MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Energy, Sustainability & Climate Task Force
Decarbonization Solutions for Industry Sector

Mitsubishi Power's
Decarbonization Solutions

Mitsubishi Power, Ltd.

September 29, 2022. Jakarta, Indonesia

MITSUBISHI POWER

Contents

1. PT. Mitsubishi Power Indonesia

2. Energy Transition for Indonesia

3. Mitsubishi Power Technology

4. Importance of Maintenance

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1. **PT. Mitsubishi Power Indonesia**
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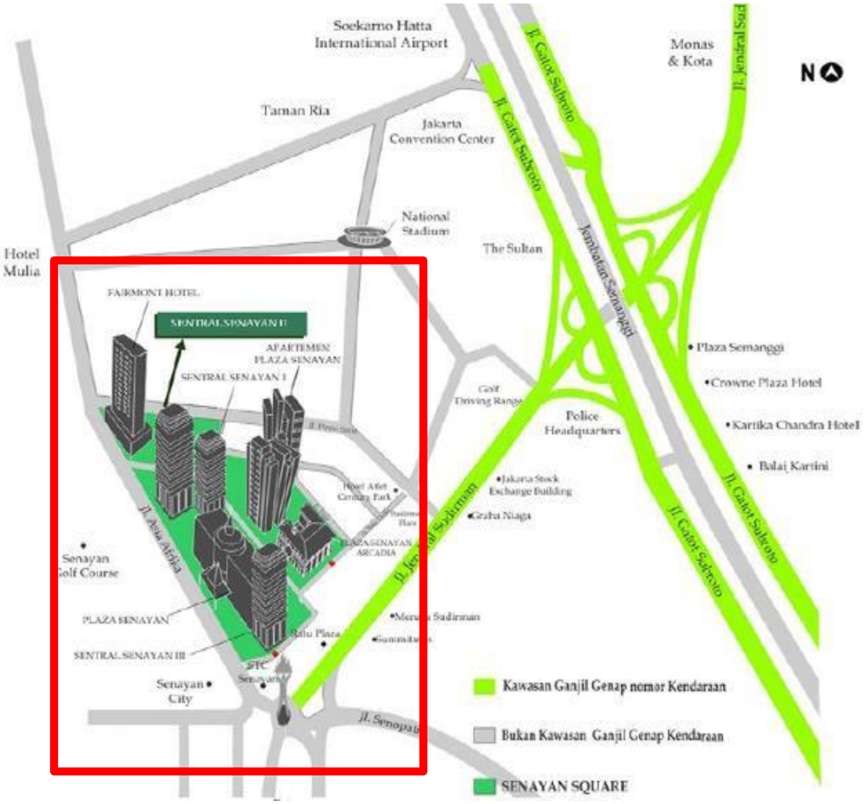
PT. Mitsubishi Power Indonesia Overview

MITSUBISHI POWER

- **Company Name : PT. Mitsubishi Power Indonesia (MPW-IDN)**

- **Establishment : August 2008**

- **Location : Jakarta (Senayan area)**



- **Number of Employee (as of May 2022):**

National Staff	39
Foreign Staff	1
Expats from MHI	10
Total	50

- **Business:**
  New Sales, Marketing & After-Sales for GTCC, Coal Fired Power Plant including AQCS and Geothermal

