Long-term Power Demand Analysis Focusing on Fast-Growing Industries

Socio-Economic Research Center
Central Research Institute of Electric Power Industry

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Self Introduction

Specialty

- ✓ Macroeconomic analysis
- ✓ Input-output（IO） analysis

→IO analysis is commonly used for estimating the impacts of positive or negative economic shocks and analyzing the ripple effects throughout an economy.

Recent work

- ✓ **A long-term analysis for Japanese economy, industry and power demand towards 2050**
- ✓ Assessing the economic and energy impact of car electrification with the use of input-output analysis

Central Research Institute of Electric Power Industry (CRIEPI)

Established Year: 1951
Corporate Status: Nonprofit foundation

Operational Budget (FY2021)

¥30.1 billion

Personnel (FY2020)

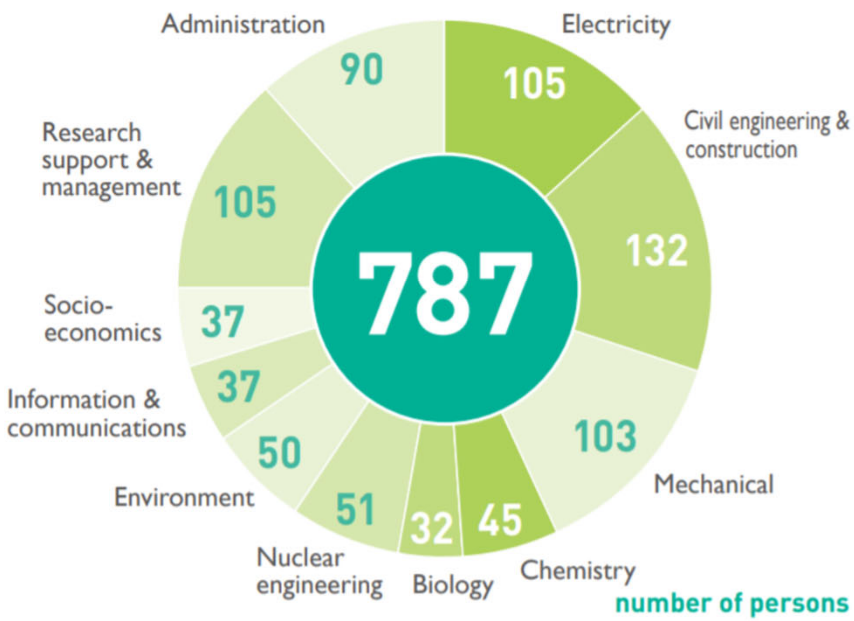
787

Research : 697

Staff with doctorate degrees **397**

Administration : 90

Personnel Configuration by Subject Field



Note: https://criepi.denken.or.jp/en/publications/pamphletslabo/criepi.pdf?v2

Today's Contents

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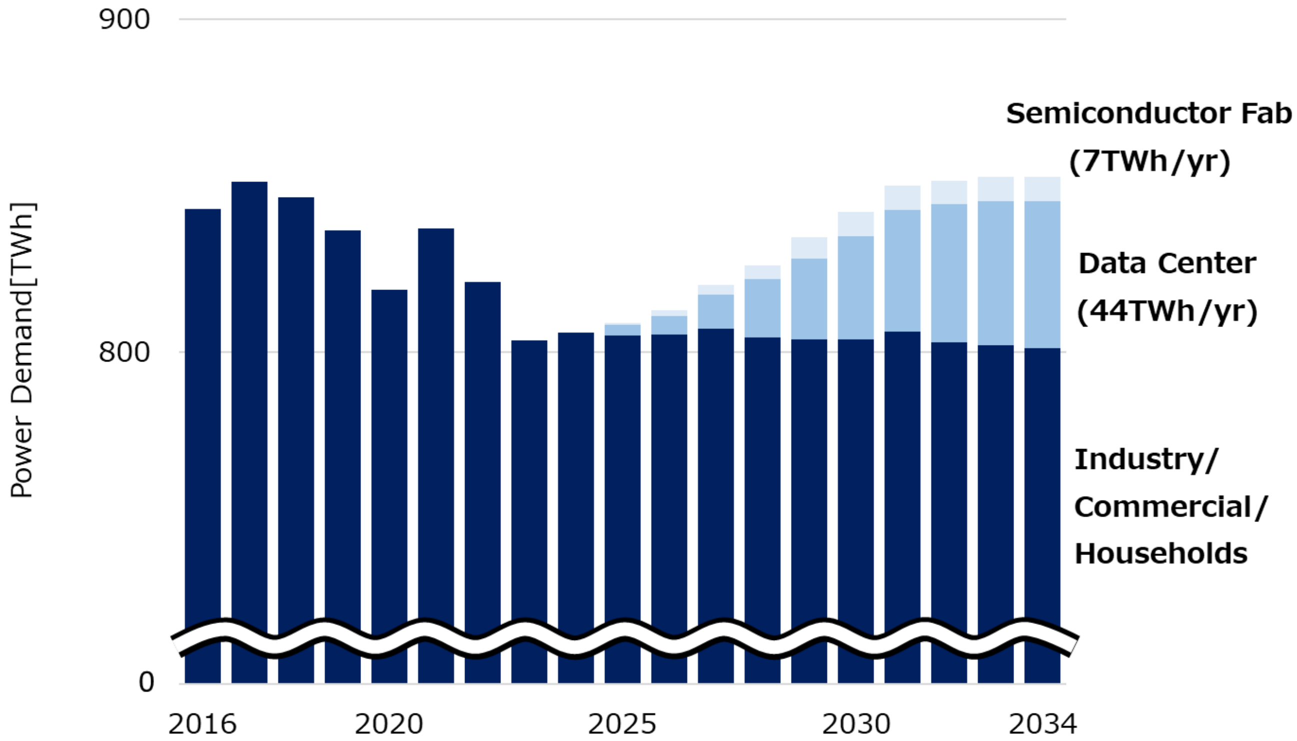
OCCTO: Upward Revision in Power Demand Outlook

