The Development and Operation of Connect & Management System

September 12th, 2025
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Introduction

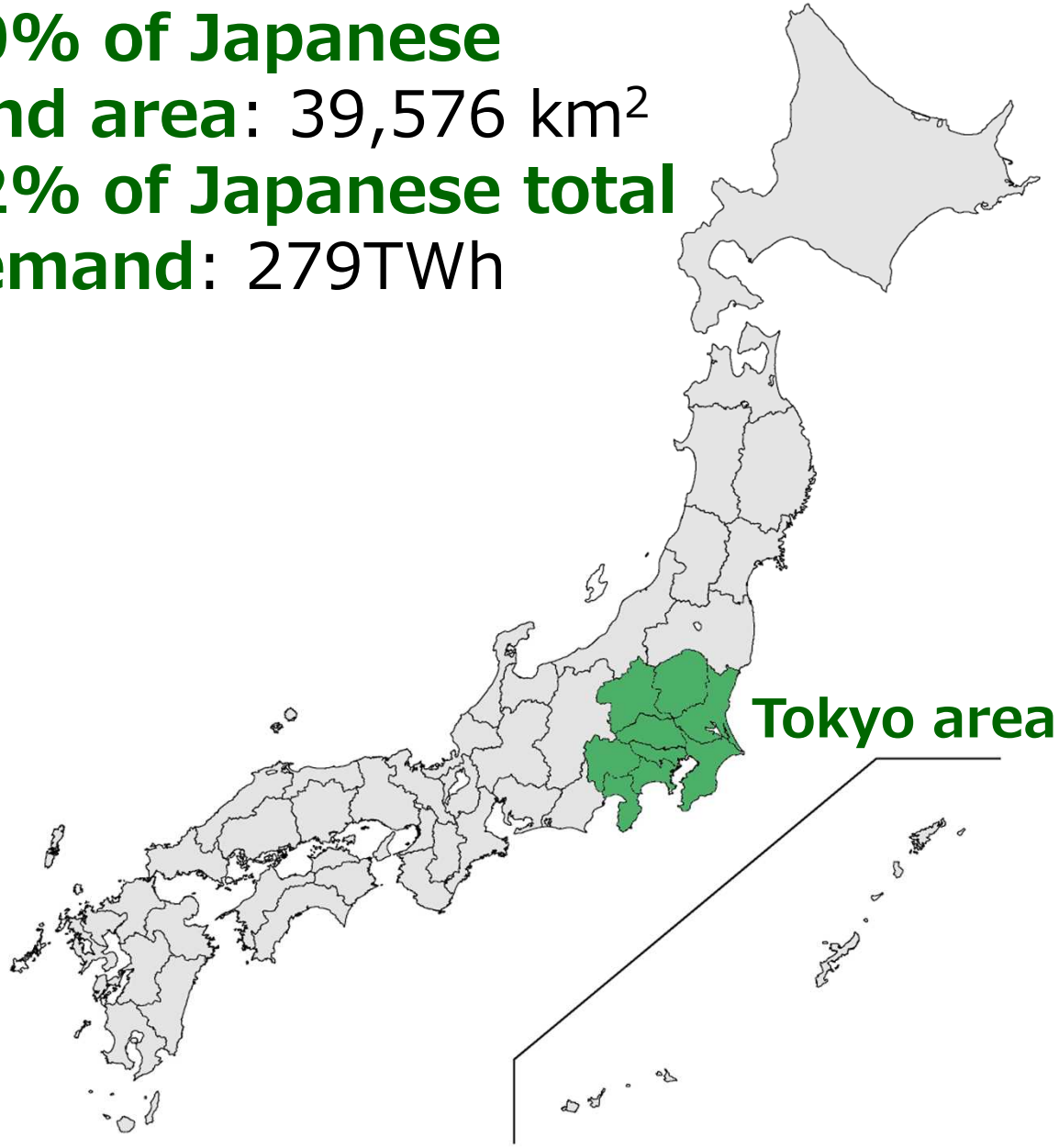
- ✓ The **integration of renewable energy (RE) has progressed rapidly since the start of the Feed-in Tariff** (FIT) scheme in July 2012.
- ✓ As a Transmission System Operator (TSO), **TEPCO Power Grid aims to utilize existing power infrastructure to deliver low-cost, high-quality electricity to all customers**.
- ✓ Therefore, We **have developed a "Connect & Management System** (C&M System)" that combines hardware and software to **appropriately control power generation output according to demand and grid conditions**.

Table of Contents

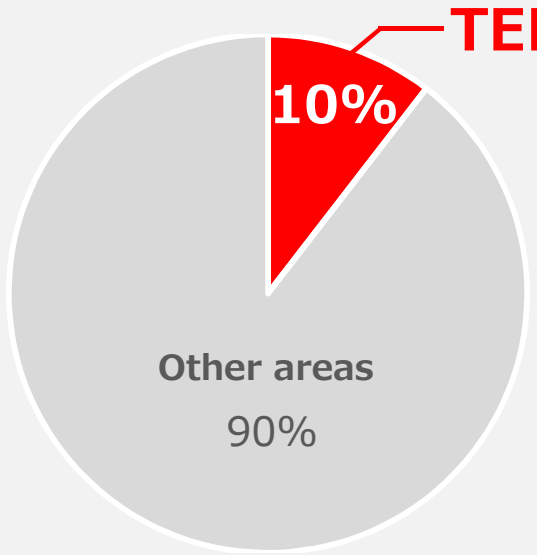
Overview of TEPCO Power Grid

Distribution area and Demand of TEPCO Power Grid

- ✓ **10% of Japanese land area**: 39,576 km²
- ✓ **32% of Japanese total demand**: 279TWh

