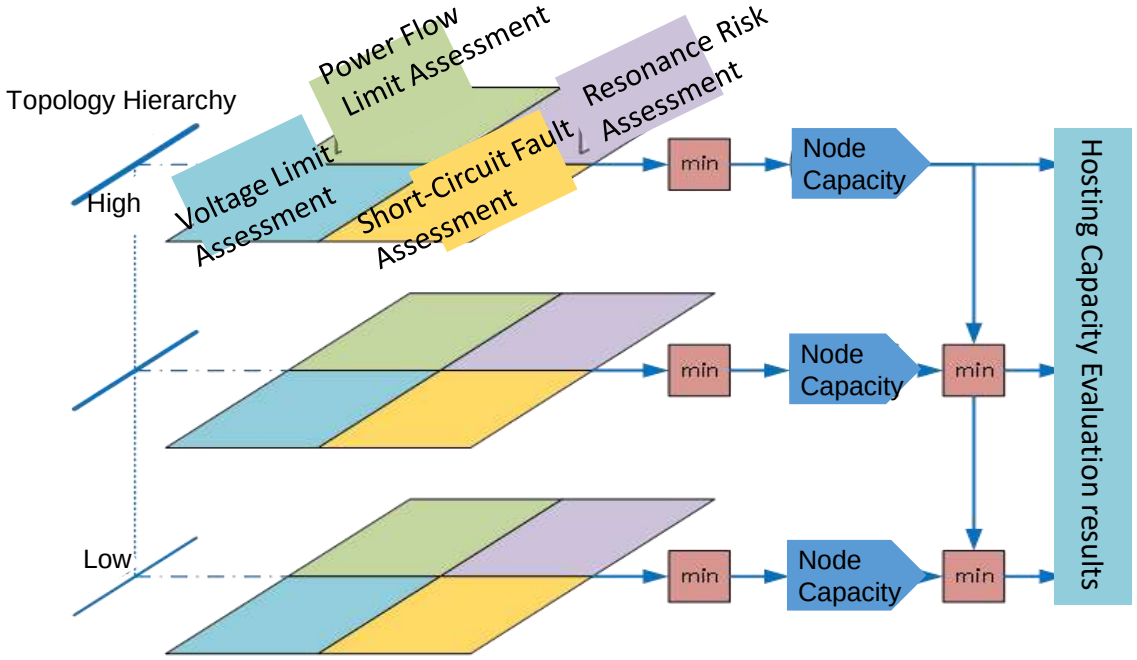
- ✓ By the end of 2024, China had completed **42 Ultra-High Voltage** transmission projects (**22 AC, 20 DC**), with an cross-regional power transmission capacity exceeding **300 GW**.
- ✓ Transmitted clean energy should account for over 50% in the newly construction projects.

Voltage level	Capacity/MW	UHV project (Start-End location)	Type
±800 kV	5000	Yunnan-Guangdong	LCC-HVDC
	6400	**Yunnan-Shanghai**	
	7200	**Guizhou-Jiangsu**	
	8000	**Xinjiang-Henan**	
	8000	Sichuan-Guangdong-Guangxi	LCC-VSC Hybrid HVDC
	8000	**Sichuan-Jiangsu**	LCC-VSC Hybrid HVDC
	10000	**Inner Mongolia-Shandong**	LCC-HVDC
±1100 kV	**12000**	**Xinjiang-Anhui**	LCC-HVDC

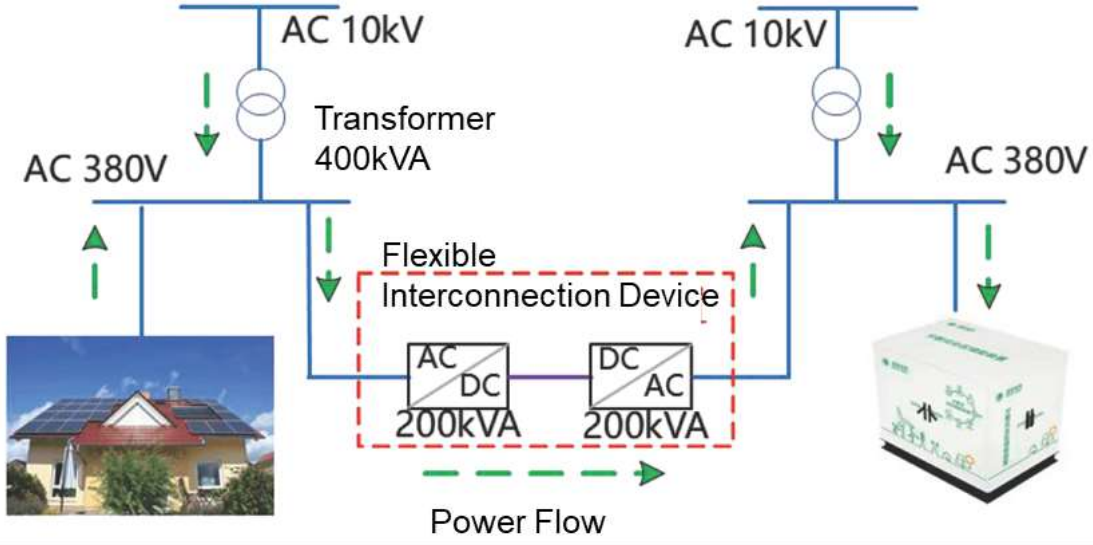
China's Cross-Regional Transmission Lines for Clean Energy

