Japan-U.S. Workshop on Sustainable Energy Futures:
Research Directions and their Supportive Environments

Japanese Private Sector Perspectives: Research and Technology for Sustainable Energy among Industries

Technology & Innovation Headquarters
Mitsubishi Heavy Industries, Ltd. (MHI)

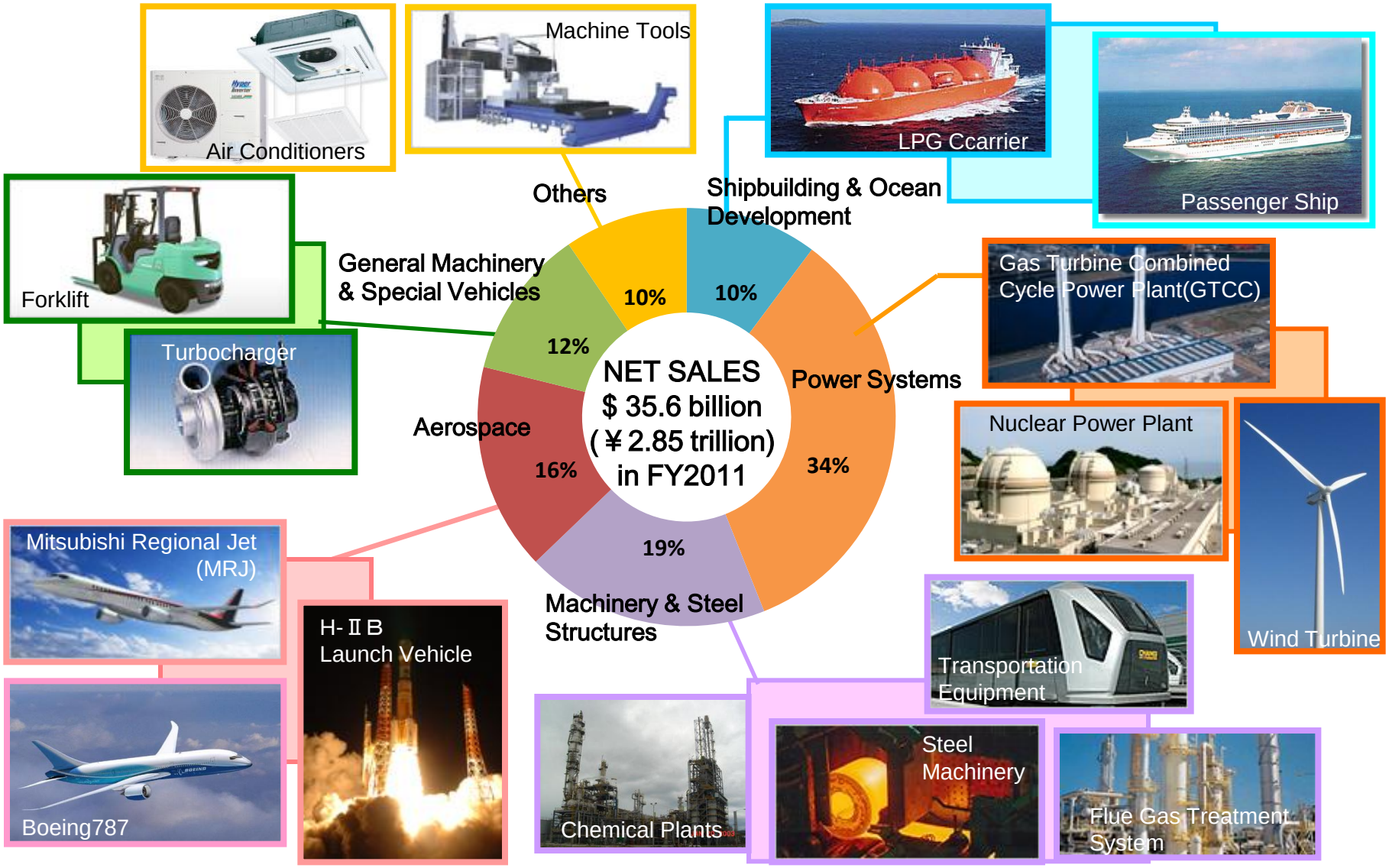
Mamoru Tanaka,
Chief Engineer, Technology & Innovation Headquarters,
Mitsubishi Heavy Industries, Ltd.
Vice President, Japan Society of Mechanical Engineers

MITSUBISHI HEAVY INDUSTRIES, LTD.
Our Technologies, Your Tomorrow

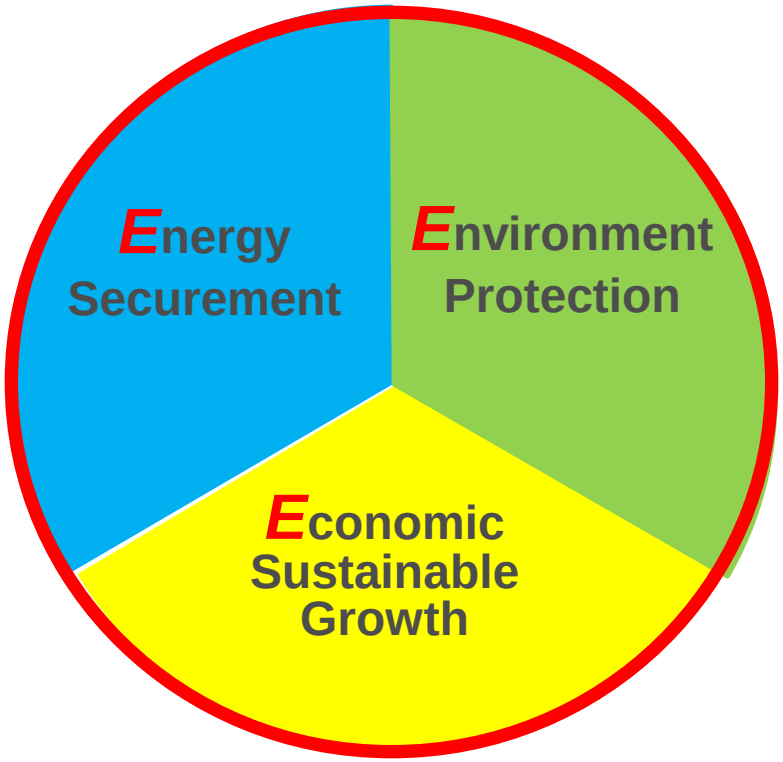
Contents

1. Outline of MHI

三菱重工
技術統括本部



2. Sustainable Energy System



Sustainable Energy System

When a country seeks to construct an energy system that meets its specific needs and will satisfy the three E's of

Energy securement,

Environmental protection, and

sustainable Economic growth,

developing a sustainable energy system is necessary.

Depending on which E is focused on, each country, whether advanced, developing or least developed, has its own interpretation of "sustainable energy." The same is true even on the individual level.

3. Key technologies for three E's

三菱重工
技術統括本部

Key technologies in the creation of an energy system that satisfies the three E's are:

Technologies that support Energy securement

- Enhancement of Thermal Power Generation Efficiency
- Production of Alternative Fuels to Oil
- Wider Use of Renewable Energy through improved cost efficiency
- Safe Use of Nuclear Power

Technologies that support Environmental Protection

- Flue Gas Treatment System
- Carbon-dioxide Capture and Storage (CCS)

Technologies that Support Sustainable Economic Growth

- Low-Carbon Emissions in Final Energy Consumption
- Energy Decentralization & Stabilization System
- Smart City (Smart Community)

