Energy Transition
- New Frontier for MHI Group -

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Introduction

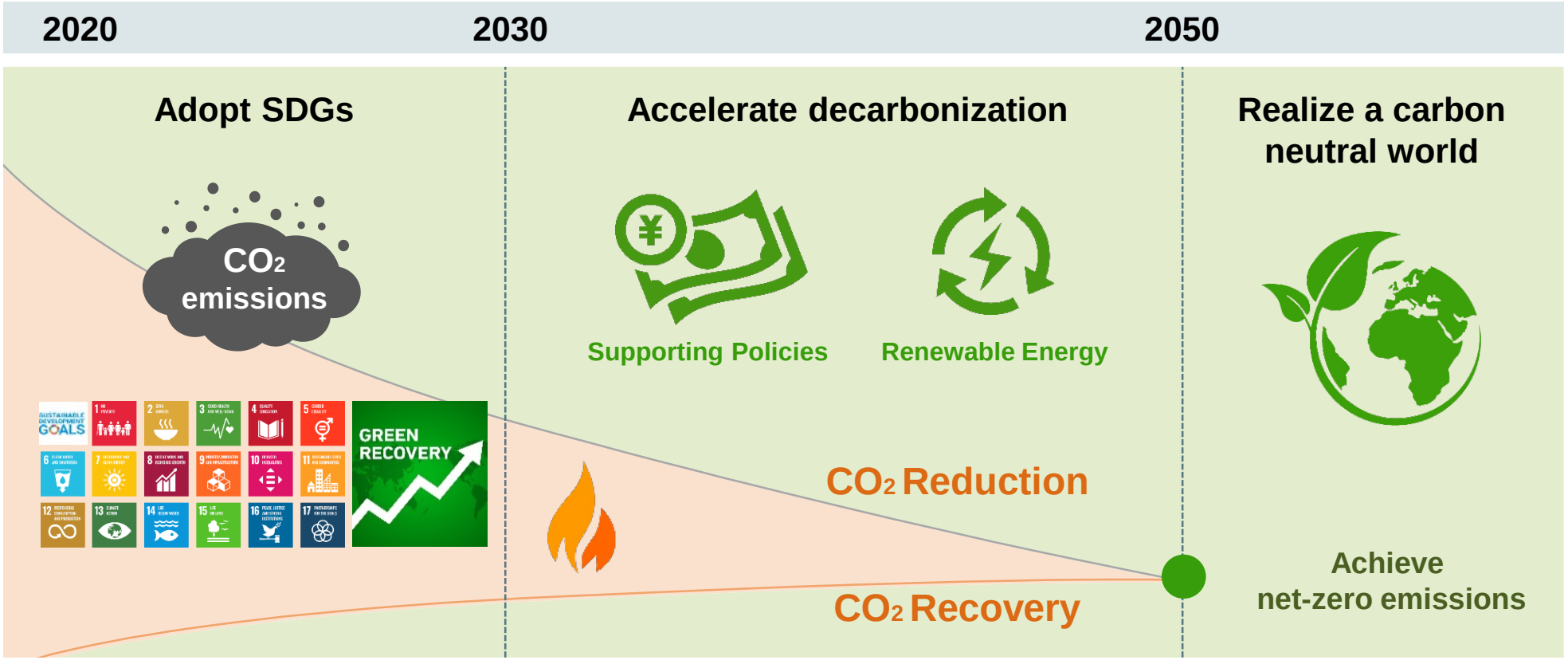
Global warming and climate change are common challenges for humanity

***Our Commitment*:**

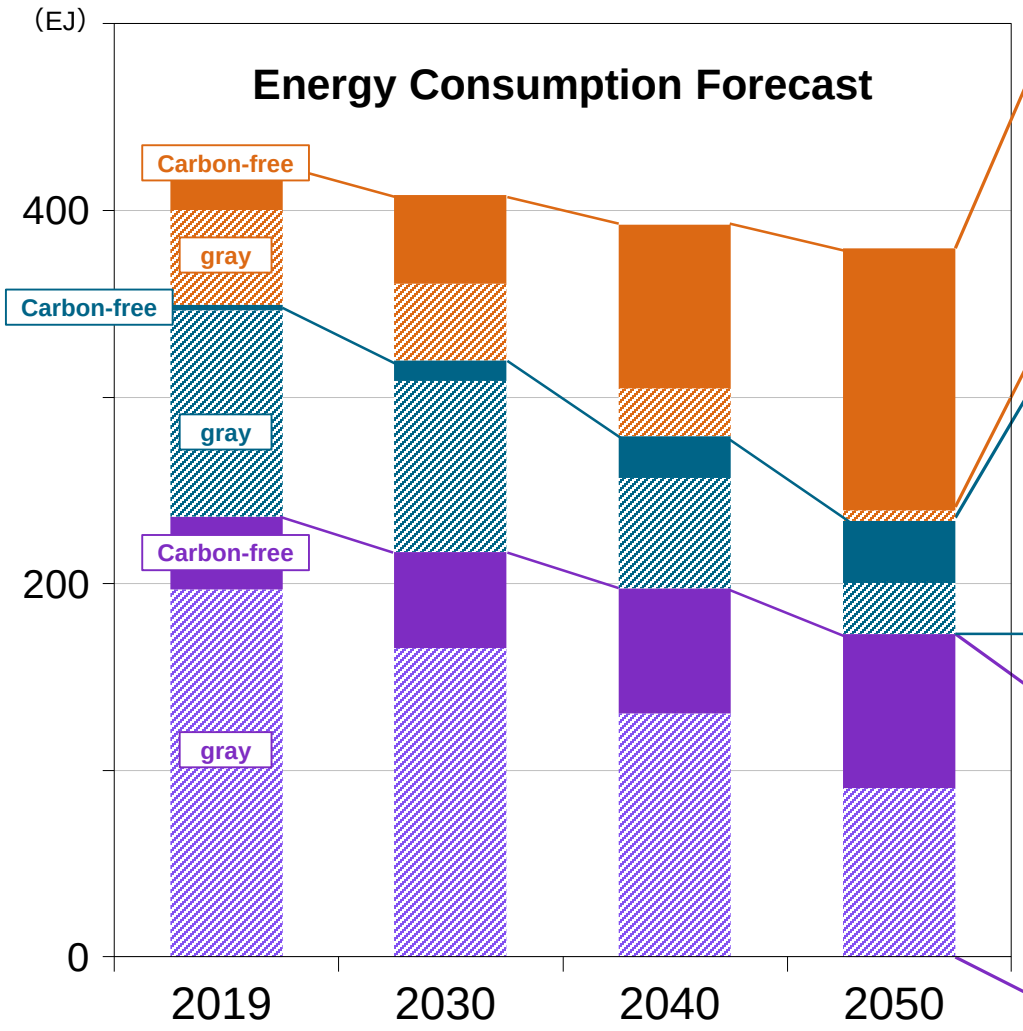
- **Achieve a carbon-neutral world by 2050**
- **Need for decarbonization and electrification of mobility, life, and industry**
- **Stable supply of affordable energy is essential**
- **Our goal is to bring about net-zero carbon world**

Global Trends

- The world is shifting to a carbon-neutral society
- Reducing and recovering CO_2, net-zero carbon society is to be achieved by 2050



Energy Trends



Electricity

- Electricity demand increases along with the growth of electrification
- Achieve carbon neutral in 2050 through the use of renewable energy and hydrogen

Mobility

- Passenger automobiles electrified
- Adoption of hybrid trucks increase through improved battery performance
- Carbon-free fueled ships and aircraft developed

Industry

- Growing use of carbon-free fuel in large scale industries such as steel industry
- Some industries such as chemical industry continue using gray fuel

