Advanced Energy Technologies towards “Beyond Zero Society”

September 10, 2020
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CEO, Steam Power Business Unit
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Mitsubishi Power, Ltd.
A new brand:

“MITSUBISHI POWER”

Launched on 1\textsuperscript{st} September, 2020

✓ MHPS (Mitsubishi Hitachi Power Systems) changed its name to Mitsubishi Power
✓ A new corporate logo with the three-diamonds mark adopted

From a power equipment manufacturer
Joint Venture between MHI* and Hitachi

To an Energy Solution Company
100% MHI* owned subsidiary

MHI* : Mitsubishi Heavy Industries, Ltd
Agenda

1. Mitsubishi Power’s Initiatives

2. Driving toward Low-Carbonization
   2-1. Biomass Fired
   2-2. Ammonia Fired
   2-3. Rehabilitation for Performance Improvement
   2-4. Complementing Renewable Energy

3. Efforts toward De-Carbonization
   3-1. IGCC & Gasification Technologies
   3-2. CO$_2$ Removal
1. Mitsubishi Power’s Initiatives
Global Electric Generation and CO₂ Emissions

➢ Toward “Beyond zero society”, CO₂ emissions to be reduced with the SDS as the target.

![Generation and Power Sector CO₂ emissions graph]

- **Generation**
- **Current Policies**
- **STEPS**
- **SDS**

### 1. Mitsubishi Power’s Initiatives

**Current Policies**

- 0
- 2,000
- 4,000
- 6,000
- 8,000
- 10,000
- 2,000
- 4,000
- 6,000
- 8,000
- 10,000
- 2018
- 2025
- 2030
- 2035
- 2040

**Source**: IEA World Energy Outlook 2019

- **STEPS**: Stated Policies Scenario, Scenarios that consider the latest policies of each country.
- **SDS**: Sustainable Development Scenario, Scenario to comply with Paris Agreement* (*Before the Industrial Revolution Pursue efforts to keep the temperature rise from the global average temperature well below 2°C and within 1.5°C*)
Mitsubishi Power aims to grow our business by improving the global environment and the global economy, through low-carbonized and de-carbonized technologies.

### 1. Mitsubishi Power’s Initiatives

#### Low-Carbonization
- High Efficiency GTCC
- Hydrogen mixed GTCC
- Biomass co-firing
- Ammonia co-firing
- Performance improvement

#### De-Carbonization
- Renewable Energy + Battery
- Hydrogen 100% GTCC
- CCS
- CCUS

#### Complementing Renewable Energy
- Grid Stabilization
- Battery Storage • Thermal Storage • P2G
- Emergency Back-up

#### Load Agility
- Improvement of Geothermal
- Emergency Back-up
2. Driving toward Low-Carbonization

2.1 Biomass Fired
2.2 Ammonia Fired
2.3 Rehabilitation for Performance Improvement
2.4 Complementing Renewable Energy
Various Biomass can be fired by using our Biomass fired Boiler technologies.

<table>
<thead>
<tr>
<th>Type</th>
<th>Pulverized</th>
<th>Fluidized Bed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>25MW ~ 1,000MW</td>
<td>~75MW</td>
</tr>
<tr>
<td>Biomass Fuel</td>
<td>Wood Pellet</td>
<td>Wood chip PKS Scrap wood etc.</td>
</tr>
</tbody>
</table>
| Feature       | • Higher efficiency, larger capacity  
• Higher operability  
• Pulverized fuel to be applied  | • Various biomass applicable  
• Efficient burning due to sufficient residence time  
• Mixture of bed material at high temperature  |
| Structure     |                             | CFB (Circulating Fluidized Bed)         
BFB (Bubbling Fluidized Bed) |
2. Driving toward Low-Carbonization  (2.2 Ammonia Fired)

Global Supply Chain

- Ammonia has the advantage of easy transportation in hydrogen utilization.
- Therefore the ammonia combustion is getting attention.

### Production

**Fossil - Hydrogen with CO₂ Capture & Storage**

- CH₄ + 2H₂O → CO₂ + 4H₂

**Hydrogen from renewable source**

- Wind
- Solar
- Hydro

### Transportation

**Hydrogen transportation**

- Liquid Hydrogen / Methylcyclohexane (LH₂ / MCH)
- Ammonia (NH₃)
- Nitrogen gas (N₂)

**Carbon dioxide capture & utilization**

- Synthesis of Fuels / Materials
- Methanol (CH₃OH) / Methane (CH₄)
- Carbon dioxide

### Demand

- Power
- Mobility
- Industry
- Building

- Green H₂
- Blue H₂
Merits & Tasks

Ammonia combustion is applicable conventional technology.