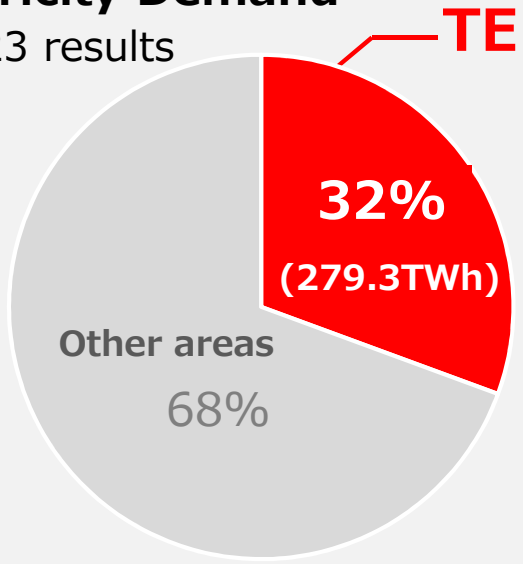


Service Area

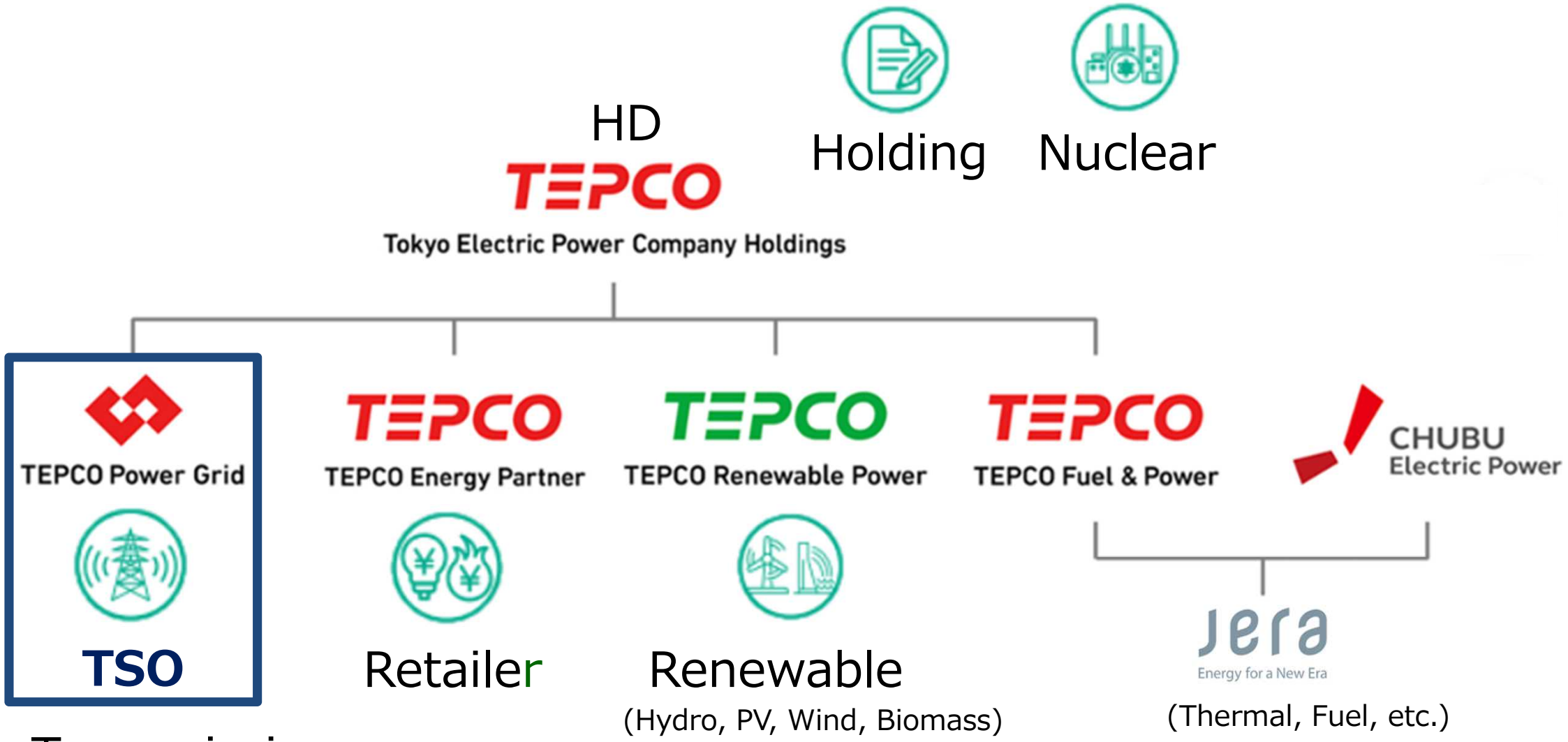


Electricity Demand

FY2023 results

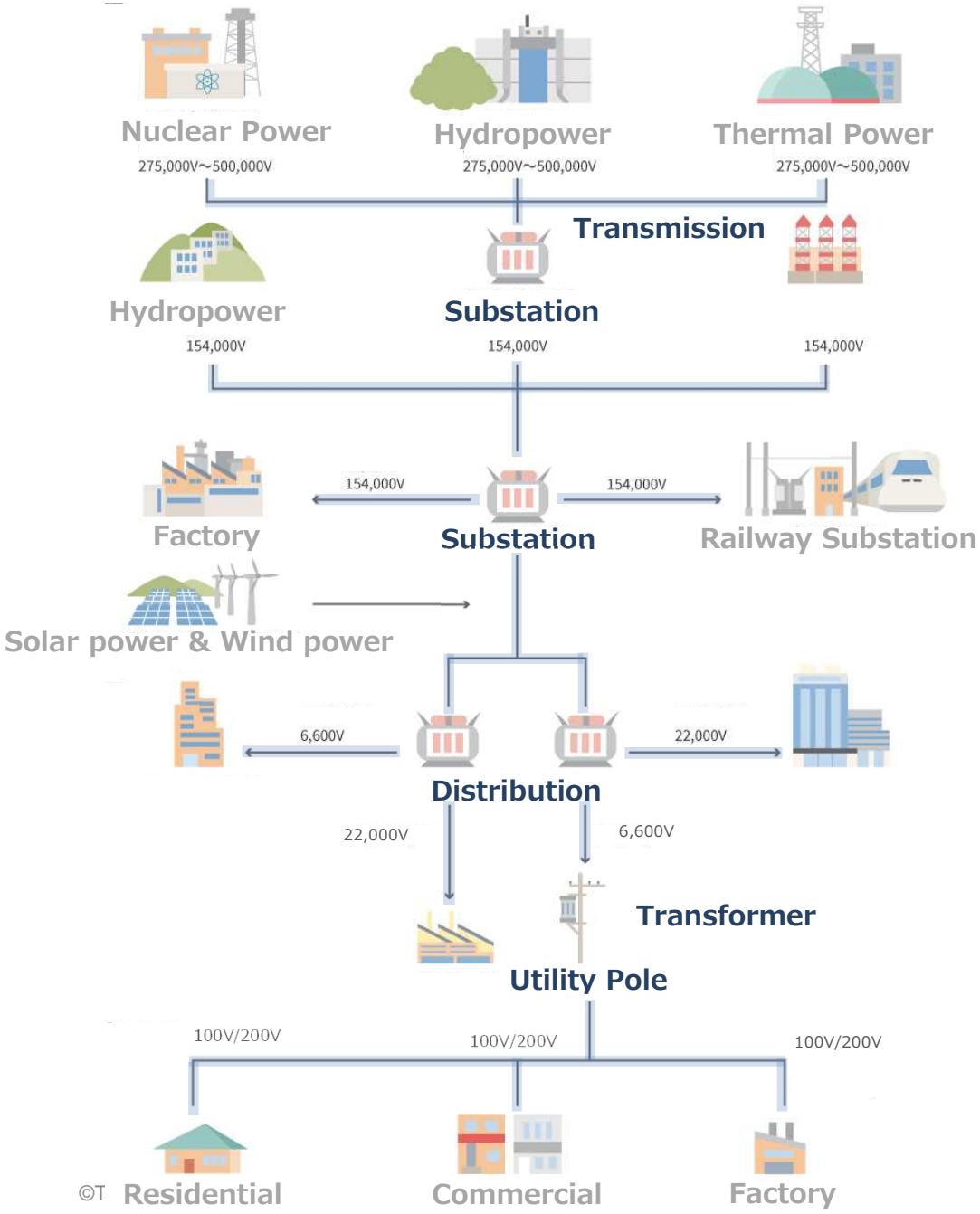


Tokyo Electric Power Company structure since 2016



Transmission System Operator

Voltage classes used in our power grids



Generation

TEPCO Holdings, TEPCO Fuel & Power, and TEPCO Renewable Power operate and manage power generation businesses.

Power Grids

TEPCO Power Grid operates and manages substations and transmission and distribution lines .

Transmission

Bulk power grid: **500kV, 275kV**
Regional power grid: **154kV, 66kV**

Distribution

High-Voltage: **22kV, 6.6kV**
Low-Voltage: **200V, 100V**

Customers

TEPCO Energy Partner operates a retail electricity business for customers.

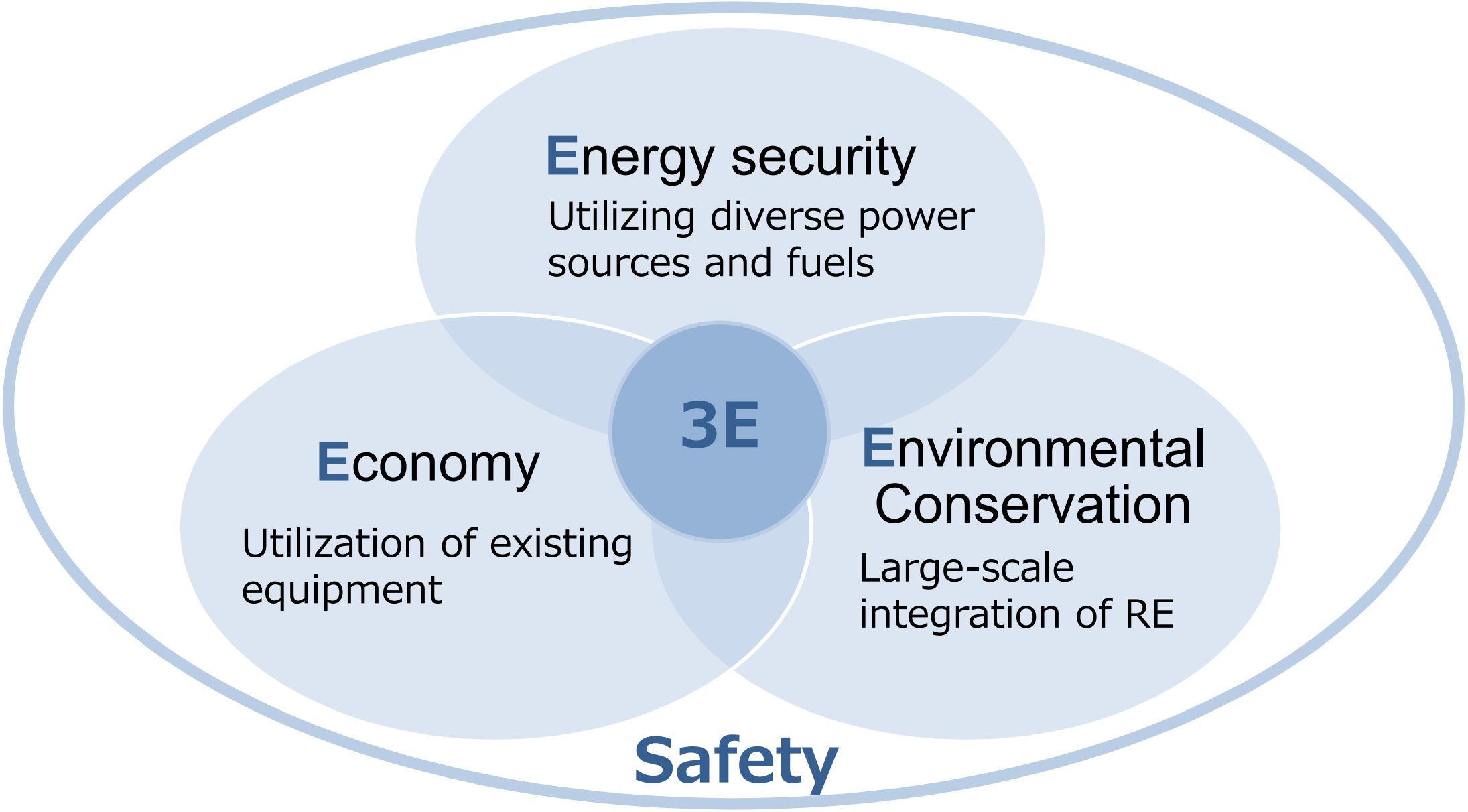
Power transmission and distribution facilities.

- ✓ We operates one of the largest power grids in Japan and aims to provide a stable supply of electricity to all customers.
- ✓ Last fiscal year, we succeeded in reducing the **average annual power outage duration per household to about 5 minutes**.

 Overhead Transmission	Length 28,410 km	Towers 49,822 sets
 Underground Transmission	Length 12,589 km	Underground Ratio 31%
 Substations	Locations 1,613	Capacity 282 GVA
 Distribution	Overhead Line Length 345,883 km	Underground Line Length 39,767 km
 Smart Meters	Number of Units 28.4 million units	

(As of March 2024)

Contributing to Japan's energy policy, "3E + S"