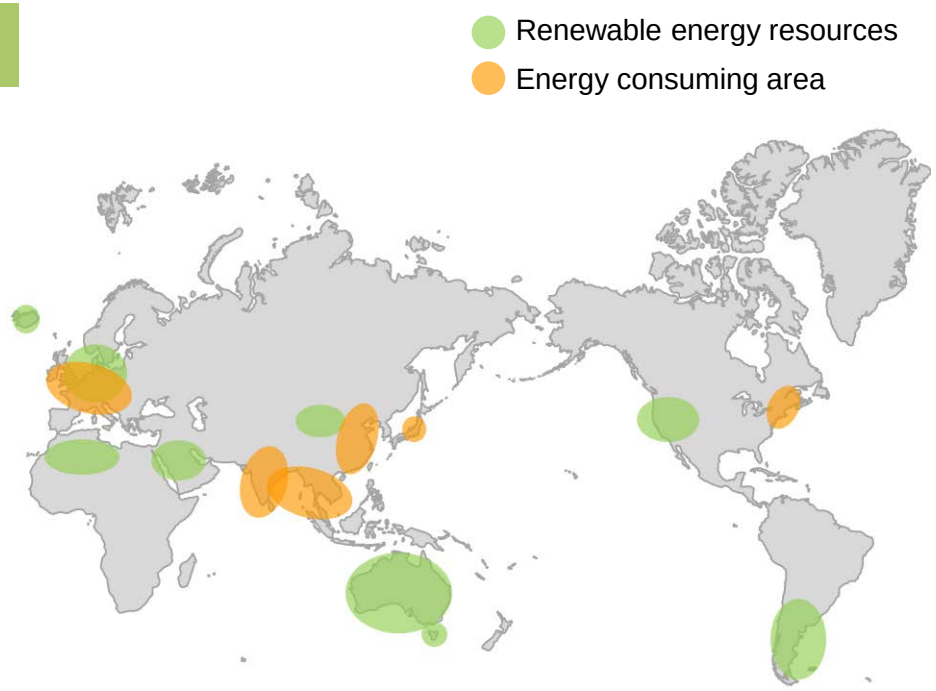
Based on IEA World Energy Outlook 2020 Sustainable Development Scenario, IEA Energy Technology Perspective 2017/2020

EJ:exajoule：10^{18}J

Our View of Energy Transition

Expansion of Renewable Energy

- Widening regional gap in electricity cost and industrial competitiveness
- Increasing costs implementing large-scale storage batteries and long-distance transmission lines
- Basic industries consume large amounts of heat – steel and chemical industries face difficulty adopting electrification



Along with expansion of renewable energy, utilize carbon-free fuels and CO_2 recovery technologies

Our View of the Energy Transition

Contribute to achieving a carbon-neutral world by 2050 through decarbonization technologies and hydrogen value chain