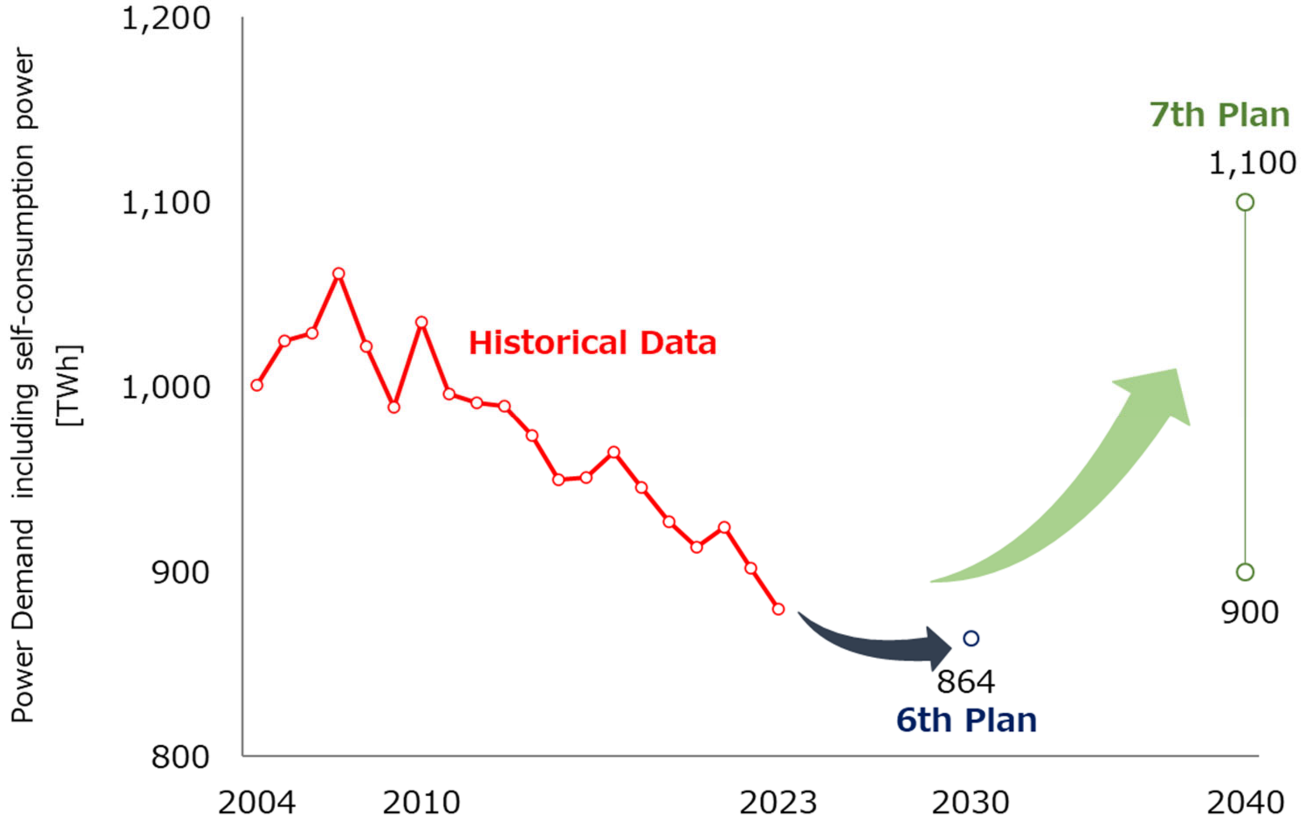
- OCCTO publishes an annual outlook in Japan of power demand for the next 10 years.
- Previously, OCCTO presented a decline in power demand, but **the outlook since 2024 explicitly included power demand from datacenter(DC) and semiconductor fab and indicated an increase over the next 10 years.**



Note: The figure above shows the power demand outlook published by OCCTO in 2025.

Japanese Government: Outlook of Power Demand in Japan

- In 2021, the Japanese government formulated the “6th Strategic Energy Plan” (6th Plan), which projected a reduction in power demand by 2030 based on energy-saving assumptions.
- Subsequently, the 7th Strategic Energy Plan(7th plan) outlooked that power demand would increase through 2040, driven by advances in digital transformation (DX) and green transformation (GX).



The Key Factors in Long-term Power Demand Analysis

- While socio-economic and power-saving have traditionally guided demand outlook, electrification has now become crucial for achieving a carbon-neutral society and must be included in long-term power demand outlook.

I. Socio-economic ⇩⇧

- Number of **population** and **households**
- **Macroeconomic conditions** such as GDP
- **Industrial activity（automotive industry and DC etc.)** etc.

II. Power Saving ⇩

・**Improving the energy efficiency** for energy devices
・**Changing demand structures in sectors** such as industry and household
⇒This report defines energy savings as a reduction in energy intensity.

II. Electrification ⇧

- Conversion of fuel to electricity through the use of energy devices such as **electric vehicles** and **heat pumps** etc.

The Increasing Importance of Long-Term Power Demand Outlook

- OCCTO considered the long-term scenarios for electricity supply and demand by 2050 in order to establish a new framework for planning the development of supply capacity, which CRIEPI have contributed to through discussions at expert committee.

- In this committee, long-term power demand analyses have paid strong attention to how much DC power demand is expected to grow in the future.

This report presents CRIEPI's long-term power demand analysis, focusing on datacenter in Japan.

Today’s Contents

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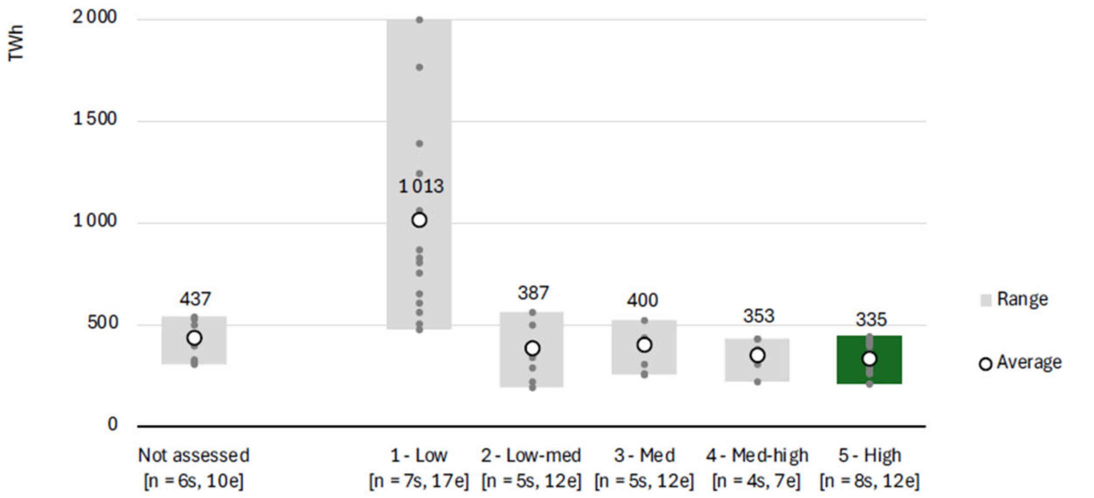
Datacenter Energy Use: Critical Review

- The 4E TCP* project critically reviewed 50+ studies on global DC power demand.
- Two experts ranked studies subjectively based on their extensive experience in the field.
  - ✓ **"High"**-rated studies were mostly based on a bottom-up approach, and their estimates showed a much narrower range.
  - ✓ Bottom-up approach estimates DC power demand by aggregating individual technological factors such as the number of installed servers and power usage efficiency.

*The 4E TCP is established under the auspices of the IEA as a functionally and legally autonomous body.

Figure ES.1 Estimates of global data centre energy use in 2023, by assessed quality



Notes: Range of estimates include all scenarios, while average values are for base cases only. Numbers in parentheses indicate the number of studies (s) and estimates (e). "Not assessed" are studies that did not share sufficient methodological detail to assess their quality.