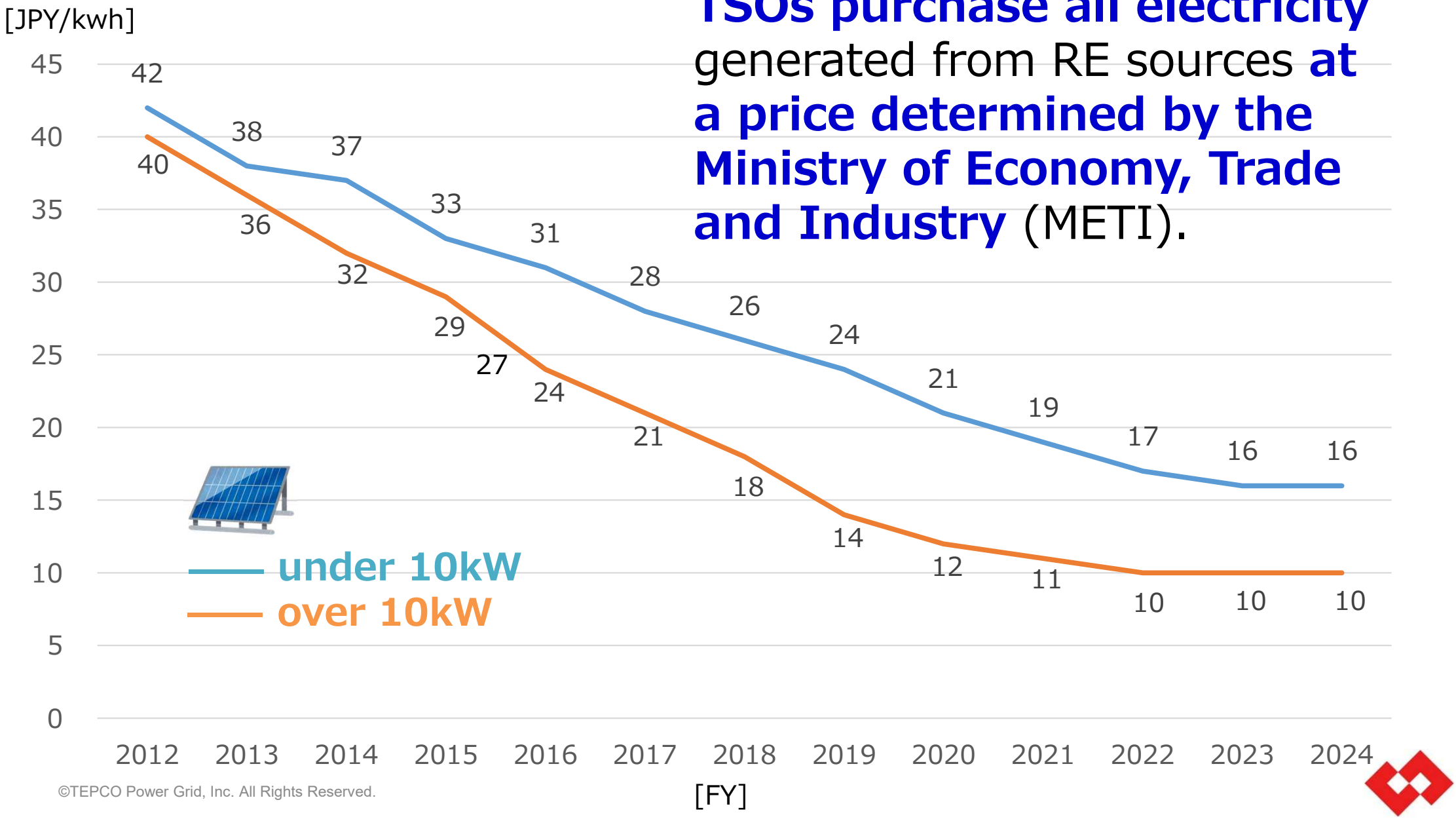


Development of disaster-resistant power grid, including interconnectors

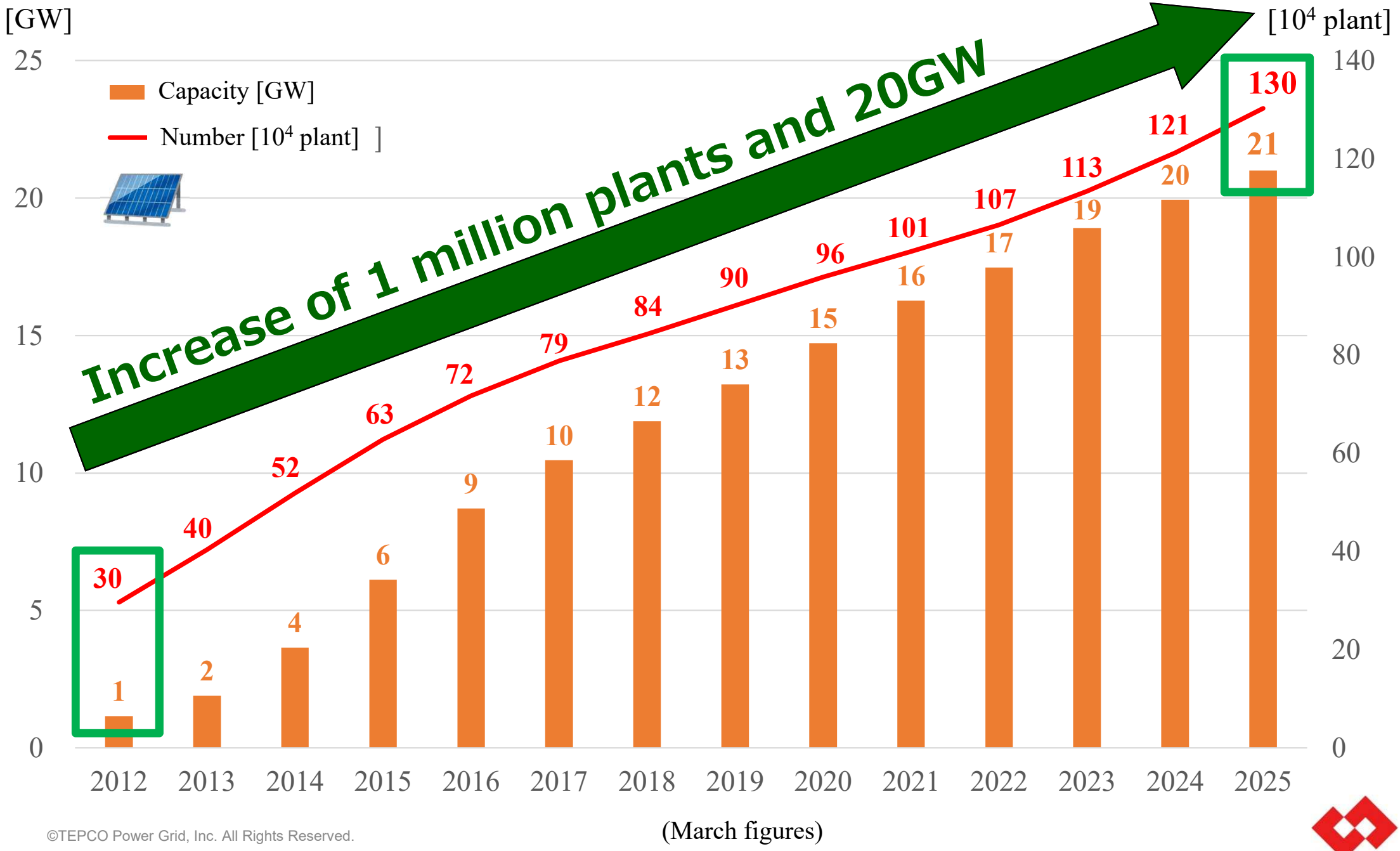
Overview of expanding RE connections

Average PV purchase price trends under FIT scheme

Feed in Tariff scheme:
TSOs purchase all electricity generated from RE sources **at a price determined by the Ministry of Economy, Trade and Industry** (METI).



Acceleration of PV installation in the Tokyo area

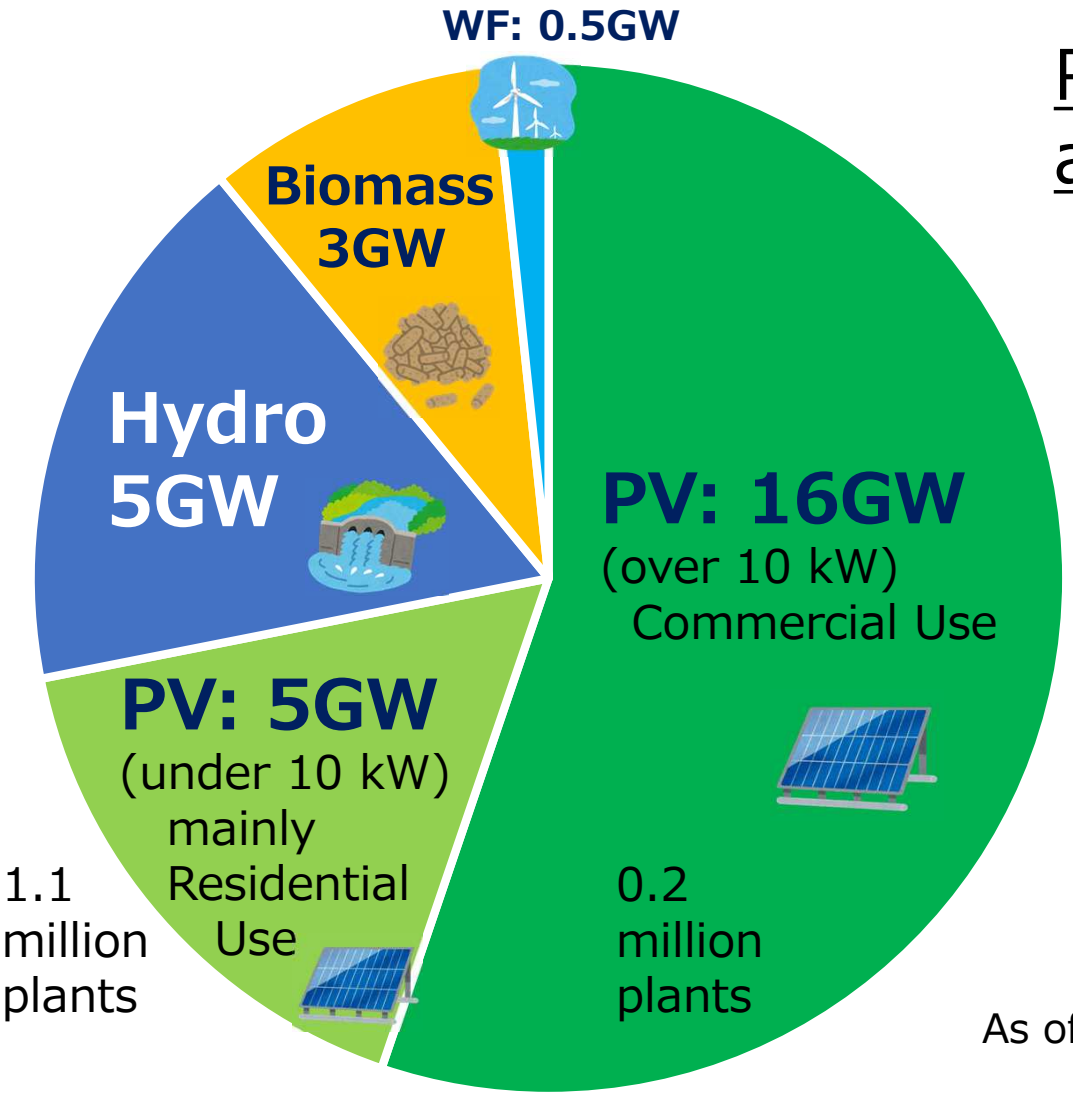


(March figures)

RE source ratio in the Tokyo area

PV accounts for around 70% of all RE of around 30GW, with two-thirds of PV being for commercial use and one-third mainly for residential use.