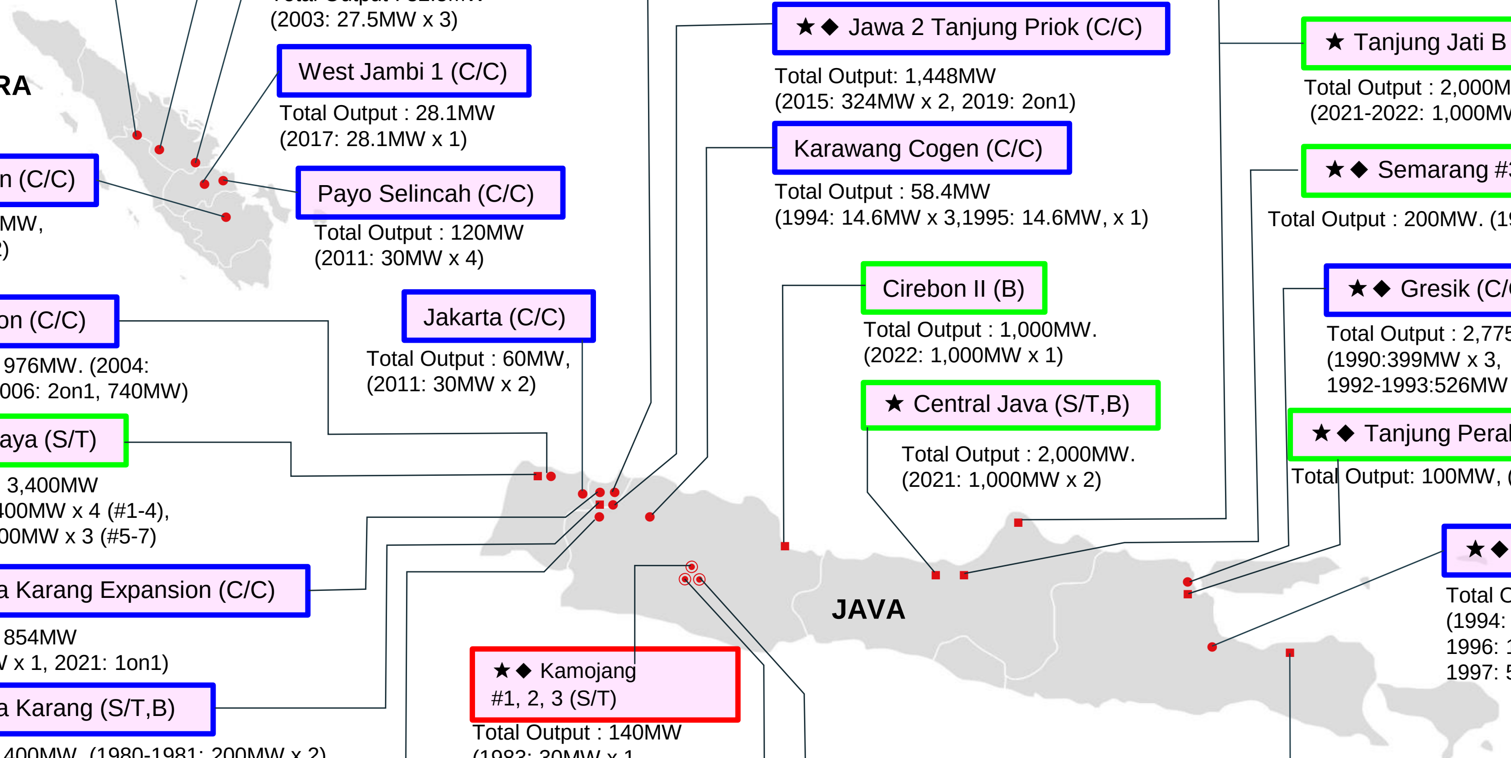
Mitsubishi Power's Footprint in Indonesia

MITSUBISHI POWER

Total Supply Capacity in Indonesia: 18GW by 2022

Gas Turbine
Geothermal
Coal Fired

★: Full Turn Key/Turn Key
◆: PLN Group



Central Sumatra (C/C)
Total Output : 60MW
(2011: 30MW x 2)

◆ Sumatra Keramasan (C/C)
Total Output : 80MW (2013: 1on1 x 2)

Betara (C/C)
Total Output : 82.5MW
(2003: 27.5MW x 3)

West Jambi 1 (C/C)
Total Output : 28.1MW
(2017: 28.1MW x 1)

◆ Keramasan (C/C)
Total Output : 64MW,
(2011: 32MW x 2)

Payo Selincah (C/C)
Total Output : 120MW
(2011: 30MW x 4)

★◆ Cilegon (C/C)
Total Output : 976MW. (2004: 238MW x 2, 2006: 2on1, 740MW)

Jakarta (C/C)
Total Output : 60MW,
(2011: 30MW x 2)

★◆ Suralaya (S/T)
Total Output : 3,400MW
(1985-1989: 400MW x 4 (#1-4),
1997-1998: 600MW x 3 (#5-7)

★◆ Muara Karang Expansion (C/C)
Total Output : 854MW
(2016: 354MW x 1, 2021: 1on1)

★◆ Muara Karang (S/T,B)
Total Output : 400MW (1980-1981: 200MW x 2)

★◆ Muara Karang Repowering (C/C)
Total Output : 1,234MW (2007: 270MW x 2, 2011: 2on3, 694MW)

★◆ Kamojang #1, 2, 3 (S/T)
Total Output : 140MW
(1983: 30MW x 1,
1987: 55MW x 2)

◆Darajat #1 (S/T)
Total Output : 55MW
(1994: 55MW x 1)

★◆ Tanjung Priok (C/C)
Total Output : 740MW
(2008: 270MW x 2, 2012: 2on1, 740MW)

★◆ Jawa 2 Tanjung Priok (C/C)
Total Output: 1,448MW
(2015: 324MW x 2, 2019: 2on1)

Karawang Cogen (C/C)
Total Output : 58.4MW
(1994: 14.6MW x 3,1995: 14.6MW, x 1)

Cirebon II (B)
Total Output : 1,000MW.
(2022: 1,000MW x 1)

★ Central Java (S/T,B)
Total Output : 2,000MW.
(2021: 1,000MW x 2)

