Taiwan Power Grid Resilience and Innovation Research Partnership

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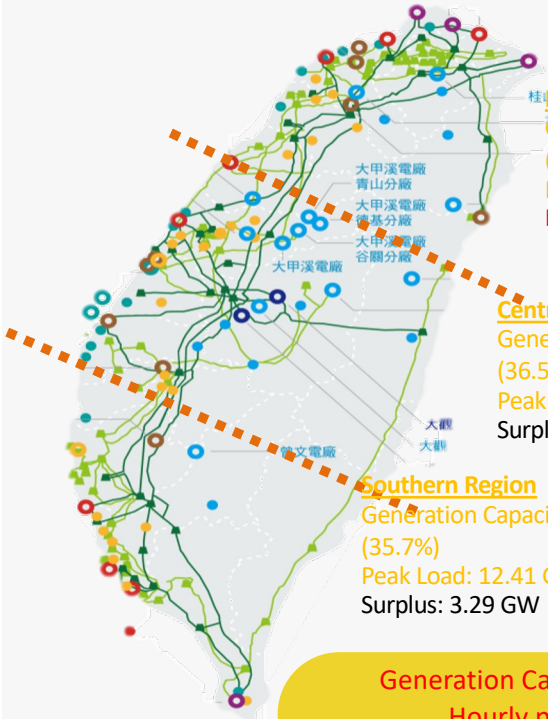


Northern Region
Generation Capacity: 12.19 GW (27.8%)
Peak Load: 14.64 GW (37.1%)
Deficit: 2.45 GW

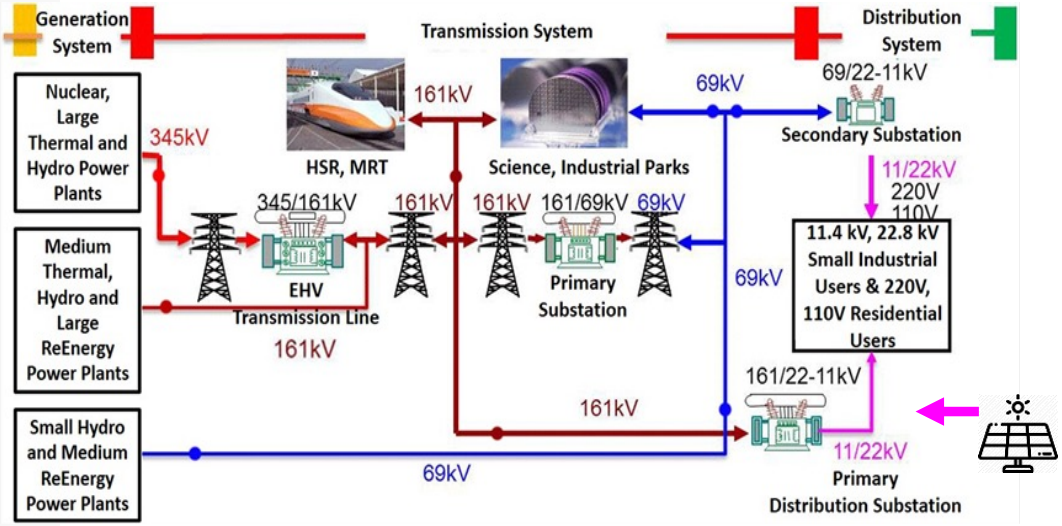
Central Region
Generation Capacity: 16.06 GW (36.5%)
Peak Load: 12.45 GW (31.5%)
Surplus: 3.59 GW

Southern Region
Generation Capacity: 15.70 GW (35.7%)
Peak Load: 12.41 GW (31.4%)
Surplus: 3.29 GW

Generation Capacity in 2023 was **43.92 GW**
Hourly peak load was 39.49 GW
With a capacity reserve of **4.43 GW**

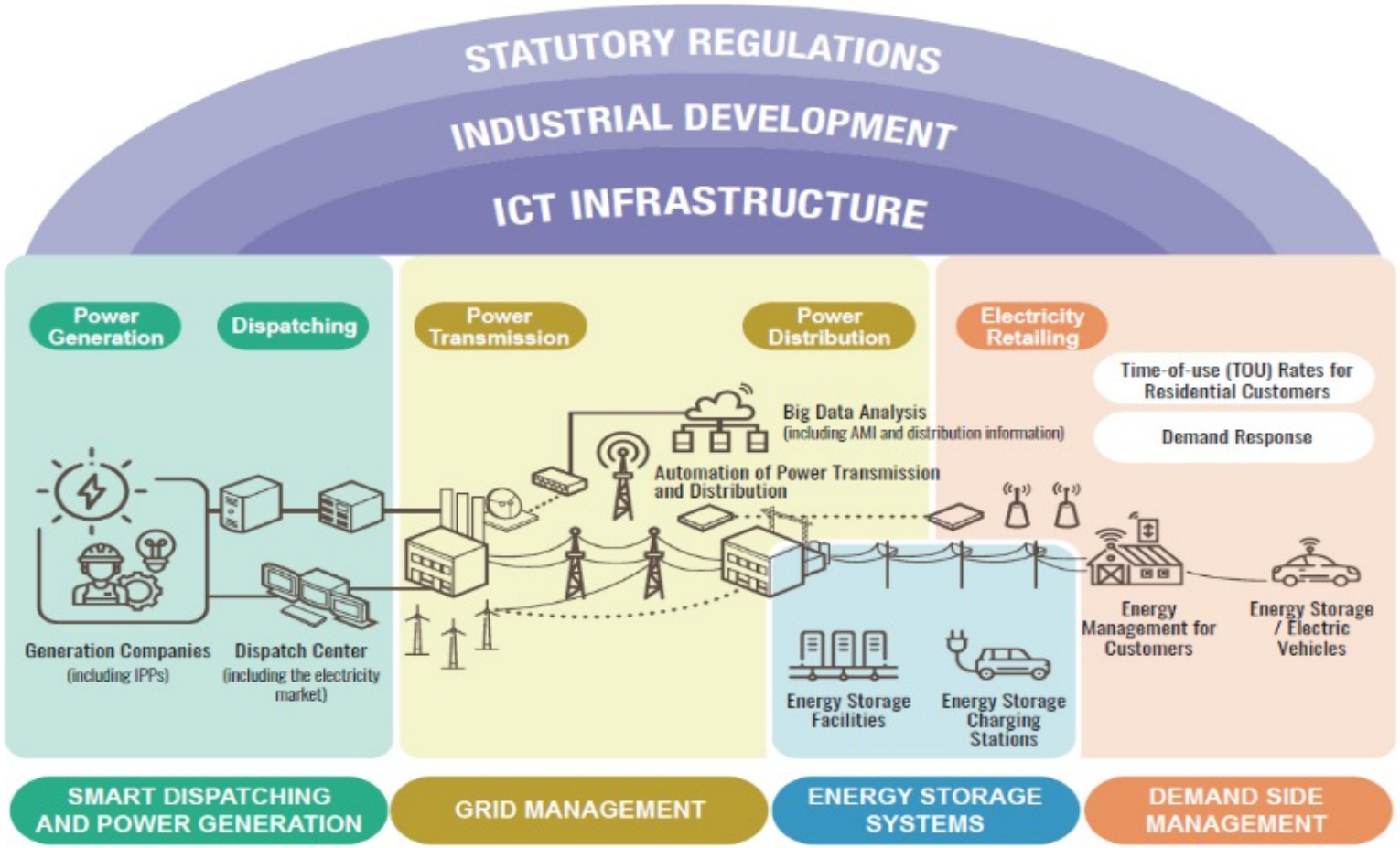
Source: Taiwan Power Company (TPC) website