- PV (over 10kW)
- PV (under 10kW)
- Hydro
- Biomass
- WF



RE total: around 30GW

* Biomass includes co-fuel biomass

PV Total: 21GW

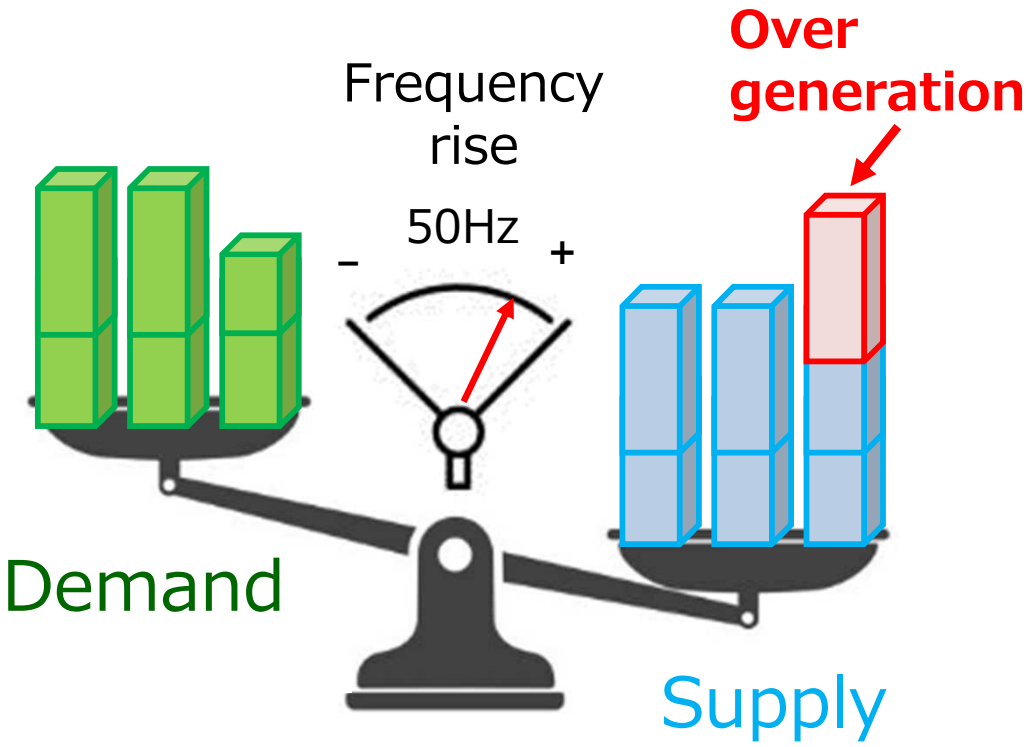
As of March 2025

Issues associated with the large-scale integration of RE

Two major issues with integrating RE

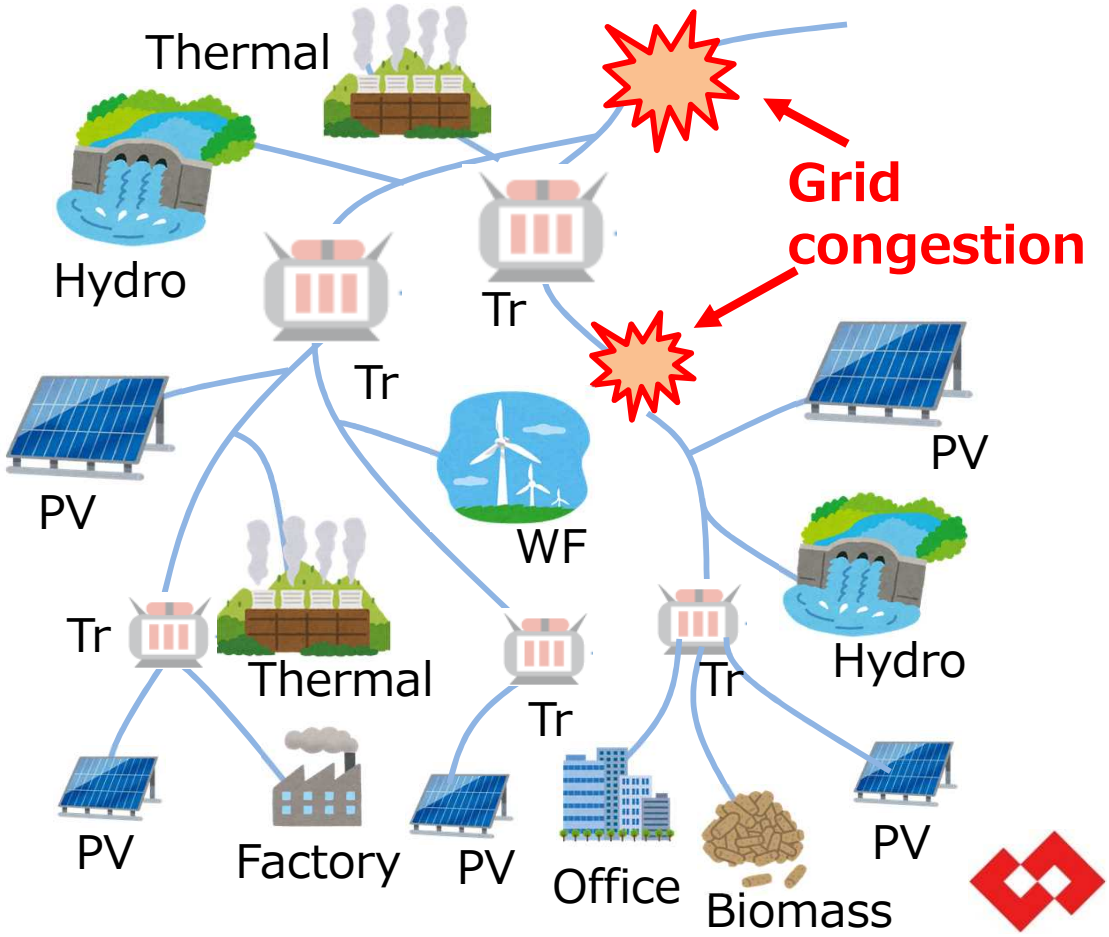
1. Over-generation

If supply exceeds demand, **frequency may exceed standards**, which could have a **negative impact on power facilities**.



2. Grid congestion

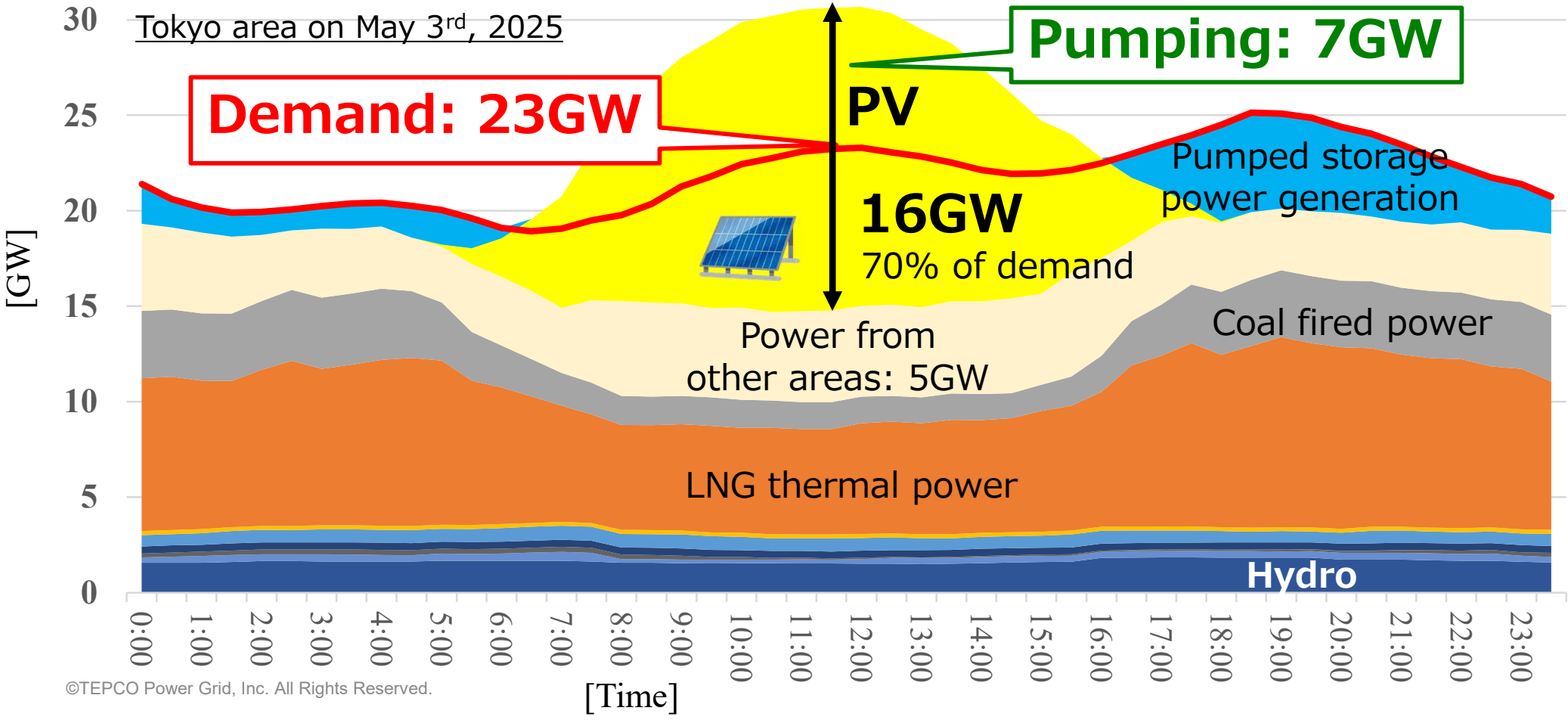
If **power line current exceeds the allowable limits**, there is a risk of **equipment damage**.



Over-generation issues and solutions

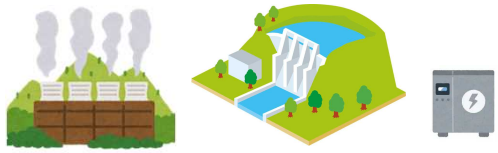
Supply & demand situation on low-load, high-PV day

- ✓ In mild temperatures, **total supply may exceed total demand** due to decreased demand and increased PV output.
- ✓ If measures such as **reducing the output of other power plants or increasing the load through pumping are insufficient**, it will be **necessary to control RE output**.