Darajat #2/3 (S/T)
Total Output : 191MW
(1998: 81MW x 1,2007: 110MW x 1)

★ Tanjung Jati B #3/4 (B)
Total Output : 1,320MW
(2012: 660MW x 2)

★ Tanjung Jati B #5/6 (B)
Total Output : 2,000MW
(2021-2022: 1,000MW x 2)

★◆ Semarang #3 (S/T)
Total Output : 200MW. (1983: 200MW x 1)

★◆ Gresik (C/C)
Total Output : 2,775MW
(1990:399MW x 3,
1992-1993:526MW x 3)

★◆ Tanjung Perak #3/4 (S/T, B)
Total Output: 100MW, (1978: 50MW x 2)

★◆ Grati (C/C)
Total Output : 1,673.6MW
(1994: 134.1MW x 6,
1996: 114MW x 3,
1997: 527MW x 1)

★ Paiton 3 (S/T,B)
Total Output : 866MW (Gross)
(2012: 866MW x 1)

Mitsubishi Power's Footprint in Indonesia (Industries)

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Mobil (ARUN LNG) @Ace Utara
(4 units x 181t/h, 1976)
(2 units x 181/h, 1983)
(1 unit x 181t/h, ?)

Pertamina @Lawi Lawi
(3 units x17t/h, 1982)

Kertas Nusantara (PTKK) @Mangkajang
(1 unit x 27MW, 1996)

Badak NGL @Bontang
(6 units x 295t/h, 1975)
(5 units x 294t/h, 1981)

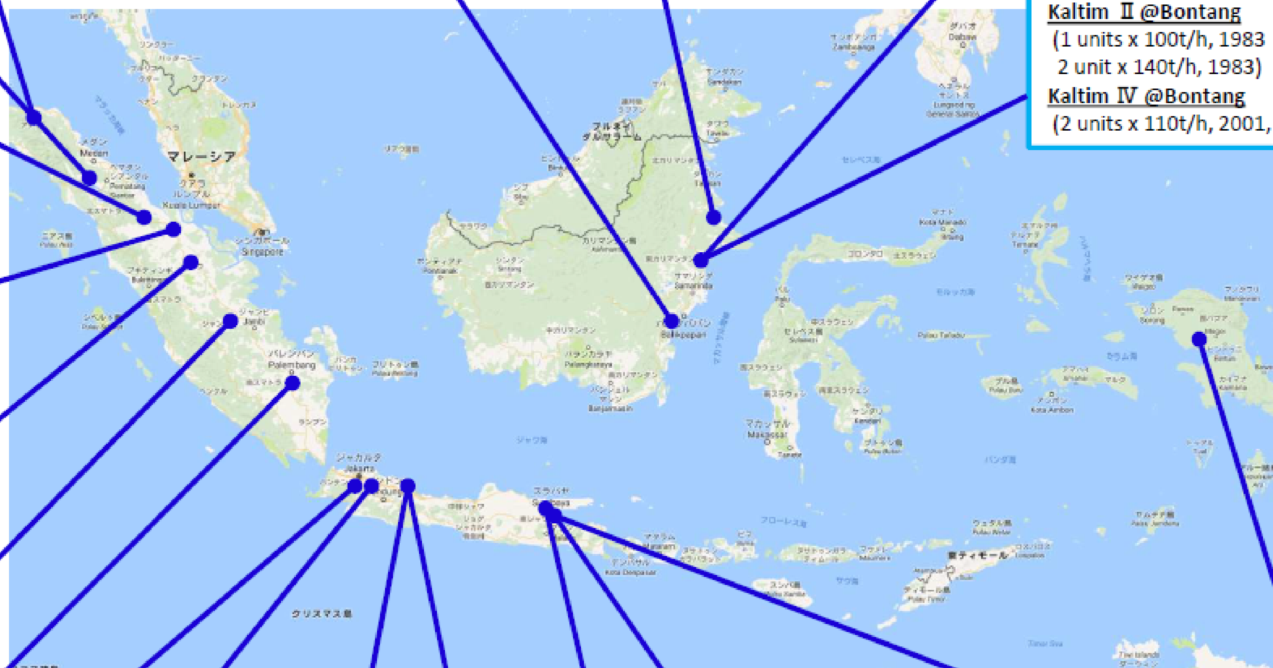
S/T
30Units

Boiler
25Units

Toba Pulp @Porsea（April系）
(1unit x 54MW, 1992)

Kaltim Ⅱ @Bontang
(1 units x 100t/h, 1983
2 unit x 140t/h, 1983)
Kaltim Ⅳ @Bontang
(2 units x 110t/h, 2001, 02)

Pertamina @Dumai
(1 units x 60t/h, 1984)
(2 units x 68t/h, 1991)



