IEEJ Outlook 2026

AI and Future of Energy Demand

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Outline

- **Interrelationship between energy and AI**
  - Recent trends on DC electricity demand
  - Outlook of DC electricity demand and saving potential
- **Use cases of AI for the demand side**
- **Energy savings potential of AI in the energy sector : Outlook by 2035**
- **Implications**

Background and Study Objectives

Background

- **The close interrelationship between artificial intelligence (AI) and energy is attracting global attention.**
  - The growing use of generative AI and the advancement of digitalization will lead to a significant expansion of data centers.
  - Locally, there are concerns that the construction of power supply facilities will not keep up with the pace of data center construction.
- **AI is expected to bring significant benefits in key sectors related to energy use.**
  - Various energy-saving and CO_2 emission reduction effects are expected
- **However, there are challenges to using AI on the demand side, such as a lack of awareness, human resources, and investment.**

Study Objectives

- **To analyze the future electricity demand in data centres and its energy-saving potential.**
- **To analyze the energy-saving potential of AI in the demand sectors (industry, transport, commercial, and residential).**

Interrelationship between energy and AI

Electricity Consumption at Data Centres：Was 2020 a turning point？

Trends in Data Centres Electricity Consumption

2015-2019

Data center electricity consumption remained flat

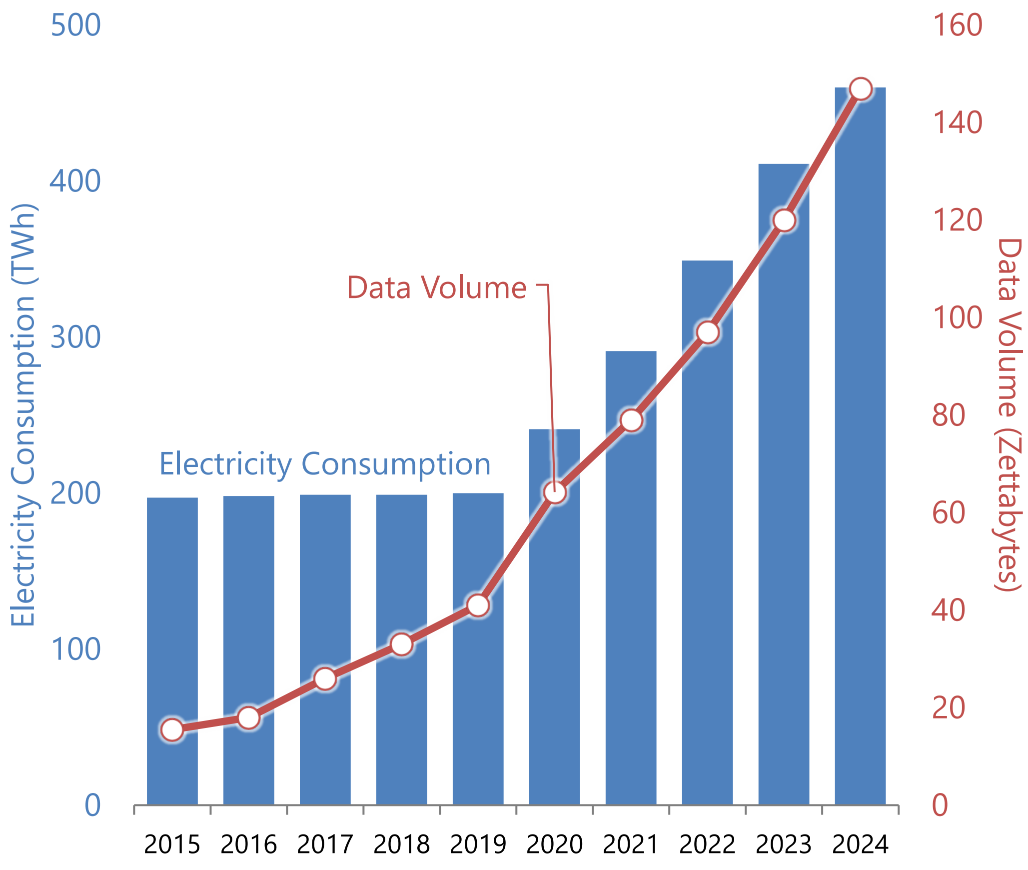
- Data volume triples
- Energy efficiency advances in servers, storage, networking, infrastructure, etc.
- Shift from small data centers to large cloud and hyperscale data centers
- Improved efficiency of Graphics Processing Units (GPUs) contributes

After 2020

Data centre electricity consumption increased by 70%

- The emergence of ChatGPT-3 and the expansion of generative AI use
- Advancing digitalization
- Increased use of cloud services due to the establishment of remote work
- Preparation for the construction of high-speed 5G equipment to cover unserved areas is underway

Global Data Centre Electricity Consumption and Data Volume



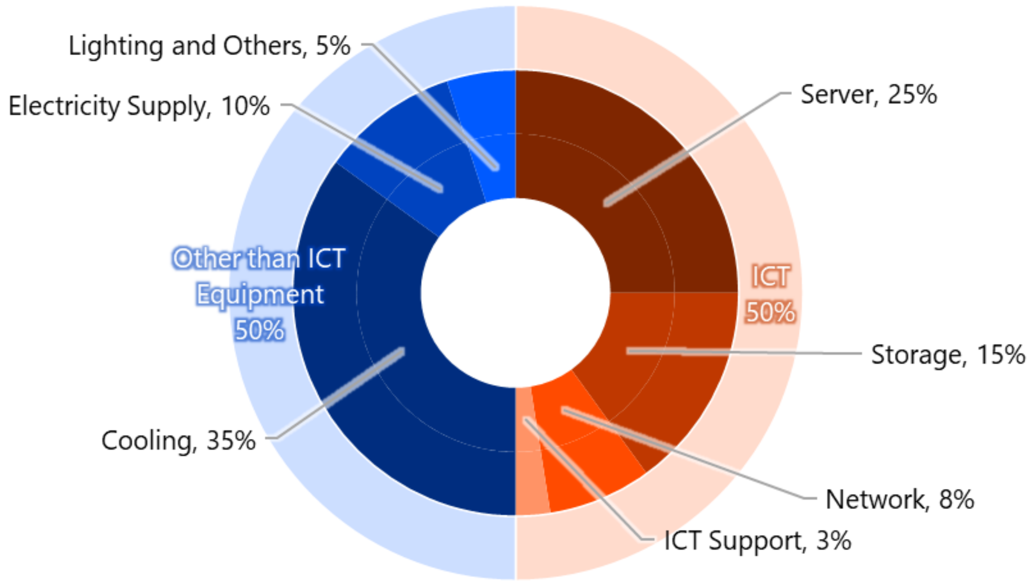
Source : Masanet et al. (2020), Cisco, IEA, Goldman Sachs Research,

Source： https://www.goldmansachs.com/insights/articles/AI-poised-to-drive-160-increase-in-power-demand, https://explodingtopics.com/blog/data-generated-per-day
https://www.forbes.com/sites/siemens-smart-infrastructure/2023/03/13/how-data-centers-are-driving-the-renewable-energy-transition/?sh=1396b0fb4214
https://www.jaif.or.jp/en/news/7022#:~:text=Among%20other%20things%2C%20it%20showed,/%20floor%20area)%20as%20parameters.

Data Centre Electricity Consumption：Technology Contributions

- Data centres accounted for approximately **1.6% of global electricity consumption (2023)**. A data centre efficiency is measured by **the Power Usage Effectiveness (PUE) index**, with **the global average being around 1.5**.
- **In addition to PUE, evaluation is also required using other indicators, such as ICT energy efficiency.**

Data Centre Electricity Consumption by Technology（PUE=2）



Note：PUE is a measure of data center energy efficiency, which can be calculated by dividing the total data center facility energy by the IT equipment energy consumption. The closer PUE gets to 1, the more efficient a data center is.