Voltage Levels of T/D systems



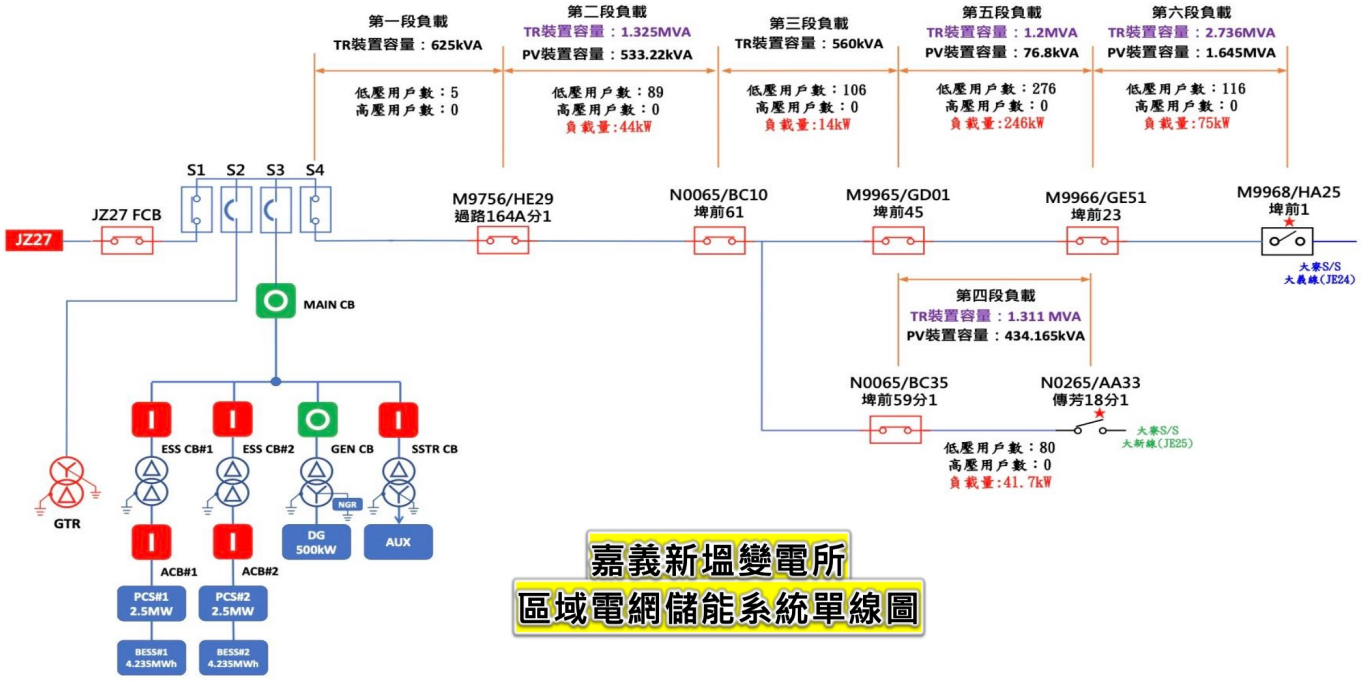
Peak load on July 23rd , 2024 was **41.42 GW**

Smart Grid Master Plan



Source: Energy Administration

How TPC Maintains Stable Power Supply

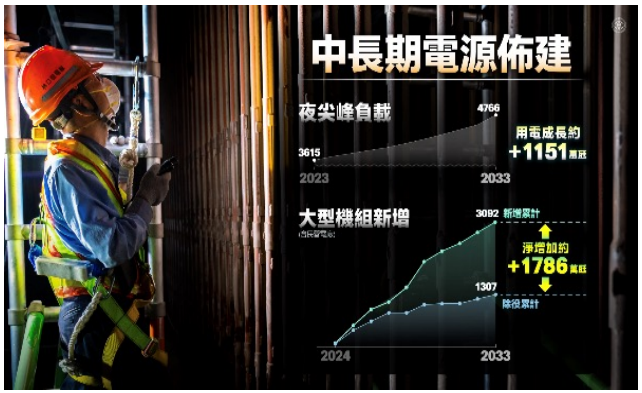


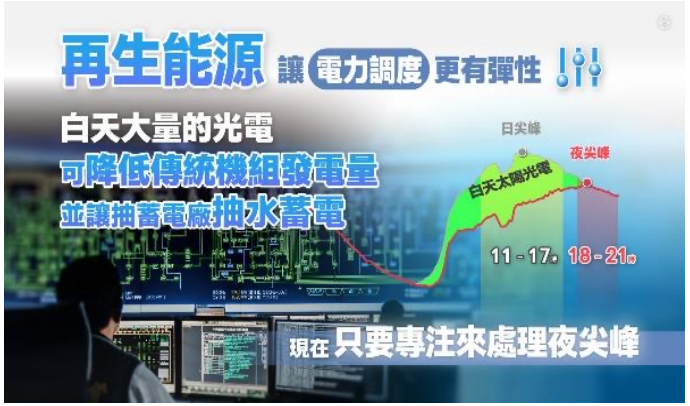
Source: TPC

- **9537**distribution feeders are automated with switches (**94.3%**) in 2024.
- Target: fully automated in 2025 with feeder outage downstream customers service restored **in 5 minutes** for **70%** of the feeder outages.

- Number of **smart meters (AMI) is 3.361 millions** in Sept. 2024.
- Target: **14 million smart meters** in 2035.

How TPC Meets Taiwan Power Requirements





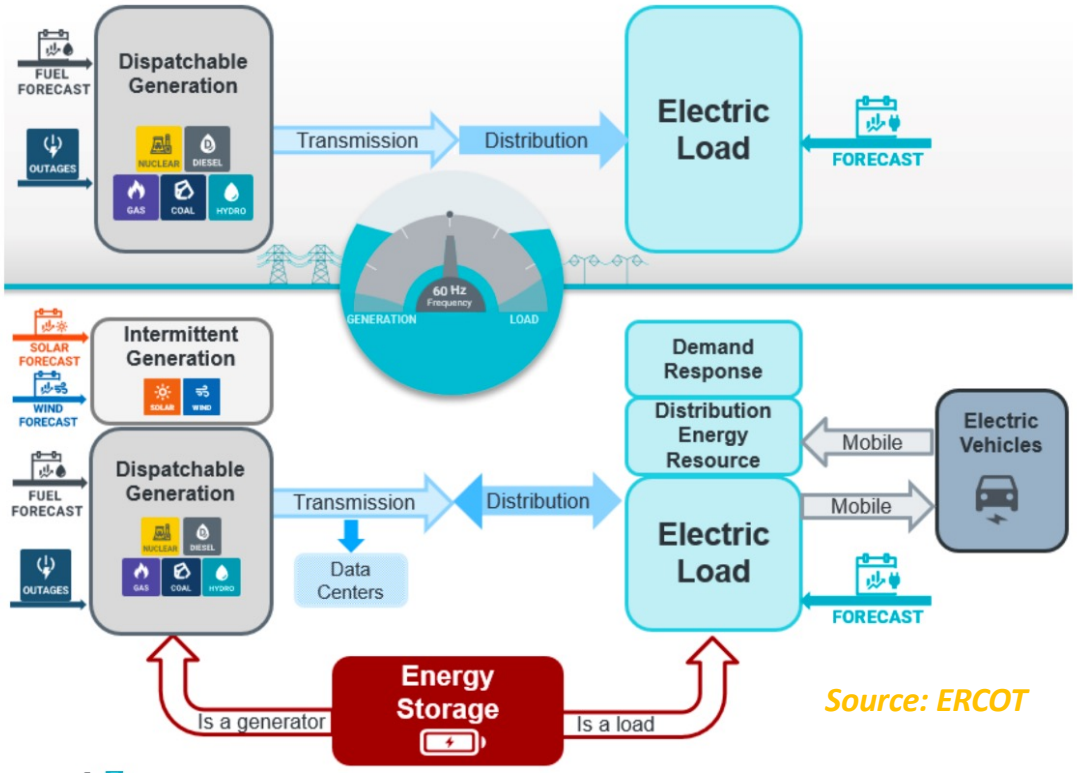
TPC is accelerating its efforts to

- Maintain **network reliability and resources adequacy,**
- Maximize the use of **green energy**, and
- Enhance **grid resilience** with **demand side resources**.

Source: Taiwan Power Company (TPC) website

Evolution of Taiwan Smart Grid

Evolving Grid Structures



Source: ERCOT

- **Grid Digitalization**
- **Renewable and Distributed Energy Resources Integration**
- **Power Market and Customer Participation**
- **AI and Machine Learning Applications**

2021-2022 TPC's Smart Grid Development
Ranked 2nd in **Smart Grid Index (SGI)**
announced by Singapore Power Ltd. (SP Group).

Utilities	Country/Market	Score %	Best Practices
Enedis	FRA	98.2	
TaiPower	TWN	96.4	
UKPN	GBR	96.4	
CitiPower & Powercor	AUS	94.6	
DEWA	ARE	94.6	

Monitoring & control, data analytics, supply reliability, DER integration, security, green energy, customer empowerment and satisfaction

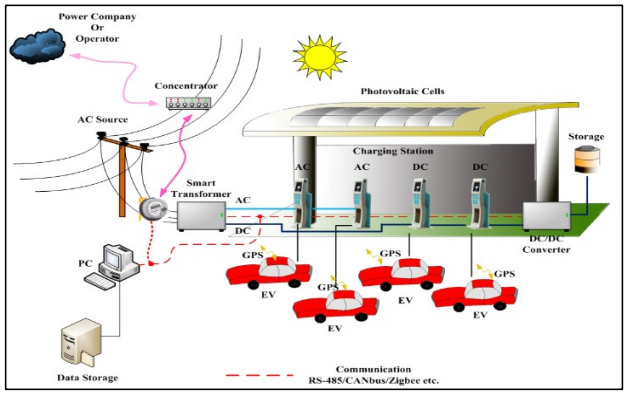
Maintaining Power System Resilience needs Adequate Power Capacity, Power Grid, Protection and Human Resources

B

Resource Adequacy and Operational Performance

Electricity Demands

Source: IEEE Spectrum



Eight Taiwanese Sites Are Among World's Top 500 Carbon Emitters

Taichung Power Plant	No.51
China Steel Mill	No.114
Mailiao Power Plant	No.191
Hsinta Power Plant	No.192
Talin Power Plant	No.258
Linkou Power Plant	No.266
Datan Power Plant	No.353
Dragon Steel Mill	No.417

Source:
https://udn.com/news/story/7238/8379197

Driven by the increase of data centers, AI and semiconductor industry, the load growth predicted by Ministry of Economic Affairs is **2.8% annually** for the next ten years.