Using the existing distribution infrastructure to accommodate RE

- ✓ Publishing the maximum integration capacity of distributed PV in the city area，to guide the rational distribution of PV.
- ✓ **Flexible interconnecting** between substation feeder sections, to expand the dynamic balance capacity of distributed PV.



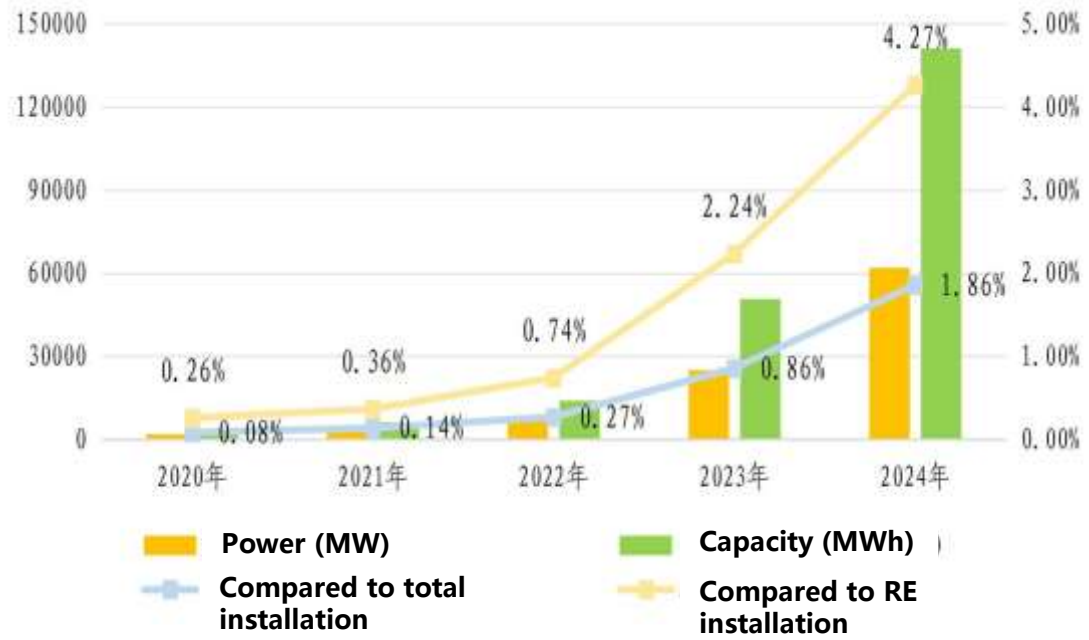
Principles of Mamimum Integration Capacity Assessing



Low-Voltage Flexible Interconnection Device

Research & Practices——Various Energy Storage

- By the end of 2024, China's installed capacity of pumped-storage hydropower (PSH) reached **58 GW**, while total battery energy storage systems(BES) installation is **73 GW / 168 GWh**.
- In 2030，battery energy storage systems will be over 200GW (averge 2.5h).