Merits

✓ Easy handling as H₂ carrier
  (a) Utilization of existing facilities such as production, transportation and storage
  (b) Easy liquidation
  (c) Direct combustion

Tasks

✓ Availability of existing combustion technology
✓ Material handling and storage safety.
  (a) Safety measures around burner.
  (b) Following related laws and regulations. (Fire law, High pressure gas law, etc…)
High availability and high unit heat rate should be maintained throughout plant operation.

### Boiler Efficiency Improvement

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH outlet Gas Temp. (deg.C)</td>
<td>-10°C*</td>
</tr>
<tr>
<td>Increased Efficiency (%) (relative)</td>
<td>+0.5%*</td>
</tr>
<tr>
<td>CO₂ Reduction (%) (relative)</td>
<td>-0.5%*</td>
</tr>
</tbody>
</table>

### Performance Improvement of Aged Unit

- **Abradable Seals**
- **Active Clearance Control (ACC) Seals**
- **High Efficiency Reaction Blades**
- **Direct Lubrication Bearing**

**Detail**

- **Rotor fin**
- **Abradable coating**

**TB Effi.** approximately 1.5%*

*Note: *Actual efficiency improvement depends on a scope of application with detailed engineering study.
Thermal power generation control needs improvement to complement renewable energy.

1) Increased agility, 2) Lowering Minimum load, 3) Expansion of mill band operation.

### Image of supply/demand situation on the lowest demand day (such as a sunny day in May) (*1)

<table>
<thead>
<tr>
<th>Supply</th>
<th>Noon</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant power sources (Nuclear, Hydro, Geothermal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind, Biomass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Thermal Power Control

1) **Increased agility**
   - Latest control technology

2) **Expansion of Mill band operation**
   - Modification of Mill

3) **Lowering Minimum load**
   - Latest combustion technology
   - Thermal Energy Storage System

➢ For further improvement, “Thermal Energy Storage System” being developed.
➢ Utilizes recovered boiler waste heat to assist rapid load change and save fuel.
3. Efforts toward De-carbonization

3-1. IGCC & Gasification Technologies
3-2. CO₂ Removal
Gasification Technologies can be applied to various fields such as Power Generation, Chemical Synthesis, and Hydrogen Production which are technologies toward a future decarbonization.
IGCC Technology

- IGCC is a power generation system to achieve higher efficiency, and there are two units under operation and two units under commissioning.

**What is IGCC?**

**Integrated coal Gasification Combined Cycle**

Higher efficiencies and reduced CO₂ emissions through a coal gasification process coupled with a combined cycle (CC) system.

**Combination Power Generation**

(Combination of Brayton & Rankine Cycles)

- Gasifier
- Steam Turbine
- Combustor
- Gas Turbine
- HRSG
- Clean up
- Air Comp.

**Fukushima Revitalization Power**

- 543MW Hirono (COD : 2021)
- 543MW Nakoso (COD : 2020)

**Osaki CoolGen Corp.**

Osaki CoolGen Project (Demo. 2017-)

**Joban Joint Power Co. LTD**

Nakoso #10 (Demo. 2007-, Commercial 2013-)

Higher efficiencies and reduced CO₂ emissions through a coal gasification process coupled with a combined cycle (CC) system.
IGCC has benefits such as Environmental Advantages and Coal Flexibility.

Higher Efficiency and Least Environmental Impact

Coal-fired USC power plant Benchmark (steam 600°C)

Merits of IGCC

1. The gasifier unit turns coal into Syngas and molten ash, which collects on the inside wall by way of centrifugal force

2. The molten ash is then drained from the gasifier into a water bath

⇒ This process allows IGCC to minimize gasifier size while utilizing a wide range of coal types
Fukushima Revitalization Power IGCC Projects

- Mitsubishi Power is constructing two commercial plants: the new Nakoso & the Hirono IGCC Powers Projects.