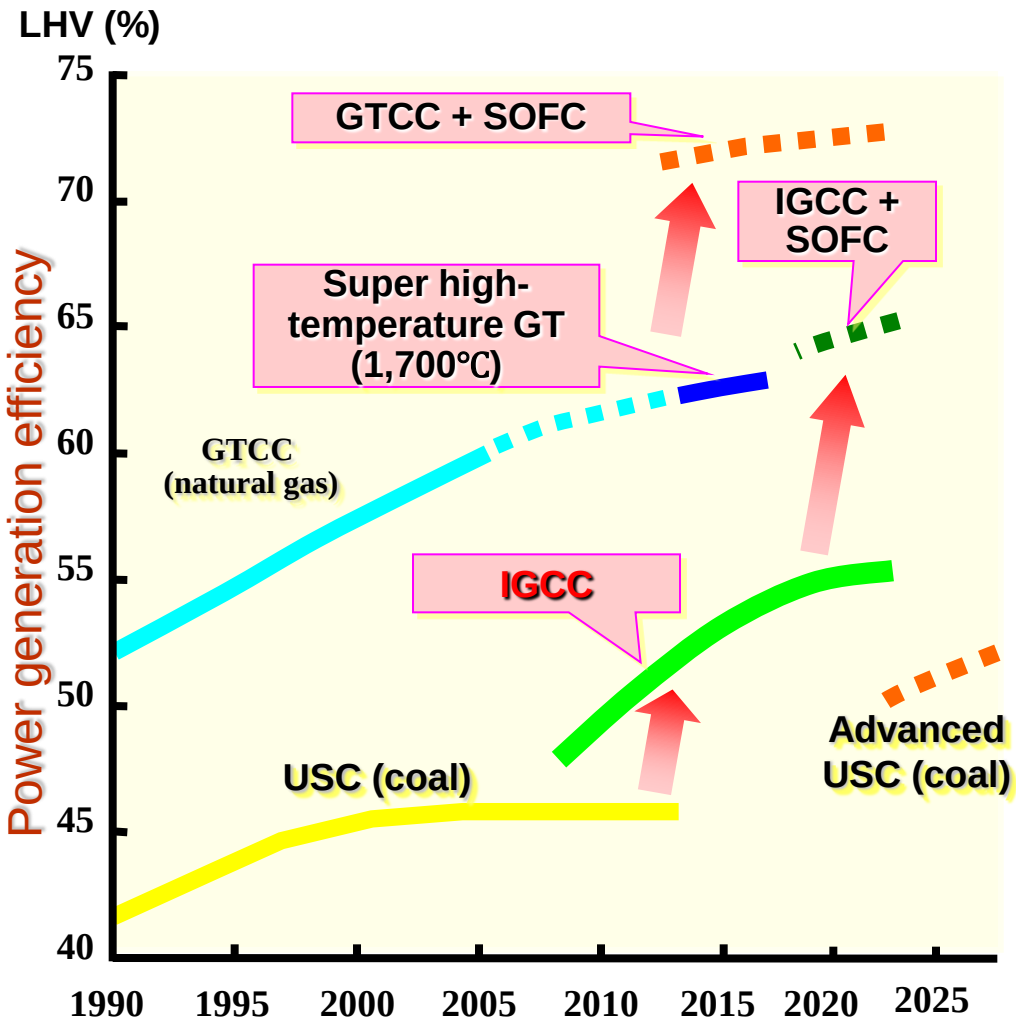
Technologies that support Energy securement

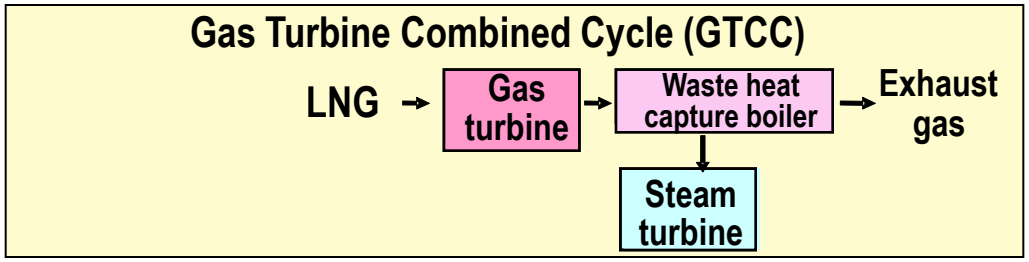
三菱重工
技術統括本部

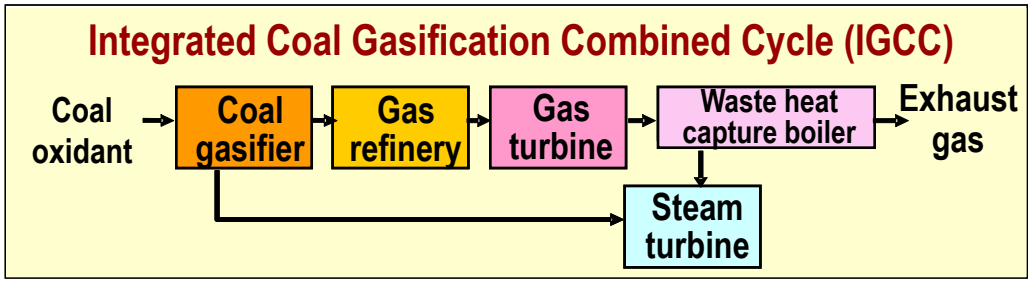
- Enhancement of Thermal Power Generation Efficiency
- Production of Alternative Fuels to Oil
- Wider Use of Renewable Energy through improved cost efficiency
- Safe Use of Nuclear Power

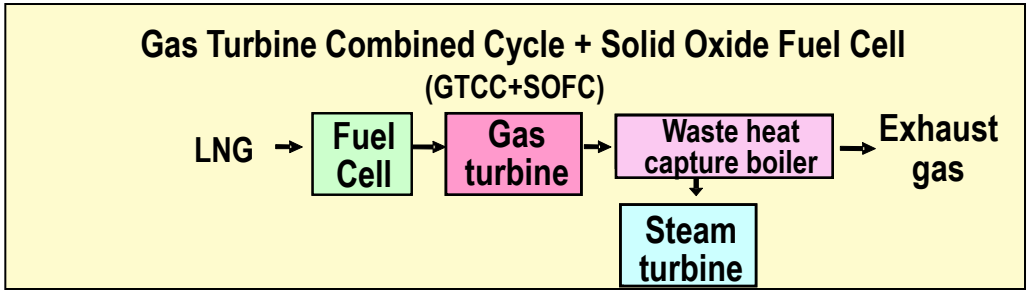
Enhancement of Thermal Power Generation Efficiency