Note: Kamiya, Geroge and Coroamă, V. C. (2025)「Data Centre Energy Use:Critical Review of Modelsand Results」

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DC Power Demand Modeling Approaches: Bottom-up

- IEA apply bottom-up methods, using industry outlooks to set assumptions on IT equipment installations and energy efficiency.
- This approach can capture short-term trends in server shipments and specifications.
- However, it faces a major limitation in projecting the installed base and power efficiency over the medium to long term, due to the average five-year server lifetime and the rapid pace of technological progress.

Key inputs	・Equipment specifications, e.g., server power draw ・Data center infrastructure characteristics, e.g., PUE ・Installed base/equipment shipment values
Assumptions for future growth	・Future equipment shipment values ・Future equipment trends, e.g., power density, GPUs ・Energy efficiency improvements, e.g., PUE improvements
Main limitations	・Availability of installed base and server equipment values ・Ability to project trends in equipment type and energy efficiency improvements more than a few years into the future

Note: Mytton, David and Ashtine, Masaō.（2022）「Sources of Data Center Energy Estimates: A Comprehensive Review」

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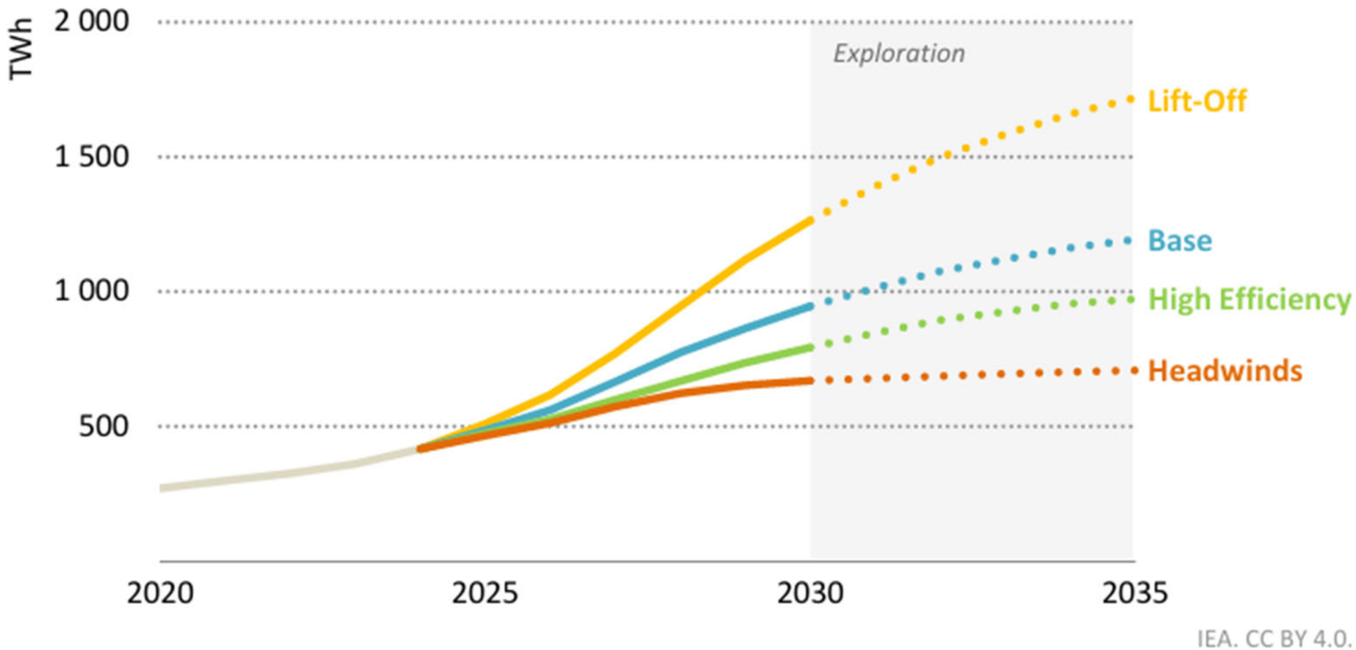
IEA: Outlook of Datacenter Power Demand

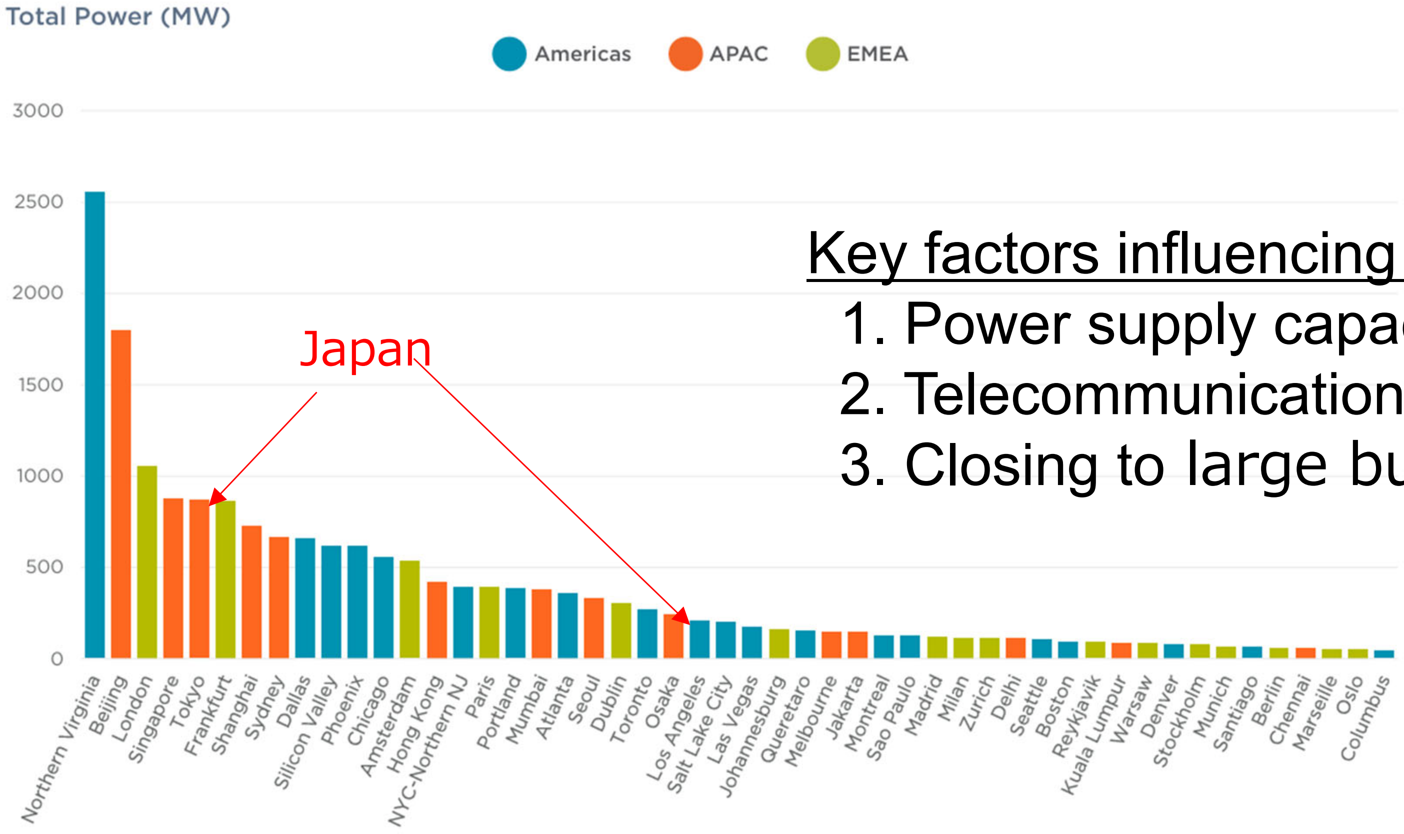
- Using a bottom-up model, IEA presented multiple scenarios for global DC power demand. Results show an increase from 416 TWh in 2024 to 700–1,700 TWh by 2035.
  - ✓**Base**: Moderate growth based on server shipment forecasts.
  - ✓**Lift-off**: Rapid DC expansion with strong demand for digital services.
  - ✓**High Efficiency**:
    Same digital services demand as in the Base case, but power-saving slows growth.
  - ✓**Headwinds:** Slower digital services demand, DC development stagnates.