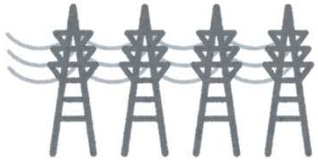


Order of measures to deal with over-generation

1.1 Output control of thermal power plants
1.2 Water pumping and Battery storage

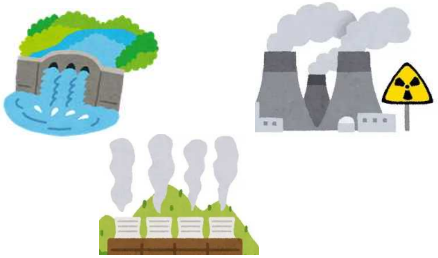


2. Power exchange using Interconnectors between other regions



3. Output control of biomass

4. Output control of PV and Wind farm

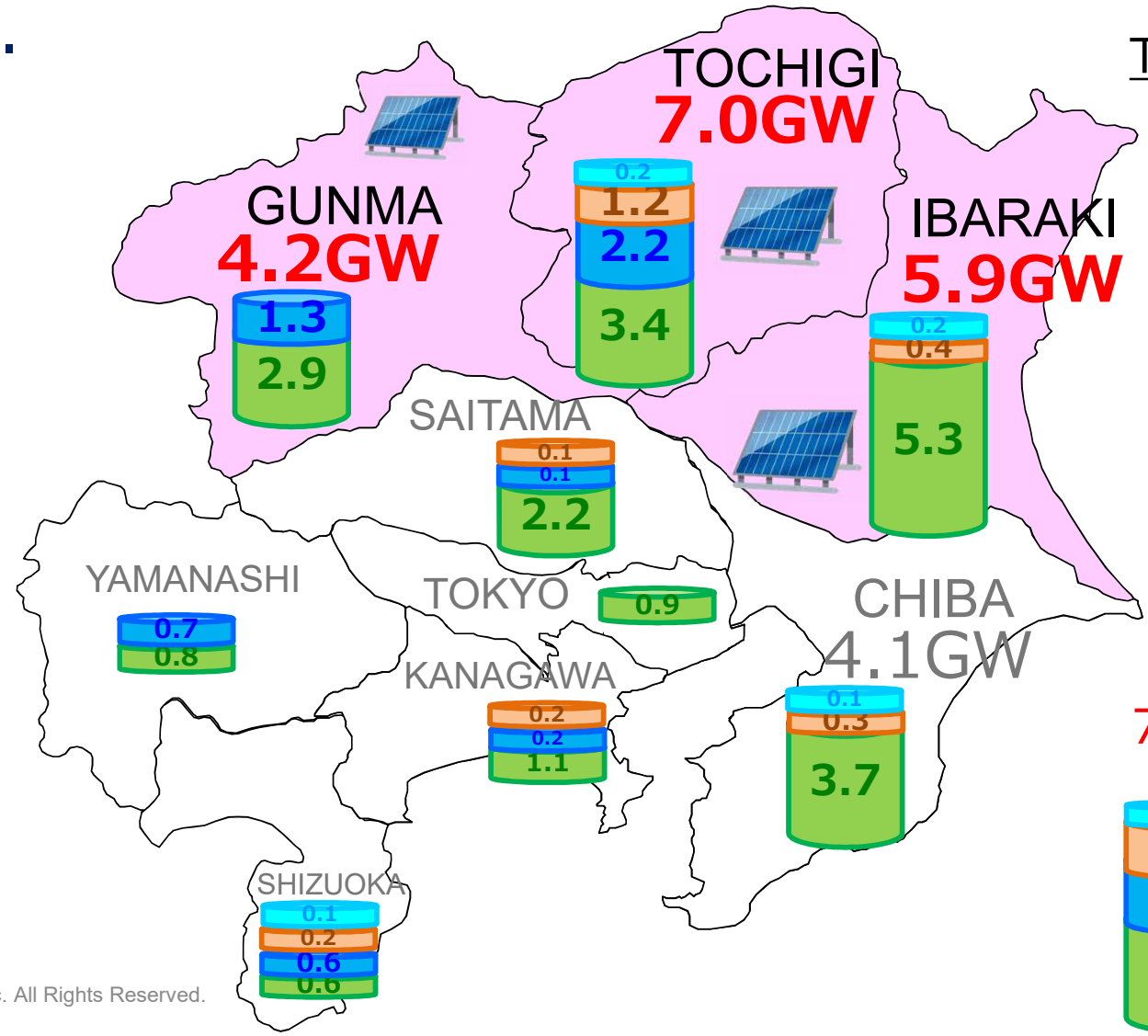


5. Output control of power sources that are difficult to control (Hydro, Nuclear, Geothermal)

Grid congestion issues and solutions

Congestion risk associated with RE distribution

In the northern regional grids, where demand is low and many RE sources are connected, **there is a high risk that power flows on transmission lines exceed their operating capacity**.

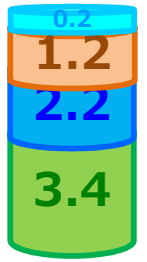


Tokyo and 8 prefectures

As of March 2025

Contract capacity

7.0GW: sum of RE



WF

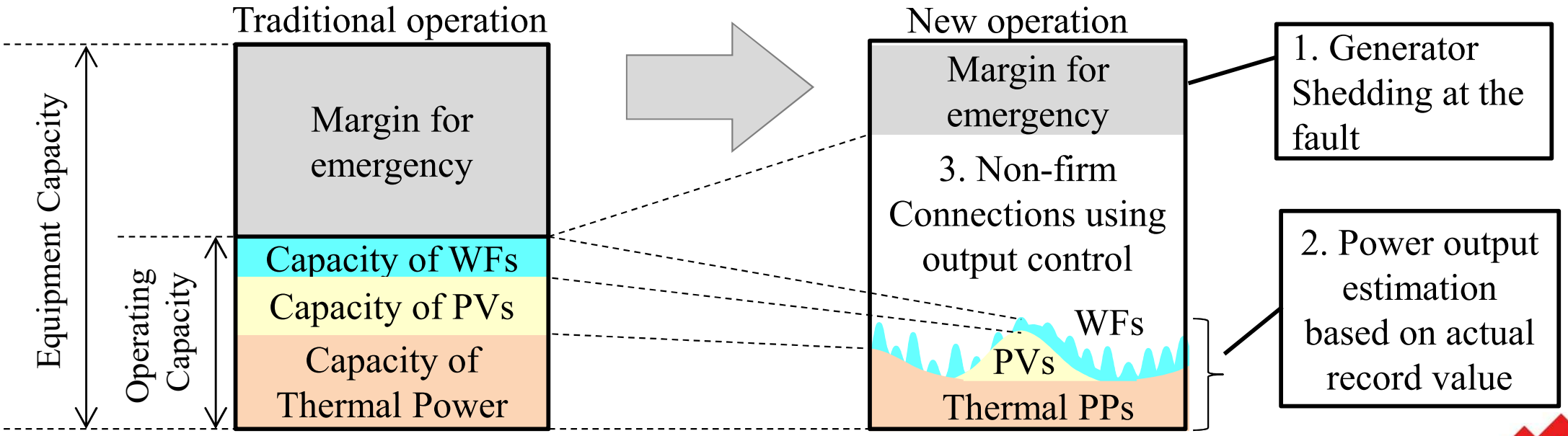
Biomass

Hydro

PV

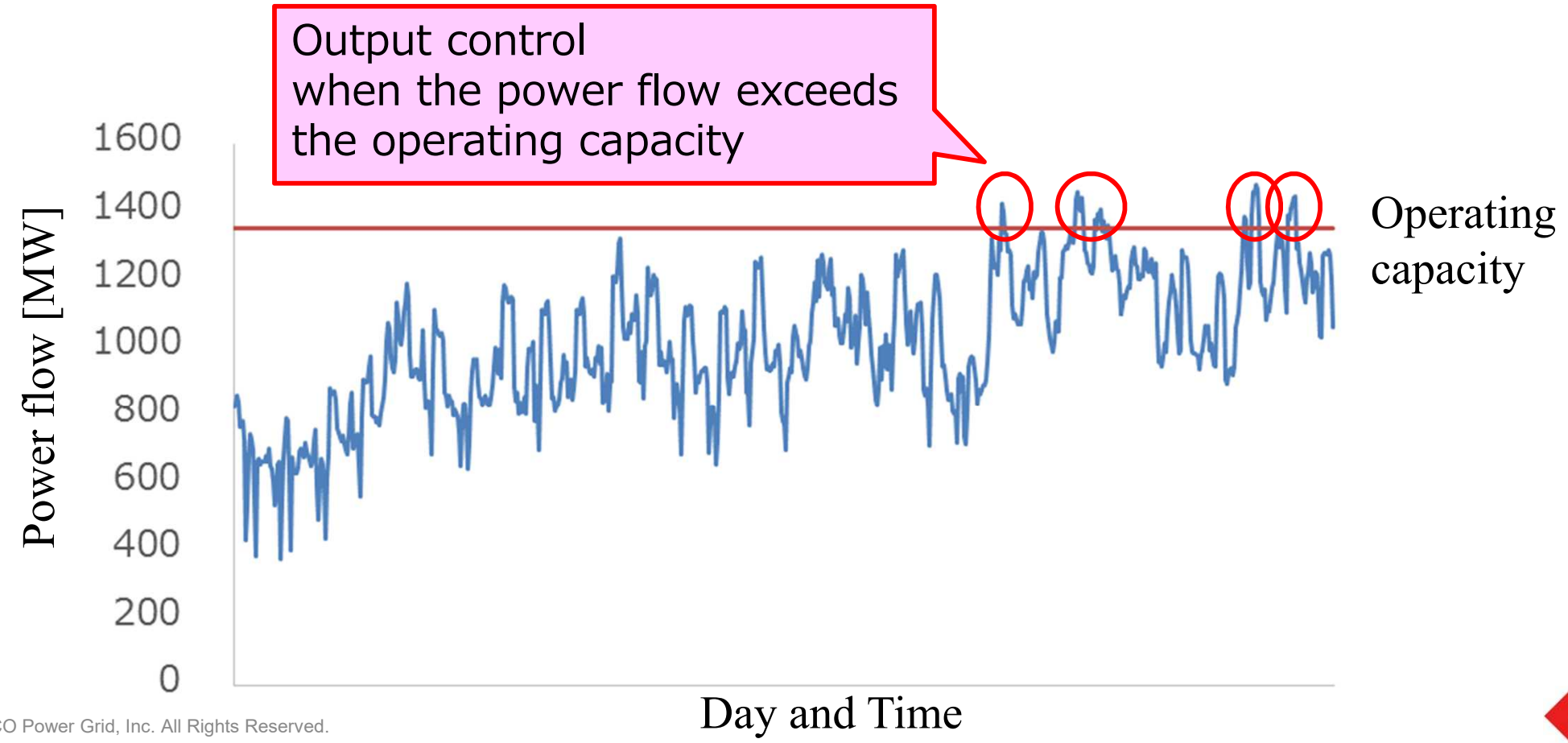
Measures to increase Available Transfer Capability

1. By installing a relay that **sheds the generator in the event of a fault**, the **margin for an accident is reduced**.
2. By **using actual power flow data** instead of rated generator capacity, **a large amount of free capacity is obtained**.
3. By **adopting a Non-firm contract scheme** that **controls power generation output in advance when grid congestion occurs**, **early grid connection is achieved**.



Output control during power grid congestion

- ✓ Power flow changes depending on the season, weather, and demand trends.
- ✓ By **controlling generator output only when the grids is congested**, we can **keep the power flow under the operating value without strengthening power grids**.