Generation Capacity Adequacy

New Units (x10MW)

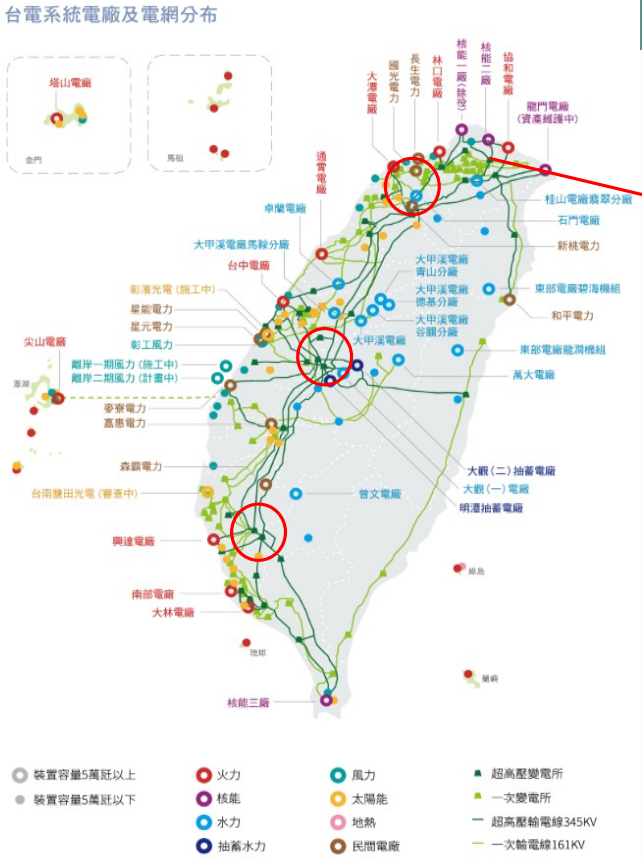
2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Tongxiao Power Plant SGT JAN(18)	Tatan CC#8 APR(112.36)	Tatan CC#7 JAN(91.3)	Taichung New CC#2 JUN(130)	Solar PV **(200)**	Talin New CC#1 SEP(65)	Tongxiao New CC#6 DEC(65)	Hsieh-ho New CC#1 JUN(130)	Solar PV **(150)**	Solar PV **(150)**	Solar PV **(150)**
Solar PV **(269.4)**	Tatan CC#9 DEC(112.36)	Hsinta New CC#1 FEB(130)	Hsinta New CC#3 NOV(130)	Offshore Wind **(90)**	Talin New CC#2 OCT(65)	Tongxiao New CC#7 DEC(65)	Tongxiao New CC#8 DEC(65)	Offshore Wind **(150)**	Offshore Wind **(150)**	Offshore Wind **(150)**
Offshore Wind **(101.8)**	Sun Ba#3 AUG(110)	Taichung New CC#1 AUG(130)	Solar PV **(479.1)**	RES (0.8)	Tongxiao New CC#4 DEC(65)	Solar PV **(200)**	Solar PV **(200)**	RES (10.1)	RES (13)	RES (10.1)
RES (7.1)	Solar PV **(379.1)**	Hsinta New CC#2 NOV(130)	Offshore Wind **(79.8)**	NGPU SEP(60)	Tongxiao New CC#5 DEC(65)	Offshore Wind **(150)**	Offshore Wind **(150)**	NGPP APR(130)	NGPP APR(130)	NGPP APR(130)
BESS **(33)**	Offshore Wind **(128.0)**	Solar PV **(200)**	RES (2.7)		Solar PV **(200)**	RES (2.4)	RES (12.6)	NGPP DEC(130)	NGPP DEC(130)	
	RES (7.0)	Offshore Wind **(173.3)**	Chung Chia DEC(61.2)		Offshore Wind **(143.5)**	NGPP JUN(120)				
	BESS **(39)**	RES (6.1)			RES (3.2)	NGPP JUN(120)				
		BESS **(28)**			NGPP JUN(180)					
					NGPP JUN(120)					
					NGPP OCT(120)					

Source: National Electricity Supply and Demand Report

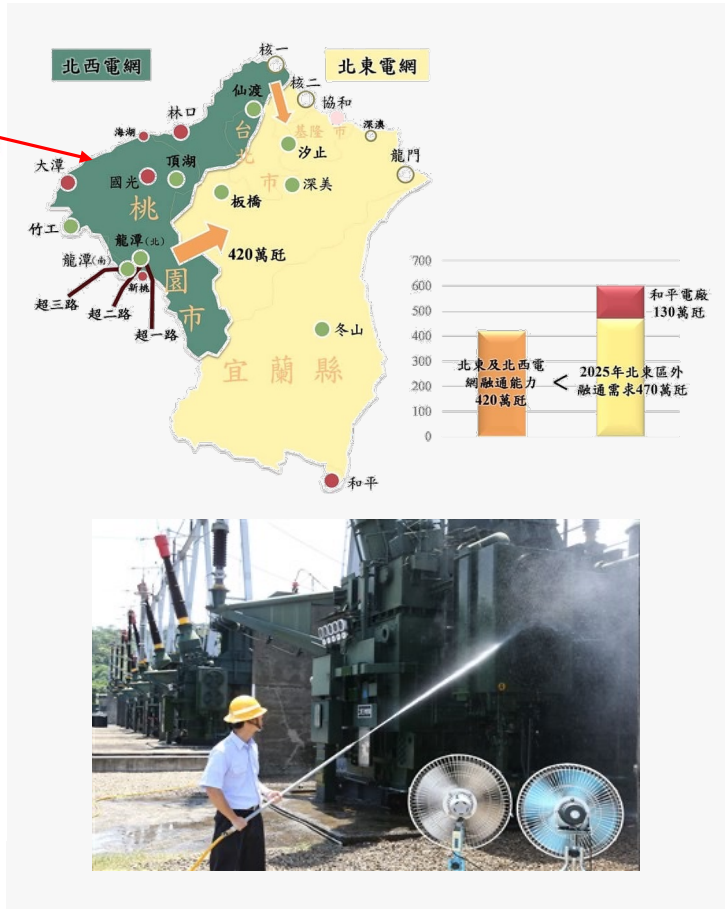
Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Night peak demand (x10 MW)	3,725	3,809	3,895	3,977	4,090	4,207	4,339	4,481	4,622	4,766
Night net peak capability (x10 MW)	4,027	4,133	4,294	4,315	4,634	5,071	5,335	5,552	5,724	5,900
Night capacity reserve margin (%)	8.1	8.5	10.3	8.5	13.3	20.5	23.0	23.9	23.8	23.8

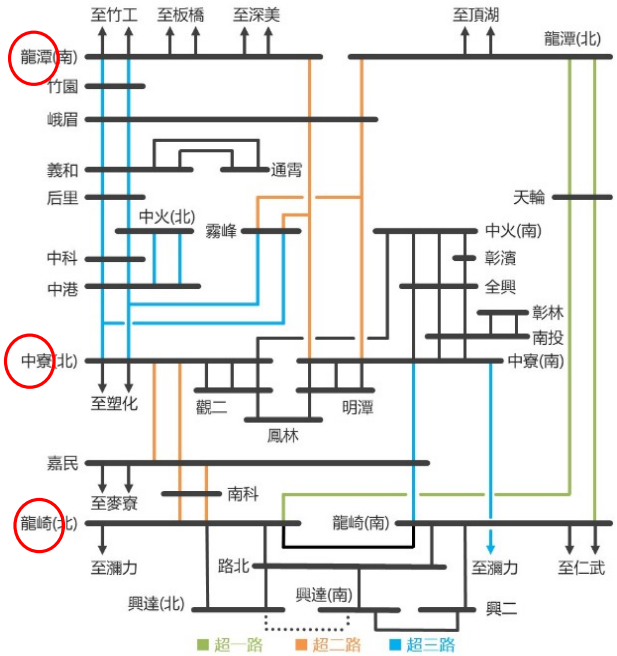
Note: The short-term reserve margin would lower than the targeted 15%, Taipower will employ multiple measures, such as demand response and power market mechanism to stabilize the power supply.