What is PUE？

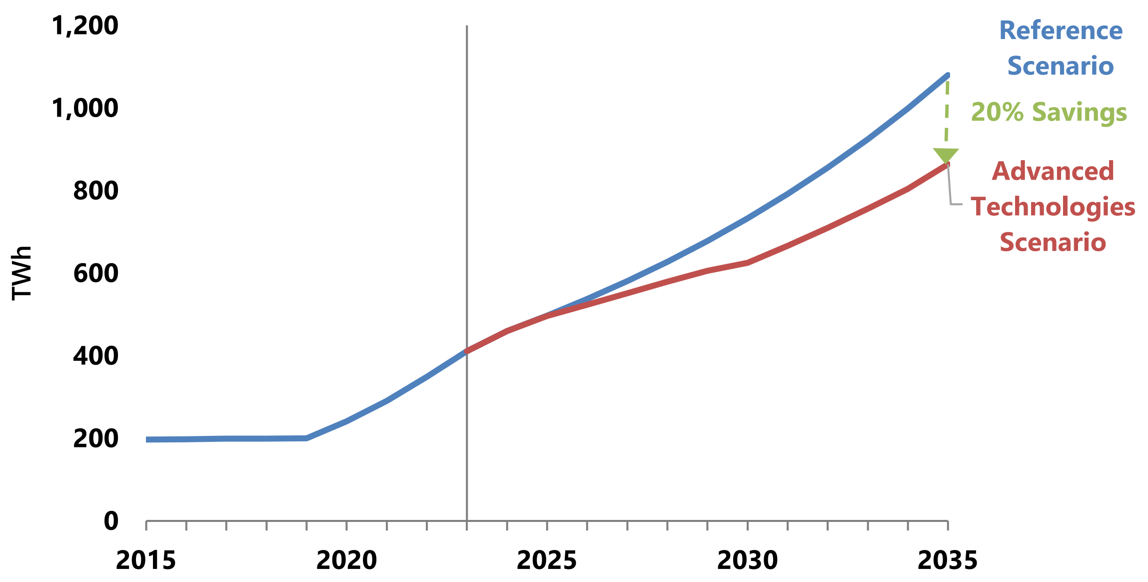
$$\text{PUE} = \frac{\text{Data centre facility electricity consumption}}{\text{ICT electricity consumption}}$$

Source（Left Side Figure）：Hongyu Zhu et. Al.（2023). Future data center energy-conservation and emission-reduction technologies in the context of smart and low-carbon city construction . Sustainable Cities and Society | VOL 89 | 2023 |

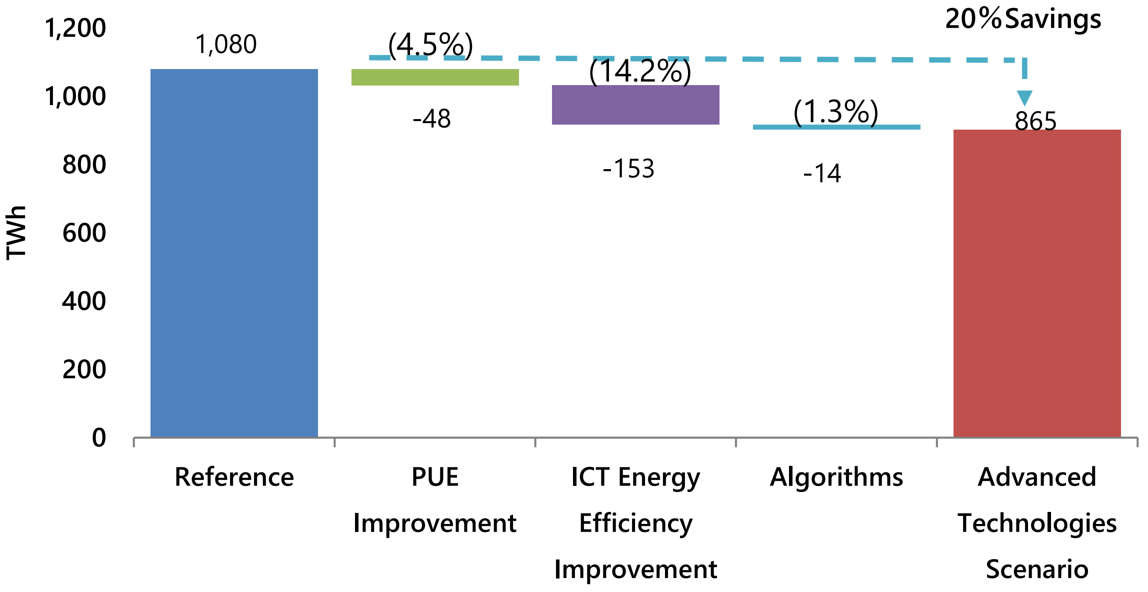
Data Centre Electricity Demand Outlook and Electricity Savings Potential（2035）

- Global data center (DC) electricity demand is expected to **more than double from the current level of 497 TWh to 1,080 TWh by 2035.**
- Improving PUE through the introduction of **high-efficiency cooling technology, ICT energy efficiency improvement** and **rationalization of algorithms** has the potential to **save electricity demand by 20% by 2035.**

Data Centre Electricity Demand Outlook（2025-2035）



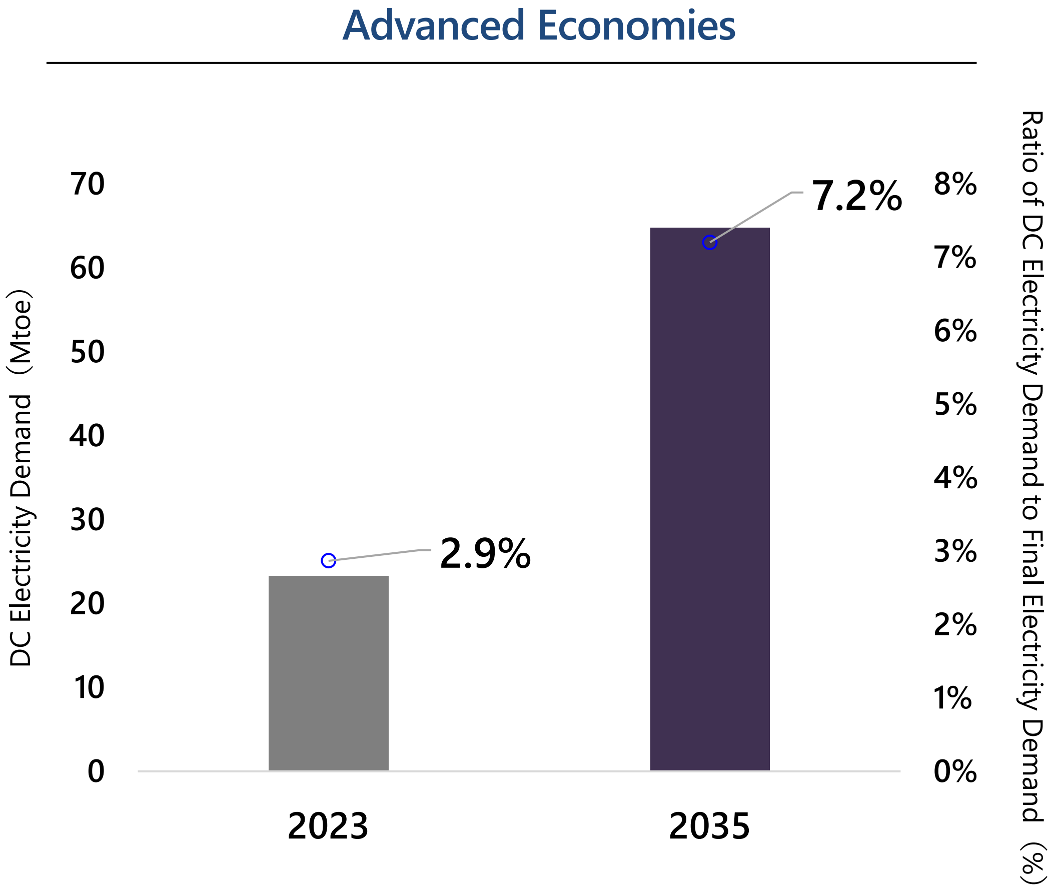
Data Centre Electricity Savings Potential（2035）