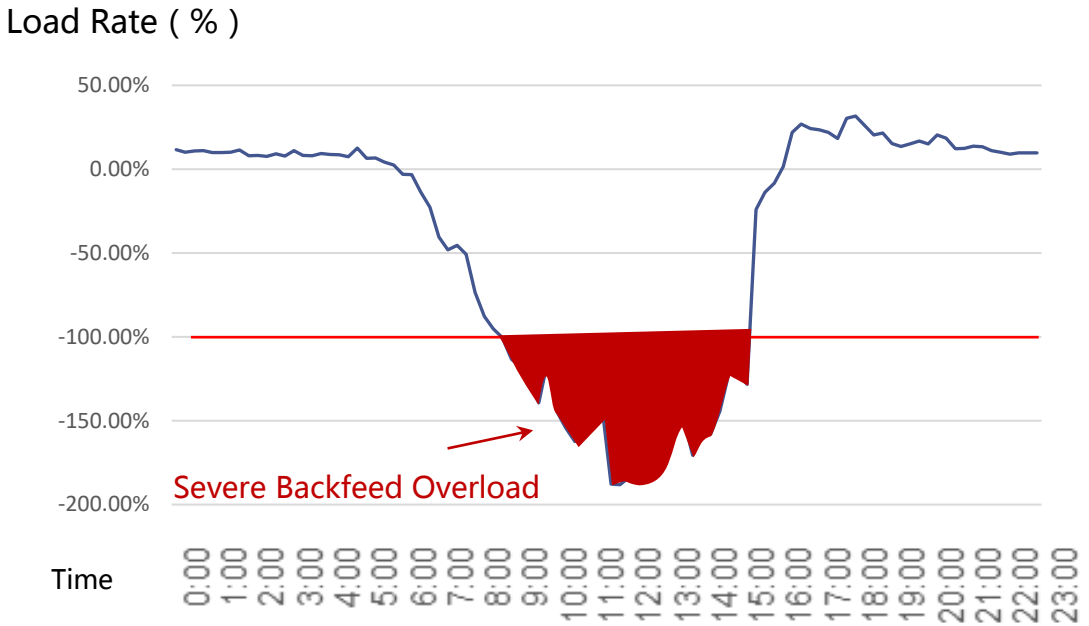


Installation of Battery Energy Storage in Recent Years

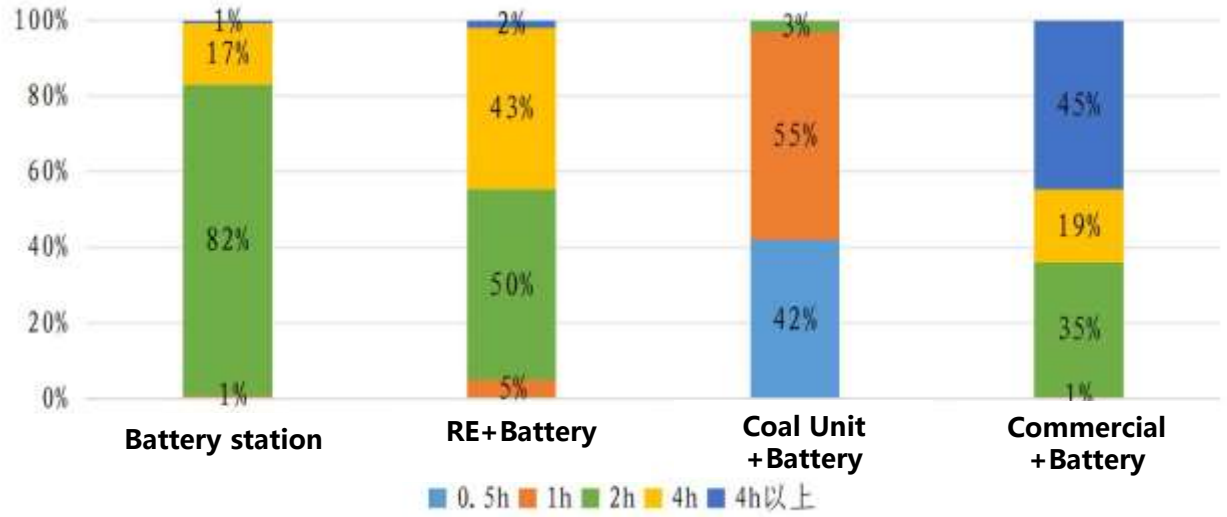
A Large-Scale BES Station in Qinghai

Research & Practices——Various Energy Storage

- **Large-scale** energy storage stations.
- Some **wind plants and PV stations** with 10%~20% battery energy storage.
- Configuration battery energy storage where distribution **transformers was overload**.