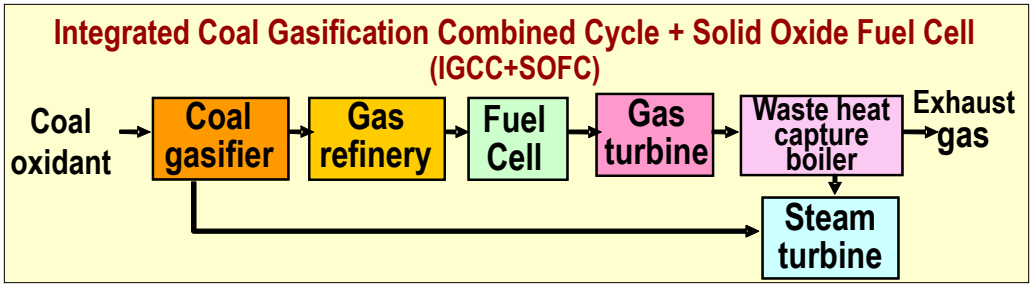
三菱重工
技術統括本部











IGCC: Integrated coal Gasification Combined Cycle
SOFC: Solid Oxide Fuel Cell

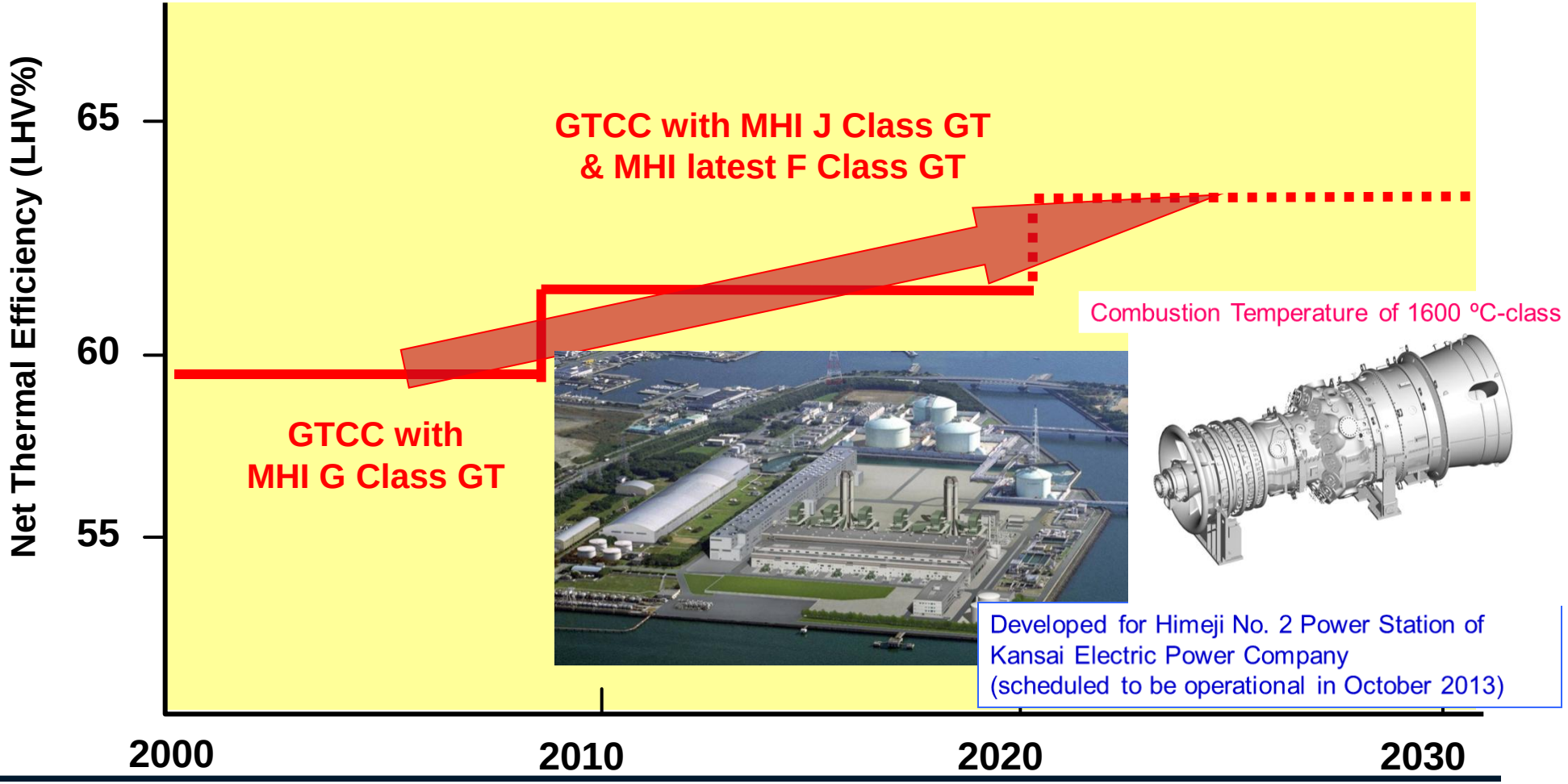
GTCC: Gas Turbine Combined Cycle
USC: Ultra Super Critical pressure Coal-fired plant

Combined-Cycle Gas Power Generation

三菱重工
技術統括本部

- High efficiency combined-cycle with the latest gas turbine technologies substantially reduces CO_2 emissions

Gas Power Generation: Forecasted Efficiency Improvement

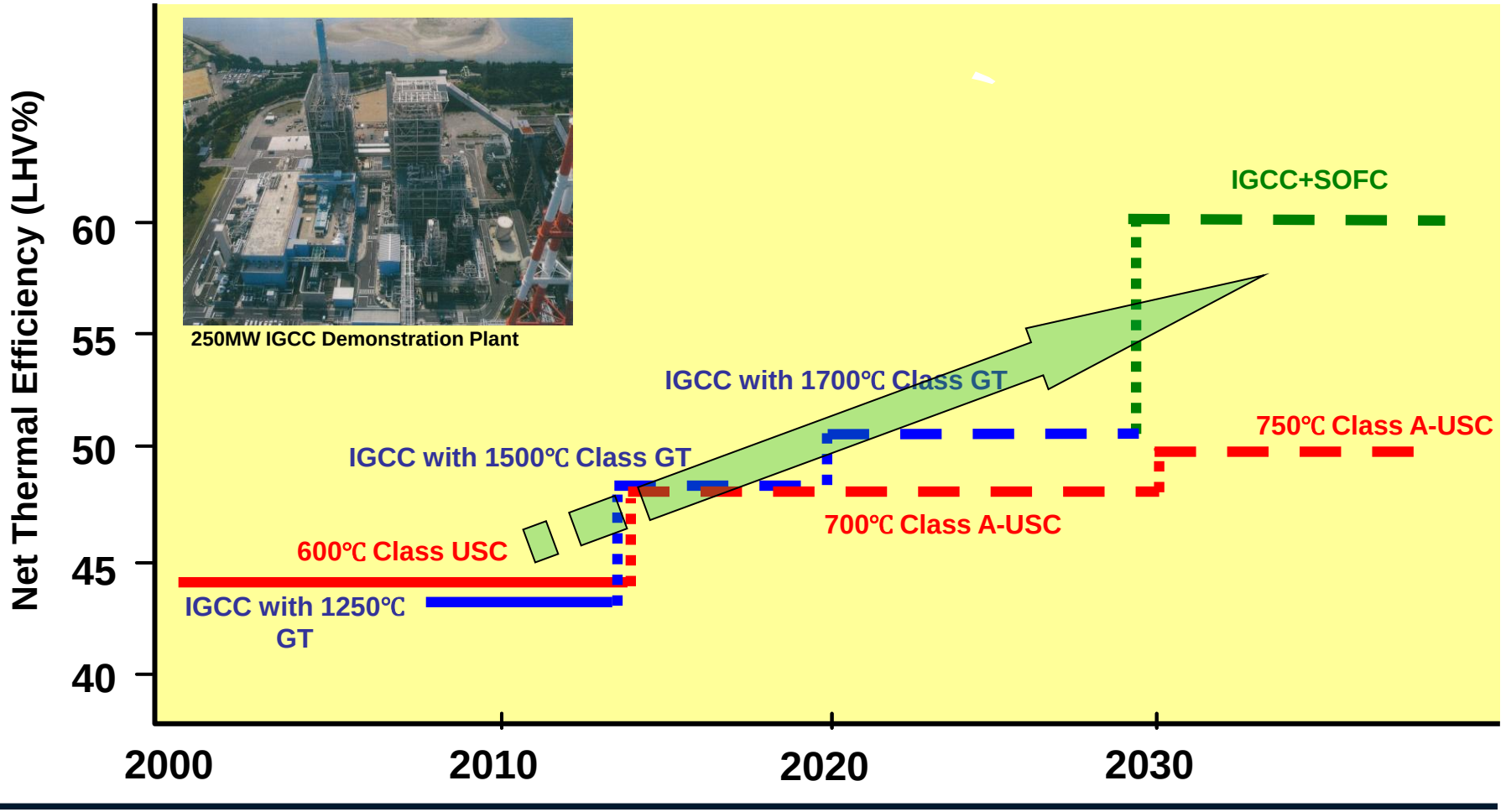


High-Efficiency Coal Power Generation

三菱重工
技術統括本部

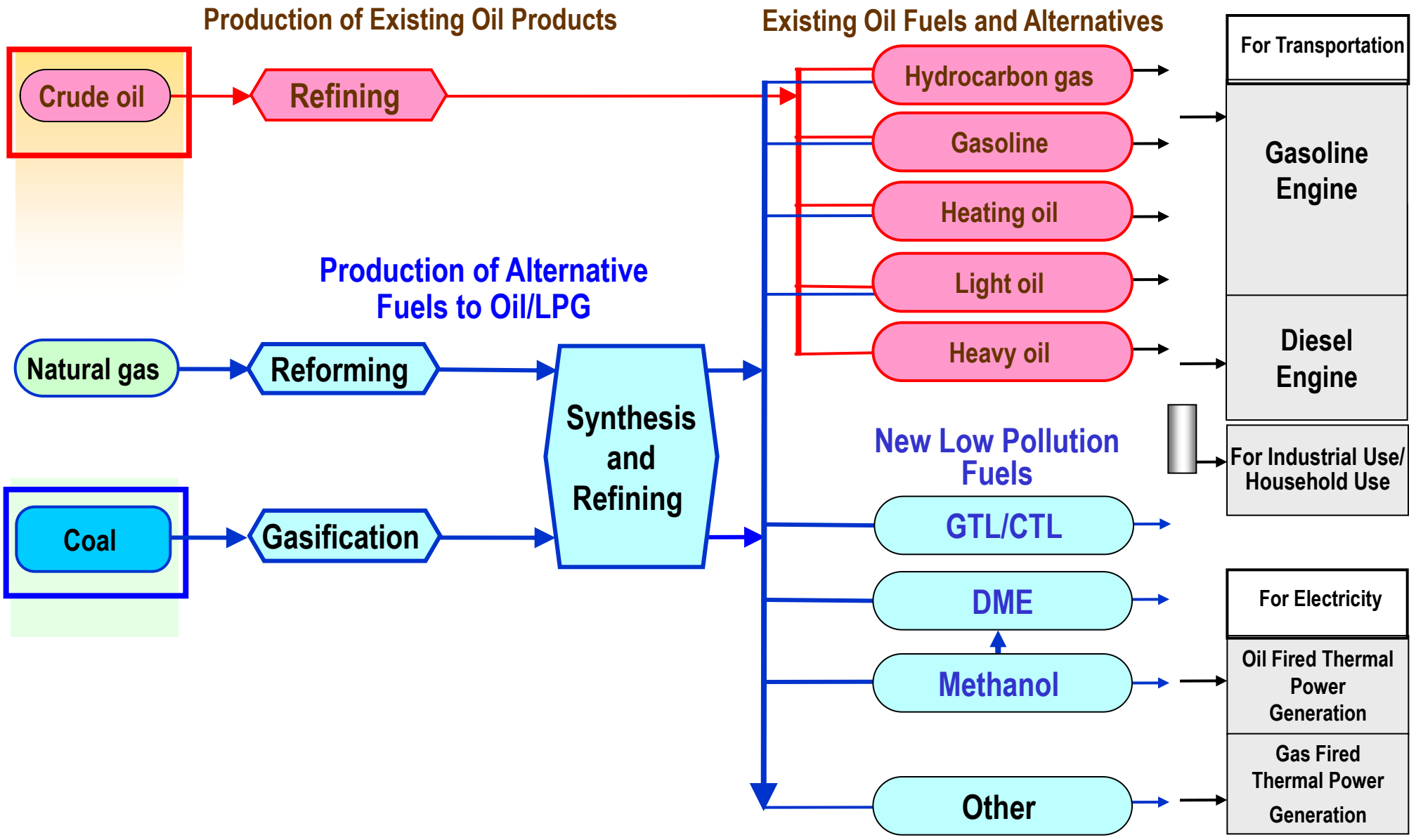
- Abundant coal reserves and low price
- IGCC and A-USC are viable technologies to improve coal use efficiency