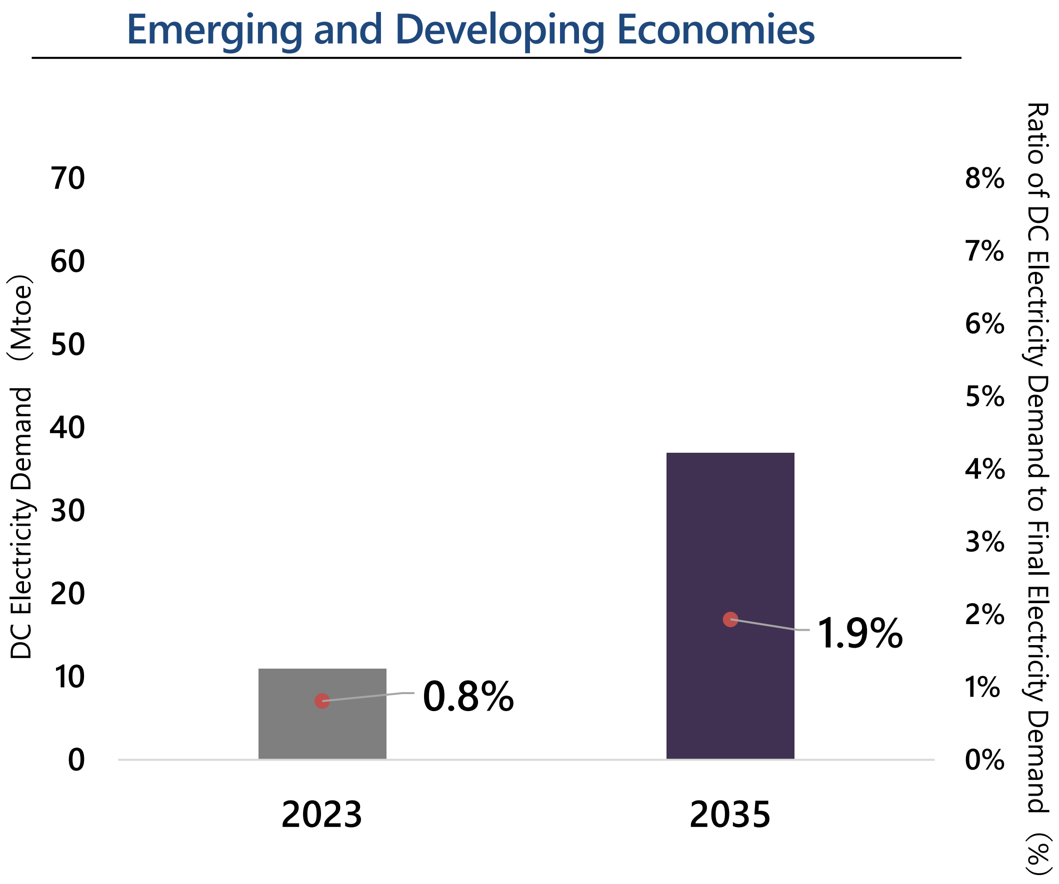


Source：IEEJ (2025).

Data Centre Electricity Demand and Ratio to Final Electricity Demand (2023 and 2035)

- In **developed countries**, the share of electricity demand from data centers (DCs) in final electricity demand will **increase from 2.9% (2023) to 7.2% (2035)**.
- In **emerging and developing countries**, the share will **increase from 0.8% (2023) to 1.9% (2035)**.





Source：IEEJ (2025).

Use cases of AI for the energy sector

What contributions does AI can make to the energy sector?

- AI is expected various benefits to the energy sector.
- This study conducted **a quantitative analysis of the energy savings potential of AI for optimization of the demand sector**.

Examples

Detection	▪ Automatic **detection of malfunctions** and other issues, detection of methane leaks ▪ Remote sensing
Prediction	▪ **Weather forecasting** and renewable energy use ▪ **Industrial production forecasting** and building operation forecasting ▪ **Transportation demand forecasting** and vehicle route optimization
Optimization	▪ Optimizing **industrial production processes** ▪ Optimizing energy usage in **buildings and equipment** ▪ Improving fuel efficiency through **autonomous driving** ▪ **Demand response** through energy supply and demand optimization
Simulation	▪ Simulations related to **identifying new materials** and **manufacturing new products** ▪ Simulations of the effects of energy conservation and clean energy adoption

Source：ICEF（2024).

Examples of AI use in the Industry Sector

Examples

Toshiba	▪ **Demand forecasting** using AI (weather and production planning). ▪ **Mathematical models** are used to control **boilers, generators, and chillers** with the aim of minimizing costs.
Azbil	▪ Implementing optimal control based on real-time plant data. ▪ Providing **model update technology** to **keep the model up to date with changes in the factorys**
JFE Steel	▪ A **cyber-physical system (CPS)**. In addition to data such as temperature and pressure obtained by sensors, video information from inside the blast furnace is also collected in real time, and **the condition of the blast furnace is visualized on the CPS**.
Yokokawa × Sumitomo Chemical	▪ **Maintains the distillate quality and liquid level** in the distillation tower at appropriate levels while making maximum use of waste heat.

Source： https://www.global.toshiba/jp/company/energy/topics/digital-transformation/dx008-210324.html, https://www.azbil.com/jp/corporate/pr/library/review/pdf/Review2025_05.pdf, https://belgium.arcelormittal.com/en/arcelormittal-chooses-energiencys-artificial-intelligence-to-save-energy-in-steel-coils-processing/, https://www.jfe-steel.co.jp/products/solution/data-science/01-blast-furnace.html, https://www.yokogawa.co.jp/news/press-releases/2022/2022-03-22-ja/

Energy savings potential of AI in the energy sector : Outlook by 2035

Energy Savings Potential of AI for the Demand Sector

- This analysis examines **the energy savings potential of AI for the demand sector up to 2035**.

Cases

Reference Scenario	✓ The trend of change will continue against the backdrop of current energy and environmental policies. ✓ *This does not mean that the status quo of policies, technologies, etc. will remain unchanged.
Advanced Technologies Scenario (ATS)	✓ Policies for stable energy supply and strengthening climate change countermeasures will be **vigorously implemented**, and **the introduction of low-carbon technologies** such as renewable energy and high-efficiency equipment will be **promoted to the maximum extent possible**.
AI Advancement Scenario	✓ The introduction of **AI for efficient energy use will advance energy savings** through new technologies and improvements to stock operations, in addition to ATS.