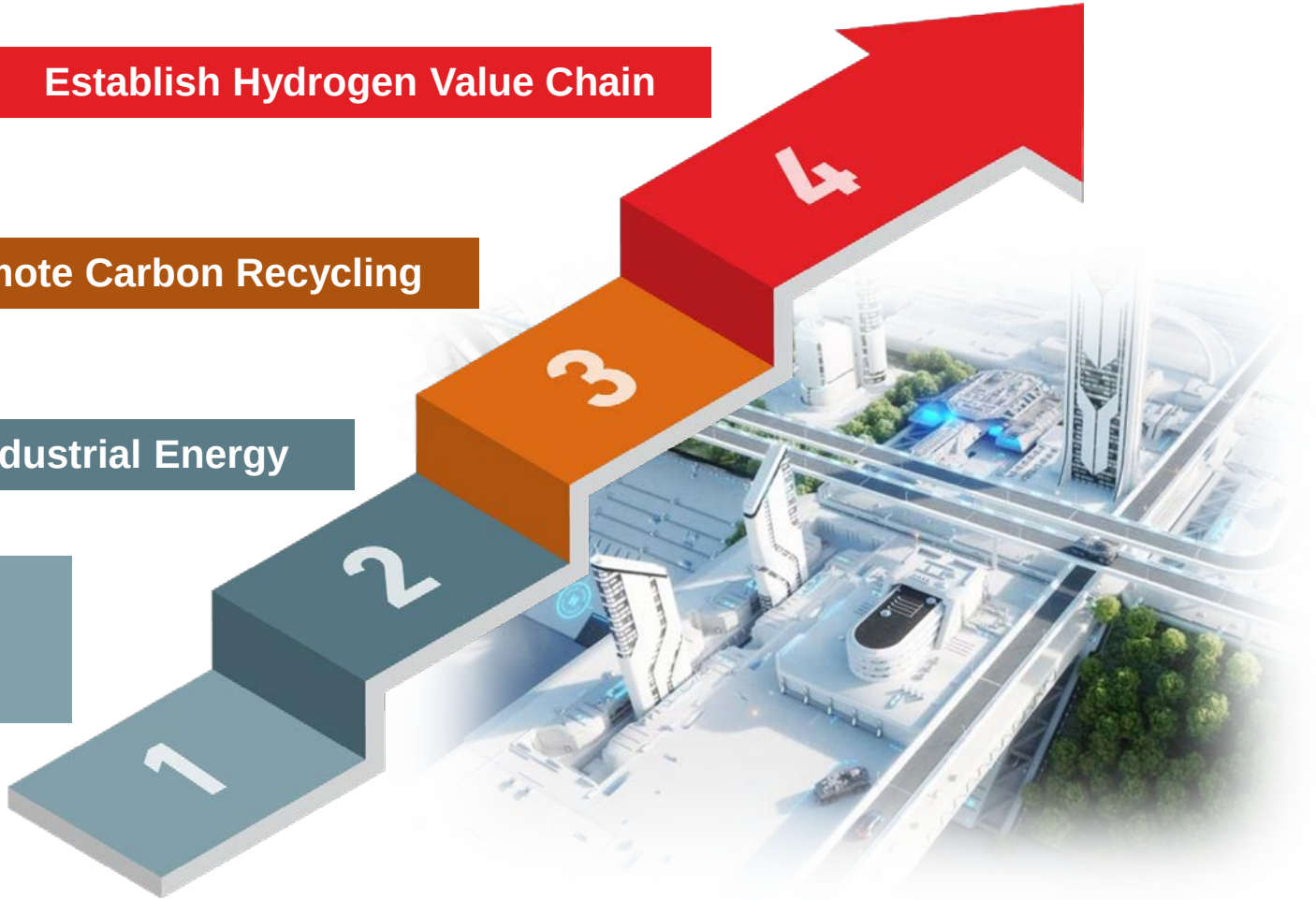
Carbon Neutral World

Establish Hydrogen Value Chain

Promote Carbon Recycling

Higher Efficiency in Industrial Energy

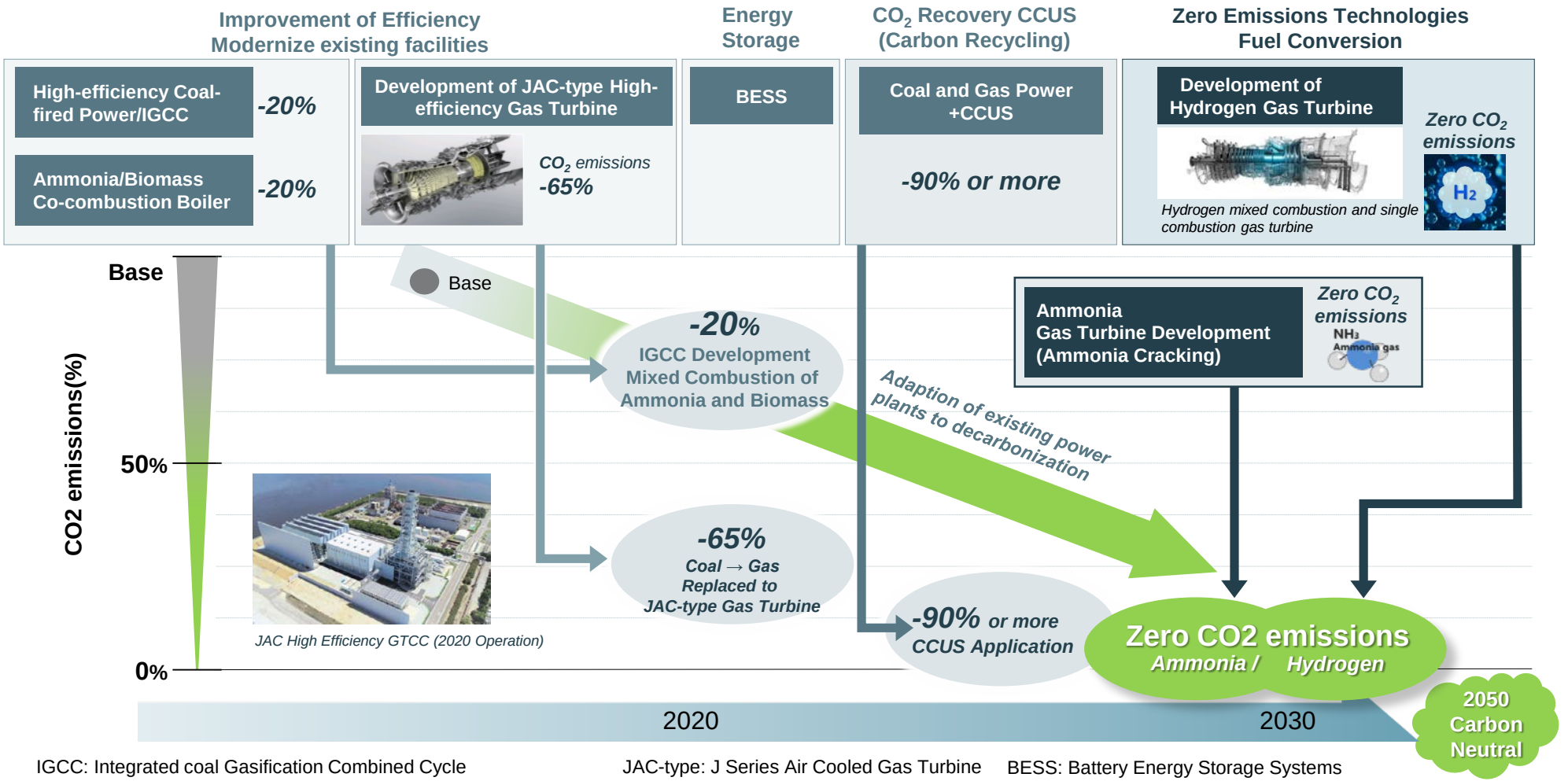
Decarbonize Thermal Power
Reduce CO_2 through Nuclear Power



Decarbonization of Thermal Power Generation

Our approach

- **Higher efficiency and adoption of hydrogen and ammonia as a fuel**
  - ・Minimize the modification in existing facilities as decarbonized facility
  - ・Reduction of additional investment in future fuel conversion
- **Enhance flexibility capability in existing facility and utilize BESS to support renewable energy systems**



IGCC: Integrated coal Gasification Combined Cycle
Base: Subcritical pressure coal fired boiler CO2 emissions standard

JAC-type: J Series Air Cooled Gas Turbine
GTCC: Gas Turbine Combined Cycle

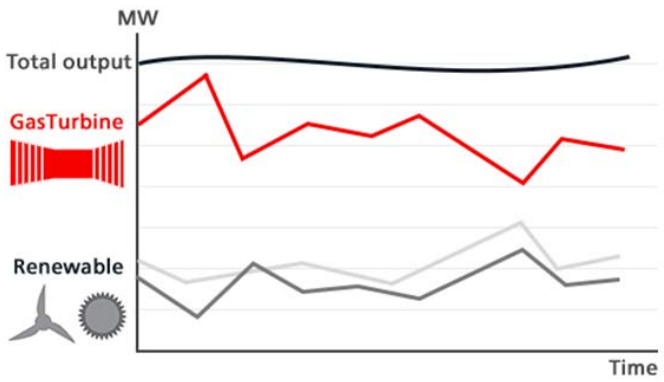
BESS: Battery Energy Storage Systems
CCUS: Carbon dioxide Capture, Utilization and Storage

Decarbonization of Thermal Power Generation

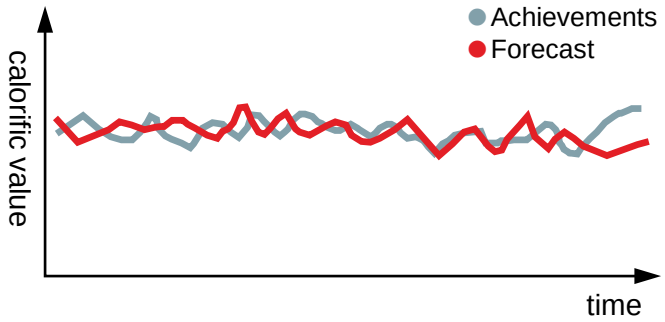
Our approach

- **Maximize overall system energy efficiency with AI**
  - ・Based on predictive models learned from field data
  - ・Sophistication of plant operation through remote monitoring

Stabilization of grid system

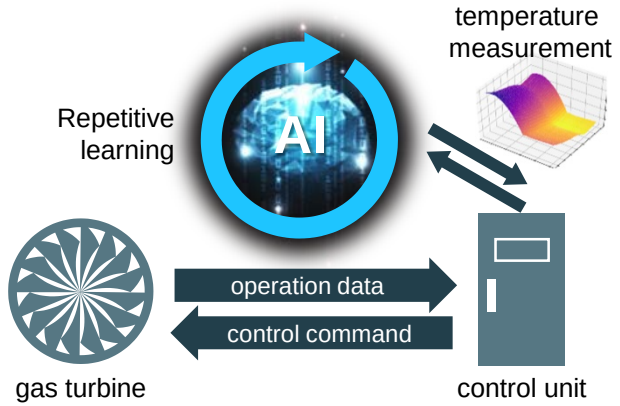


Waste-to-Energy Remote Monitoring and Autonomous Operation

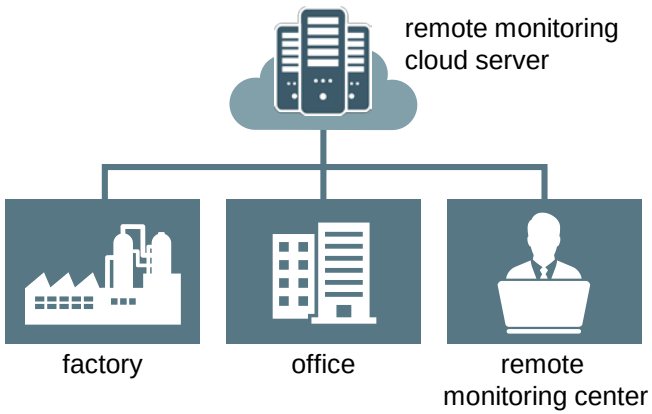


Maximize energy efficiency

Gas Turbine Optimum Operation



Remote Monitoring System Technology



CO_2 Reduction by Nuclear Power

Nuclear Power

- Significantly reduce CO_2 emissions through the restart of existing plants and next-generation LWR (light water reactors)
- Large and stable production of CO_2-free hydrogen by a HTGR (high-temperature gas-cooled reactor) (Contribute to the steel industry)