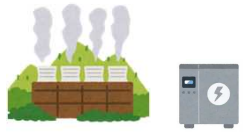


Order of output control to deal with grid congestion

1. Power sources for supply and demand adjustment

2. Non-firm thermal generators and Storage

3. Firm thermal generators and Storage



4. Non-firm Biomass

5. Non-firm PV and Wind-firm

6. Non-firm power sources that are difficult to control (Hydro, Nuclear, Geothermal)

Transition of RE output control under FIT

Transition of RE output control scheme under FIT

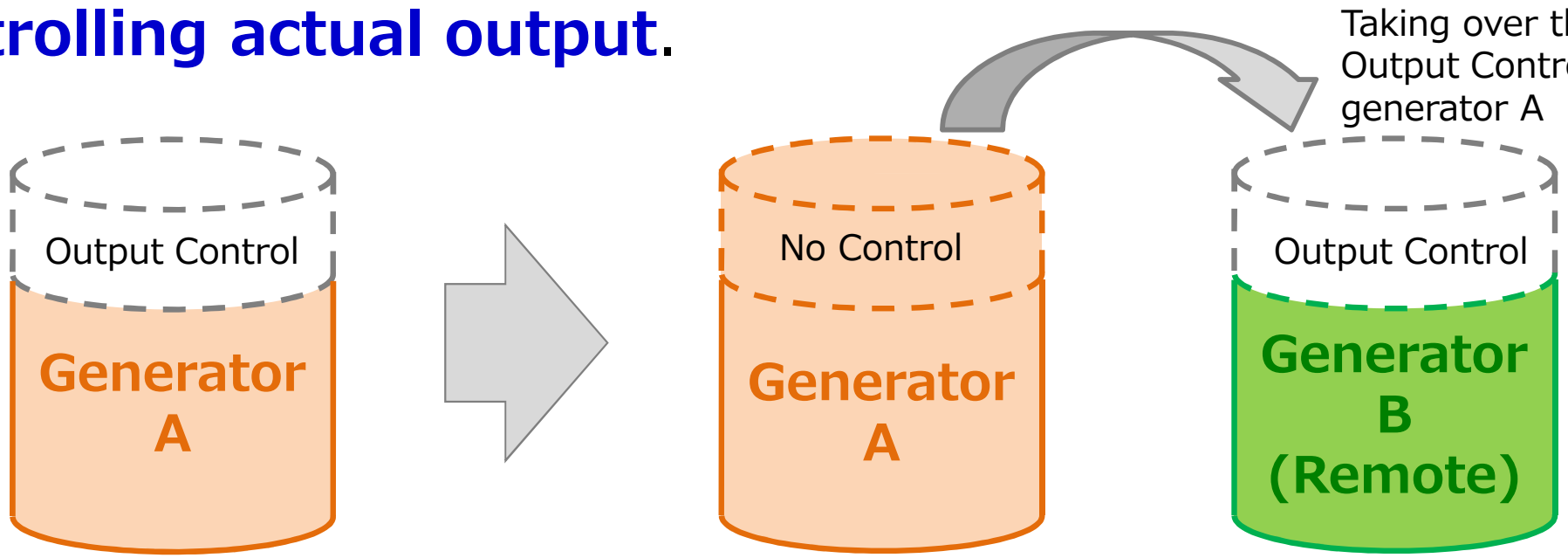
REs are required to **control their output of power according to the rule** that is decided by both "**Contract application date**" and "**Contract capacity**".

PV FIT

Contract capacity [kW]	Contract application date: Jan 2015	Apr 2015	Apr 2021
500	On-site Control	Remote Control	Remote Control	Remote Control
50	Financial compensation	Financial compensation	Remote Control	Remote Control
10	Financial compensation	Financial compensation	Financial compensation	Remote Control
	No requirements	No requirements	No requirements	No requirements

RE output control substitution by financial compensation

Because some generators are difficult to install remote control functions for, RE sources that are connected to the grid early can implement **economic compensation rather than controlling actual output**.



Normal output control

Financial compensation

After purchasing electricity from A, TEPCO receive a fee equivalent to the output control.

Retailors

TEPCO pay the compensation to B.

Development of the output control system named “Connect & Management system” planned by NEDO

New Energy and Industrial Technology Development Organization

Development schedule and structure of C&M system

- ✓ 12 organizations participated in this project
- ✓ Project leader: Prof. Shinichi Iwamoto of Waseda Univ.

TEPCO Power Grid

TEPCO Holdings

Hokkaido Electric Power Network

Tohoku Electric Power Network

Tokyo University

CRIEPI

Japan Weather Association

ITOCHU Techno-Solutions

HITACHI

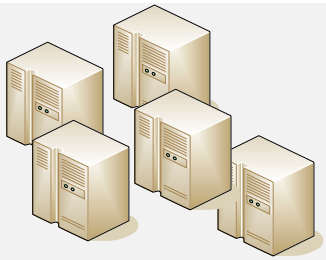
Shikoku Instrumentation

TEPCO SYSTEMS

Tokyo Densetsu Service

Connect & Management System overview

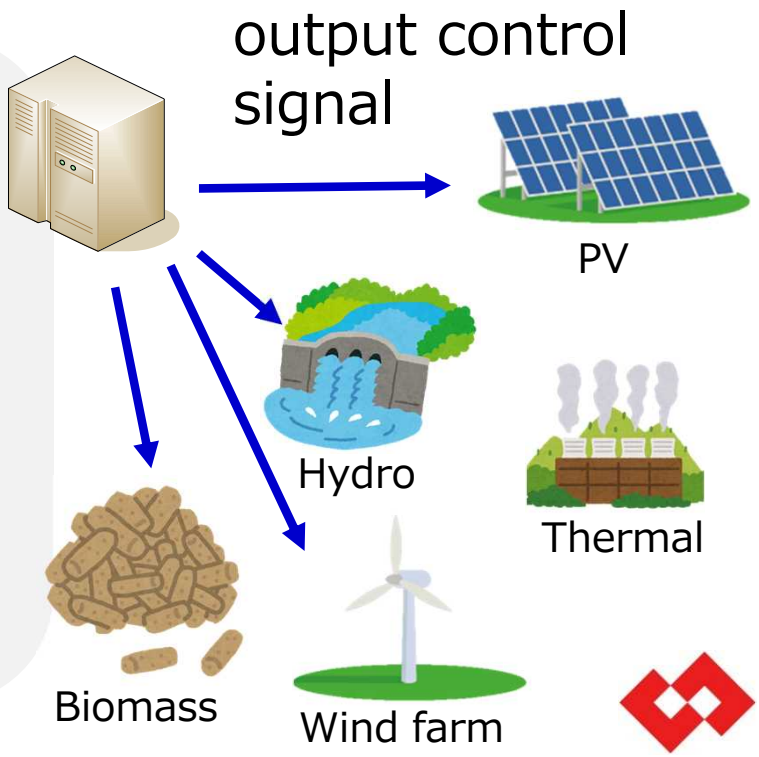
Required information



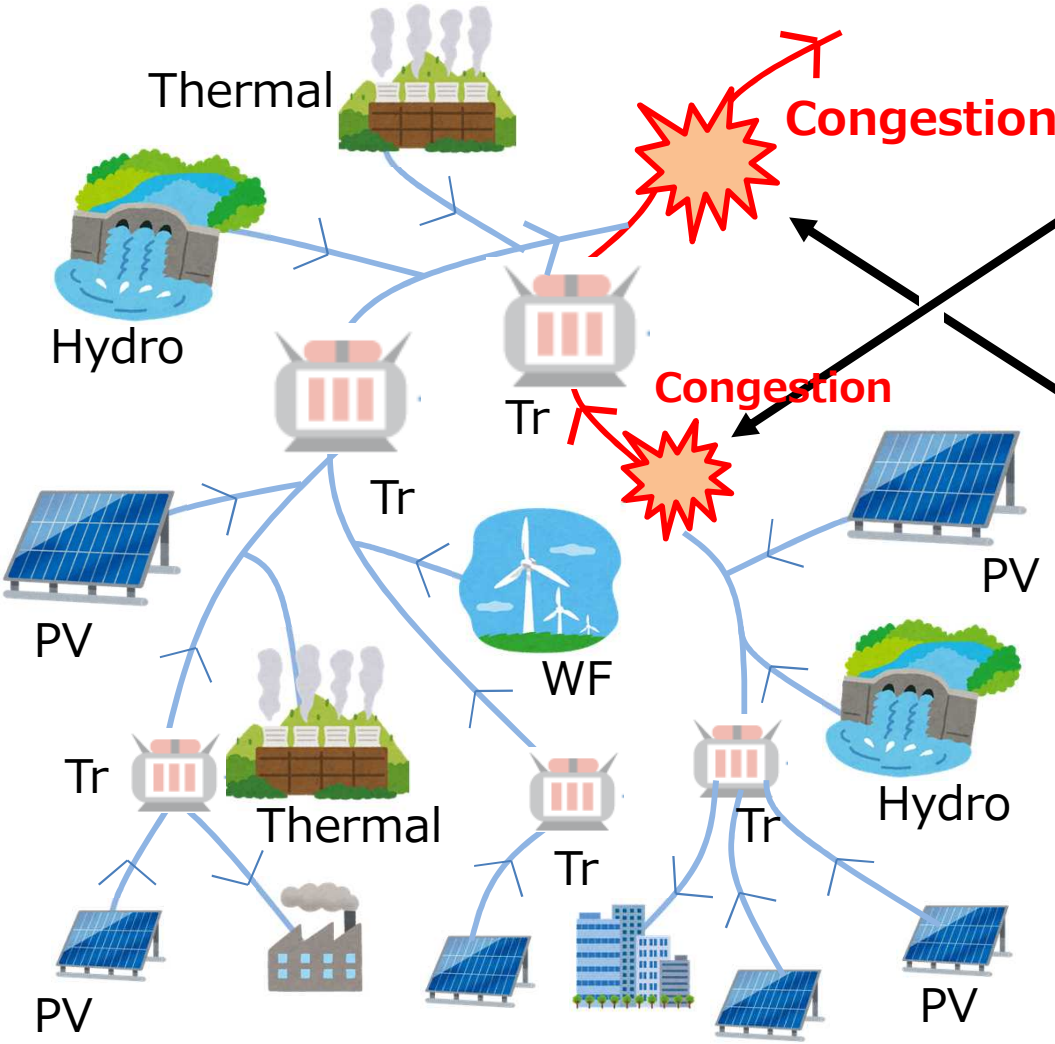
- ✓ **Demand** forecast
- ✓ **RE output** forecast
- ✓ **Contracted capacity** and **sales plan** of each generators
- ✓ **Markets execution** results
- ✓ Planned **outage of transmission facilities** etc.

Connect & Management System

1. **Output control calculation** required to **deal with grid congestion.**
2. **Output control calculation** required to **maintain frequency.**
3. **Delivering total output control** signals or schedules every 30minutes.