Transmission Network Adequacy



Regional Transmission Bottleneck

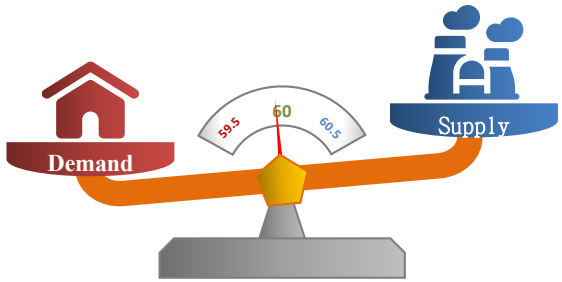


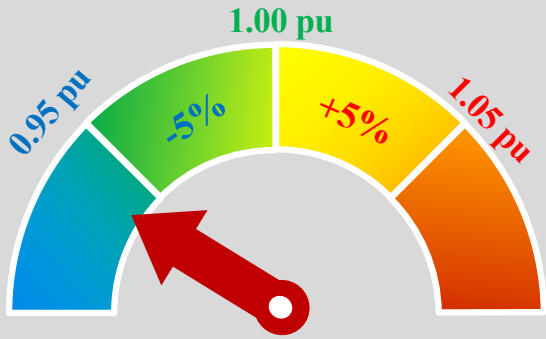


Source: Taipower company

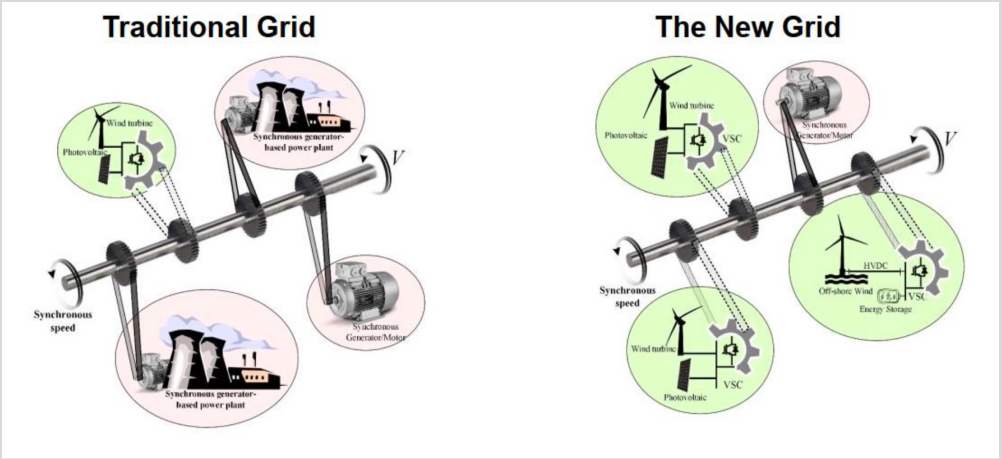
This network is geographically concentrated in three major transmission hubs.

B Flexible Resources Adequacy

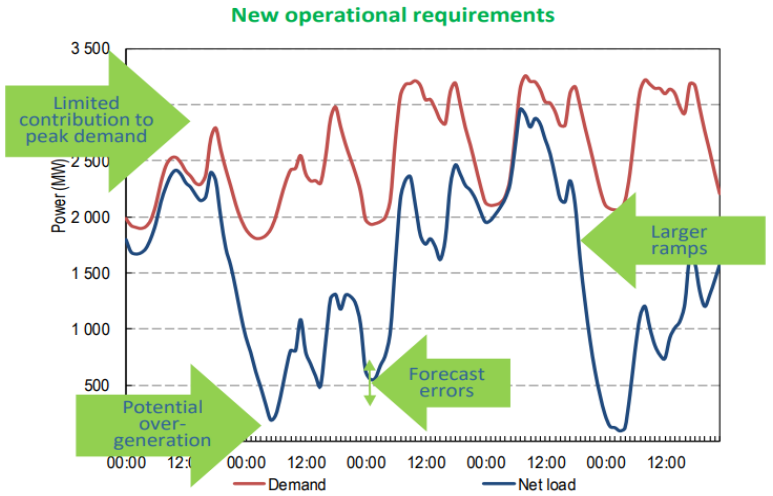




Evolving Grid Structures



The changing power landscape entails the need to introduce new technologies.



Source: EPRI

Flexible Resources

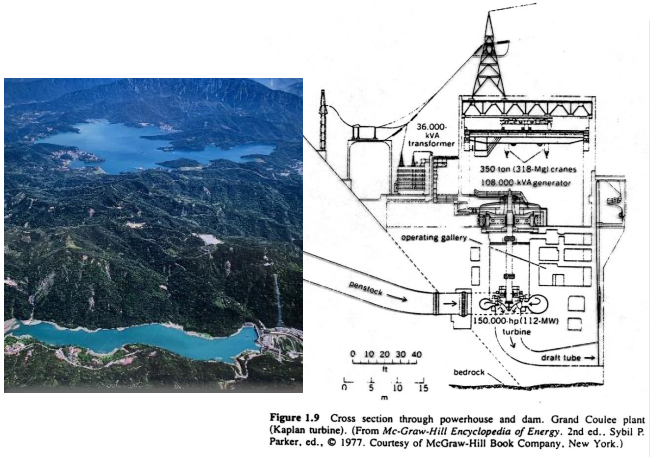
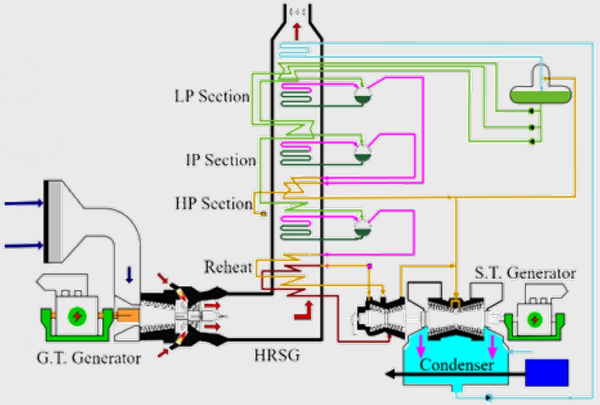
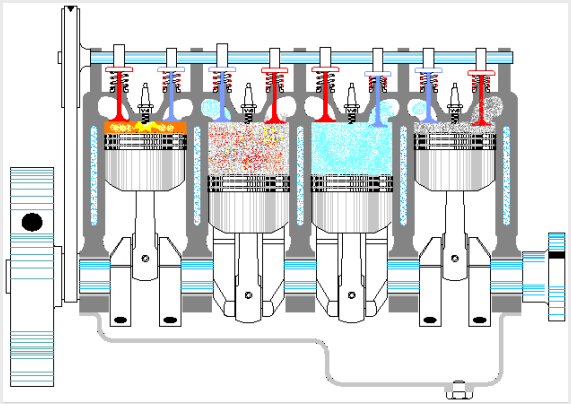
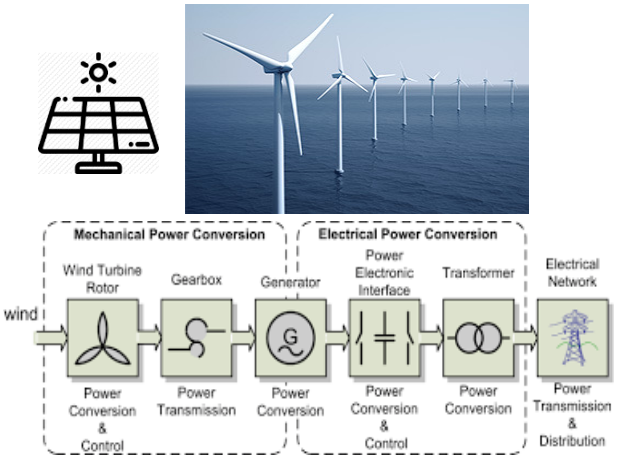
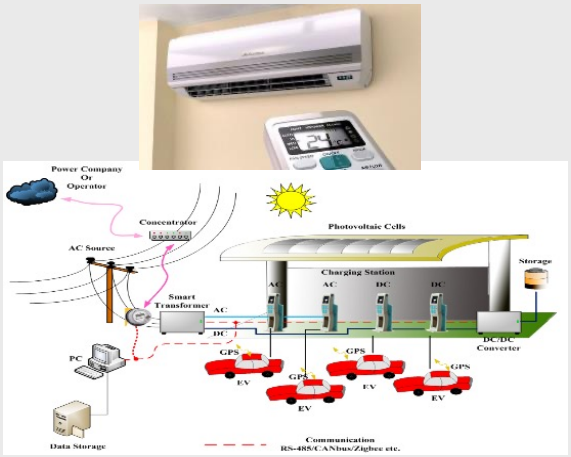


Figure 1.9 Cross section through powerhouse and dam. Grand Coulee plant (Kaplan turbine). (From *Mc-Graw-Hill Encyclopedia of Energy*. 2nd ed., Sybil P. Parker, ed., © 1977. Courtesy of McGraw-Hill Book Company, New York.)