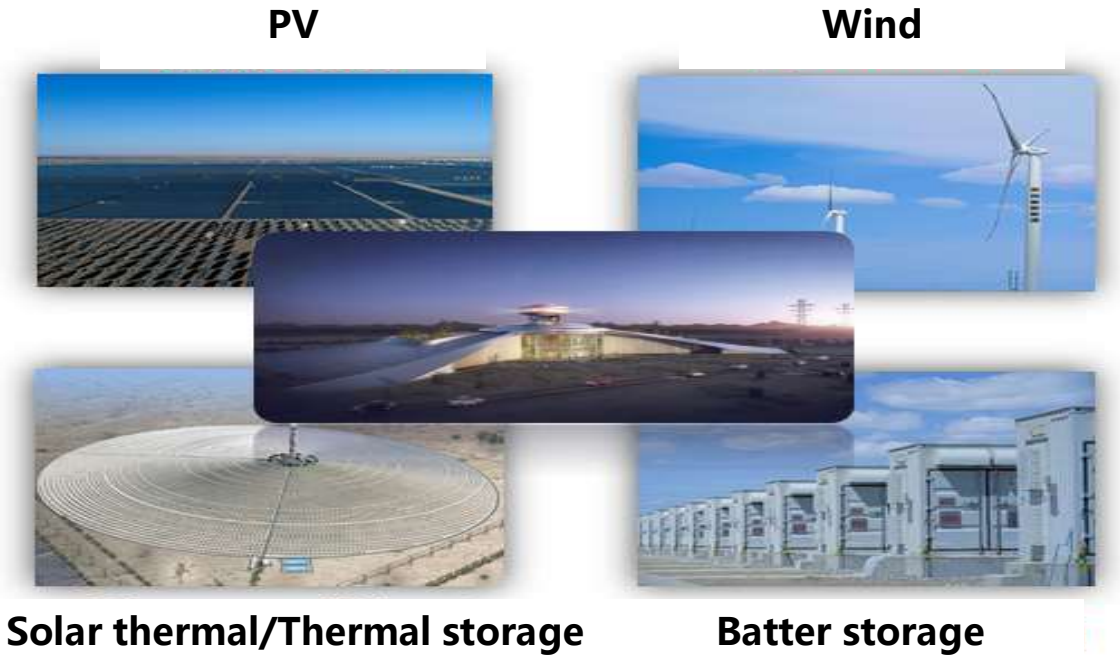
Simulated Load Rate Curve of Distribution Transformer



Duration Hours of Battery Energy Storage

Research & Practices——Polygeneration System

- At the generation side / user side, developing **multi-energy complementary power generation** to achieve smooth output / localized utilization of renewable energy.
- RE+battery storage+heat storage, micro-grid with PV+stroage, PV+Hydrogen+chemical industry applications, etc.



Multi-Energy Complementary Power Generation

PV+Hydrogen Project in Xinjiang Kuche

Electric Power Meteorological Forecasting

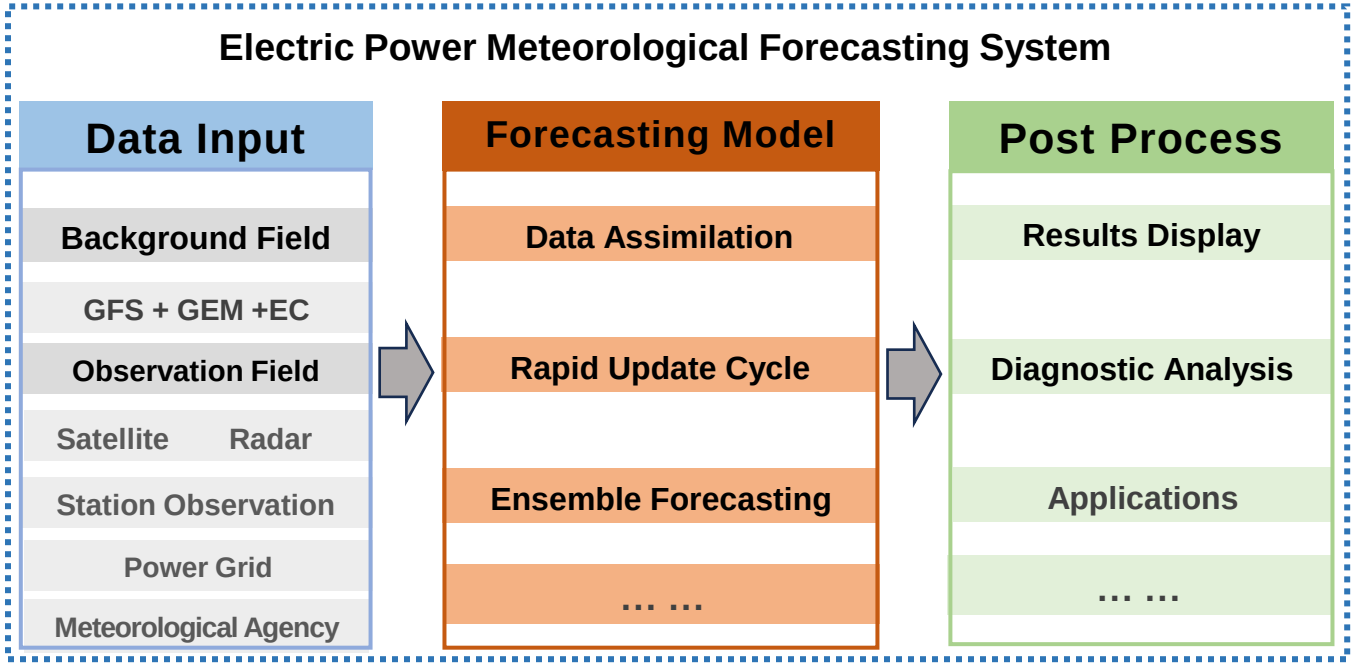
- ✓ The electric power meteorological forecasting system was developed based on the observation data from meteorological stations, satellites and weather stations of renewable power plants.
- ✓ Provide high-resolution weather prediction services, data services, etic.