Promotion of CO_2-free Power Sources

Resuming existing plants operation

Next-generation light water reactors with enhanced safety

Small and fast reactors

Participating in the ITER Project

Fusion reactor

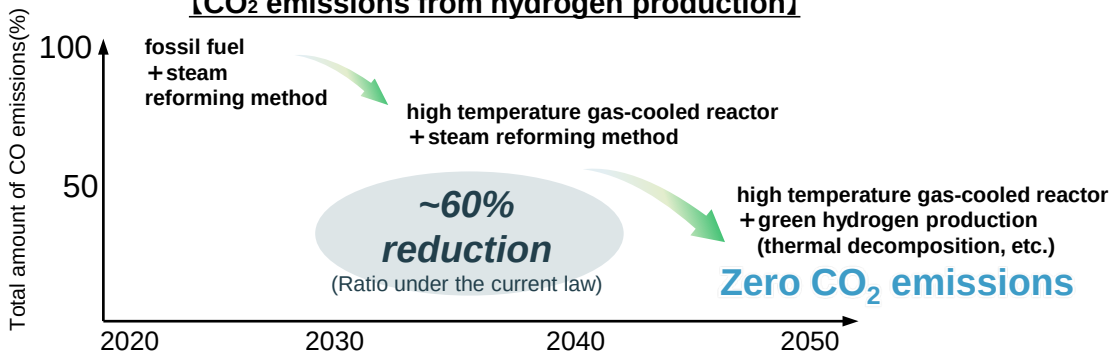
Supply of CO_2 Free Hydrogen

Hydrogen supply by high temperature gas-cooled reactor

2020 2030 2040 2050

- CO_2 free, large capacity, stable power supply
- Base load power source in a carbon-neutral society

【CO_2 emissions from hydrogen production】



For Industrial Energy

ENERGY Cloud

Accelerate decarbonization and optimize existing assets

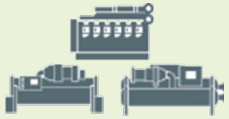
- Improve Production Efficiency. Support Fuel Conversion of Existing Assets
- Use renewable energy and supply surplus electricity through the market

Industry

Existing Assets

Fuel conversion and heat utilization

Distributed power supply

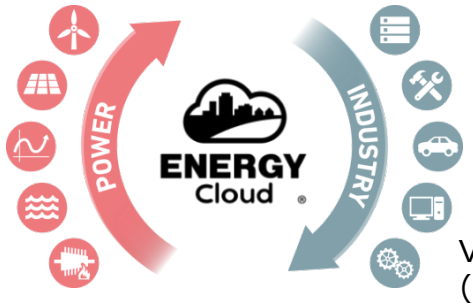


Utilization of surplus power

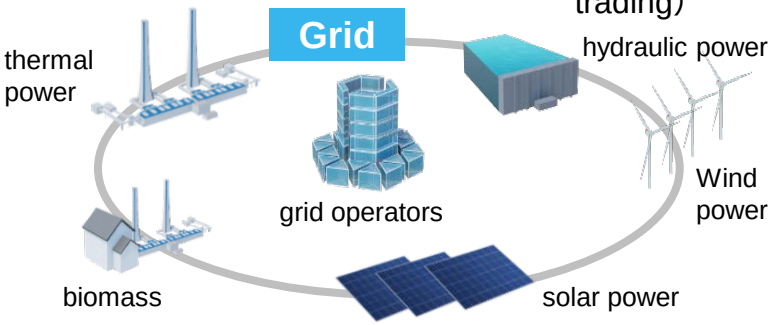
Solar

Wind

Stabilization of renewable energy



VPP/DR (electric power trading)



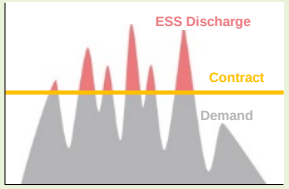
Operation data × Operation plan, etc.

Prediction of heat, power, etc.

Forecast

Energy demand × Facility operation status, etc.

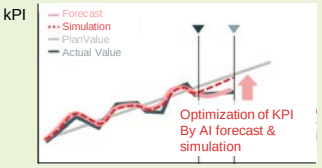
Supply-demand optimization



Energy conservation plans

Energy price × Facility utilization rate, etc.

Procurement optimization



Total optimization

By reducing energy consumption

Eliminating waste of energy use

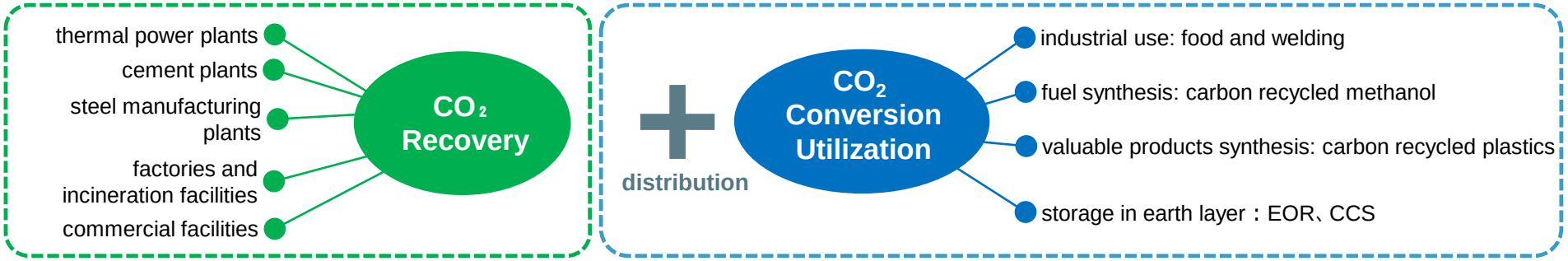
Use renewable energy and green fuel

decarbonization

Promotion of Carbon Recycling

CO_2 Value Chain

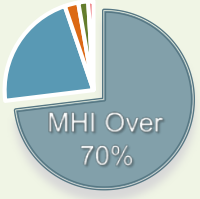
- Expanding our advantage in CO_2 recovery through further technology development
- Enter into the value chain of CO_2 conversion and utilization



Expanding CO_2 Recovery Business

Drax Power Plant (U.K)
Pilot test of CO_2 recovery for biomass power generation started in June 2020

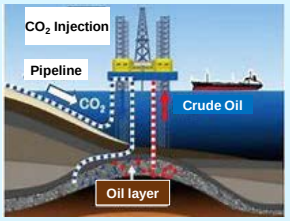
NO.1 market share in CO_2 recovery systems from exhaust gas



Introduction of the world's largest CO_2 recovery plant for U.S. coal power generation in 2016

Expansion of Technology Development and Product Lineup

Provide one-stop solutions to meet diverse needs for CO_2 transportation and use



EOR(enhanced oil recovery)

press-fit compressor

LCO_2 carrier

EOR：Enhanced Oil Recovery　CCS：Carbon Capture Storage　EOR graphic: excerpt from Japan Oil, Gas and Metals National Corporation Website

Creating a Hydrogen Society

- **Improve H_2 manufacturing processes and H_2 usage applications will lead to an increase in hydrogen demand**

Manufacturing Processes → **Market Size** ← **Usage Applications**

Reforming	Fossil Fuel emissions of CO_2

Decarbonization

Electrolysis	Renewable Energy
Pyrolysis	Nuclear Power (High temperature gas-cooled reactor)
	Fossil Fuel Carbon Recovery / Utilization
Reforming & CO_2 recovery	Fossil Fuel CO_2 recovery

- Ammonia Fueled Ships
- Hydrogen Reduction Steel Manufacturing
- Hydrogen Trucks & Buses
- Power Generation
- Hydrogen Gas Turbines
- Fuel Cell Forklifts
- Ammonia Mixed Combustion Boilers
- Utility Gas
- Fuel Cells

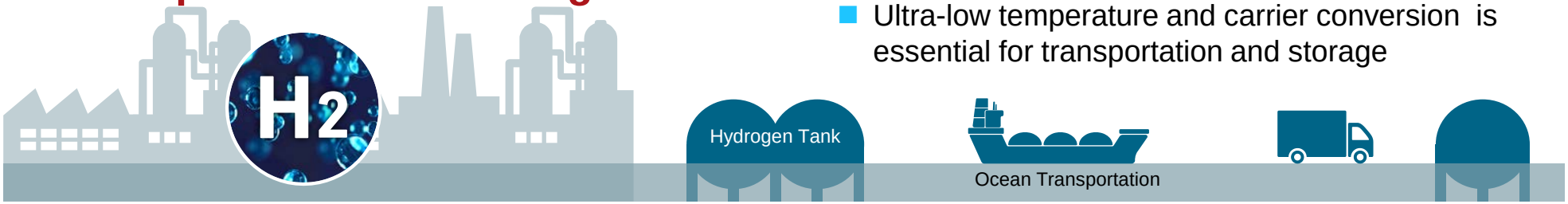
Hydrogen market size from IEA Energy Technology Perspective 2020