Note: IEA（2025）「Energy and AI」

Largest Markets Worldwide

- DC are typically located near major business hubs to enable high-speed communication with minimal latency.
- In the financial sector, rapid communication and efficient data processing are essential for trading and transactions.



<u>Key factors influencing the location</u>

1. Power supply capacity
2. Telecommunications infrastructure
3. Closing to large business hubs

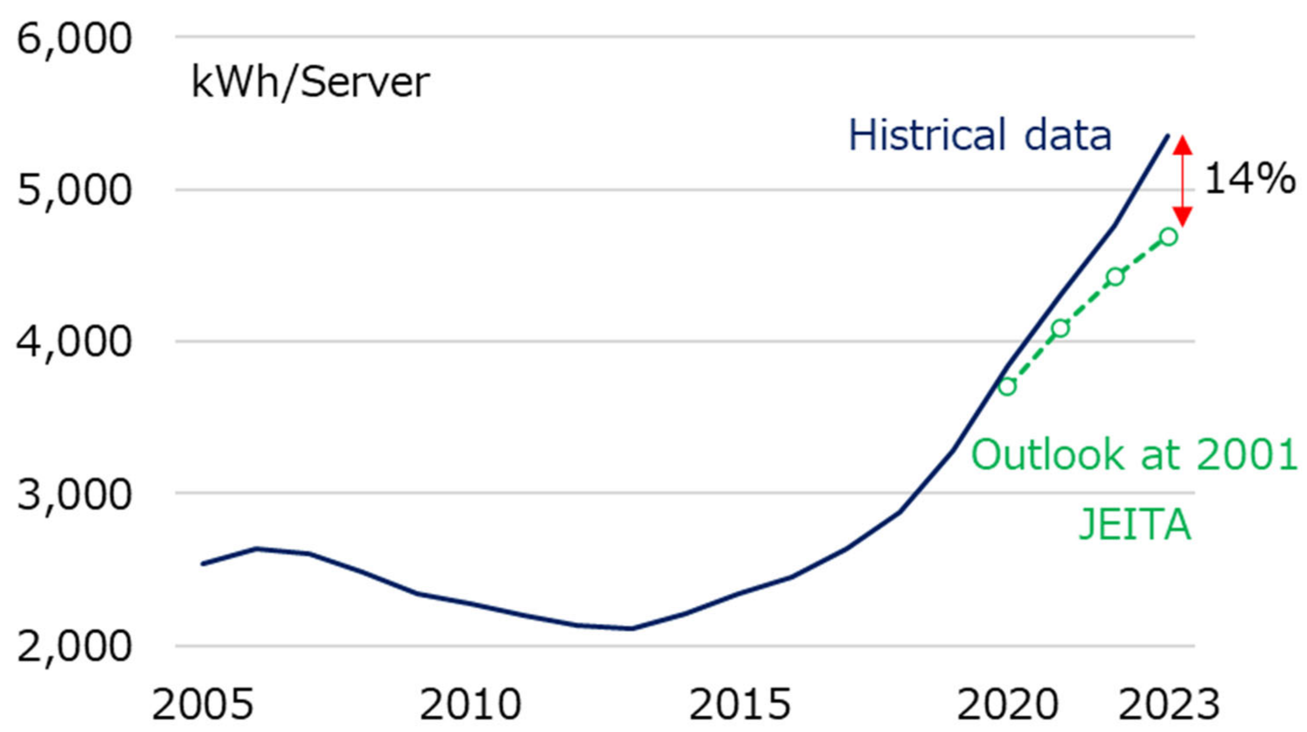
Source: Cushman & Wakefield Research

Note: Cushman & Wakefield（2023）「Global Data Center Market Comparison」

Uncertainties in Datacenter Power Demand ①

- As with the wide range of outlooks for DC power demand, there are various uncertainties of both upward and downward deviations.
- For servers, which account for much of IT equipment's power demand, actual 2023 demand was 14% higher than forecasts, showing that even 3–4 years ahead accurate prediction is difficult.

Annual power demand per server（Energy Efficiency)



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Uncertainties in Datacenter Power Demand ②

- Technological developments in hardware and software are underway to curb the increase in power demand in DC (see left).
- Technologies with considerable potential for future energy savings include “Low-power processors”,“Energy-efficient algorithms”,” Task-specific models”、” Neuromorphic computing”. (see right)

Table 2.1 ▷ Current and potential 2030 energy savings in data centres from key technologies and approaches

Technology/approach	Current adoption	Expected adoption in 2030	Scale of energy savings potential
Hardware			
Low-power processors	●●	●●●	●●●●
AI accelerators	●●●	●●●●	●●
Task-optimised hybrid processors	●●	●●●	●●
Photonic integrated circuits	●	●●	●●●
Energy-efficient memory and storage	●●●	●●●●	●●
Memory proximity	●●	●●●	●●
Innovative cooling technologies	●●	●●●●	●●
Software			
Energy-efficient algorithms	●●	●●●●	●●●●
Task-specific models	●●	●●●●	●●●●
Model and code optimisation	●●	●●●	●●●
Cross-cutting			
Codesign of software/hardware	●●	●●●	●●
Edge computing	●●	●●●	●●●
Virtualisation	●●●●	●●●●	●●
Intelligent energy management	●●●	●●●●	●●
Quantum computing	●	●	●●●
Neuromorphic computing	●	●●	●●●●

Note: A greater number of dots indicates a higher scale.

Note: IEA（2025）「Energy and AI」

Low-power processors

・processors designed to minimise power consumption, e.g. ARM-based CPUs, Intel Atom processors.

Energy-efficient algorithms

・developing AI algorithms that require less energy.

Task-specific models

・smaller and more specialised AI models that are tailored to specific tasks rather than large, general-purpose models.