Coal Power Generation: Forecasted Efficiency Improvement



Production of Alternative Fuels to Oil

三菱重工
技術統括本部



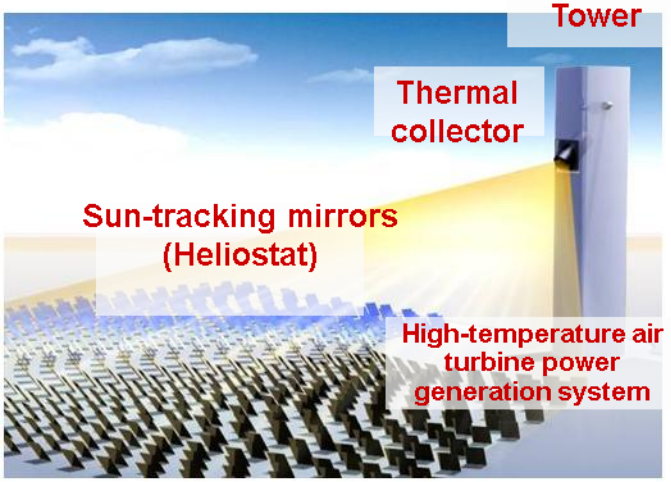
Wider Use of Renewable Energy through improved cost efficiency

三菱重工
技術統括本部

- Developed and applied for energy source diversification, reduction of CO_2 emissions and industry revitalization

Wind

Biomass



Solar Power

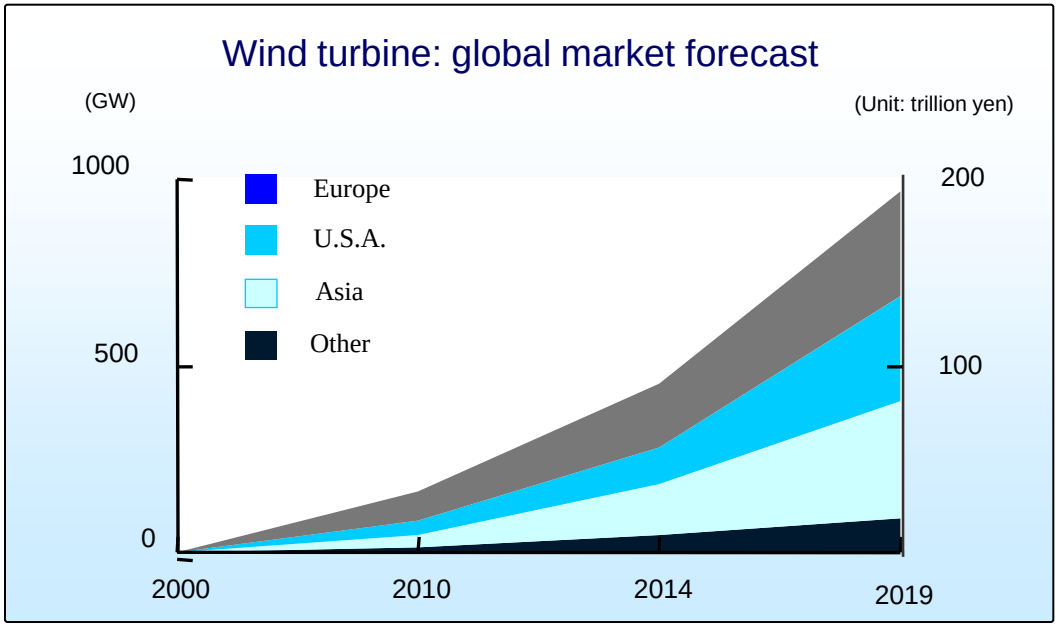
Hydraulic

Geothermal

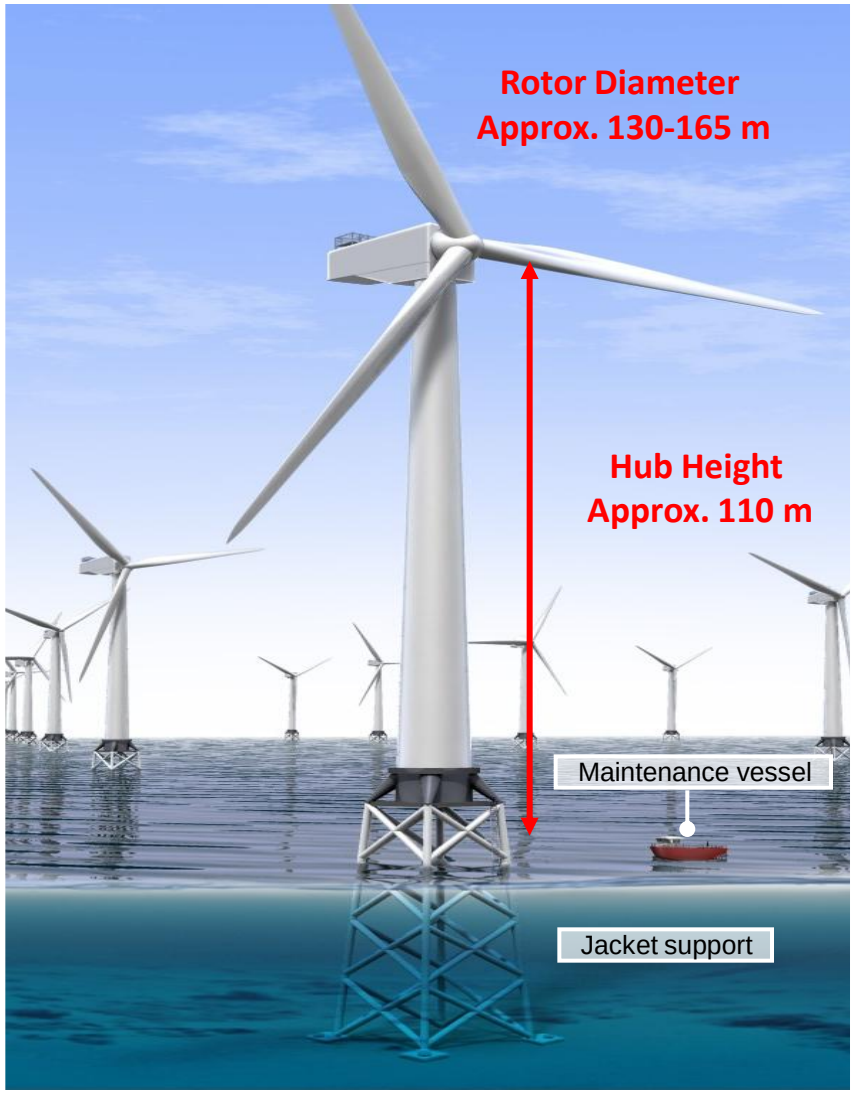
Wind Power Generation

三菱重工
技術統括本部

- Wind power generation:
  most widely-used renewable energy
- Conventional onshore wind turbines and development of offshore facilities for greater power generating capacity