Challenges in Realizing a Hydrogen Society

1. Cost Reduction

- Large amount of primary energy is required for hydrogen production
- Low energy density requires heavy transportation and storage

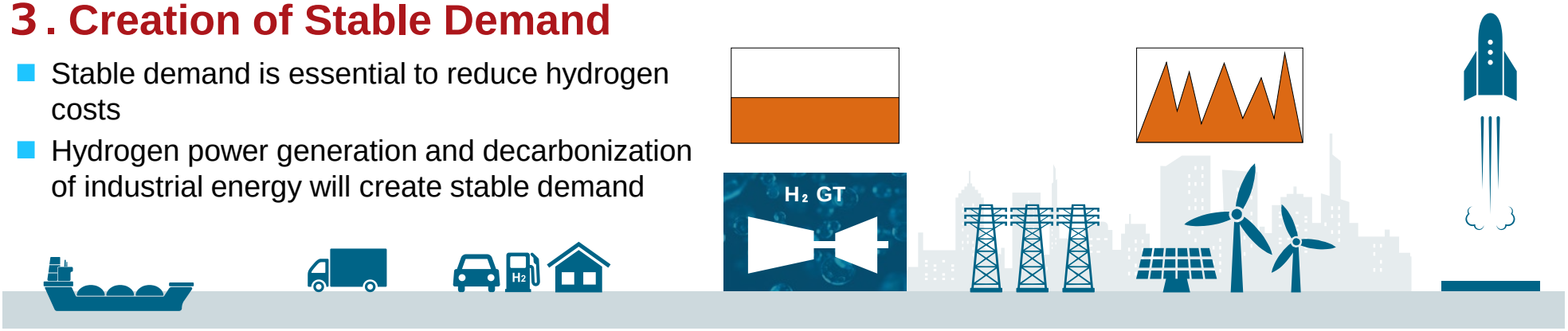
2. Manufacturing, Transportation and Storage



- Massive and long-distance transport requires new infrastructure
- Ultra-low temperature and carrier conversion is essential for transportation and storage

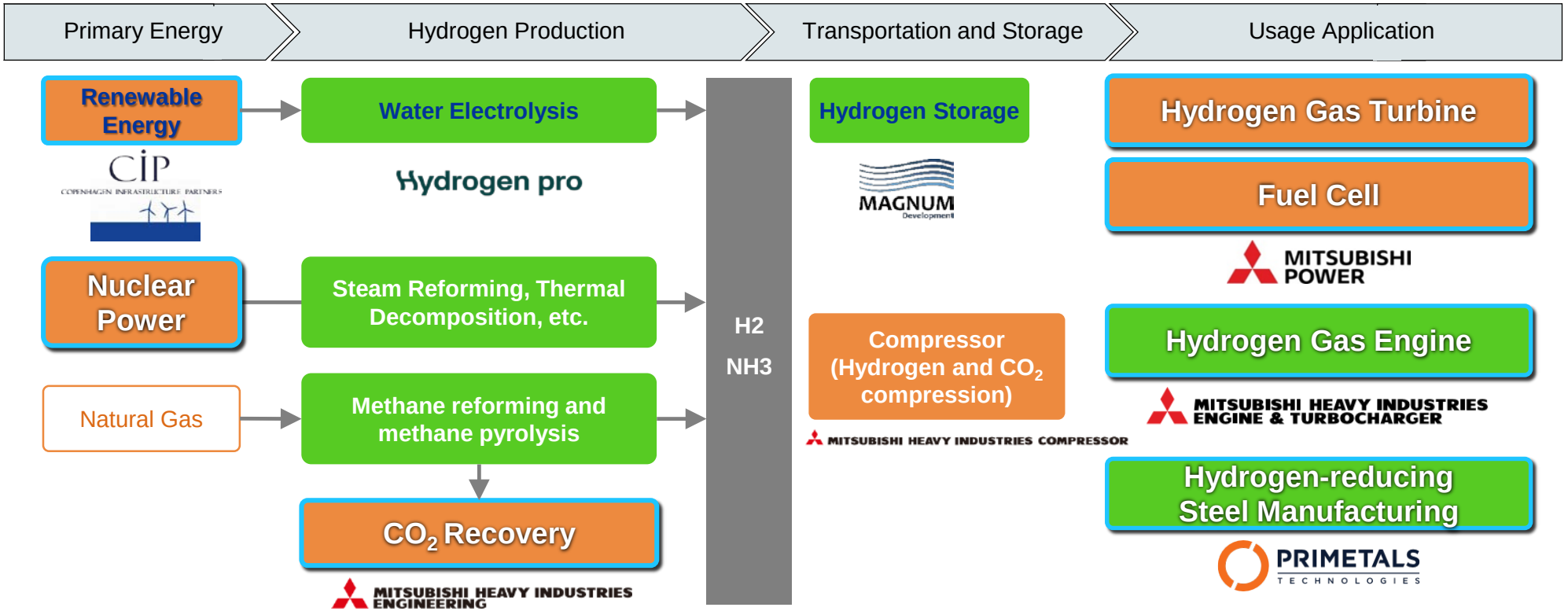
3. Creation of Stable Demand

- Stable demand is essential to reduce hydrogen costs
- Hydrogen power generation and decarbonization of industrial energy will create stable demand



Our approach to a Hydrogen Society

- **Contributing to the establishment of infrastructure and cost reduction through the provision of technologies, products, and services from hydrogen production to utilization**
- **Creating a value chain by our unique technologies and active cooperation with partners**
- **Transition towards utilization of ammonia**



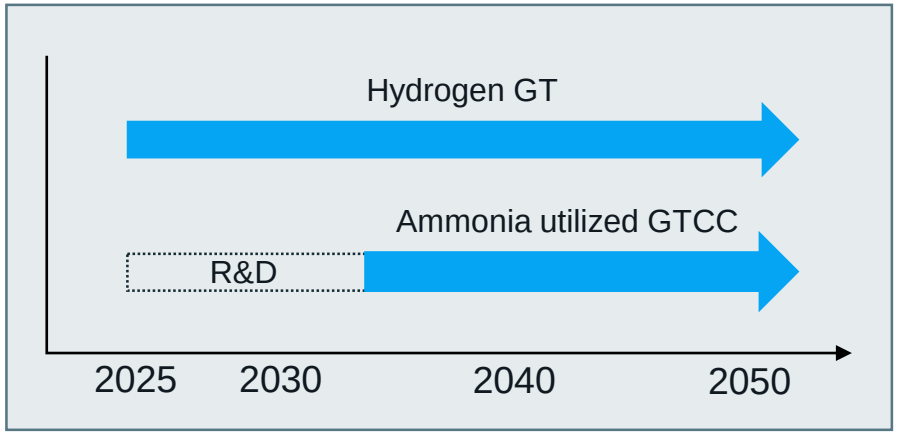
CIP: Development of Offshore Wind Turbines in Hokkaido
Hydrogen Pro: Investing in Hydrogen Production Plant Supply
Magnum : Green Hydrogen Production, Storage and Supply Business Development in Utah, USA

Our approach to a Hydrogen Society - Ammonia-

- **Utilization of ammonia is a path to H_2 society mitigating economical impact**