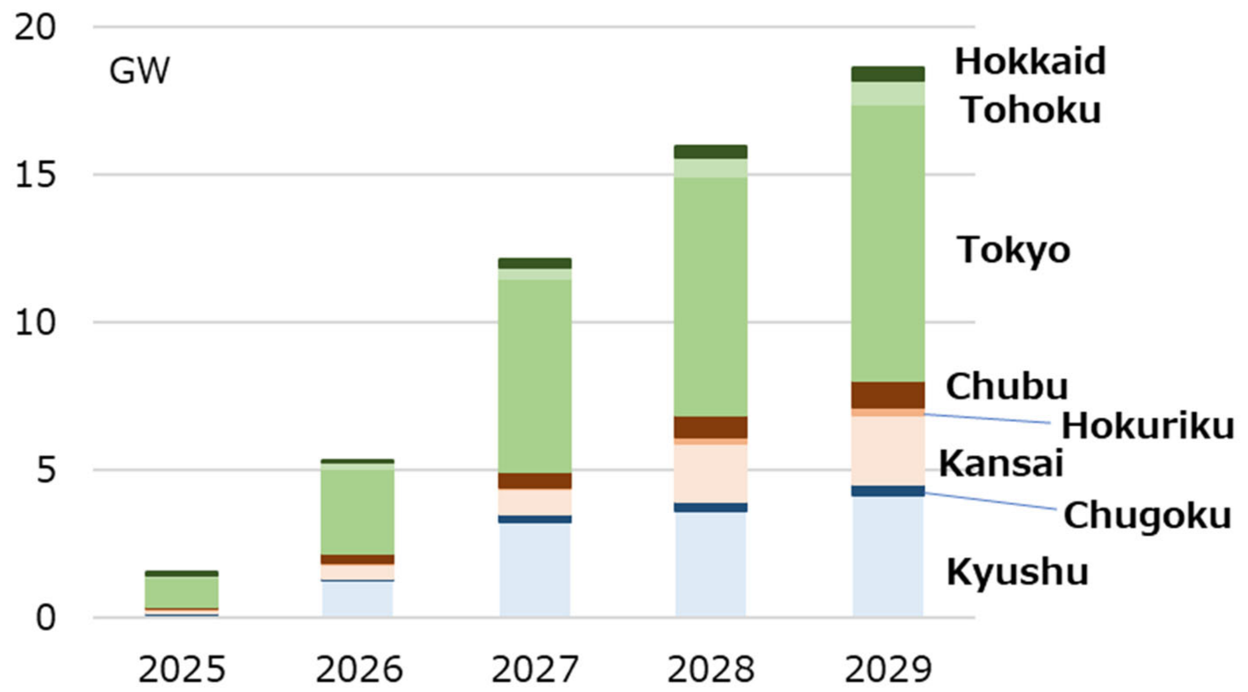
Neuromorphic computing

・computing that mimics the brain’s neural architecture to process data and computations more efficiently compared to classical computing ,e.g. IBM TrueNorth and Intel Loihi 2.

Datacenter Trends in Japan ①

- The Transmission and Distribution Grid Council (TDGC) has begun to disclose new extra-high-voltage grid connection applications, including those from DC and semiconductor fab.
- Over the next five years, applications in the Tokyo area are seen to be on the rise.

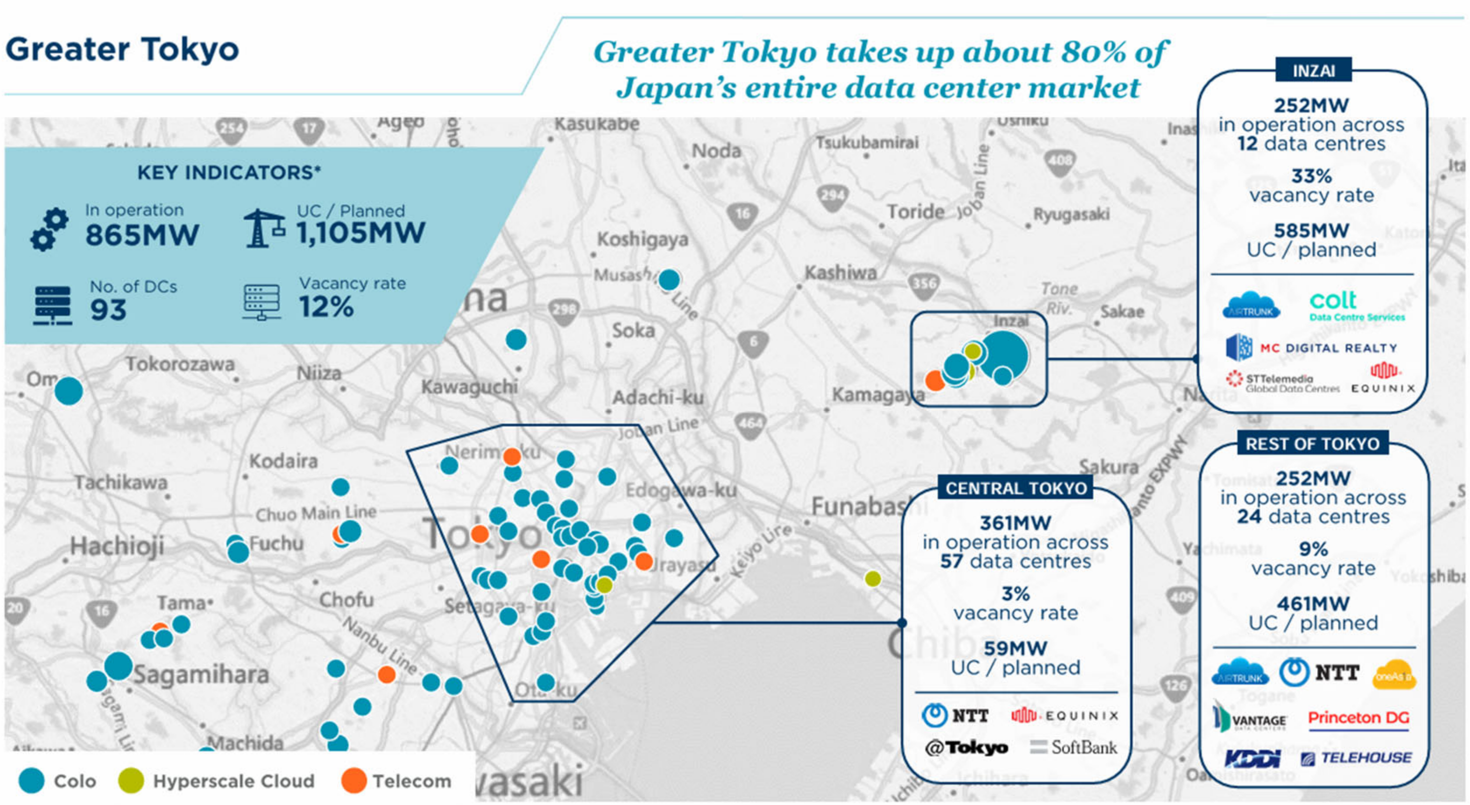
New Grid Connection Applications for Extra High-voltage Demand



Note: Transmission and Distribution Grid Council

Datacenter Trends in Japan ②

- Currently, DC in Japan are concentrated in Tokyo, while the government is promoting new core sites in Hokkaido and Kyushu, where construction is already planned.
- Especially, Hyperscale DC will be concentrated in Inzai, Chiba Prefecture.