Estimation of Technical Potential Energy Savings

Sector・Sub-sector・Technology

1. Industry
- Iron and Steel, Cement, Petrochemical, Paper and Pulp, and Other industry

2. Residential
- Cooling/Heating, and Hot Water

3. Commercial
- Cooling/Heating, Ventilation and Lighting

4. Road
- Passenger Vehicles, Buses・Trucks

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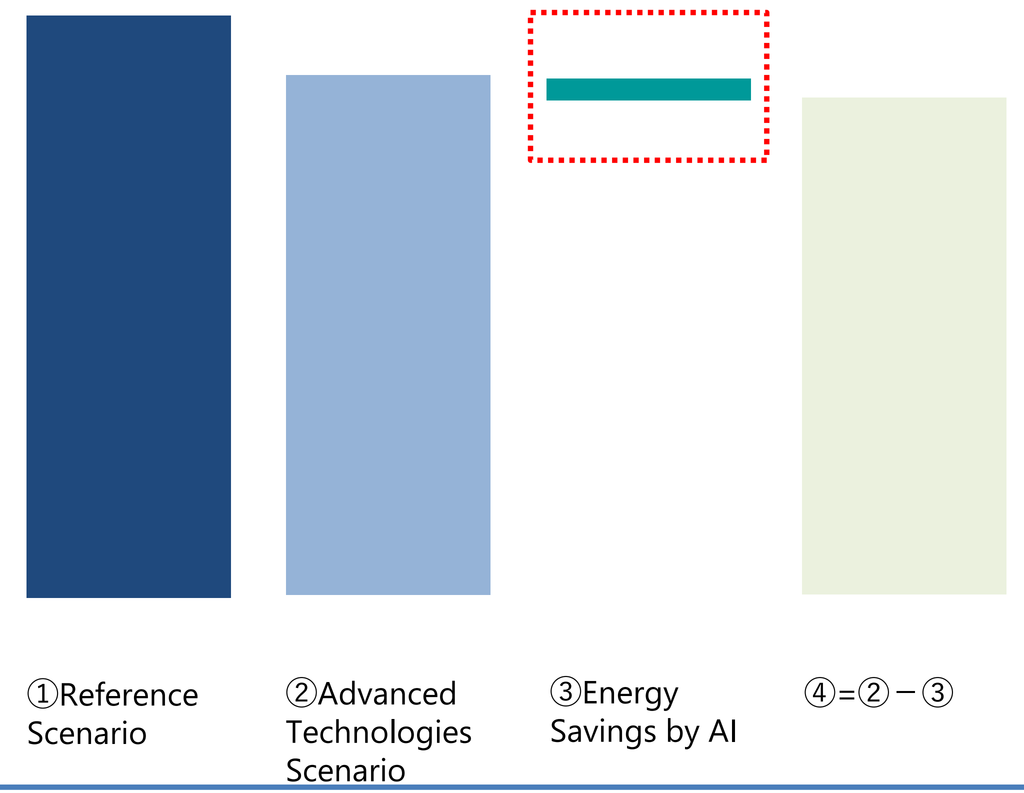
Simulation	▪ Simulations related to identifying new materials and manufacturing new products ▪ Simulations of the effects of energy conservation and clean energy adoption

Image of Energy Savings Potential by AI

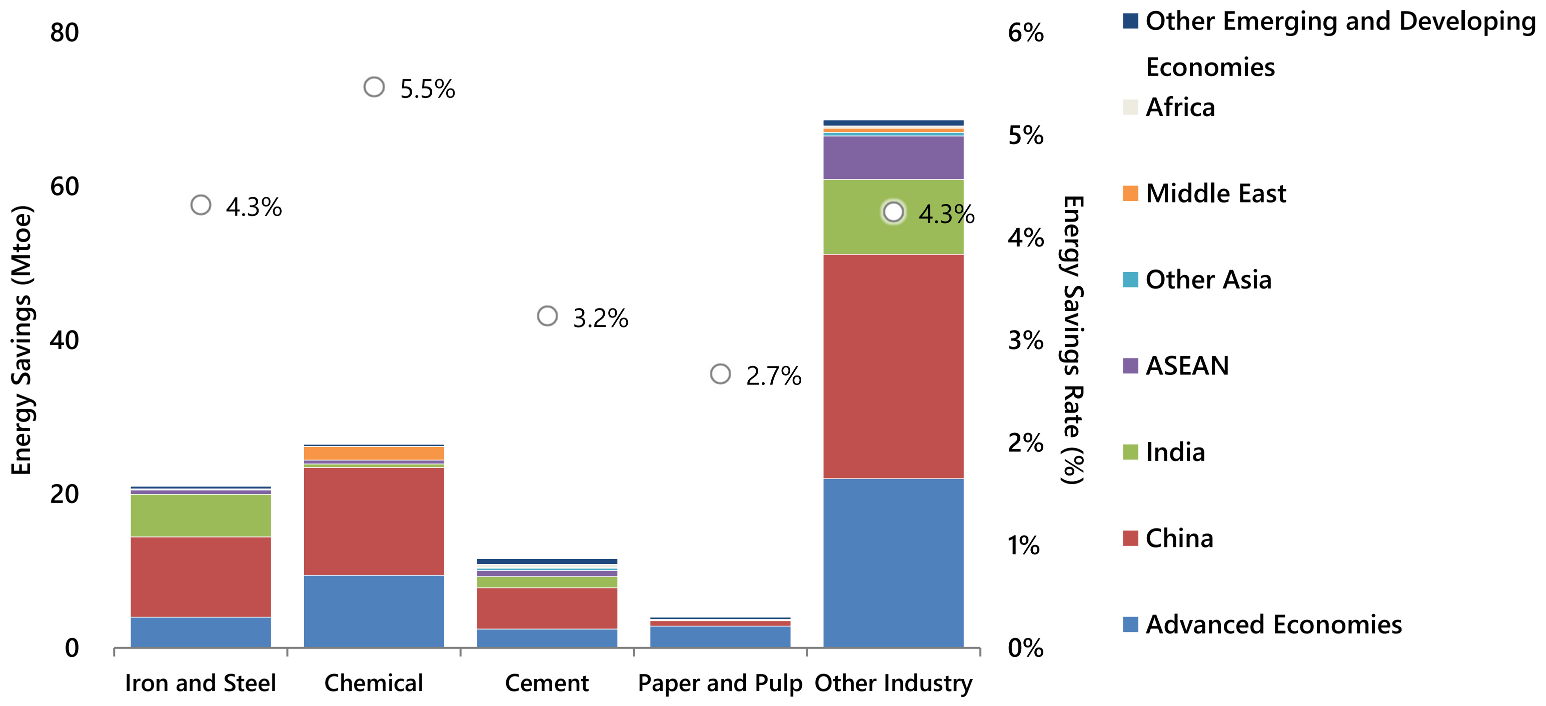


Source：ICEF（2024）他より作成。

Industry: Energy Savings Potential of AI (Ratio to Advanced Technologies Scenario)

- Previously, **operational improvements were mainly based on the experience and knowledge of experienced operators**, but **by combining this with AI**, energy savings become possible through dynamic control based **on real-time predictions and an integrated approach that simultaneously optimizes multiple processes throughout the factory**.
- By 2035, **the use of AI has the potential to save 2-5%** in energy compared to **the Advanced Technologies Scenario**.

Energy Savings Potential of AI and Ratio to Advanced Technologies Scenario【2035】

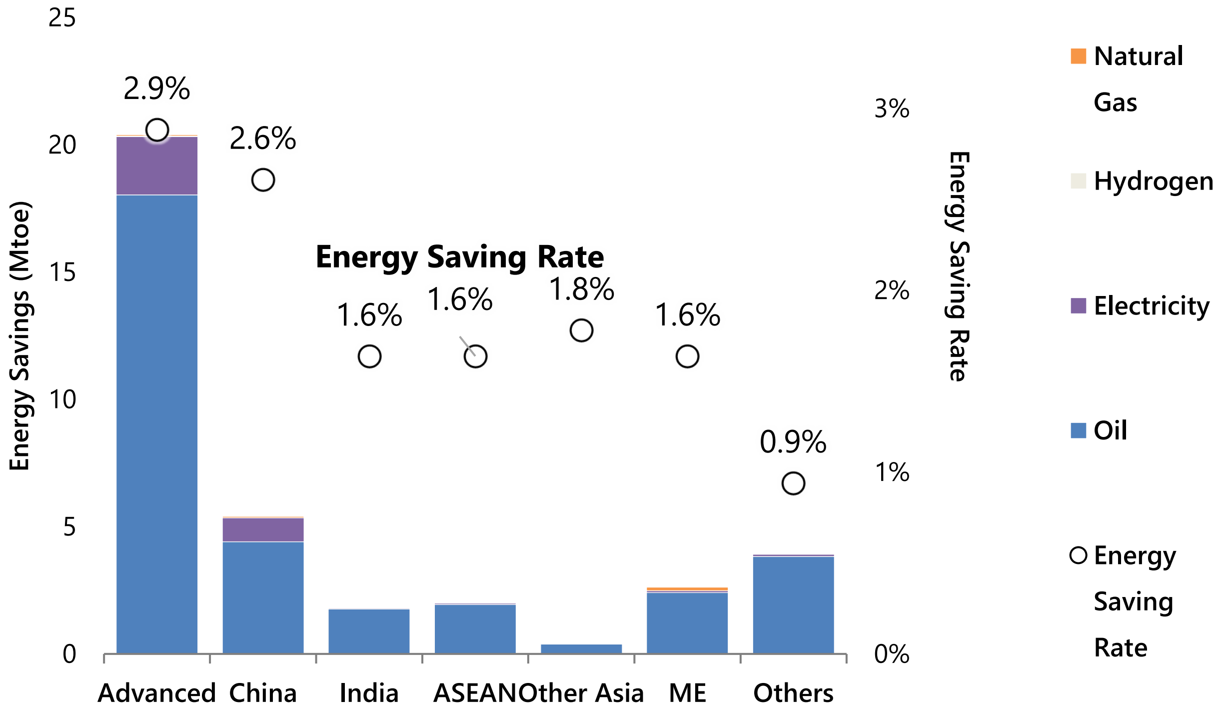


Source：IEEJ (2025).