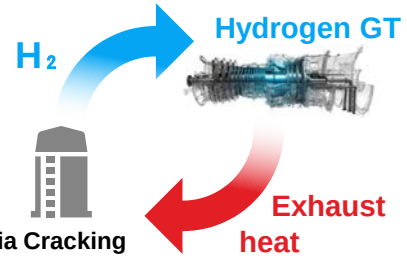
Hydrogen Carrier

- Utilize ammonia as a carrier of voluminous hydrogen
- Exhaust heat from GT used for ammonia cracking



LPG/Ammonia Multi Gas Carrier

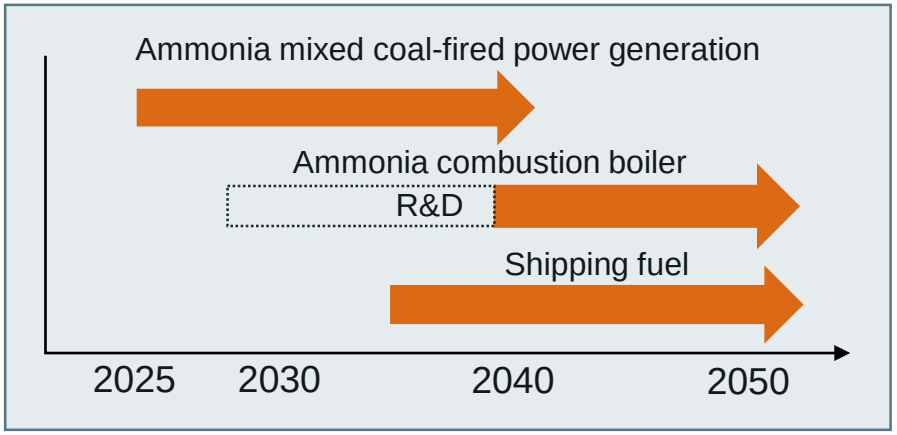
Ammonia

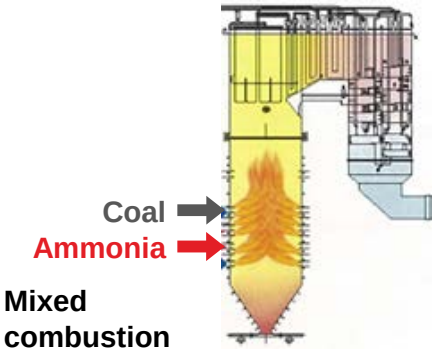


Ammonia Utilized GTCC

Fuel

- Use ammonia as low CO_2 emission or carbon-free fuel





Mixed combustion

Shipping Fuel

Participate in Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

Establishment of Hydrogen Energy Value chain

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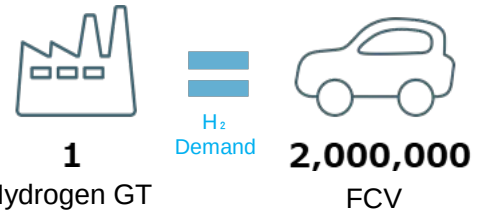
Technology Development

Most Advanced Hydrogen Combustion Technologies

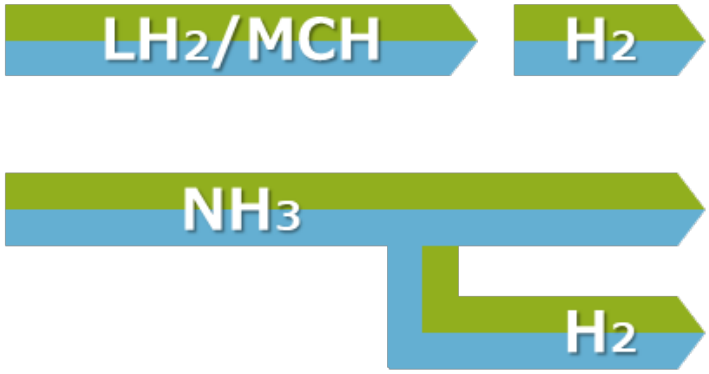
Hydrogen GT

- **Saving Investment Costs**
  Can be applied to existing power plant facilities with minimum modifications

- **Stimulate Large-scale Hydrogen Demand**
  Expansion of hydrogen supply chain and reduction of costs



- **Carrier Flexibility**
  Low purity hydrogen is usable and can be transported with any carrier



- **Timeline**
  2018 Achieved 30% H_2 Co-combustion
  2025 Achieve 100% H_2 Combustion

Establishment of Hydrogen Energy Value chain

Technology Development

World's Most Advanced Hydrogen Combustion Technology

Fuel Cell/SOFC

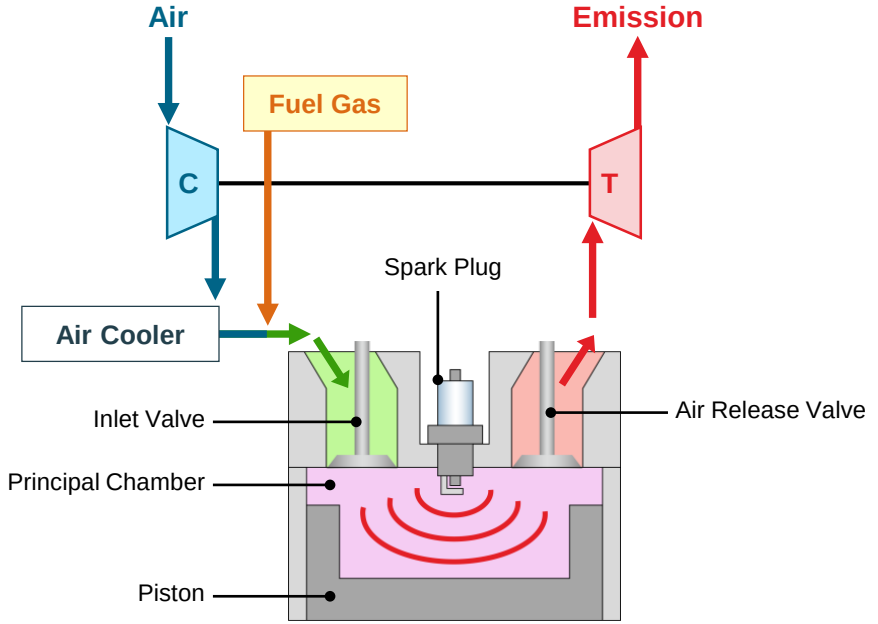
- Multi-fuel capability
  (hydrogen, natural gas biogas, etc.)
- Rated Output：200kW～1MW
- Power Generation Efficiency: 53%
  Overall Efficiency: 73%（when supplying hot water）
- First overseas order received in 2020
- Can be applied to SOEC (hydrogen production)

Biogas SOFC at Asahi Breweries Ibaraki Brewery

SOFC：Solid Oxide Fuel Cell　　SOEC：Solid Oxide Electrolysis Cell

H_2 Gas Engine

- Development started
  in 2019. Combustion test
  and simulation in progress
- Rated Output：300kW～ 1 MW
- Market release by 2030s supporting hydrogen market