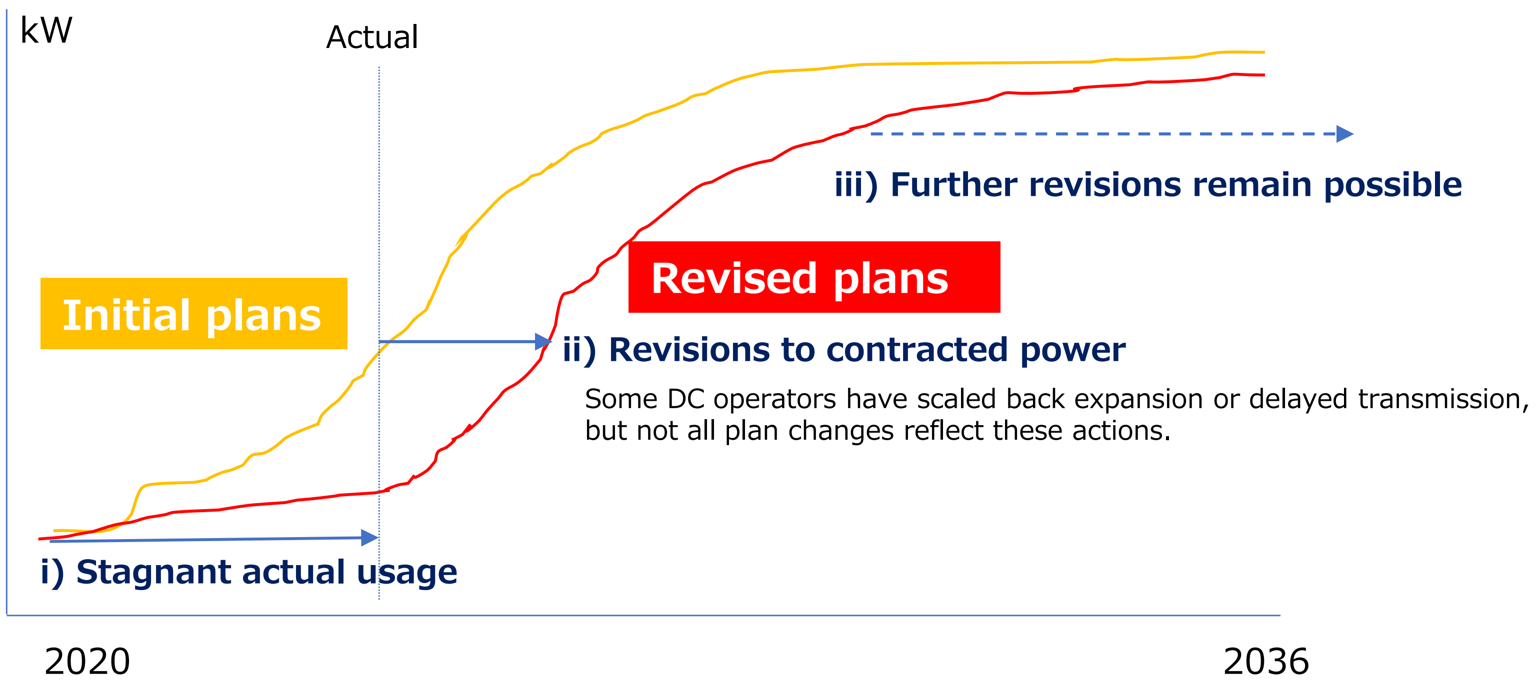
*Definition: Key indicators are based on operational Hyperscale Cloud, Colo, Edge & Telco data centre facilities in the market and excludes Captive & ICT.

Note: Cushman & Wakefield（2023）「Global Data Center Market Comparison」.

Contract Power Plan Changes in Inzai

- In the Inzai, applications for stepwise contract increases have been followed by (i) stagnant actual usage and (ii) revisions to contracted power. The gap between "initial" and "revised" plans has been narrowing over time.
- Since changes to applied power involve no penalties, iii) further revisions remain possible.

Applied contracted capacity for grid facility planning



Today's Contents

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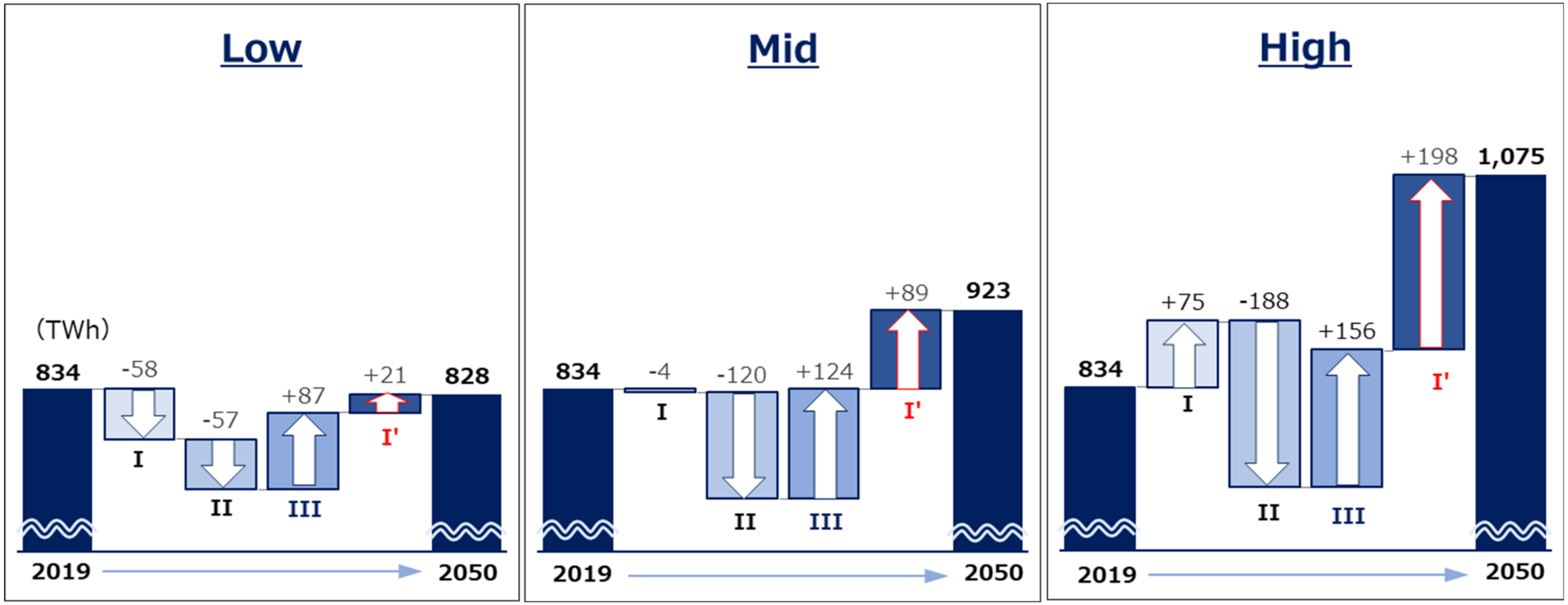
Variable Factor from 2019 to 2050

- CRIEPI's analysis developed three scenarios for each variable factor.
  - ✓ **Socio-economic** factors included populations and GDP.
  - ✓ **Energy savings** are determined based on historical trends.
  - ✓ **Electrification** reflects differences in policy intensity.
  - ✓ **DC power demand** are included in published information.