7MW - 11MW Class Wind Turbine

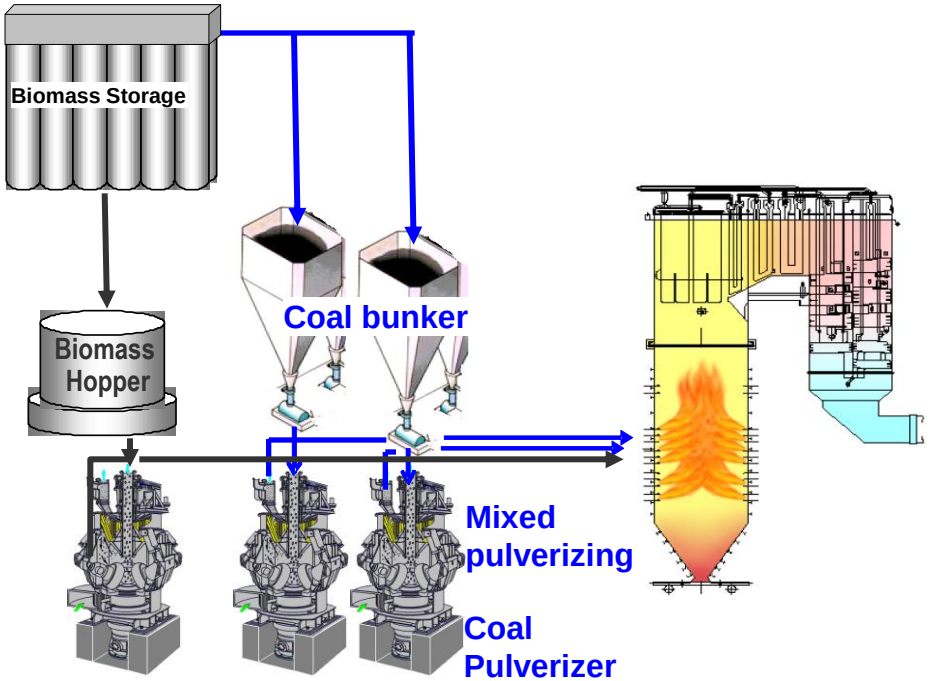


Biomass: Dual Fuel Power Generation with Coal

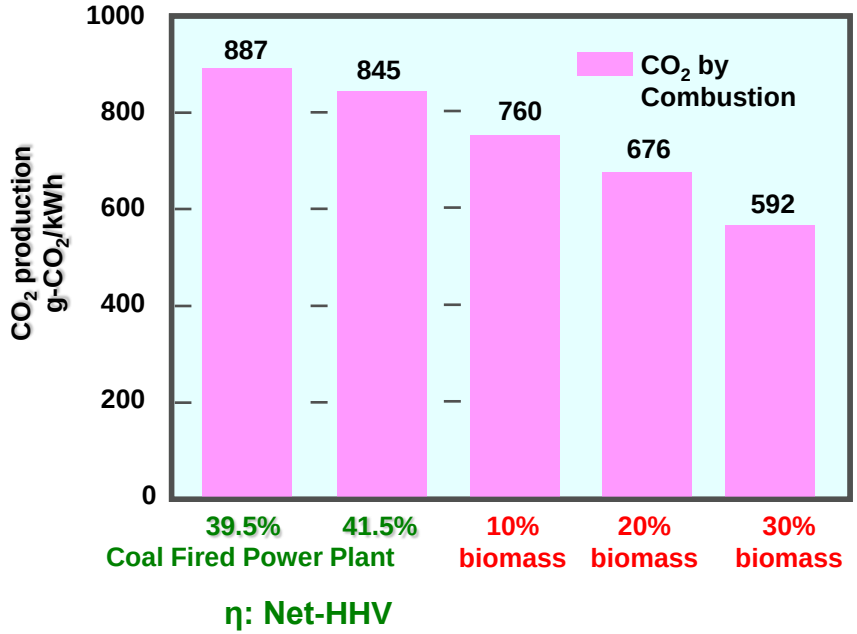
三菱重工
技術統括本部

- Reduction in CO_2 emissions and effective use of lumber materials achieved by combining wood pellets with coal for boiler firing

Coal/biomass co-firing power generation system



Reduction Effect of CO_2 by Biomass co-firing

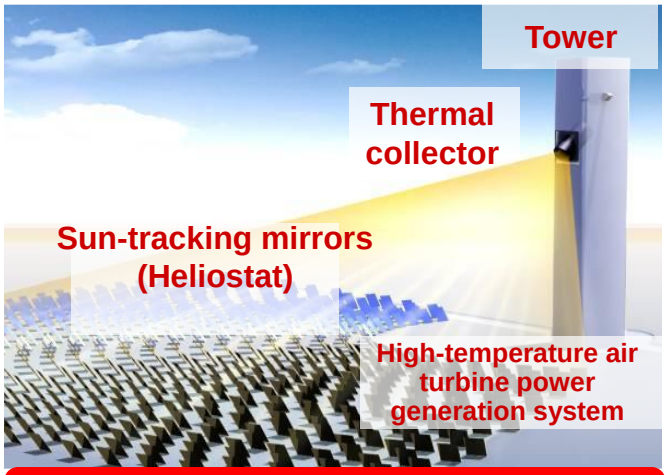


Ref: CRIEPI review No. 44

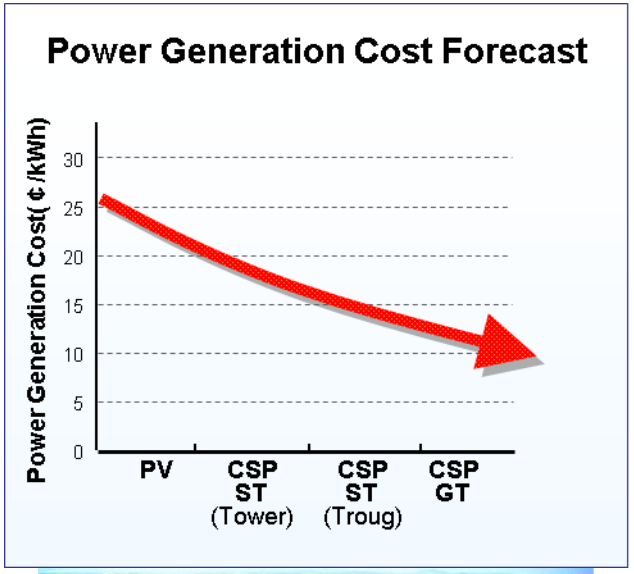
Solar Energy Power Generation

三菱重工
技術統括本部

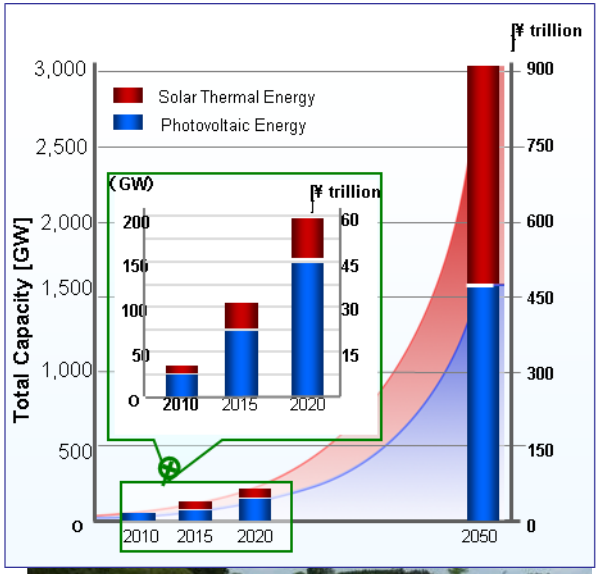
- Photovoltaic modules in growing demand due to preferential policies
- Power generation using concentrated solar thermal energy already put to practical application; development of large-capacity, high-temperature solar air thermal power generation system with high efficiency