Road Transport: Energy Savings Potential of AI（Ratio to Advanced Technologies Scenario）

- ✓ Autonomous driving using AI is expected to improve fuel efficiency and optimize (shorten) travel routes.
- ✓ The energy saving potential of AI for **passenger cars, buses, and trucks is estimated to reach 36.5 Mtoe in 2035 (0.9%-2.9% compared to ATS).**

Energy Savings Potential of AI and Ratio to Advanced Technologies Scenario【2035】



Examples for Energy Savings of AI in the Road Transport

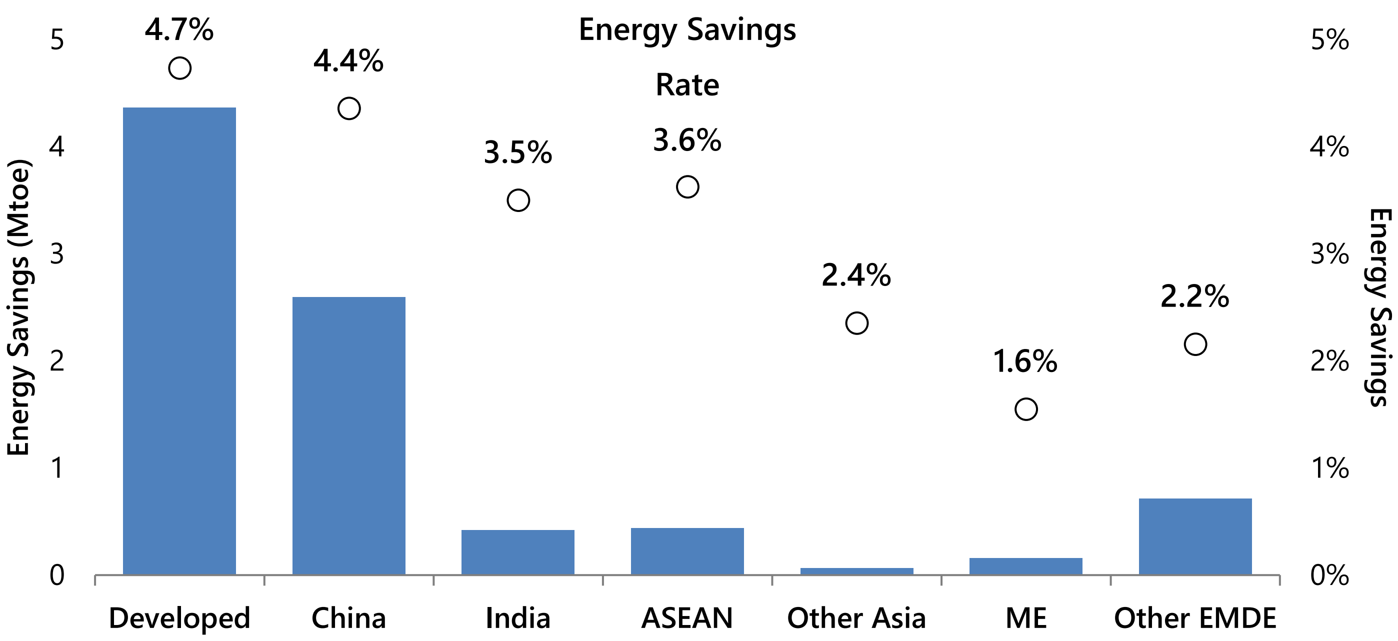
	Examples
Demand Projection	The loading efficiency and passenger efficiency of cargo trucks, buses, taxis, etc. can be improved by taking into account weather and traffic information.
Route Optimization	Through machine learning, AI suggests route optimization that takes into account the driver's travel preferences and, in the case of cargo trucks, delivery efficiency.
Maintain distance between vehicles	By maintaining a constant distance between vehicles through autonomous driving, vehicles can move without congestion, contributing to improved fuel efficiency. Platooning also reduces air resistance, contributing to improved fuel efficiency.

Source：IEEJ (2025).

Commercial/Buildings: Energy Savings Potential of AI（Ratio to Advanced Technologies Scenario）

✓ The energy savings potential for heating, cooling, ventilation, and lighting in 2035 is 8.8 Mtoe (102 TWh), which is equivalent to a reduction of approximately 10% of the data center's electricity demand in 2035.

Energy Savings Potential of AI by Cooling/Heating/Ventilation/Lighting and Ratio to Advanced Technologies Scenario【2035】



Examples for Energy Savings of AI in the Commercial Sector

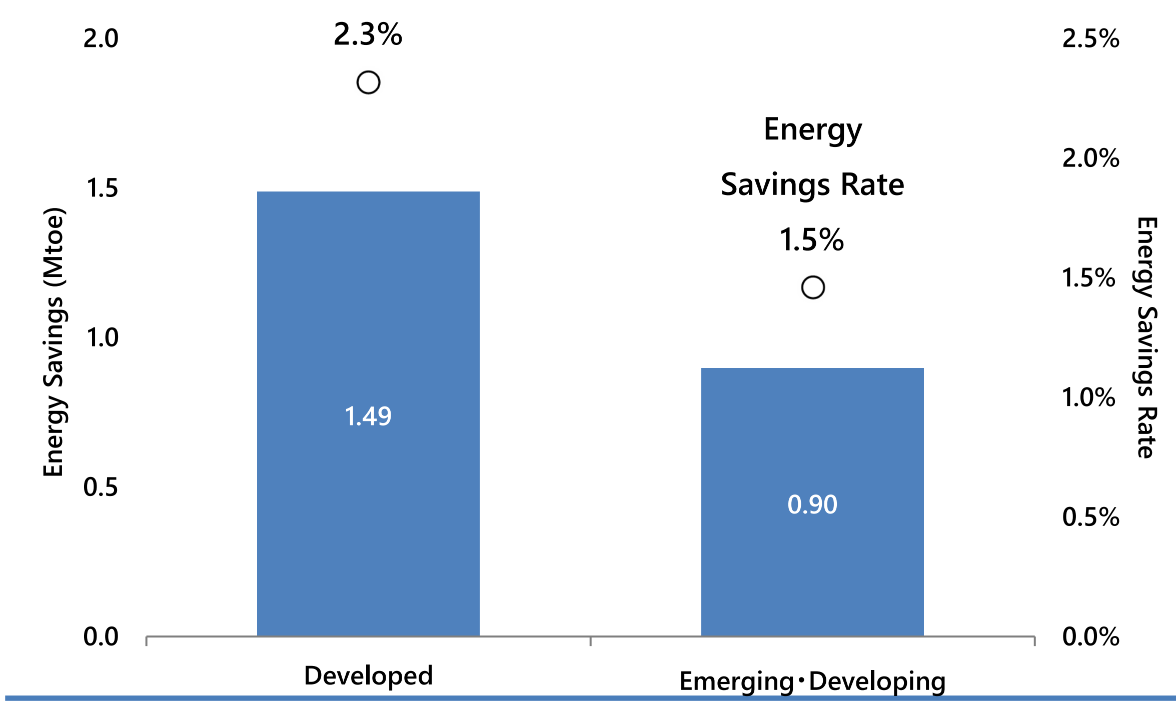
Design Phase	▪ Utilizing AI technology to leverage large amounts of accumulated past data, highly energy-efficient buildings can be designed for new construction and renovations. ▪ It is possible to simulate not only individual buildings but also improvements to the energy efficiency of the entire region.
Operational Phase	▪ Sensors collect information on people flow and the weather, and optimally control lighting, air conditioning, and power throughout the building, achieving both efficient energy use and comfort. ▪ It is possible to improve the operation of not only individual buildings but also regional energy demand.