Establishment of Hydrogen Energy Value chain

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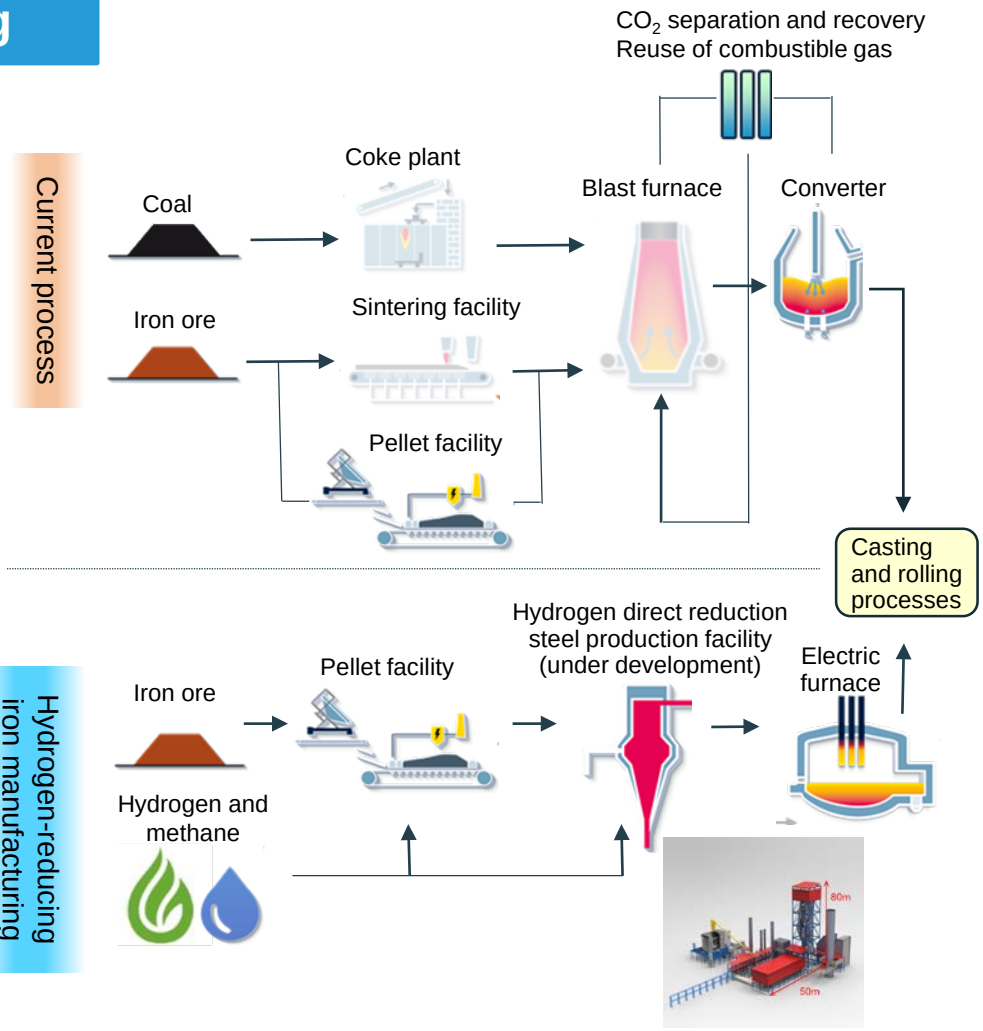
Technology Development

Use of Hydrogen in Steel Production

Hydrogen-reducing steel manufacturing

- Today, about 70% of global steel produced by blast furnace consuming large amounts of coal, generating massive CO_2 in the process
- Hydrogen steel production eliminates blast furnace extracting reduced iron directly from iron ore
- 80% or more CO_2 can be reduced compared to current production process
- Eliminate blast furnace equipment and reduce raw materials and operating costs
- Pilot plant under construction in Austria and scheduled to start trial operation in 2021



Establishment of Hydrogen Energy Value chain

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Partnership | **Energy Decarbonization Project in the US**

- Entergy and Mitsubishi Power started collaboration in September, 2020
- Package agreement for decarbonizing Entergy's utility business in 4 southern states

Entergy and Mitsubishi Power signed Agreement

- Collaborative Area
  1) Hydrogen GTCC
  2) Production, storage, and transportation of hydrogen using renewable electricity
  3) Production and storage of hydrogen by nuclear power generation
  4) Energy storage system by large capacity battery

4 Southern States: Arkansas, Louisiana, Mississippi and Texas

Establishment of Hydrogen Energy Value chain

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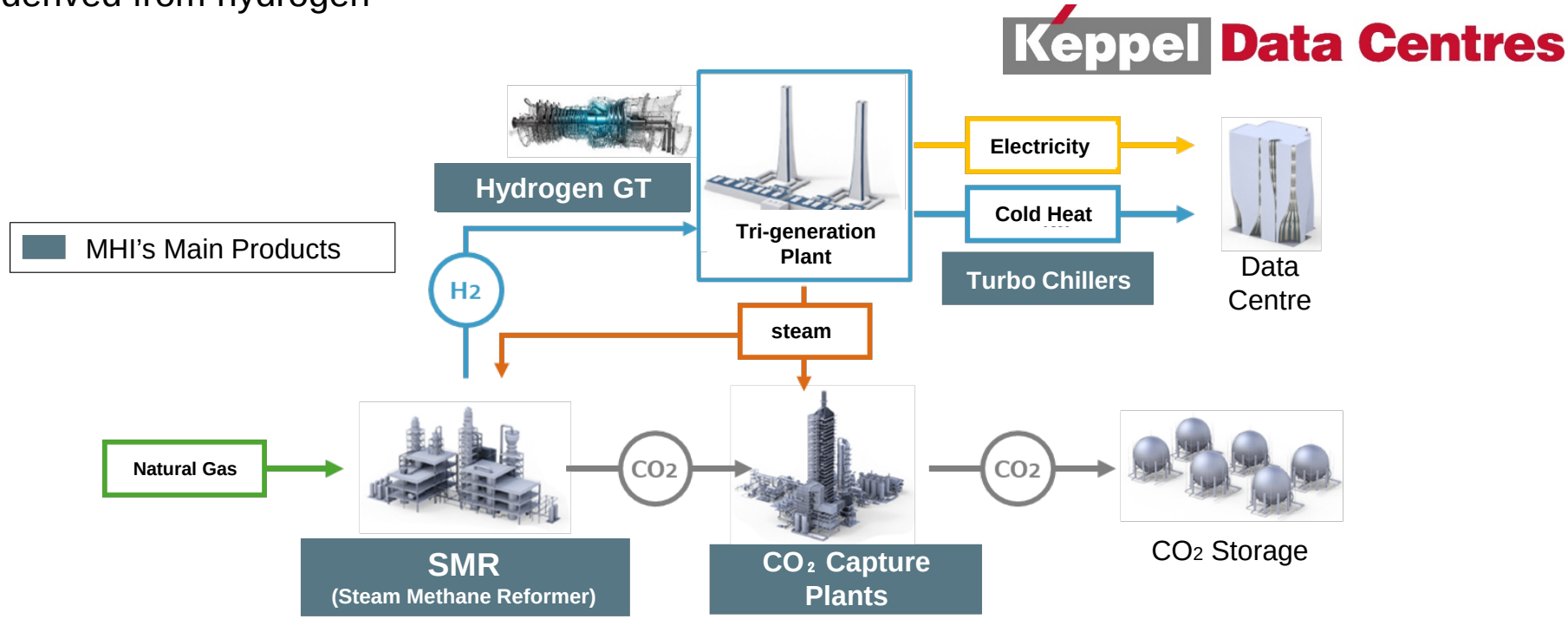
Partnership　Tri-generation in Data Centers

- In Singapore, MHI-AP and Keppel Data Centres commenced a joint study in June 2020
- Study the whole process from production of carbon-free hydrogen to supply of electricity, cooling/heat and steam
- Aiming for carbon neutrality of data centers, to supply electricity, cooling/heat and steam derived from hydrogen

Keppel Data Centres



MHI-AP：Mitsubishi Heavy Industries Asia Pacific Pte. Ltd.