Future Impact Decomposition of Power Demand



I: Socio-economic II: Power saving III: Electrification I': Datacenter etc.

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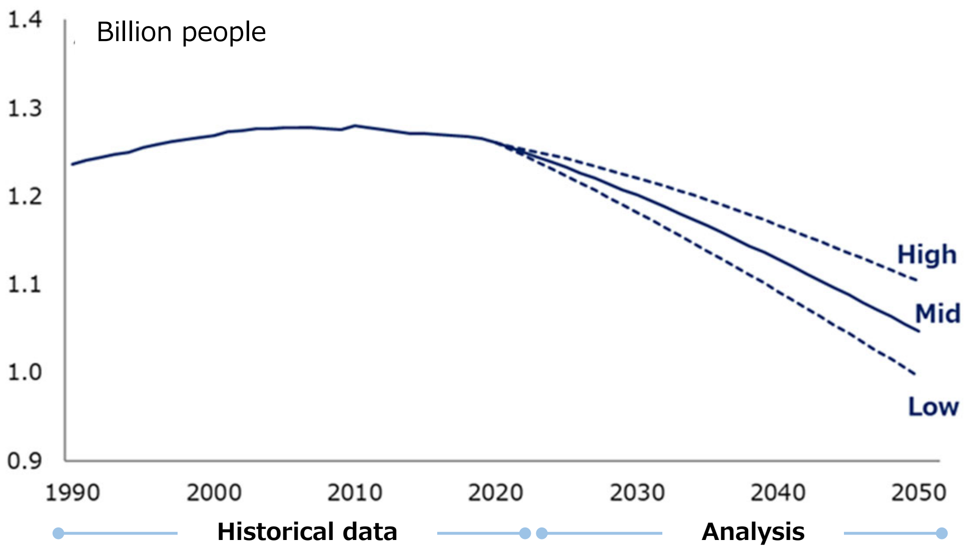
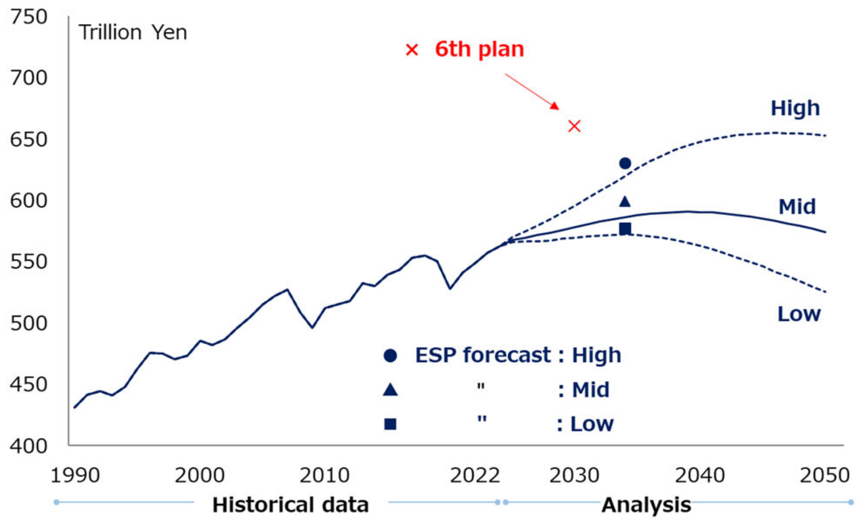
Population and Macroeconomic

	Summary
Low	・Exports cannot compensate for declining domestic demand due to population decline.
Mid	・As the global economy grows, machine-related industries will capture overseas demand and compensate for declining domestic demand.
High	・The decline in the labor force due to population decline will be offset by factory automation and other technologies. ・Exports from machine-related industries will continue to increase, creating a virtuous cycle of production, investment, income, and consumption in Japan.

Population



Macroeconomic(GDP)



Note: Consensus survey is "ESP Forecast" conducted by "Japan Center for Economic Research(JCER)".And our outlook is slightly below the consensus survey.

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Approach to Estimating Datacenter Power Demand

- CRIEPI estimates DC power demand using a bottom-up approach.
  - In particular, power demand of servers ($Server_t^{kWh}$) is estimated through factor decomposition that also accounts for floor space ($Floor_t^N$).

CRIEPI : Approach

Datacenter Power Demand (DC_t^{kWh})

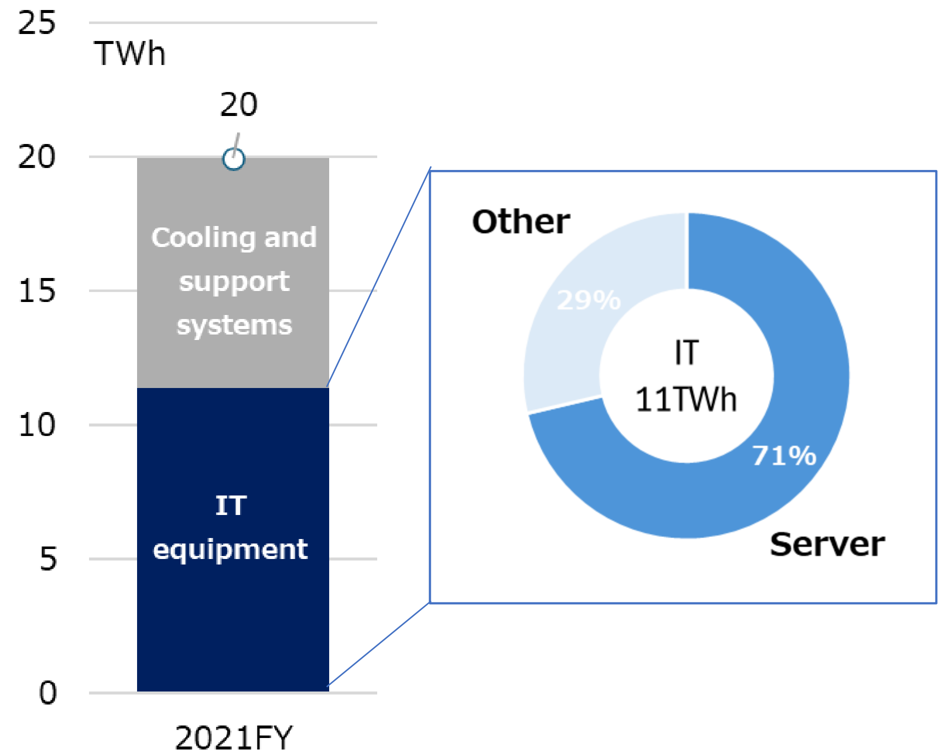
$$DC_t^{kWh} = \underbrace{(Server_t^{kWh} + Other_t^{kWh})}_{\text{IT equipment}} \times PUE_t$$

Power demand of servers ($Server_t^{kWh}$)

$$Server_t^{kWh} = \underbrace{\frac{Server_t^{kWh}}{Server_t^N}}_{\text{Energy efficiency}} \times \underbrace{\frac{Server_t^N}{Floor_t^N}}_{\text{Installation density}} \times \underbrace{Floor_t^N}_{\text{floor space}}$$

Note: $Other_t^{kWh}$ represents the power demand of non-server IT equipment (e.g., routers).
And $Server_t^N$ indicates the number of installed servers, with installation density including factors such as higher rack density (e.g., more servers per rack).