Source：IEEJ (2025).

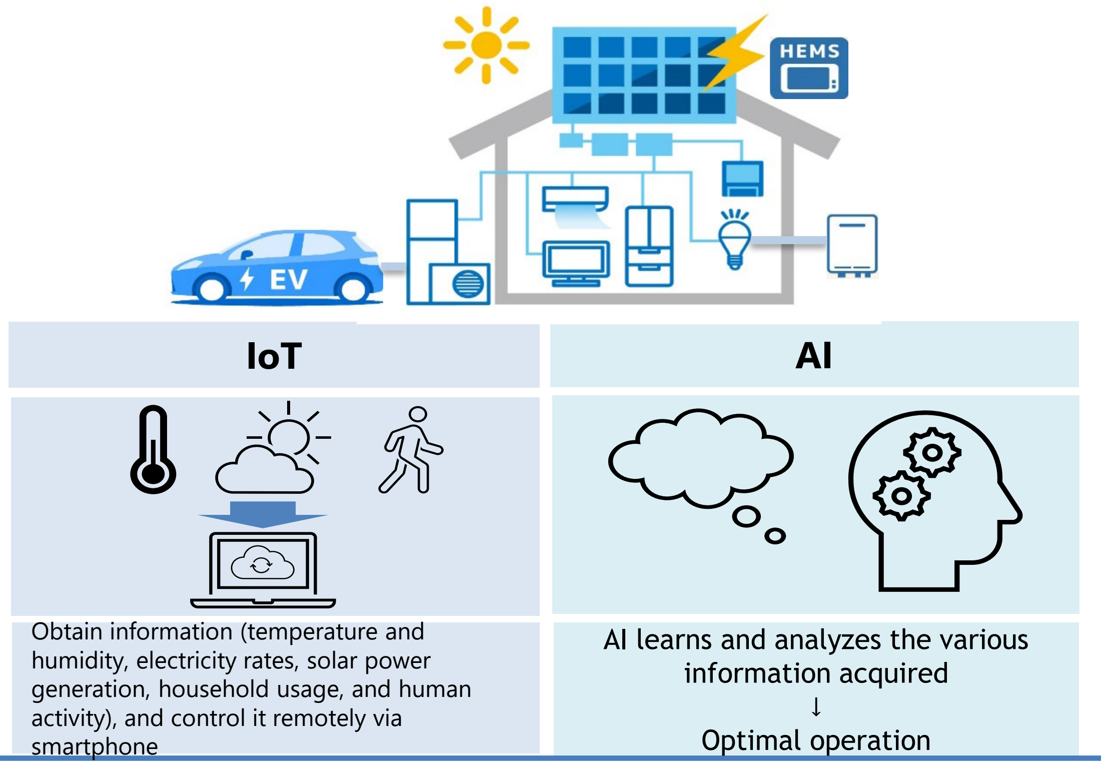
Residential : Energy Savings Potential of AI (Ratio to Advanced Technologies Scenario)

✓ Estimates of the energy savings potential for heating and cooling using AI suggest that in 2035**, it could reach 1.5 Mtoe in developed economies (a 2.3% savings compared to the ATS)** and **0.9 Mtoe in emerging and developing economies (a 1.5% savings compared to the ATS).**

Electricity Savings Potential of AI by Cooling/Heating/Hot Water Supply and Ratio to Advanced Technologies Scenario【2035】



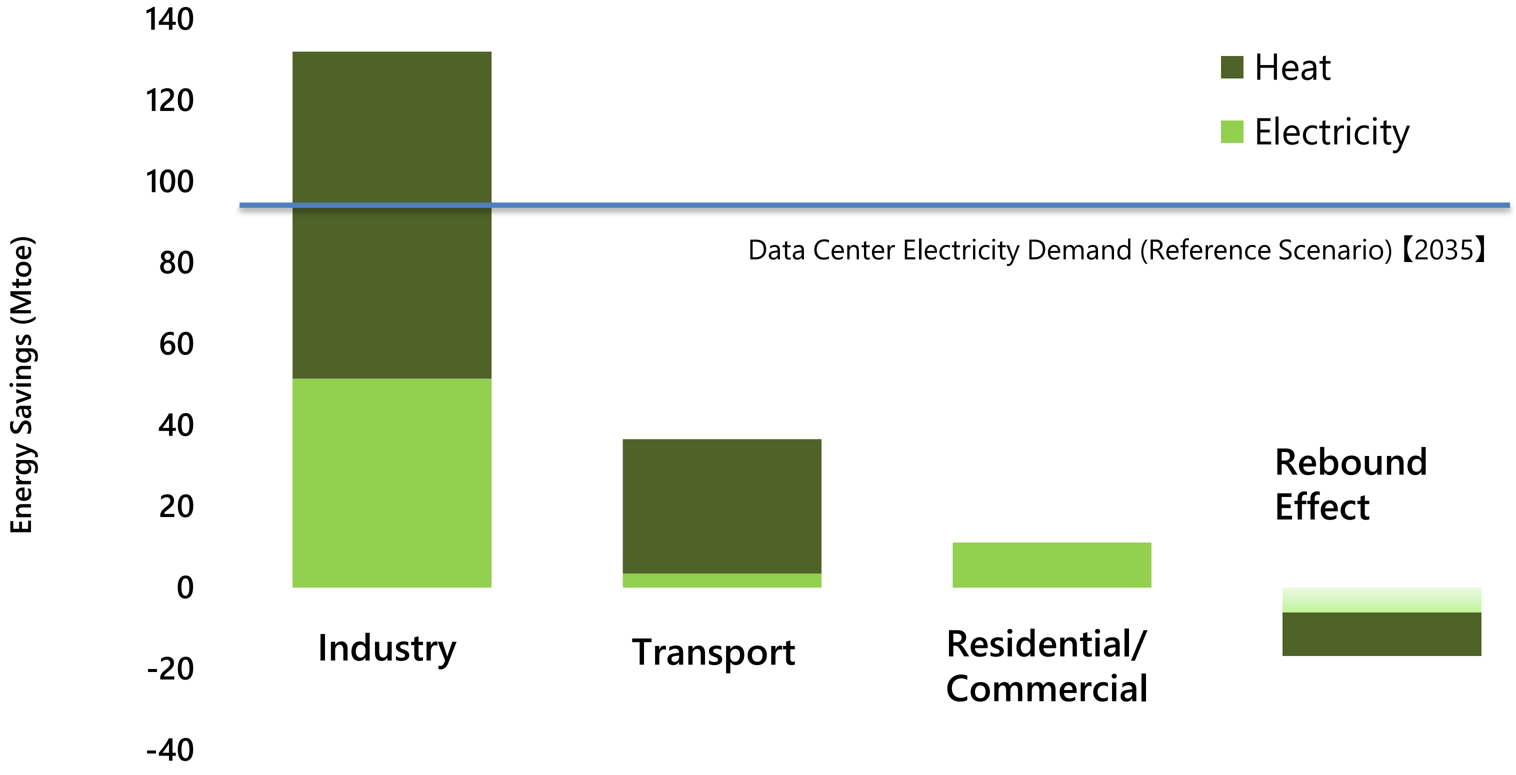
Images for Energy Savings of AI in the Residential Sector



Source：IEEJ (2025).

Energy Savings Potential of AI at the Demand Side（2035）

- ✓ Demand-side energy savings using AI have **the technical potential to reach 178 Mtoe (2,088 TWh) in 2035.**
- ✓ By sector, the energy demand reduction effect is greatest in the industry sector.



Source：IEEJ (2025).