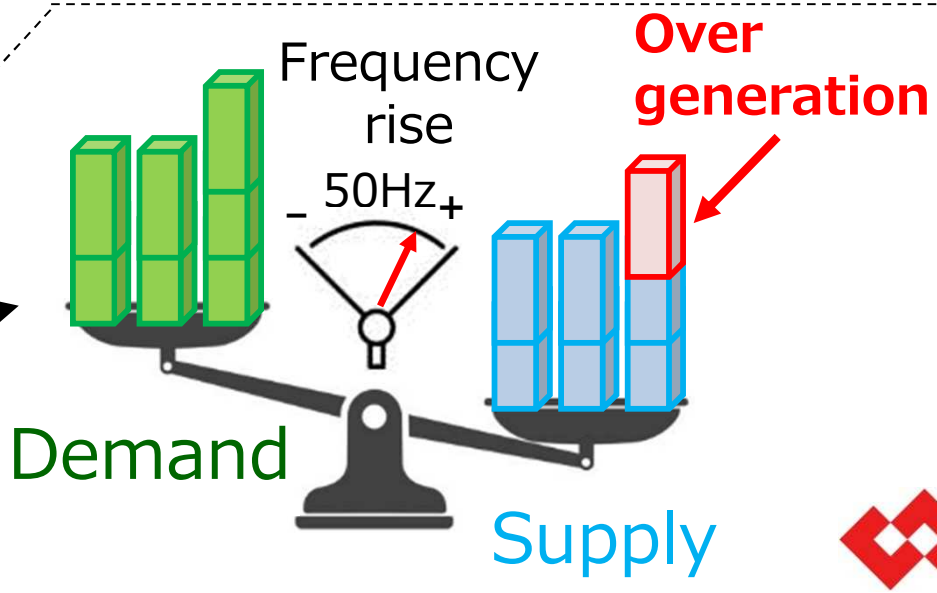
Details of output control calculation procedure



1. Calculation for **relieving the congestion of regional power grid.**

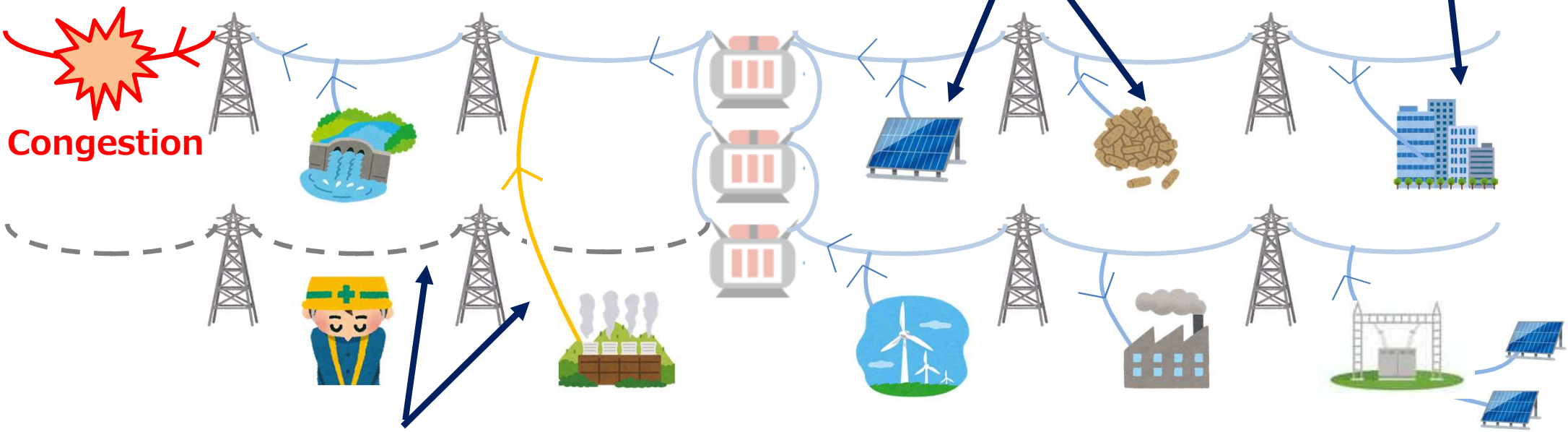
2. Calculation for **relieving the congestion of bulk power grid.**

3. Calculation for **balancing the demand and supply.**



Details of the novel power flow calculation method

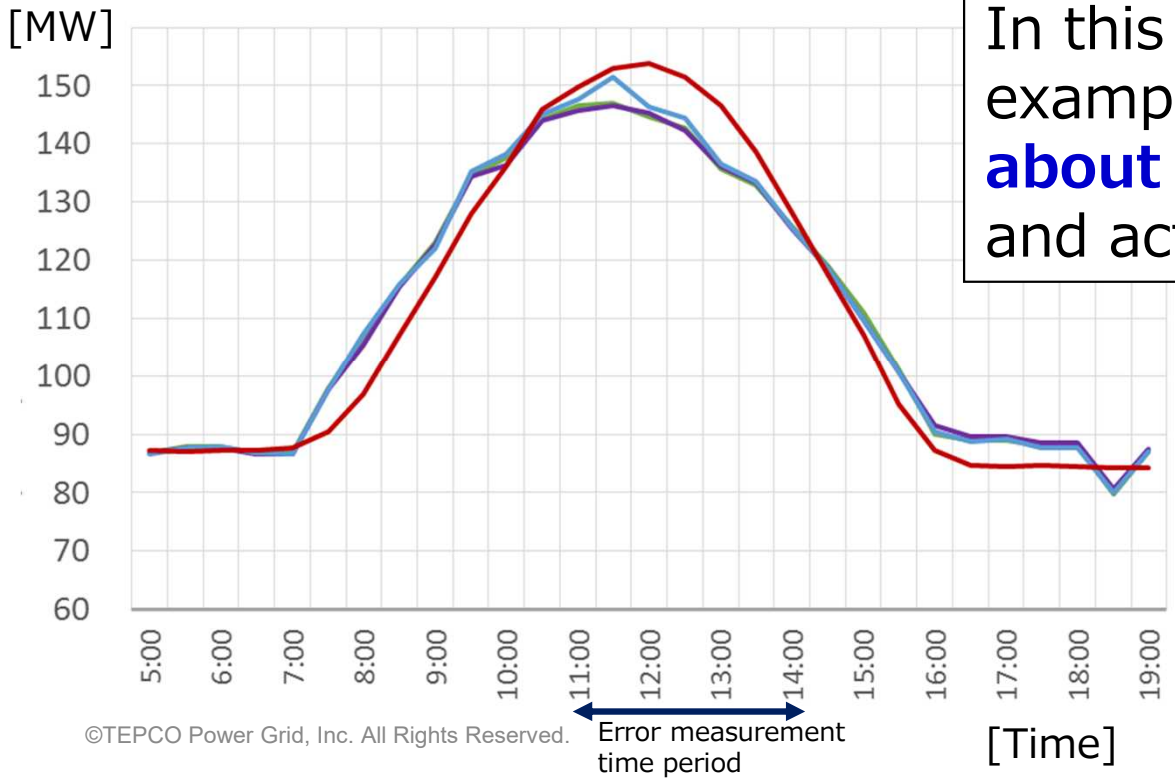
1. **Forecasting demand** for factories, offices, homes, etc.
2. **Forecasting the output of each generator**, including low and high voltage generators connected to distribution substation.



3. **Determining system configuration** taking into account for power transmission outages.
4. **Power flow calculations** that take into account losses due to transmission line resistance.

The necessity of setting the operating capacity

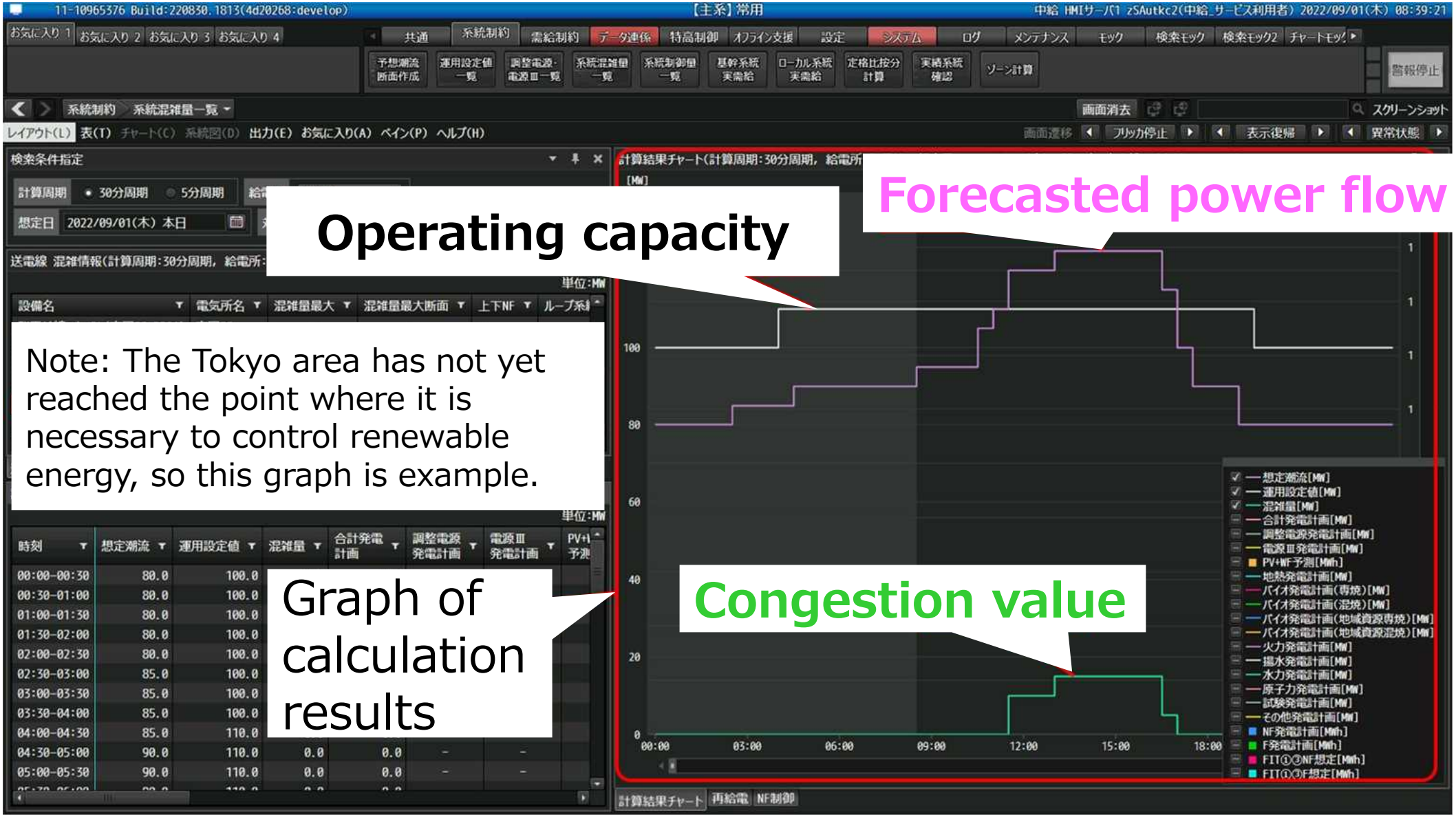
- ✓ Because **RE output fluctuates greatly due to weather conditions**, it is necessary to set the operating capacity by subtracting an appropriate margin from the rated capacity of the transmission line.
- ✓ **Margins are determined for each facility using the average error between the simulated value and the actual value**.



In this 154kV transmission line example, the **average error is about 2%** between the simulated and actual values.