High-temperature solar air thermal power generation



Solar steam thermal power generation



Photovoltaic power generation

Geothermal Power Generation

三菱重工
技術統括本部

Characteristics of geothermal power generation

1. Low CO_2 emissions
2. Virtually inexhaustible energy source
3. High availability regardless of the weather

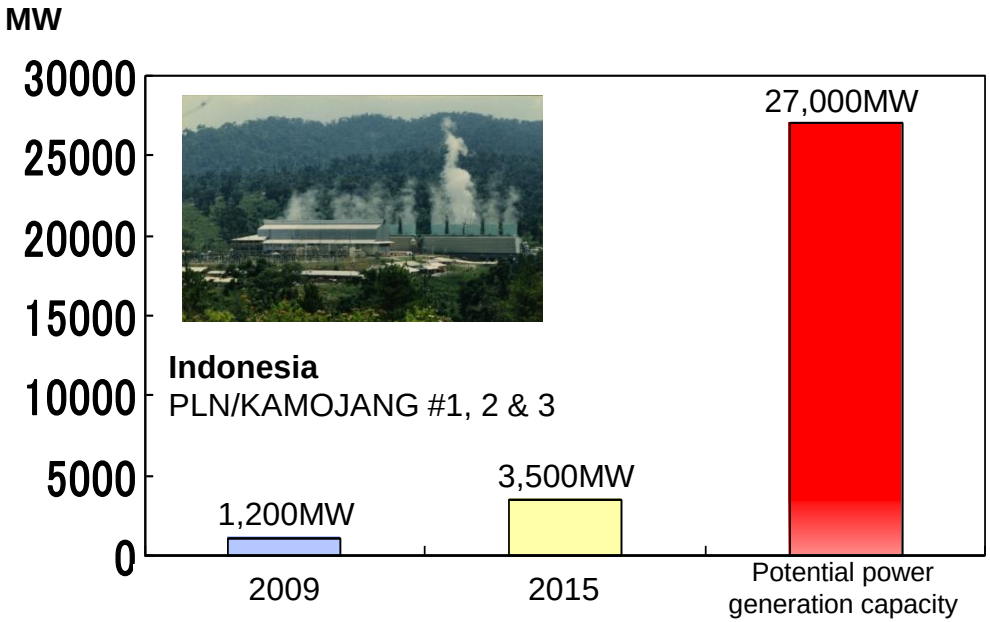
Geothermal resources in Southeast Asia

Indonesia and the Philippines have abundant geothermal resources

Source: 1) Emerging Energy Research

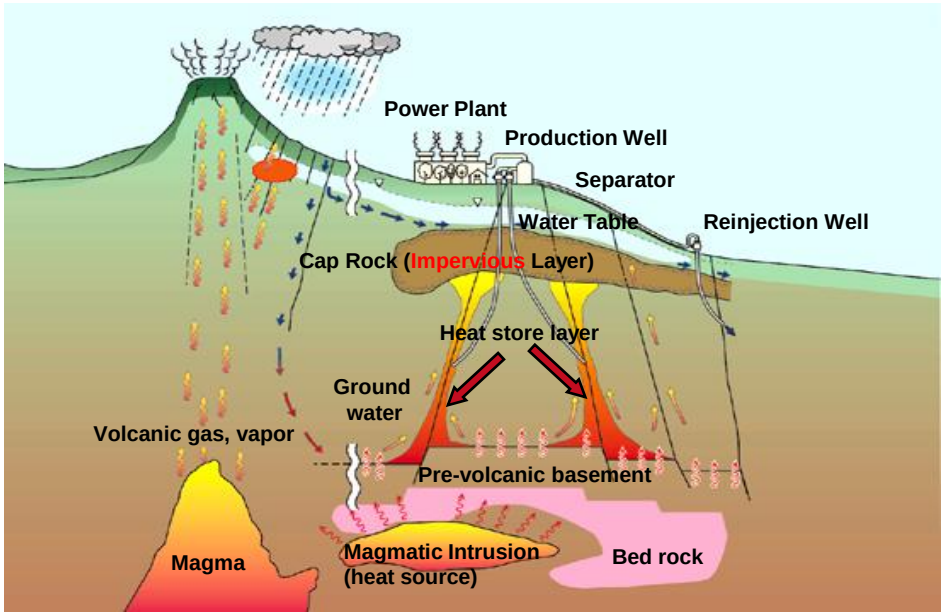
Geothermal potential

Example of geothermal energy potential in Indonesia



In 2009, Indonesia's rate of utilization was only 4.4% of its potential power generation capacity

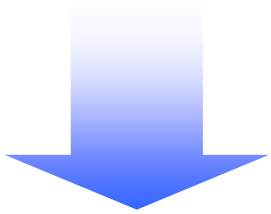
Principles of volcanic geothermal power generation



(Source: Geothermal Energy Serial No. 87, July 1999)

Safe Use of Nuclear Power

- With Japan's dependency on imported resources, diversity including the use of nuclear power is critical in ensuring energy security



Development of nuclear power promoted for peaceful applications

Building on Japan's strength, technology development that further ensures safety and security are actively pursued

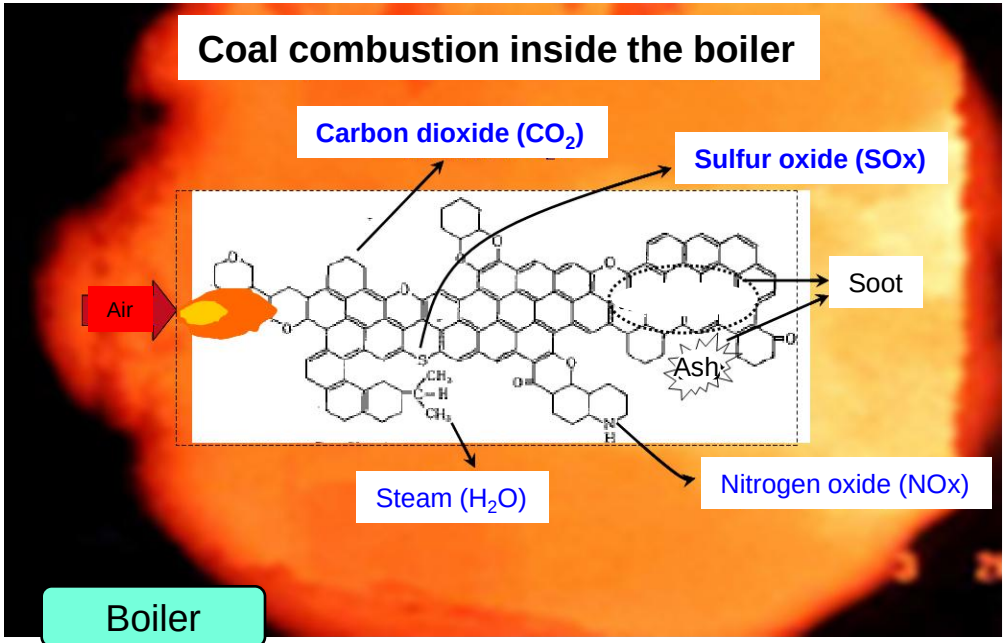
Technologies that support Environmental Protection

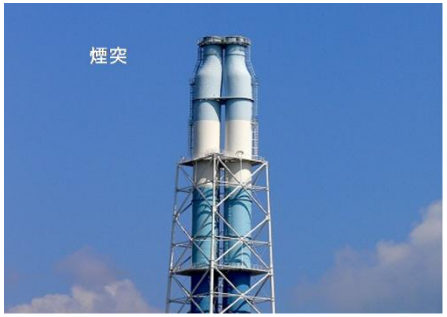
三菱重工
技術統括本部

- Flue Gas Treatment System
- Carbon-dioxide Capture and Storage (CCS)