Hurdles and Risks for AI in the Demand Side

	Hurdles	Risks
Residential and Commercial	▪ **Low adoption of digital technology** and **shortage of** digital-related **human resources** ▪ Increasing urbanization in emerging countries and a **lack of consideration for digital technology in urban planning and institutional development** ▪ **Lack of market design** for **flexible** supply and demand **adjustment**	▪ **AI is a "high-end" method** and may be outperformed by other methods, such as improved insulation performance. ▪ Possible **rebound effect** ▪ Operational risks (**safety and security risks**)
Industry	▪ Lack of investment in digitalization among **small and medium-sized enterprises** ▪ **Lack of personnel with digital-related knowledge** (energy management qualifications tend to emphasize experience, making it difficult to understand what can be done) ▪ **Various types of coordination** within large companies	▪ Increased energy consumption and CO2 emissions due to **lack of AI maintenance** ▪ Operational risks (**safety and security risks**) ▪ Increased energy consumption **due to increased production speed in industrial production processes**
Transport	▪ **Lack of data** ▪ **Lack of standardized communication protocols** ▪ **Lack of human resources**	▪ Risk of **privacy information infringement** ▪ Risk of **increased energy consumption** due to efficiency improvements

Measures	▪ Sharing data and best practices to promote understanding, developing human resources, and supporting implementation and promoting efforts to harmonize urban planning and digitalization.

Source：https://www.icef.go.jp/wp-content/themes/icef/pdf/2024/roadmap/08_ICEF2.0%20Buildings_stand%20alone.pdf

Implications

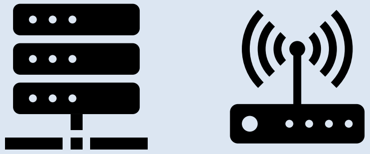
- The use of **AI on the demand side has great potential for energy savings**. By sector, the industry sector has the greatest impact on energy demand savings. However, **various challenges remain in its widespread adoption and energy savings**. By promoting the following through public-private collaboration, the use of AI can be expected to contribute to cost-effective energy savings.
  - **Human resource development and awareness building**
  - **Providing incentives for increased adoption**
  - **Data standardization**
  - **Cybersecurity measures**
- Considering the energy-saving potential of data centres, **the contribution of improving ICT efficiency is relatively large**. For this reason, **additional evaluations (other than PUE) are required, such as measuring ICT efficiency improvements** as an indicator of data center energy savings. In addition to improving cooling efficiency, which has traditionally been the central issue**, measures and methods are required to improve the efficiency of ICT equipment**. Furthermore, cooperation is important not only with data center operators, but also with a variety of stakeholders, such as semiconductor manufacturers and ICT-related manufacturers.

Reference Materials

Data Centre, AI and Energy：Current and Future

Hardware (Data Centre)

ICT



Servers, storage, and IT auxiliary equipment

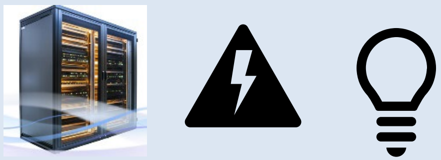
Current

- IT equipment accounts for the largest proportion of electricity consumption at **data centers, at around 50%.**
- Data centers are often located near cities, and in order to make efficient use of land, **ICT equipment is being packed more densely per rack**, which can result in a decrease in efficiency when air conditioners are operating at full capacity.
- The spread of **generative AI** is leading to an increase in data volume and increased electricity consumption.

Future

- Optimizing **rack layout**
- Shifting from company data centers to **hyperscalers**
- Shifting to **edge computing** depending on the application
- Optimizing server utilization, such as **shifting from GPUs to CPUs**
- Increasing the efficiency of **integrated circuits and storage**

Support Facility



Cooling, backup power, lighting, etc.

Current

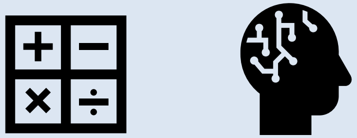
- The increase in computing volume and the increasing density of IT equipment are driving up demand for cooling.
- In particular, related power consumption accounts for **approximately 35% of total electricity consumption of traditional data centres**.
-

Future

- High efficiency from air-cooled to **rear door air conditioning**, **liquid cooling**, and immersion cooling

Software

Algorithm



Generative AI、Data Volume、Software

Current

- The electricity required for **generative AI calculations is 10 times that of a typical search**.
- On the other hand, the electricity consumption per search by the **latest generative AI is equivalent to that of a typical search**.

Future

- Reduced energy demand per task through **innovative algorithms**
Models are "right-sized" for a variety of tasks

Source：IEEJ (2025).

Hyperscalers　: Net Zero Roadmap

✓ Hyperscalers are undertaking various measures for meeting the ambitious net zero targets.

Hyperscaler	Net Zero Target	Measures for Net Zero		
		Data Centre	Supply Chain	Electricity Supply, CDR
Amazon (Amazon Web Services)	2040 (Amazon as a whole, hourly matching)	• Improve PUE by introducing efficient cooling systems • Develop efficient semiconductor chips	• Use of low-carbon building materials (steel, concrete) • Use of low-carbon fuels (SAF, renewable diesel)	• Renewable energy investments, PPAs • PPAs with battery systems, utilization of in-house systems • PPAs for nuclear power generation, support for SMR development
Microsoft (Microsoft Azure)	2030 (Microsoft as a whole, hourly matching)	• Energy-saving operation, such as standby mode Development of advanced cooling technology	• Use of low-carbon building materials (steel, concrete, wood, etc.) • Use of low-carbon fuels (SAF, renewable diesel) • Collaboration with suppliers (requesting the use of carbon-free electricity)	• Renewable energy investments and PPAs Nuclear power PPAs (including restarts) • Support for CDR technology development
Google (Google Cloud Platform)	2030 (Google as a whole, hourly matching)	• Cooling system optimization using machine learning • DR through task shifting • Data center design optimization	• Collaboration with suppliers (requesting the use of carbon-free electricity) • Use of low-carbon building materials	• Renewable energy investments and PPAs Support for the implementation of decarbonized energy using our own technology
META	2030	• Workload monitoring and power profile optimization • Energy-efficient hardware design • Efficient cooling using fresh air and direct evaporative cooling	• Collaboration with suppliers (aiming for more than two-thirds of suppliers to set emissions targets by 2026) Utilization of decarbonized fuels (SAF, biofuels)	• Investment in renewable energy batteries, PPA • Support for CDR technology development