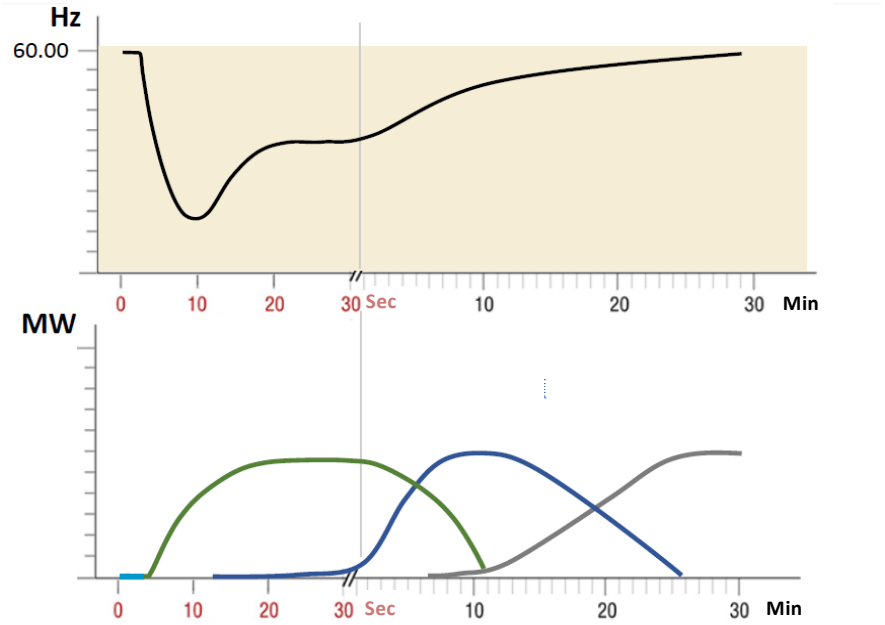




Source: https://www.pinterest.com/pin/313633561533558482/

Frequency Regulation Services

Frequency Control Ancillary Services in Taiwan Power Market



Regulation Reserve
Response in **1-second**
Last for at least **15 mins**

Spinning Reserve
Response in 10 mins
Last for **1 hour**

Supplemental Reserve
Response in **30 mins**
Last for 2–4 Hours or more

Regulation Reserve

Increases or decreases resource power to balance power supply and demand and reduce frequency fluctuations.

Spinning Reserve

Adjust power output and/or execute load shedding to restore system frequency back to 60 Hz.

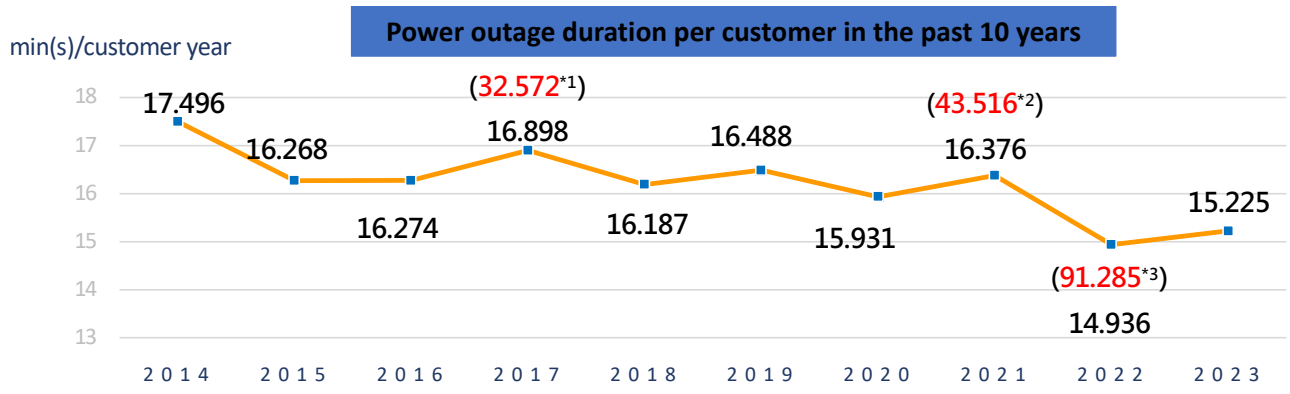
Supplemental Reserve

Handel power reserve after restoration from system incidents due to power loss.

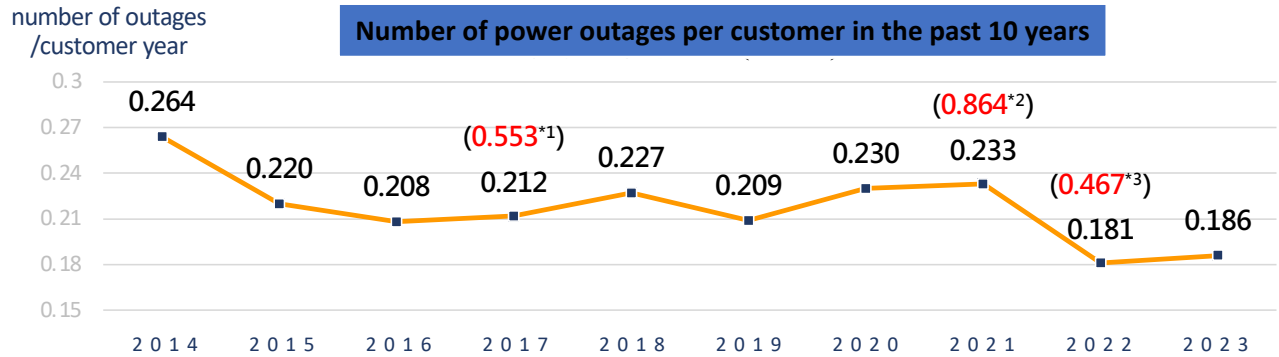
Source: Taiwan Power Company (TPC) website

B Operational Performance - Service Reliability

System Average Interruption Duration Index, SAIDI



System Average Interruption Frequency Index, SAIFI



Taiwan population: 23.136 million
TPC customers: 15.14 millions
1.53 person / meter

Note: ( ) Parentheses indicate major incident data for the respective year.

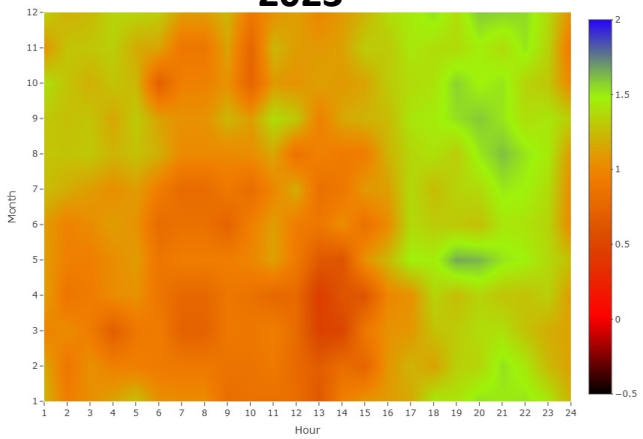
1. The major incident in 2017 was the August 15th power outage.
2. The major incidents in 2021 were the May 13th and May 17th power outages.
3. The major incident in 2022 was the March 3rd power outage.