**Major Specification**

- **Output**: 543 MW (gross) × 2
- **Gasifier**: Air-blown Dry Feed 2-stage Entrained Flow
- **Gas Clean-Up**: MDEA (Methyl Di-ethanol Amine)
- **Gas Turbine**: M701F GT (1 on 1)
- **Plant Efficiency**: 48% (LHV, net)

**Schedule**

- 2014. 5: EIA (Environmental Impact Assessment) Started
- 2016. 9: EIA Completed / Permit Obtained
- 2016.10: Site Mobilization Started
- 2016.12: EPC Full Turn-Key Contracts Awarded
- 2017. 4: Construction Started
  - Fabrication of Main Equipment Started
- Commercial Operation (Scheduled)
  - 2020: Nakoso IGCC
  - 2021: Hirono IGCC

Source: Nakoso IGCC Power GK website
Osaki CoolGen Project

➢ Second Step of Osaki CoolGen Project using oxygen-blown gasification technology is undergoing with CO₂ capture demonstration.

Major Specification

- **Output**: 166 MW (gross)
- **Gasifier**: Oxygen-blown Single-chamber Two-stage Entrained-flow
- **Gas Clean-Up**: MDEA (Methyldiethanol Amine)
- **Gas Turbine**: H-100 GT (1 on 1)
- **Plant Efficiency**: 44.0% (LHV, net)

Project Schedule

- **Construction Started**: March 2013
- **Demo. Ope. Started**: March 2017 (First step)
- **December 2019 (Second step)**

Subsidized by the Ministry of Economy, Trade and Industry (METI) since FY2012 and supported by New Energy and Industrial Development Organization (NEDO) since FY2016.

(*1) Demo. Operation of Second step has started in FY 2019

(*2) Demo. Operation of Third step will start in FY 2021

(*3) CO₂ Transportation and Storage are outside of the Osaki CoolGen Project.
Gasification Technologies can generate both Power and Chemical highly efficiently through optimized 2 operating modes according to power demand.

Mitsubishi Power can optimize the balance between Power and Chemical.

Operating Mode

Gasifier 100% Load
Constant

Off peak

On peak

Off peak

GT 100% Load

Chemicals

Electricity

GT 65% Load

AGR

Steam

Syngas

Char

Recycle System

GTCC

Power Block

Chemical Process

3D model of Gasifier

Coal Feed System
Adaptability for CO2 Capture

- Mitsubishi Group can provide CO₂ capture technologies for both USC and IGCC.
- Our technologies will contribute as a future decarbonization technology.

### Technology Application for CO₂ Capture

<table>
<thead>
<tr>
<th>Process</th>
<th>Footprint for CO₂ Capture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>USC</strong></td>
<td></td>
</tr>
<tr>
<td>Post-Combustion CCS</td>
<td>![Diagram of USC Post-Combustion CCS]</td>
</tr>
<tr>
<td>Air, Coal, Boiler</td>
<td>ESP, FGD, Atmospheric Pressure CO₂ 15%, CO₂ Removal, CO₂</td>
</tr>
<tr>
<td>Press.: 0.1MPa</td>
<td>CO₂: 15vol%</td>
</tr>
<tr>
<td>approx. 500m</td>
<td></td>
</tr>
<tr>
<td><strong>IGCC</strong></td>
<td></td>
</tr>
<tr>
<td>Pre-Combustion CCS</td>
<td>![Diagram of IGCC Pre-Combustion CCS]</td>
</tr>
<tr>
<td>Air, Coal, Gasifier</td>
<td>CO, Shift, High Pressure CO₂ 30~60%, AGR with CO₂ Removal, CO₂</td>
</tr>
<tr>
<td>Press.: 2-3MPa</td>
<td>CO₂: 60vol%</td>
</tr>
<tr>
<td>approx. 400m</td>
<td></td>
</tr>
</tbody>
</table>

Less Plant Area
Commitment to Ensuring Sustainability

For sustainable energy infrastructure, regional differences necessitate different roadmaps.

Coal can be one of the energy resources in our future.
Mission Statement of “Mitsubishi Power”

“Mitsubishi Power is creating a future that works for people and the planet by developing innovative power generation technology and solutions to enable the decarbonization of energy and deliver reliable power everywhere.”
ご清聴ありがとうございました。

Part of the technologies in this presentation is based on results obtained from a project subsidized by the New Energy and Industrial Technology Development Organization (NEDO).
MOVE THE WORLD FORWARD