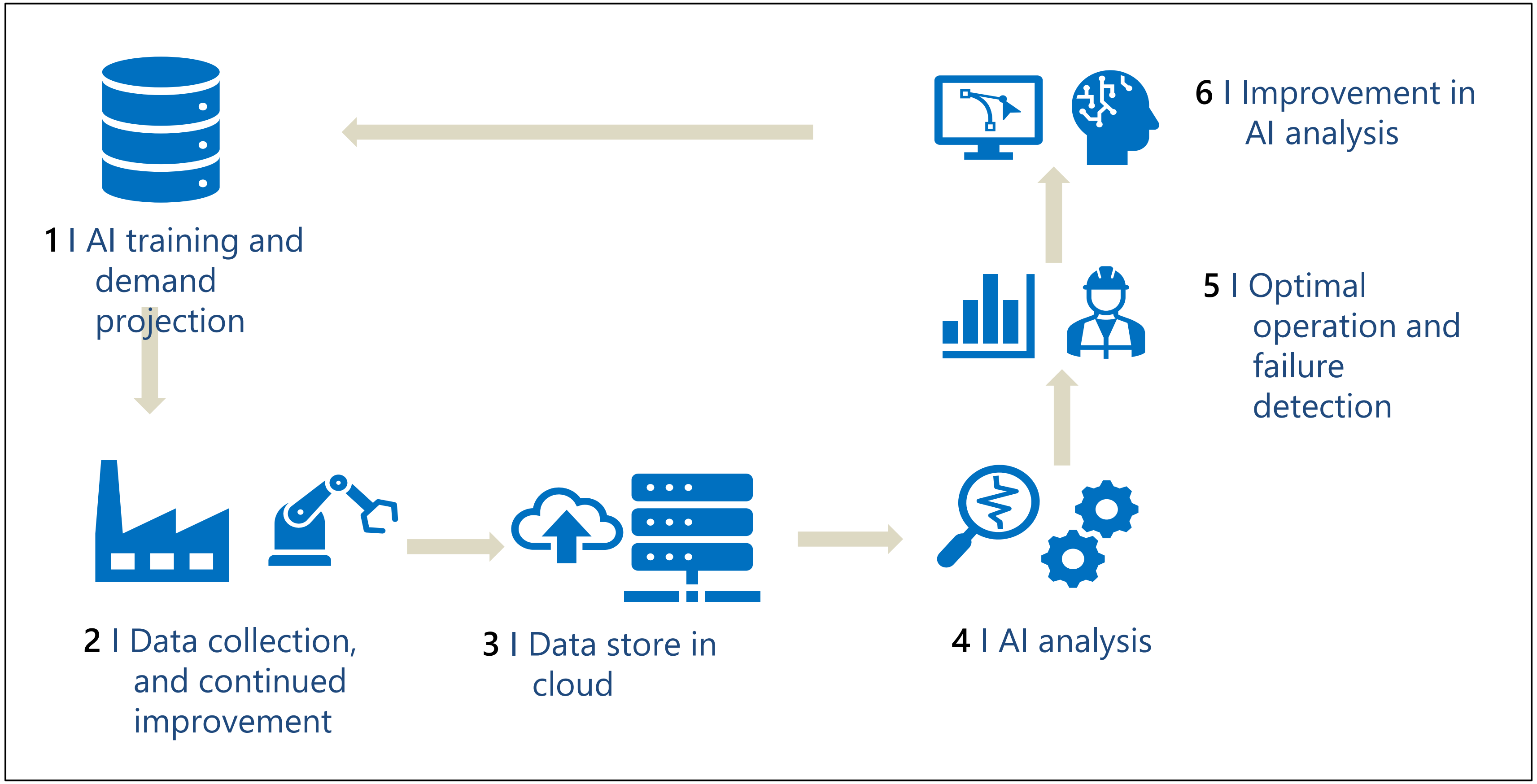
Cross Company Approaches for Net Zero

- iMasons Climate Accord (ICA)：A framework aimed at decarbonizing digital infrastructure, organized by iMasons, an industry group comprised of digital infrastructure companies, primarily big tech companies.
- Semiconductor Climate Consortium (SCC)：Framework for decarbonization in the semiconductor industry
- ZEROgrid：A framework centered on large-scale consumers aimed at decarbonizing and improving the reliability of the power grid.

Source：From sustainability report of respective company.

Use of AI in the Industry Sector : Image

- ✓ By utilizing AI, it will be possible to achieve energy savings without having to update everyone's equipment.
- ✓ AI enables optimal control based on production forecasts and energy realization based on considerable data.

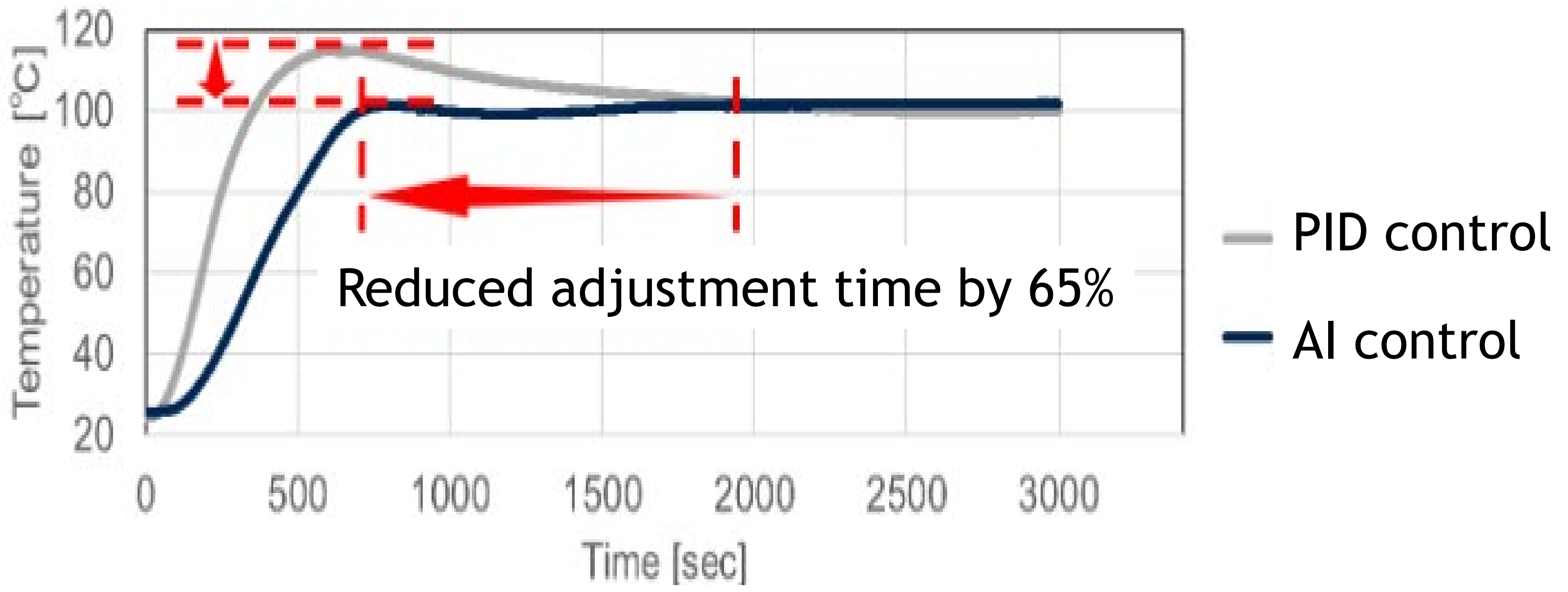


Source： https://indatalabs.com/blog/ai-use-cases-in-manufacturing.

Example: Yokokawa

- ✓ **Yokogawa Electric provides solutions using AI in factories**.
- ✓ By using AI to control furnace heating, Yokokawa managed to reduce startup and temperature adjustment time from 30 minutes to 10 minutes.

Start-up adjustment time of a furnace: from 30 minutes to 10 minutes

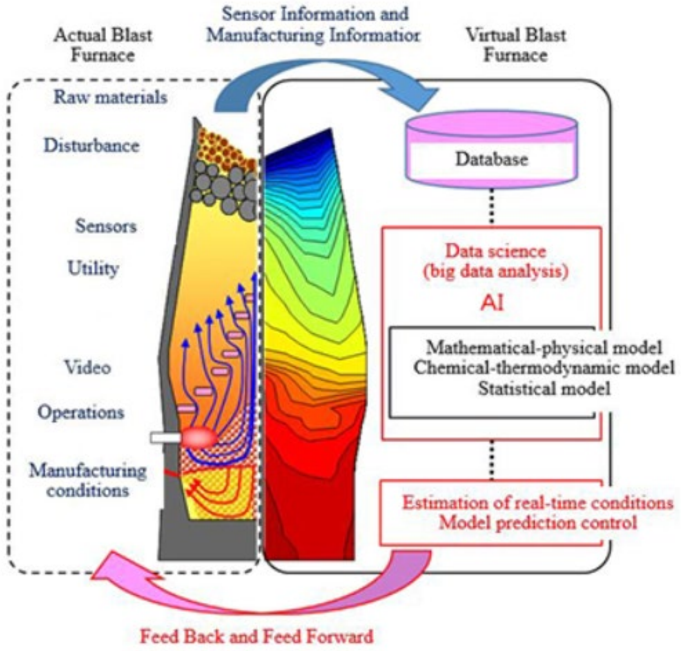


Source：https://www.yokogawa.co.jp/news/press-releases/2023/2023-02-27-ja/

Example: JFE

✓ JFE has developed a blast furnace CPS (cyber-physical system) to achieve optimal control.

Image of CPS



Projection, early error detection, advices to operators

Due to high temperature at 2,000 ℃ it is hard to put sensors inside the furnace.

CSP can detect malfunctions. Provide appropriate operation advices.

Source： https://www.jfe-steel.co.jp/en/release/2019/191105.html