Source: Taipower company

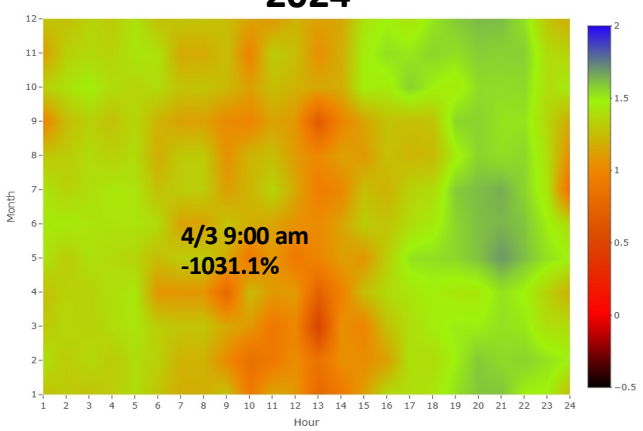
Operational Performance - Frequency Control

Hourly CPS1 Scores ($\varepsilon_1 = 35$ mHz)

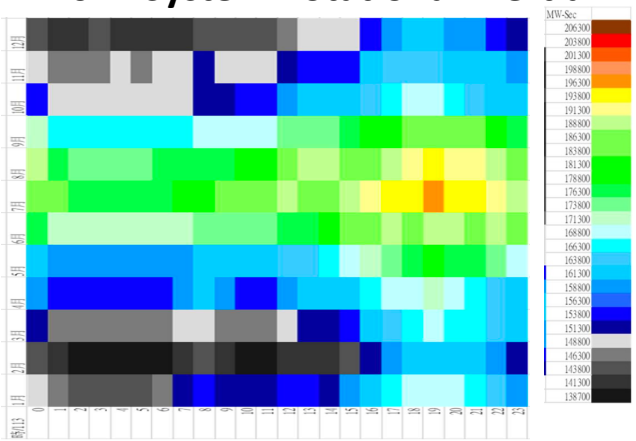
2023



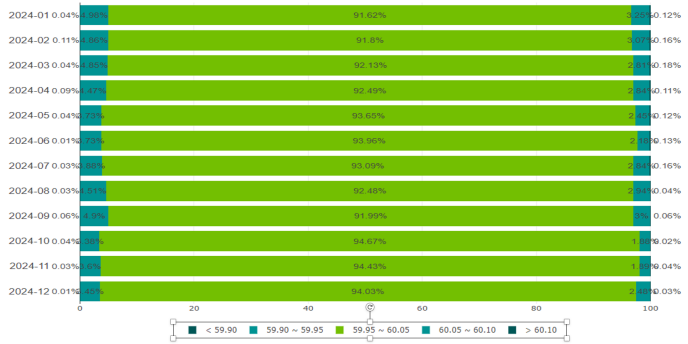
2024



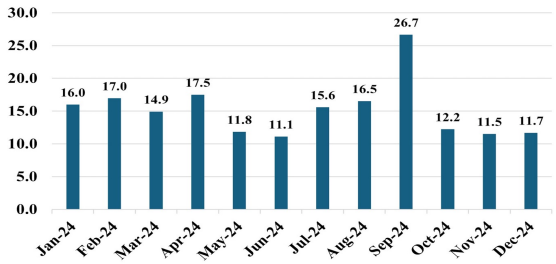
2024 System Rotational Inertia



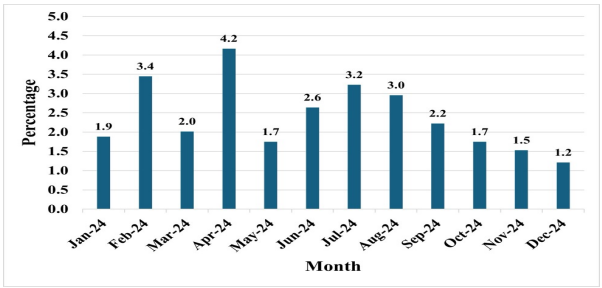
2024 System Frequency Distributions (%)



CPS1 < 100%



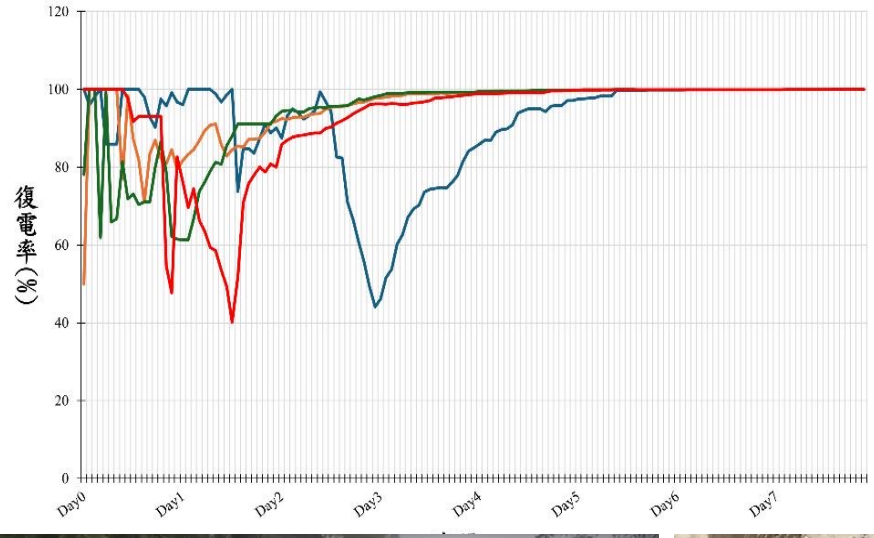
CPS1 < 0%



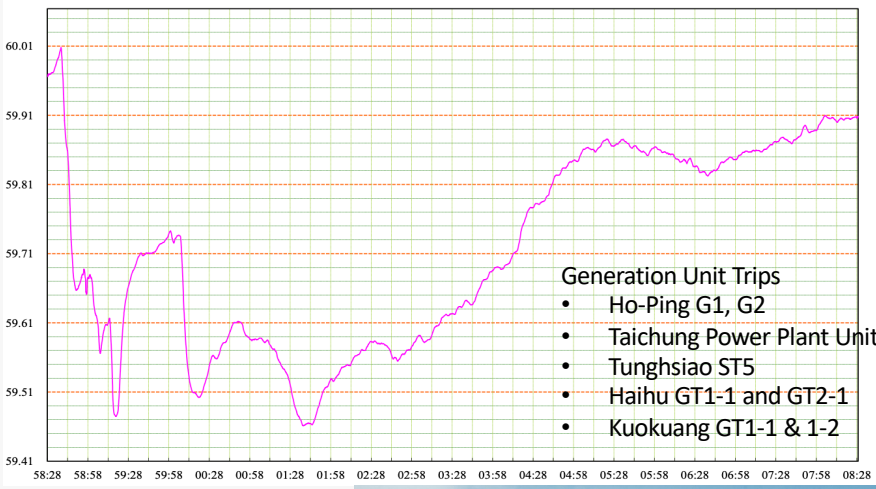
Source: Taipower company

Operational Resilience

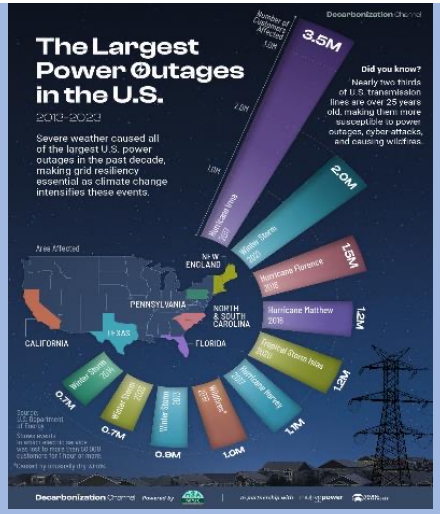
Rates of Service Restoration during 4 typhoons in 2024



Richter scale M_L 7.1 Earthquake in Hualien County at 7:58 am, **3rd April, 2024**

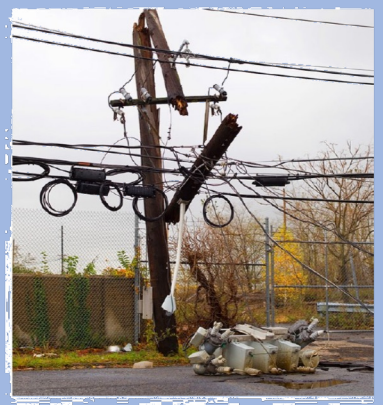


Challenges of Power System Resilience



Geopolitical and Climate Considerations

Fuel Dependency — Politics



Resiliency — Bad Weather, Terrorism

Source: IEEE Spectrum

Transmission/Distribution Infrastructure

- Aging infrastructure requiring major upgrades
- Grid congestion
- Regulatory and environmental barriers to adding new generation and transmission systems
- Limited situational awareness and automation on distribution grids