Flue Gas Treatment System

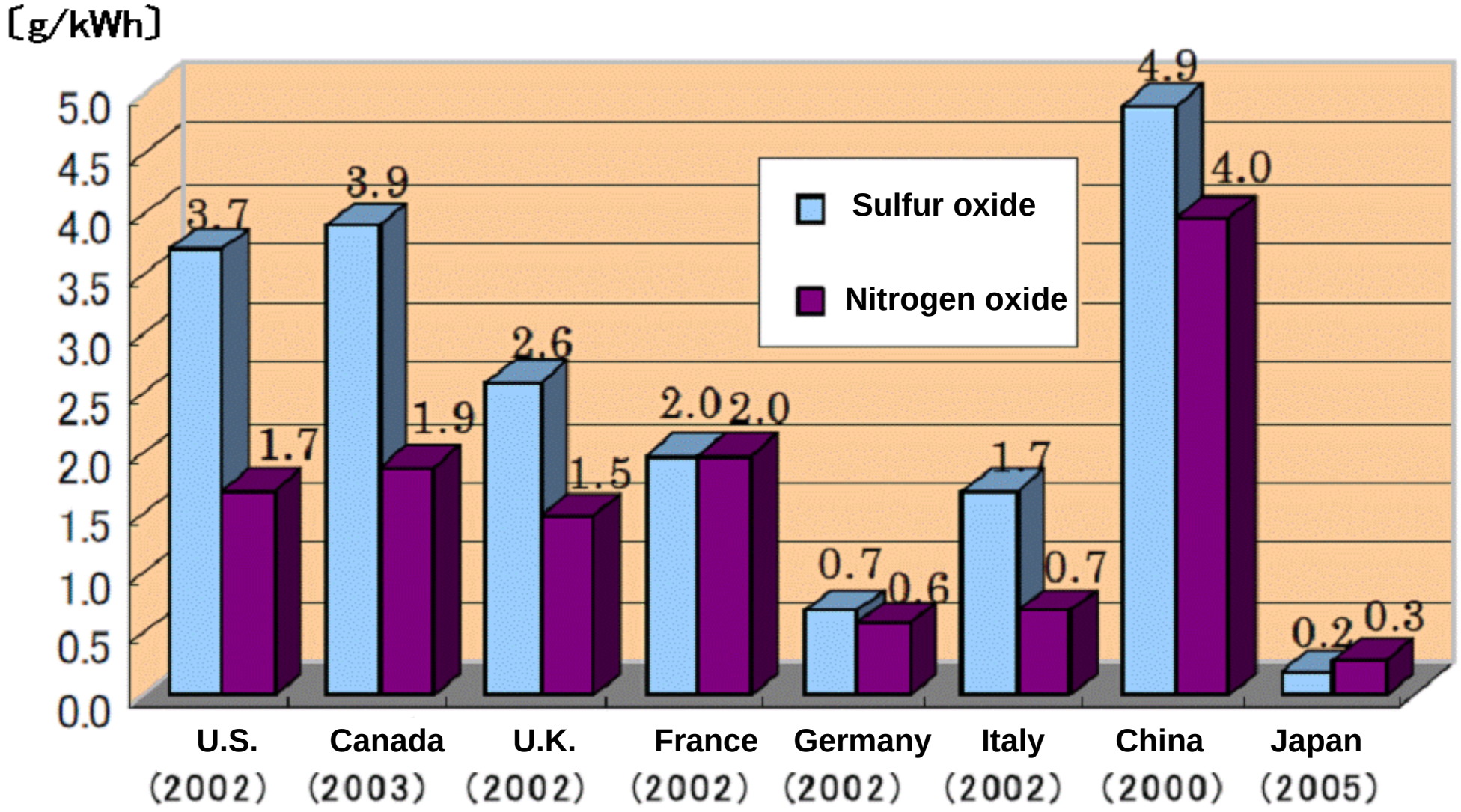
三菱重工
技術統括本部





SOx/NOx Emissions per Power Output in Key Countries

三菱重工
技術統括本部



Source: OECD Environmental Data Compendium2004, Energy Balances of OECD Countries 2002-2003
Japan's data obtained by the Federation of Electric Power Companies

CO_2 Capture and Storage Technology (CCS)

CCS: Carbon-dioxide Capture and Storage

三菱重工
技術統括本部

Fossil fuel → **CO_2 emissions source (thermal power plant)** → **CO_2 separation and capture facility** → **CO_2 transportation (pipeline, etc.)** → **CO_2 storage** Ocean and underground

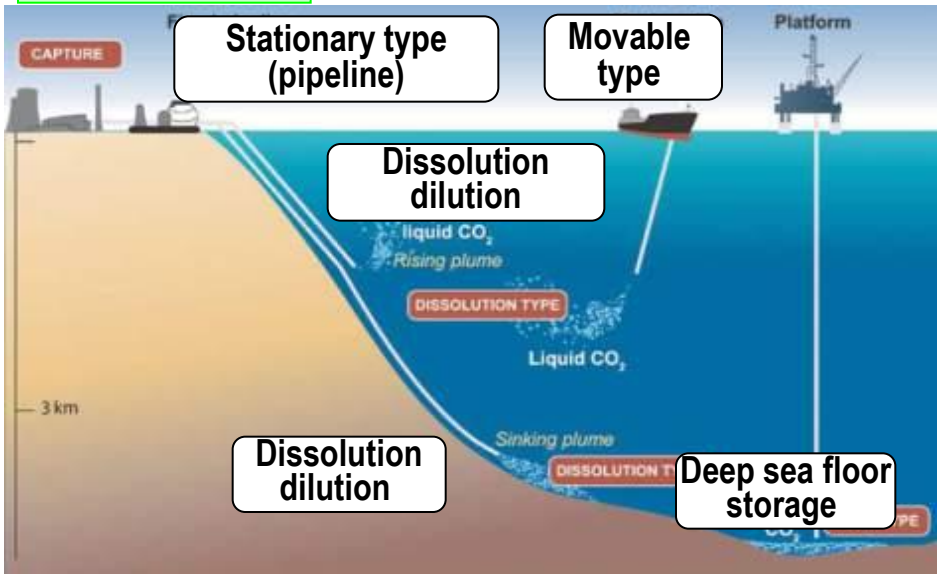
High efficiency IGCC plant

CO_2 capture plant

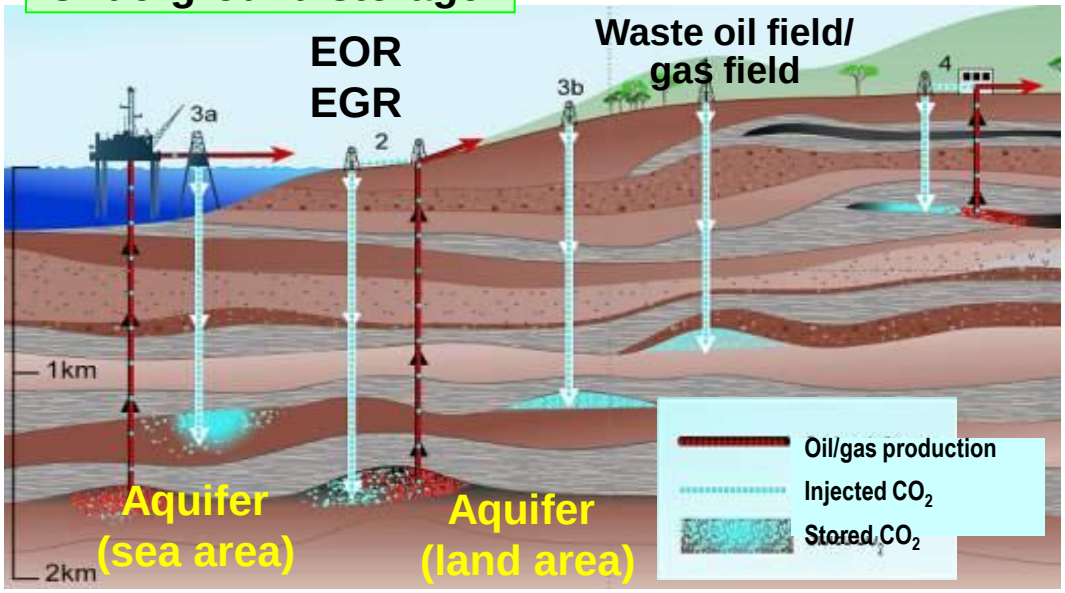
High pressure CO_2 compressor delivered to CCS plant in Algeria

CO_2 Storage Method

Sea storage



Underground storage



Source: Carbon dioxide Capture and Storage, IPCC Special Report 2005.09

CO2 recovery plant

三菱重工
技術統括本部

CO2 recovery plant located at Plant Barry in Alabama, U.S.