Actual Power flow
Power flow simulated 1hour before delivery
Power flow simulated 5hours before delivery
Power flow simulated on previous day

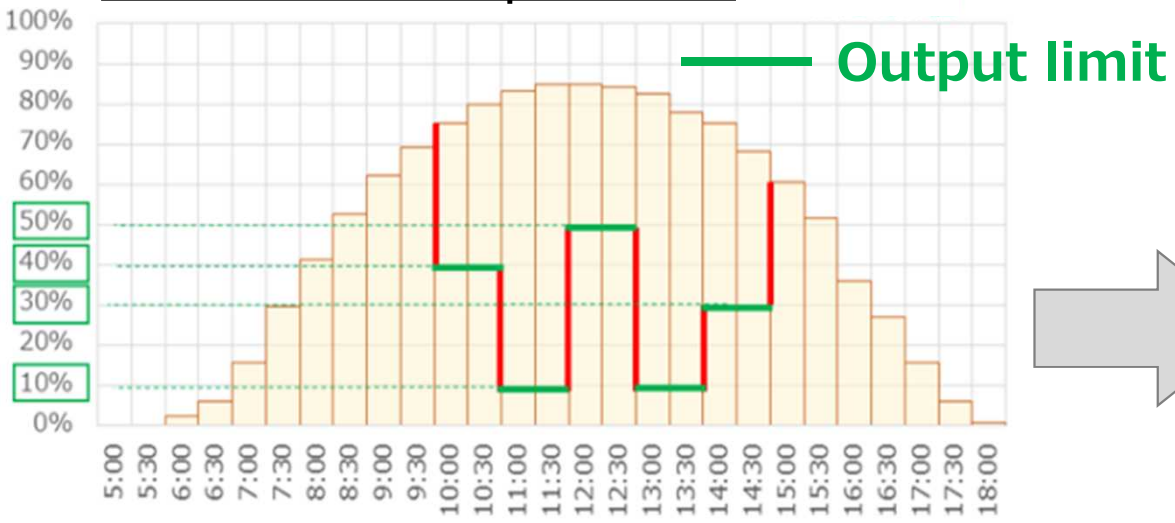
C&M system congestion forecast screen (Example)



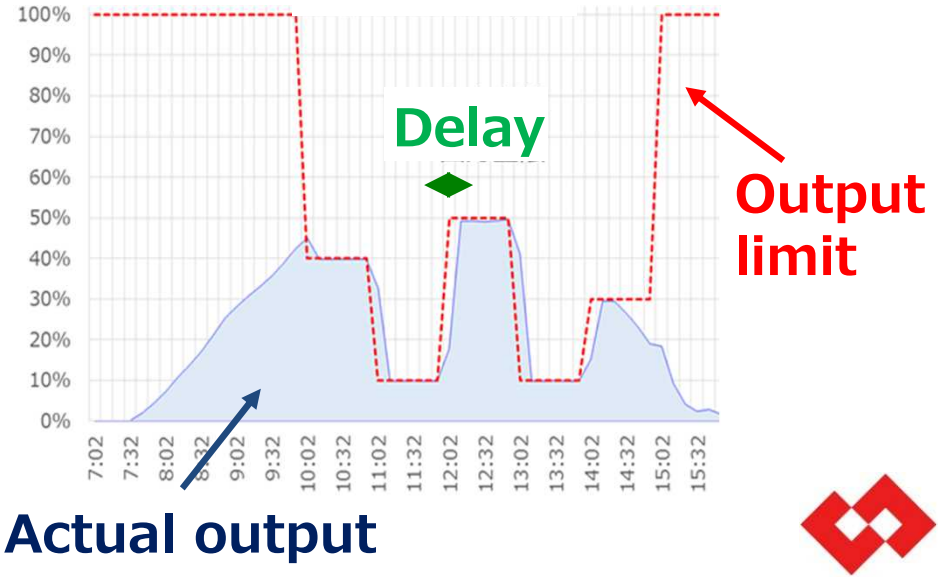
Field test results of controlling the output

- ✓ After calculating the control output, **C&M system send power generation upper limit** to each generator.
- ✓ When we carried out the actual confirmation test in 2023, **there was a slight control delay, but it was within the range of the equipment specifications.** (within 5 minutes)

Calculated output limit



Actual output of generator

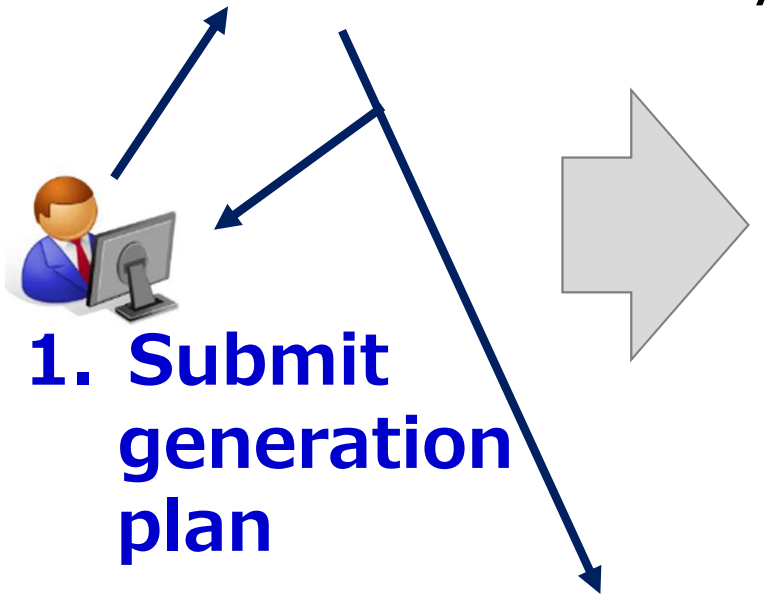


Generator output limit signaling schedule (3 times)

12:00 PM the **previous day**

Spot market bidding deadline: 10am

2. Simulate output control for next day

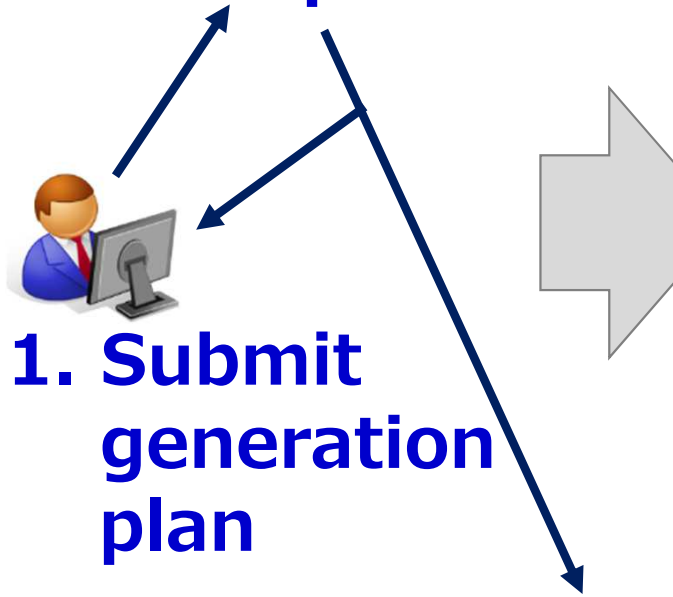


1. Submit generation plan

3. Receive output control

5 hours before Delivery time

2. Simulate output control

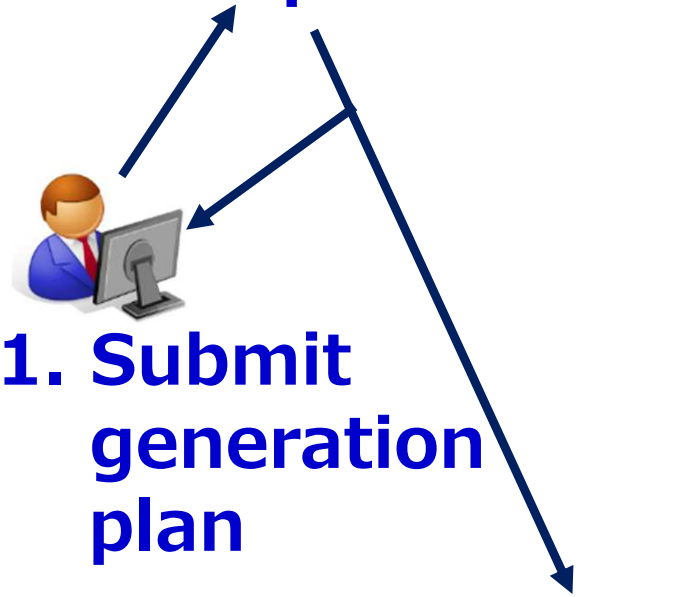


1. Submit generation plan

3. Receive output control

1 hour before Delivery time

2. Simulate output control



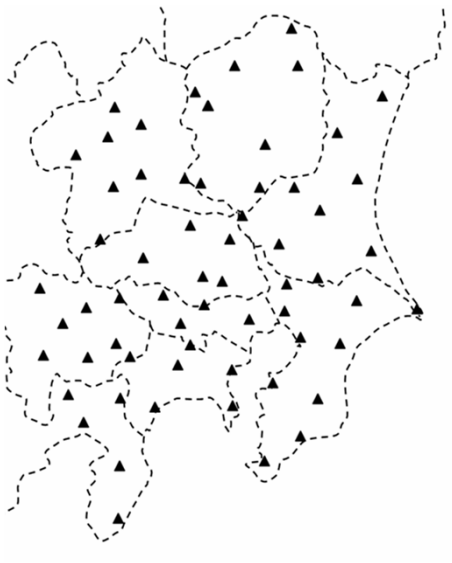
1. Submit generation plan

3. Receive output control

PV output forecasting method used in the Tokyo area

As **PV output has a strong relationship with weather information especially solar radiation**, these information is gathered by main two ways from weather organization.

[**3 days before delivery**]



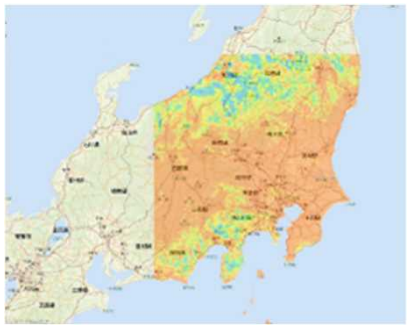
Observation points in the Tokyo area

Solar radiation and temperature forecasted 3 days ahead at **63 observation points received every 30 minutes** from weather company.

[**3 hours before delivery**]

Satellite

200,000 locations of 500m square mesh data received every 5 minutes from meteorological satellite.



Solar radiation intensity at each area

Summary

- ✓ Thanks to the introduction of FIT and maximum utilization of the power grid, the **Tokyo area has achieved the connection of around 30GW of RE** and is **promoting the integration of further RE**.
- ✓ However, **due to issues such as over-generation and grid congestion, various schemes for controlling generator output are gradually being introduced**.
- ✓ We will utilize our newly developed **"Connect & Management system"** to **respond appropriately to these scheme changes and continue to contribute to the integration of as much RE as possible**.

Thank you for listening!

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