Establishment of Hydrogen Energy Value chain

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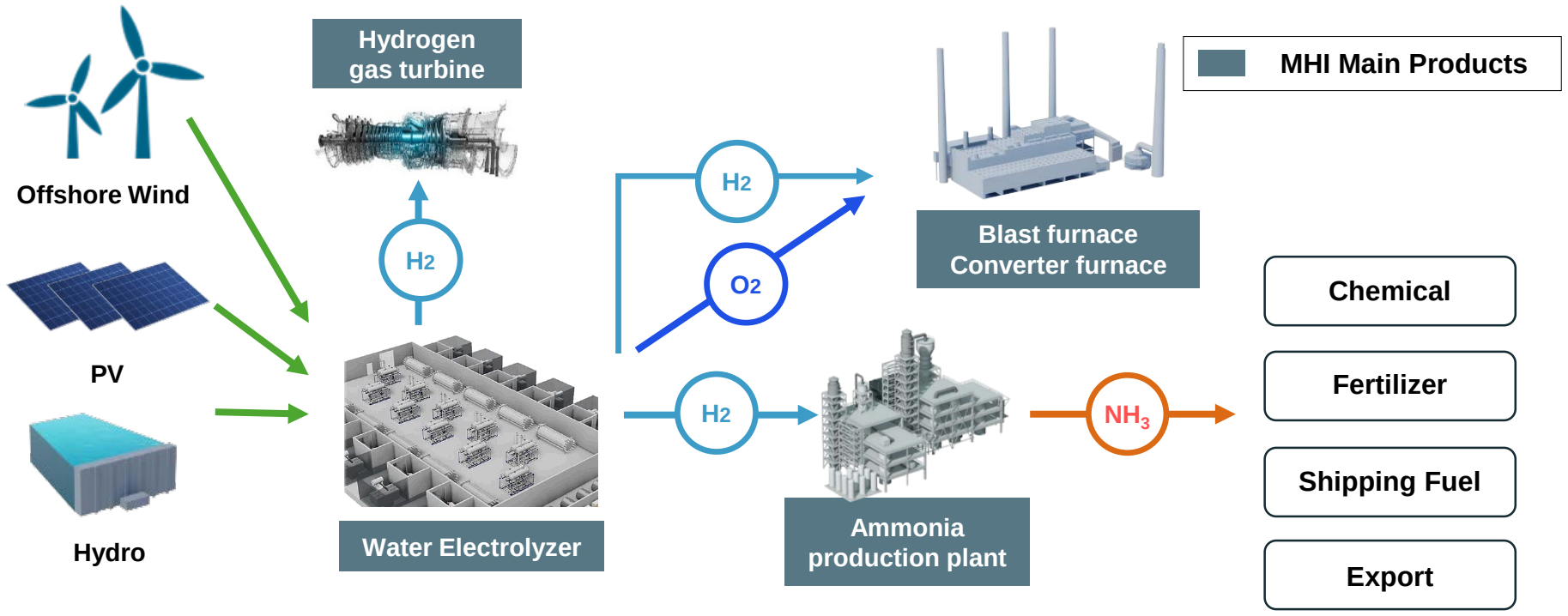
Partnership — Carbon-free Ammonia Production Project

- Capital participation in H2U Investments conducting carbon-free ammonia production project in South Australia
- Making use of abundant renewable energy in the area, producing hydrogen and ammonia. Contributing to the region's industries such as nearby steel mills, and export carbon-free ammonia



Establishment of Hydrogen Energy Value chain

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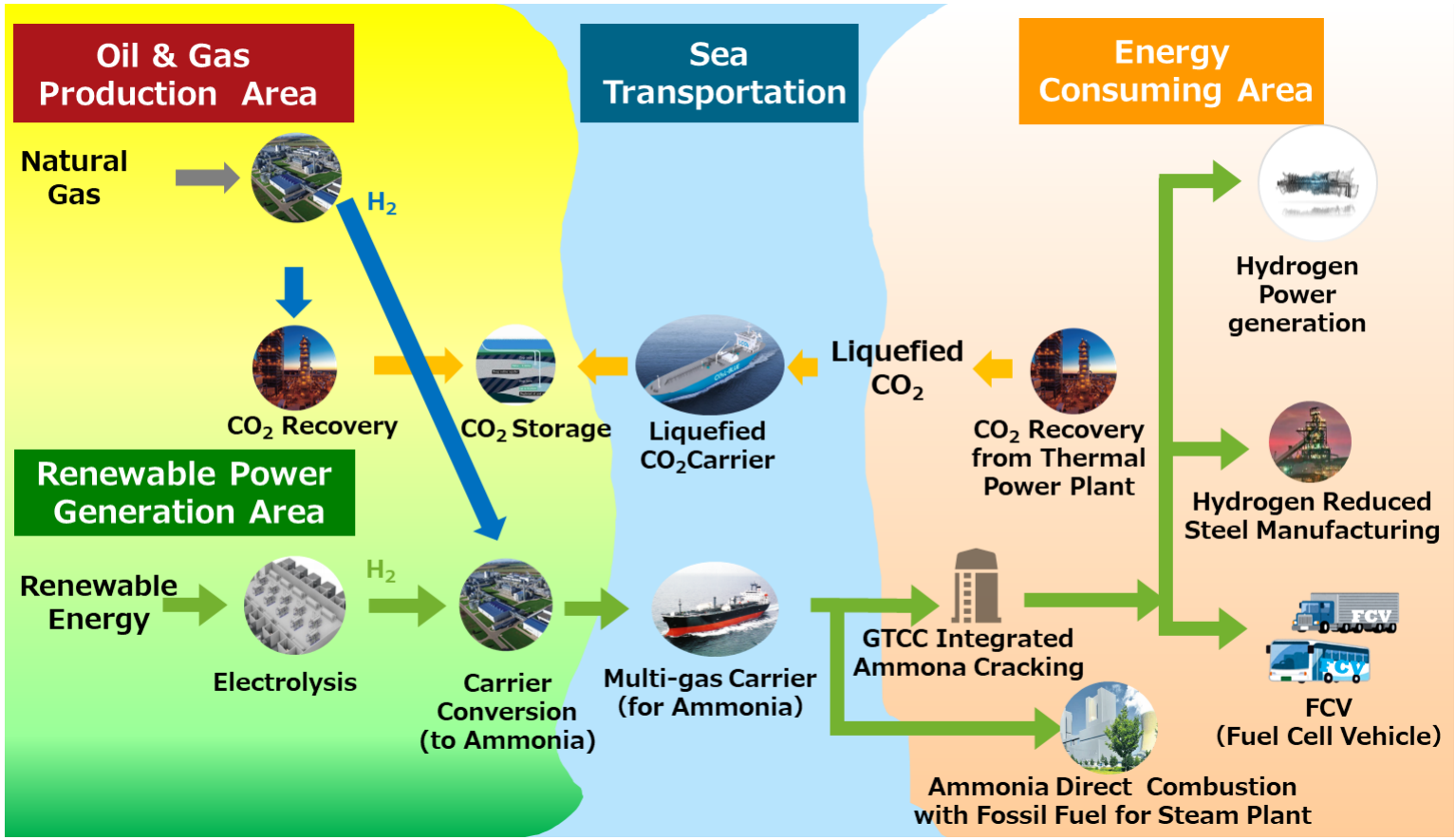
Partnership

Entering into the Fuel Business

- Participate in fuel business from production, storage through supply to promote the introduction of carbon-free hydrogen and ammonia in accordance with local needs



Establishment of Hydrogen Energy Value chain

Partnership — Strengthening Partnership in Offshore Wind Power Business

Strengthening the relationship with Vestas

- Strengthening competitiveness by integrating offshore and onshore wind turbine manufacturing business
- Strategic investment in Vestas as an industrial partner
- Consistent efforts to expand the Japanese offshore wind turbine market

©MHI VESTAS OFFSHORE WIND A/S

Participation in the development of wind power generation business

- Agreement signed with Danish company CIP for cooperation in the development of offshore wind power projects in Hokkaido in July, 2020
- Contributing to the growth of offshore wind power generation in Japan through joint development projects in Hokkaido, where it is blessed with favorable wind conditions

CIP
COPENHAGEN INFRASTRUCTURE PARTNERS

CIP: Danish fund management company specializing in investment in the renewable energy infrastructure sector

Our Commitment

Build innovative energy value chain to realize carbon neutral society by 2050

Promote well-balanced and stepwise decarbonization

Contribute to the realization of hydrogen society by technologies

Strengthen cooperation and collaboration with partners

MOVE THE WORLD FORWARD

MITSUBISHI
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