High-performance Computer Cluster System

Satellite Data Acquisition System

Observation at PV Plants

Observation at Substations

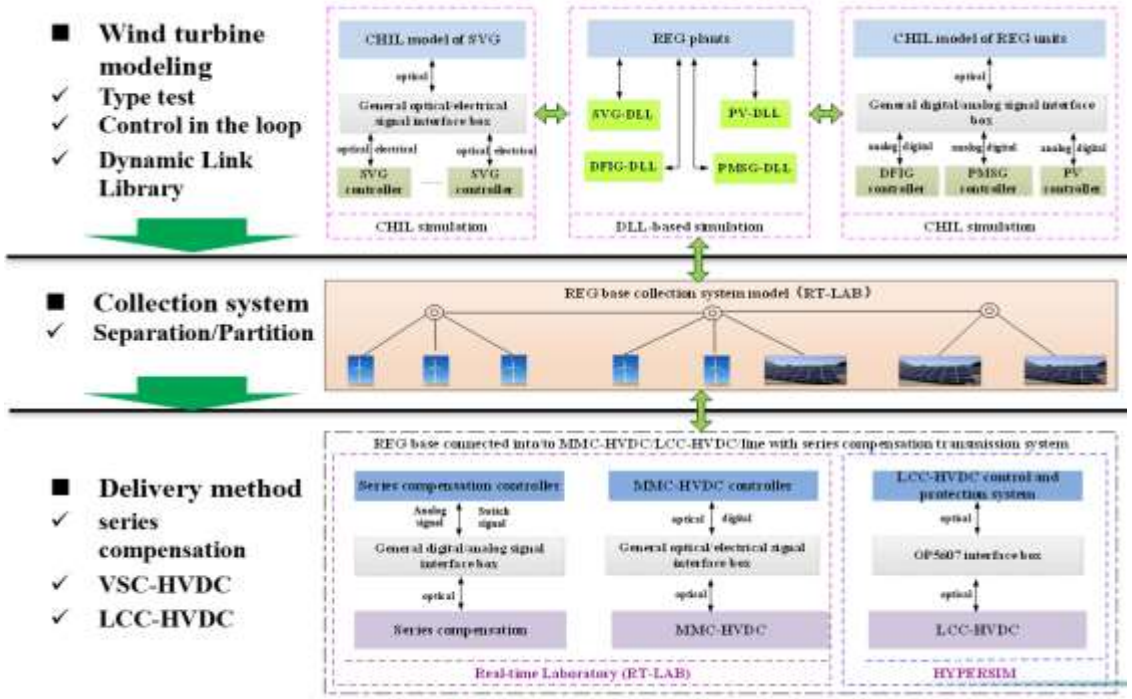


Nationwide RE power forecasting system

- ✓ Developed nationwide RE power forecasting system, providing wind/solar resource forecasts and RE power prediction services for provincial power dispatch centers across China.
- ✓ Studied multiple RE power forecasting algorithms，including energy production prediction，probabilistic forecasting and events forecasting.

Enhance Transmission Capacity and Reduce SVG Configuration

- ✓ A hybrid digital-physical simulation platform for renewable energy has been established.
- ✓ Achieving the precise simulation of the controllers of RE in10 GW-level renewable energy bases.