MHI, in partnership with Southern Company, a major American electric utility company, launches the world's largest system for CO2 recovery from the flue gases produced by a coal-fired thermal power plant.

http://www.mhi.co.jp/en/discover/graph/news/no167.html

Technologies that Support Sustainable Economic Growth

三菱重工
技術統括本部

- Low-Carbon Emissions in Final Energy Consumption
- Energy Decentralization & Stabilization System
- Smart City (Smart Community)

Low-Carbon Emissions in Final Energy Consumption

三菱重工 技術統括本部

Area	Technology option	Key aspect
Transportation	Improved fuel efficiency	Lightweight vehicles, high-efficiency engines and hybrid vehicles
	Alternative fuels	Oil-alternative fuels (gas, coal, bio, etc.) and electric vehicles
	Modal shift	Public passenger transport service, marine bullet train system and freight railway transport
	IT	Advanced traffic control system and efficient truck transport
Consumer	Heating/cooling system	High-efficiency heat pump, high-performance insulation and natural energy utilization
	Lighting	High-efficiency light transfer and solar power utilization
	Appliances	Advanced use of electricity and late-night power usage (increased nuclear power demand)
	Regional heating/cooling system	Use of low-temperature heat from river water, manufacturing plants and incineration facilities; thermal energy transport/storage/utilization
Industry	Waste heat capture/utilization	Industrial heat pump and power generation using low-temperature waste heat
	Low-carbon manufacturing	Energy-efficient industrial machinery; shift toward use of low-carbon fuels

Product

Electric vehicle

Hybrid forklifts

Lithium-ion batteries

Urban transportation (LRT)

Traffic control system

Energy-efficient carrier

Next-generation regional jet plane

Organic ELs

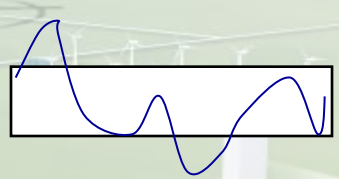
Waste heat capture hot water heat pump

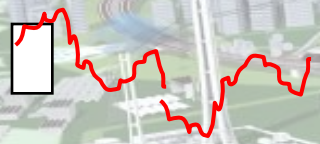
Turbo refrigerator

Energy Decentralization & Stabilization System

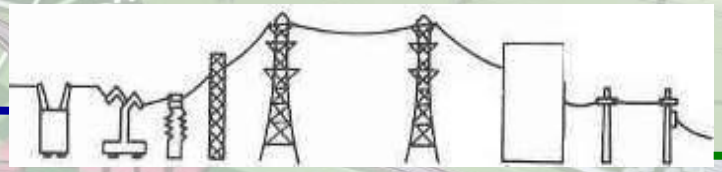
三菱重工
技術統括本部

Lithium-ion Battery
Energy Storage System



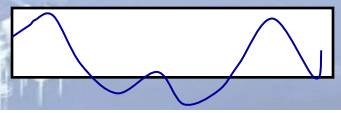


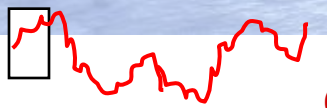
Output of PV



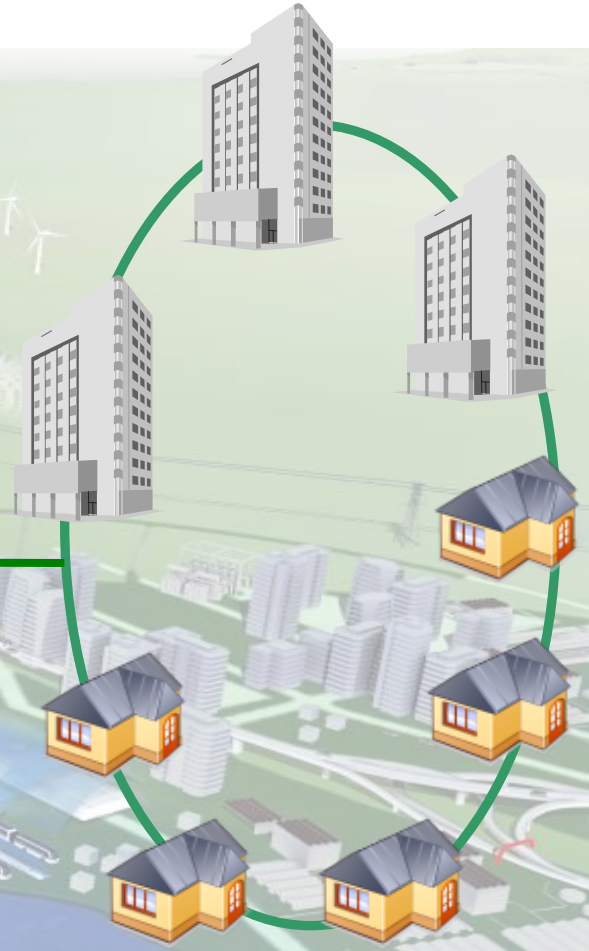
Transmission & Distribution

Lithium-ion Battery
Energy Storage System





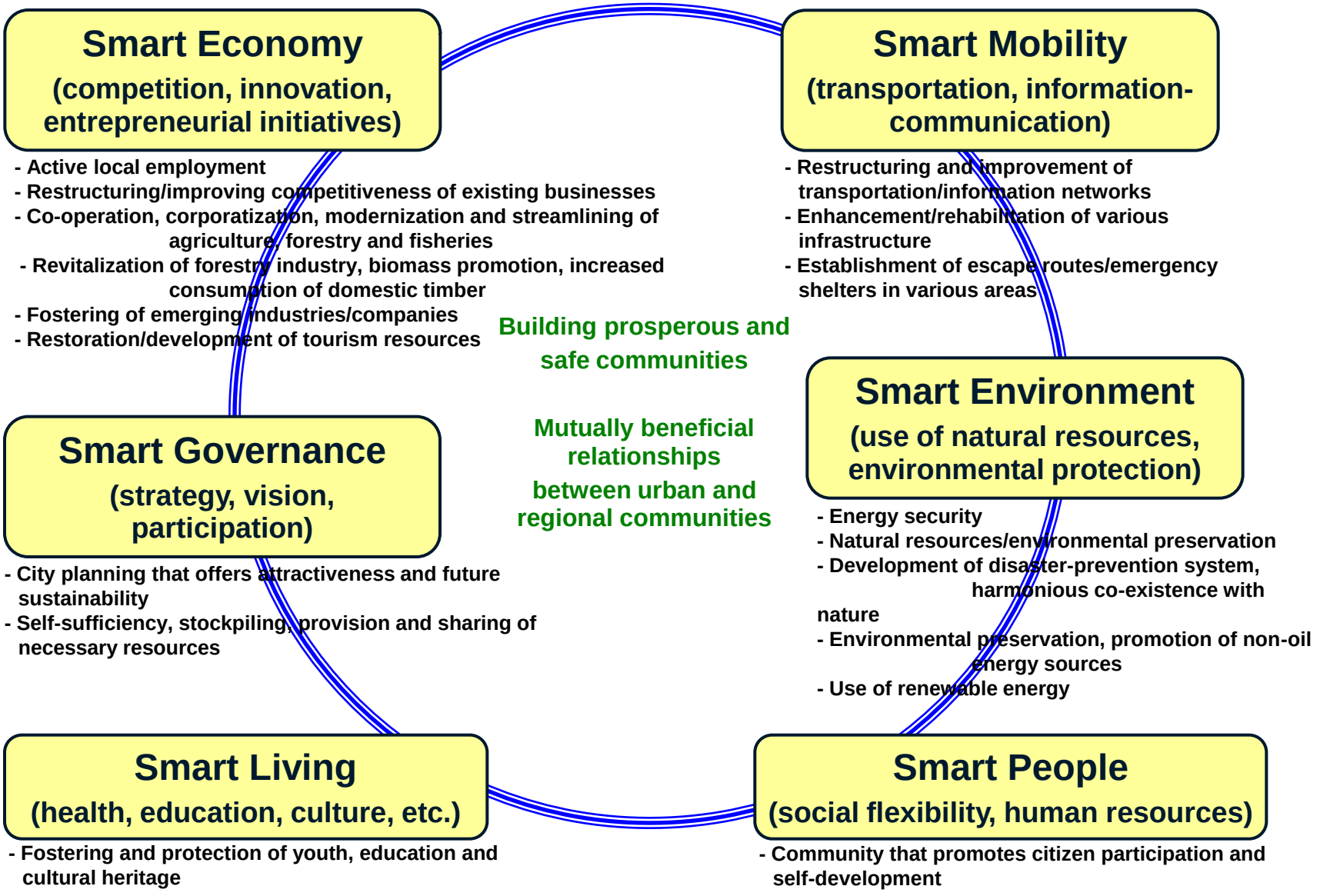
Output of Wind Farm



Community

Smart City/Community

三菱重工
技術統括本部



4. MHI's Upcoming Initiatives

Japan, as part of efforts to recover from the recent disaster, will face the challenge of developing a three-E social energy system.

In building such a social system, while incorporating lessons learned from the disaster experience, technologies to achieve energy efficiency improvement, the diversification and decentralization of energy sources and low-carbon applications are becoming increasingly important.

Partnerships and collaboration with industry, educational institutions and the government play a more crucial role in improving energy efficiency (e.g., GTCC and IGCC for fossil fuels), expanding renewable energy use, operating nuclear power plants with effective safety measures, diversifying energy sources and identifying the optimal energy mix.

MITSUBISHI
HEAVY INDUSTRIES, LTD.

Our Technologies, Your Tomorrow