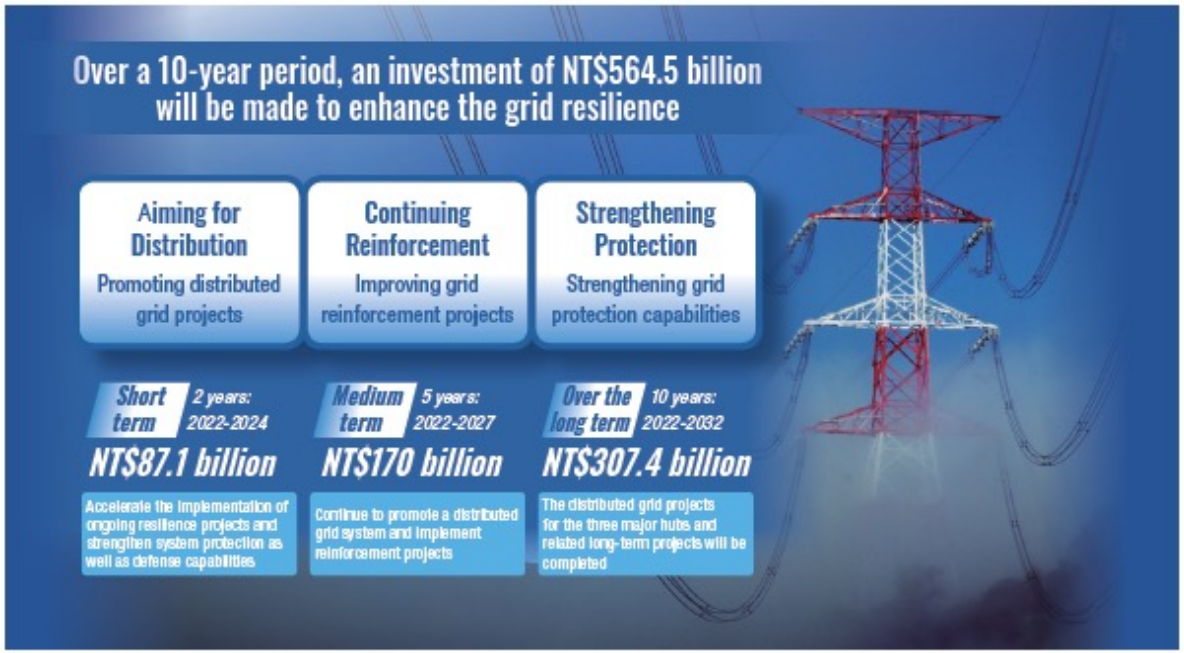
Source: S. Mokhtari, "The Power of Disruption in the Business of Energy

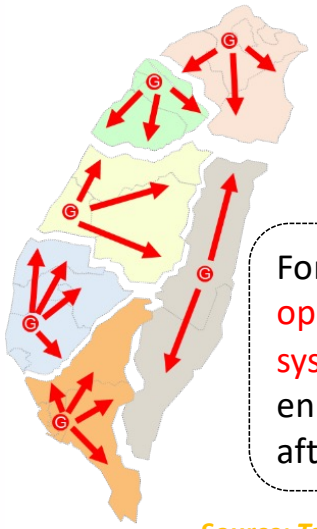
Source: TVBS

Source: Liberty Times Net

B Challenges & Opportunities

- **Rolling blackouts** on May 17, **2021**, affecting approximately **422,000** customers**,** was due to abnormal weather, increased electricity consumption, low water reservoir conditions, and delayed return of overhauled power units.
- A **human error and insufficient reserve** caused outage impacted more than **4.15 million** customers on May 13, **2021**.
- A **human error and protection failure** affected over **5.5 million** customers with prolonged interruptions at southern areas on March 3, **2022**.
- TPC announced the **'Grid Resilience Enhancement Investment Plan'** on July 15, **2022**.





Forming **6** independently operated regional dispatch systems and local microgrids to enhance power supply resilience after system separation.

Source: Taiwan Power Company (TPC)

Net-Zero Transition Plan

C Taiwan Net-Zero Strategy

Deep Energy Savings

Promote Energy Services Companies (ESCO)

Enhance Energy Efficiency

Energy System Digitalization

Versatile Sources of Green Energy

Promote Green Energy

Develop Advanced Green Energy

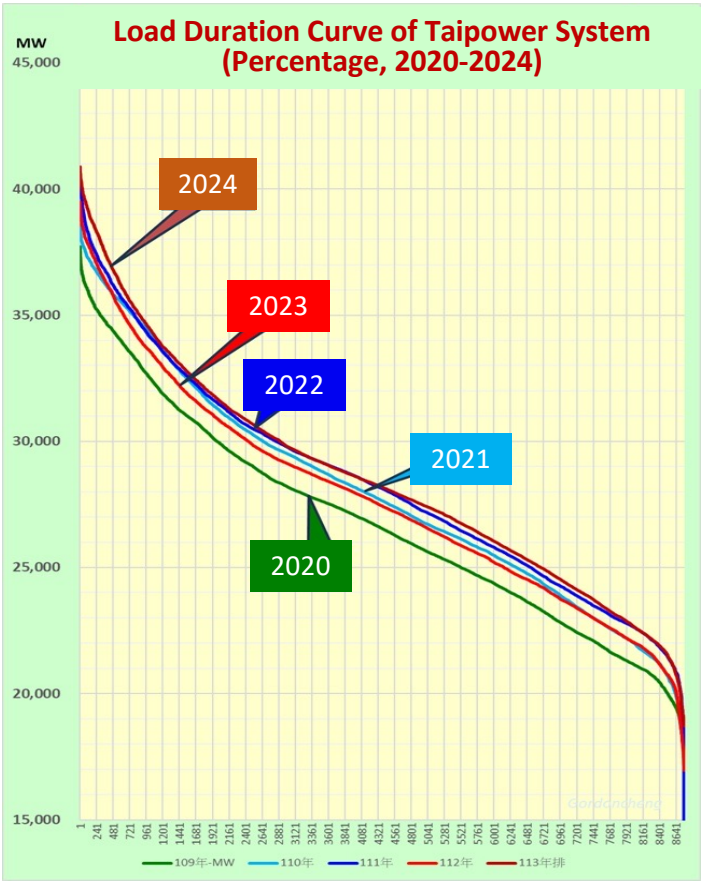
Hydrogen Applications

Natural gas as a Transitional Fuel

Bridging from Coal to Gas

Hydrogen Combustion for Carbon Reduction

CCS



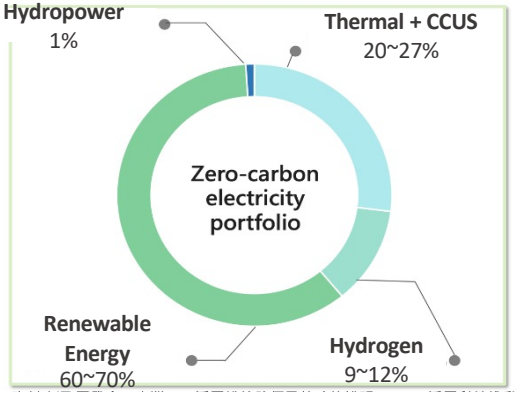
>10% of power distribution assets and >10% of generation assets are used < 3% of annual operation hours

Peak Reduction is Paramount

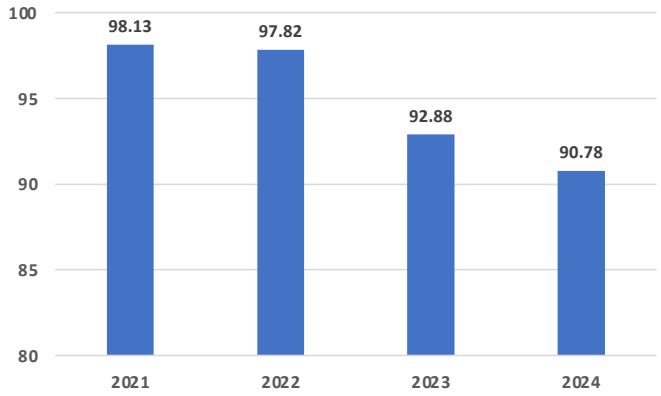
TPC's Net-Zero Emission Pathway and Outcome

- Low carbon first, then zero emission
- Increase gas, reduce coal, and promote green energy
- Integrate photovoltaic system, onshore and offshore wind farms, geothermal power plants, and energy storage systems
- Incorporate hydrogen energy and CCUS technology
- **Carbon emissions from thermal power plants reduced 7.5% in 2021-2024**