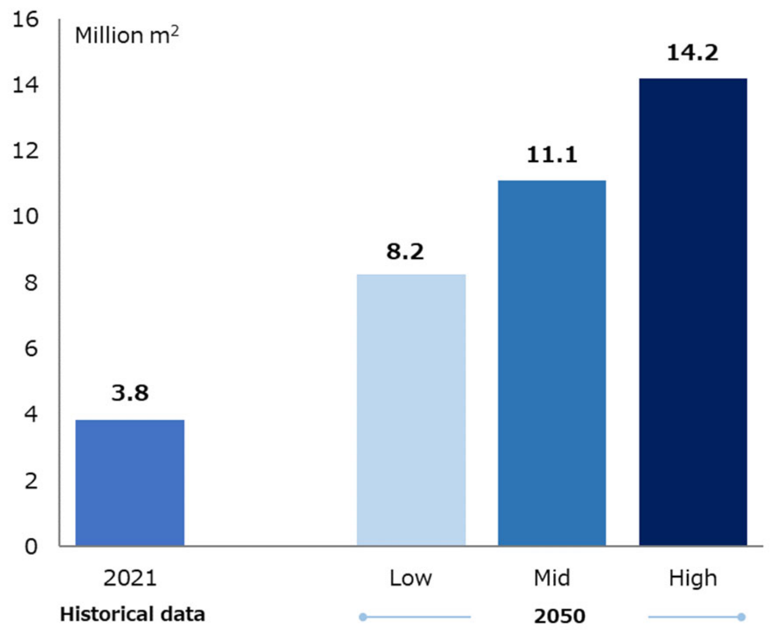
Datacenter Power Demand (2021FY)



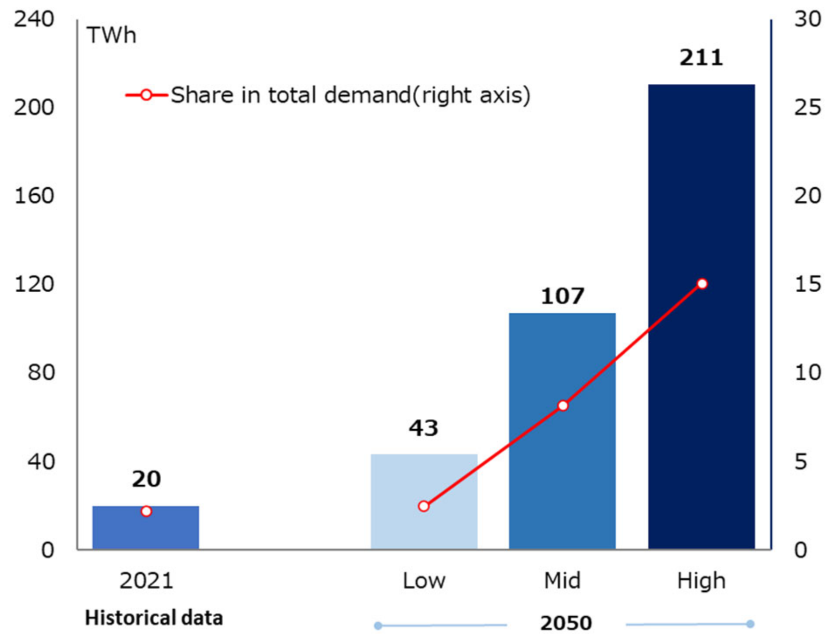
Datacenter Power Demand in Japan

- CRIEPI projected DC power demand through 2050 using publicly available sources, including OCCTO's outlook at 2024 and newspaper reports.
  - ✓ **Mid**: OCCTO's DC outlook is met by the early 2030s, with floor space and server power efficiency rising through 2050.
  - ✓ **High:** DC development expands and server power efficiency rises compared with Mid.
  - ✓ **Low:** DC development stagnates, server power efficiency does not rise either.

Floor space



Power demand



- Floor space in the high case will increase to 14 million m^2 in 2050. This is slightly less than the floor space of supermarkets and department stores in 2021.

- Share in total demand is between 2 and 15%.
- CRIEPI's analysis did not consider government regulations or power capacity.

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Summary Table: Datacenter Power Demand in Japan

		2021	2030	2040	2050
Power demand					
Mid					
Datacenter	TWh	20	37	65	107
IT equipment	〃	11	22	44	79
Severs	〃	8	19	39	75
Ohers	〃	3	4	4	5
Cooling and support systems	〃	9	14	22	27
High					
Datacenter	TWh	20	48	105	211
IT equipment	〃	11	29	71	157
Severs	〃	8	25	66	151
Ohers	〃	3	4	5	6
Cooling and support systems	〃	9	19	35	54
Low					
Datacenter	TWh	20	31	40	43
IT equipment	〃	11	19	27	32
Severs	〃	8	15	23	28
Ohers	〃	3	4	4	4
Cooling and support systems	〃	9	12	13	11
Others					
Mid					
Floor space	Million m^2	384	609	859	1,109
Numbers of installed servers	Million	198	364	598	882
Energy efficiency of servers	kWh/sever	4,092	5,133	6,603	8,493
Installation density of servers	2021＝100	100	116	135	154
PUE	－	1.8	1.6	1.5	1.3
High					
Floor space	Million m^2	384	705	1,062	1,419
Numbers of installed servers	Million	198	422	740	1,128
Energy efficiency of servers	kWh/sever	4,092	5,910	8,893	13,381
Installation density of servers	2021＝100	100	116	135	154
PUE	－	1.8	1.6	1.5	1.3
Low					
Floor space	Million m^2	384	609	764	823
Numbers of installed servers	Million	198	364	531	645
Energy efficiency of servers	kWh/sever	4,092	4,166	4,250	4,336
Installation density of servers	2021＝100	100	116	135	152
PUE	－	1.8	1.6	1.5	1.3

Today’s Contents

Discussion

- From a policy perspective, “How to secure decarbonized generation power sources in the face of projected increases in power demand?”
  - ✓ Policies promoting electrification are expected to increase demand gradually. However, datacenter power demand is projected to grow at a much faster pace. Moreover, the ongoing expansion of datacenter locations may stabilize in the short term—or may continue further.
  - ✓ The payback period for power generation investments is significantly longer than the operational life of datacenter, making investment decisions particularly challenging.
  - ✓ In short, the critical issue is how to ensure adequate power supply in the face of highly uncertain demand.

Thank you

If you have any questions, please contact t-mase@criepi.denken.or.jp