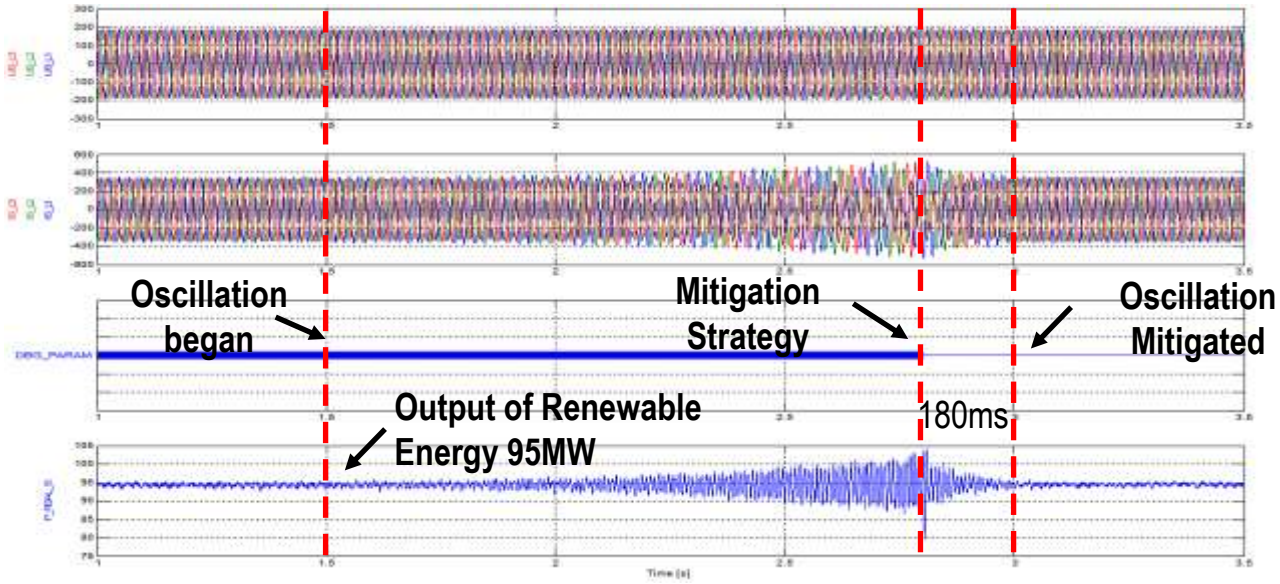


The Digital-Physical Hybrid Simulation Platform

Filed Impedance Test to Enhance system stability

- ✓ Field test the impedance to find the Oscillation possibilities in high power electronics devices penetration areas.
- ✓ Reshaping impedance of RE by control strategy improvement to mitigate broadband oscillations.
- ✓ Applied in the large-scale RE bases transmitted by HVDC systems, to maximize the transmission capacity.

Field impedance Tests



Waveforms from Field Tests

Summary

- China's power system is rapidly evolving towards high renewable energy penetration, a nationwide development trend.
- Technical innovations enhance utilization efficiency of the existing grid assets, enabling higher renewable energy penetration. At the user side, polygeneration applications such as PV + hydrogen storage , heat storage are rapidly developing.
- At the power system level, however, renewable energy integration substantially elevates requirements of infrastructure investment.

Thank for your attention !

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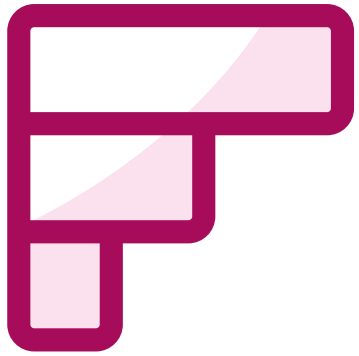

Which area should be prioritized most to close infrastructure gaps?

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Panel discussion

Moderator

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Field Italia

Panelists

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Germany

Arnis Daugulis

AST
Latvia

Stefan Kilb

Schneider Electric

Kangqiao Huang

CATL
China

Rafael San Juan Moya

Iberdrola
Spain

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Audience Q&A

What specific actions should policymakers take to bridge infrastructure gaps for the secure and cost-effective integration of renewables?

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Closing Remarks

Gao Keli

CEO, President
China Electric Power Research Institute (CEPRI)

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Closing Remarks

Danial Saleem

Associate Programme Officer
IRENA

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Renewables and Digitalisation for a Sustainable Energy Future

Thank you!

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Networking Dinner

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