Planned 2050 Energy Portfolio

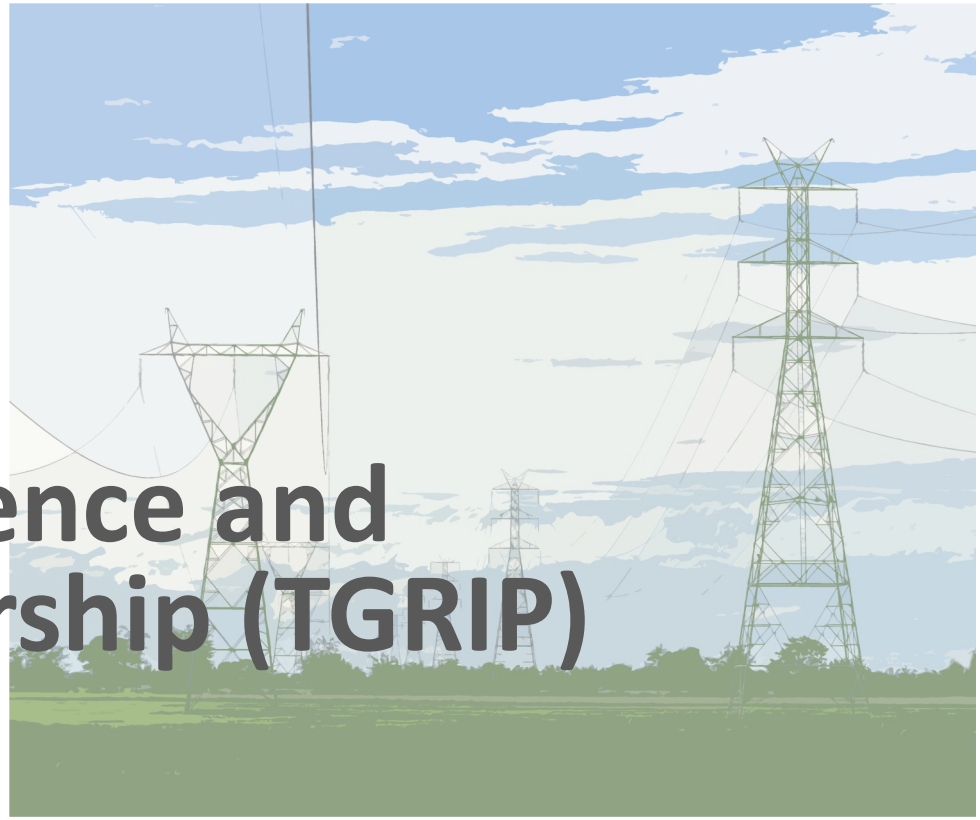


Carbon Emission of Taipower (Mt)



Source: Taiwan Power Company (TPC)

Taiwan Grid Resilience and Innovation Partnership (TGRIP)



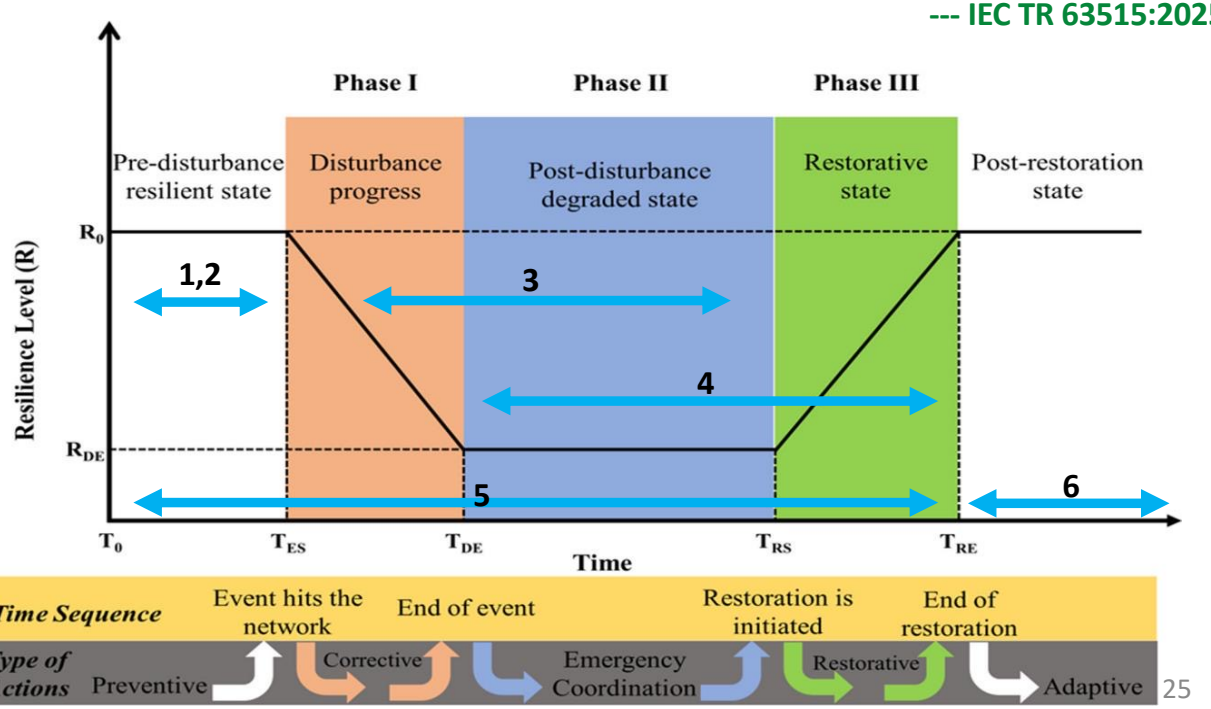
TGRIP – A Research Project Focusing on Power Grid Resilience

6 research areas with a total of 25 projects conducted by 27 organizations

1. Identification of **Hazards and System Vulnerabilities**
2. Systems **Resilience Planning**
3. **Operational Resilience** Enhancement schemes
4. Microgrid Integration and Operation
5. **Digital Twin and AI** Applications
6. **Cost-Benefit Analyses** of Power Grid Resilience Reinforcement

"**Power system resilience** is the ability of a power system to **perceive** the operating state and potential **threats**, **coordinate** internal and external **resources**, **identify, prepare for**, actively **defend** and rapidly **recover from disturbances** caused by **extreme events**, and **learn from events**."

--- IEC TR 63515:2025



TGRIP Research Project

- To leverage research and investments in emerging zero emission technologies by the **National Science and Technology Council** (**NSTC**), **Taiwan Power Company** (**TPC**), academic organizations and Industries.
- TGRIP project team applies its broad portfolio and domain expertise to help partners find the best path forward to **achieve targeted outcomes in grid resilience** (including **planning, response, and recovery**) **enhancement**, **decarbonization**, **energy efficiency**, as well as **energy equity and environmental justice**.

Global Collaborations

台灣電力公司綜合研究所
Taiwan Power Research Institute
Taiwan Power Company

ENERGY RESILIENCE PARTNERSHIP

NSTC 國科會

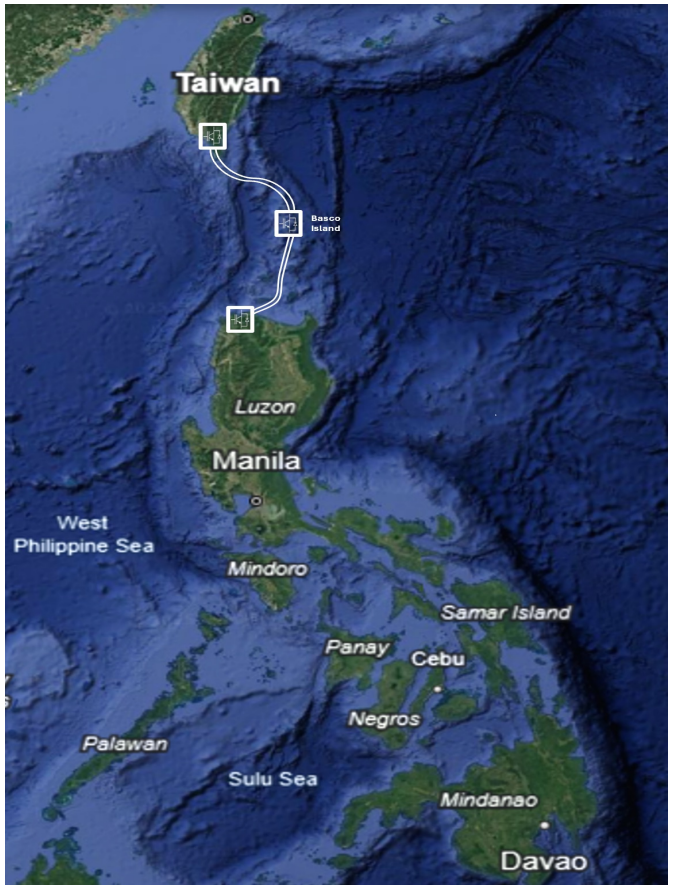
IERE Electric Power Technology Platform

International Electric Research Exchange

CRIEPI Central Research Institute of Electric Power Industry

EPRI ELECTRIC POWER RESEARCH INSTITUTE

MITei MIT Energy Initiative



D Concluding Remarks - Where Do We Go from Here -

With the intensification of **climate events, geopolitical shifts, renewables integrations** and **evolving grid structures**, it is advisable to

- **Determine the required energy reserve and grid investments** based on the renewable energy penetration, acceptable power interruption risk, and affordability,
- Proactively **quantify potential power supply risks** by assessing the probability, scale, and duration of extreme climate events, cyberattacks, resource availability, and power shortage,
- **Strengthen the protection coordination** of critical infrastructure, **energy dispatch**, and **training** of grid reliability and resilience professionals,
- **Leverage private sectors to reduce power shortage risks** and maintain a stable, reliable, and secure power supply environment,
- **Develop advanced power grid technologies and grid codes** to support the net-zero emission commitment,
- Encourage **international partnership** for **an energy secured and sustainable future.**

Thank you!