Indah Kiat Pulp & paper (IKPP) @Perawang（APP系）
(7units x 37MW, 1993)
(1 unit x 55MW, 1998)

Riau Pulp (RAPP) @Pekanbaru
(2 units x 54MW, 1994)
(1 unit x 28MW, 1994)

Lontar Papyrus (LPPPI) @Jambi（APP系）
(3 units x 37MW, 1994)

OKI Pulp & Paper @Palembang（APP系）
(4units x 125MW, 2017)

Bridgestone Tire Indonesia @Cirebon
(2 units x 12t/h, 1974, 1980)

Suparma @Surabaya
(1 unit x 27MW, 1996)

PAKERIN @Surabaya（独立系）
(1 unit x 38MW, 1996)

Gresik Power @Gresik
(2 unit x 9MW, 1998)

Cikarang Listrindo @Jakarta（GTCC）
(2 units x 62MW, 1997)

Pindo Deli Palp & Paper @Karawang（APP系）
(1 unit x 30MW, 1996)

Pertamina @Cirebon
(1 units x 16t/h,1972,1973)

Freeport Papua
(3 units x 77MW, 1997)

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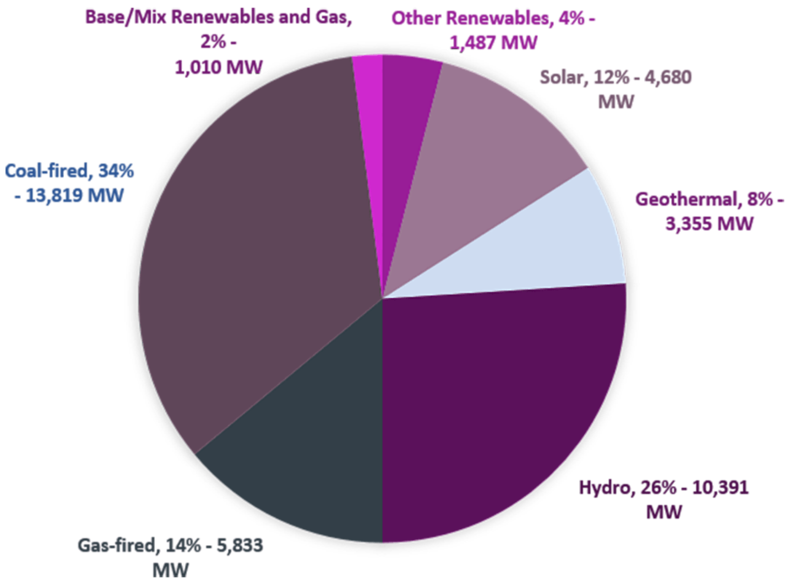
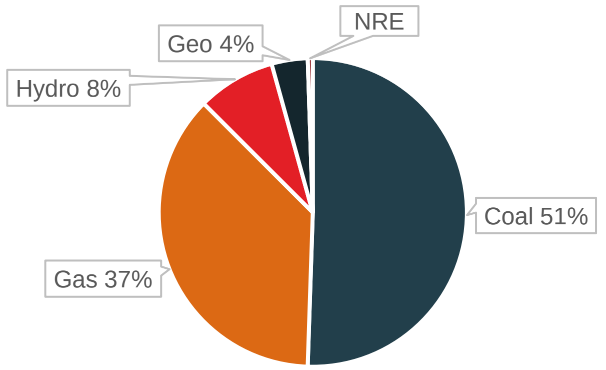
Indonesia's Decarbonization Journey

The Indonesia government and PLN revealed targets to **reduce greenhouse gas emissions by at least 29% by 2030** and **achieve net zero carbon emissions by 2060** in the Electricity Business Plan (RUPTL) 2021-30

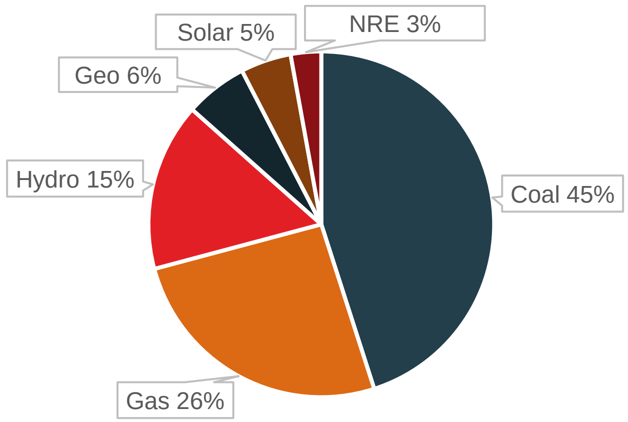
Indonesia aims to have **new and renewable energy** make up **52% of planned power generation capacity** by 2030.



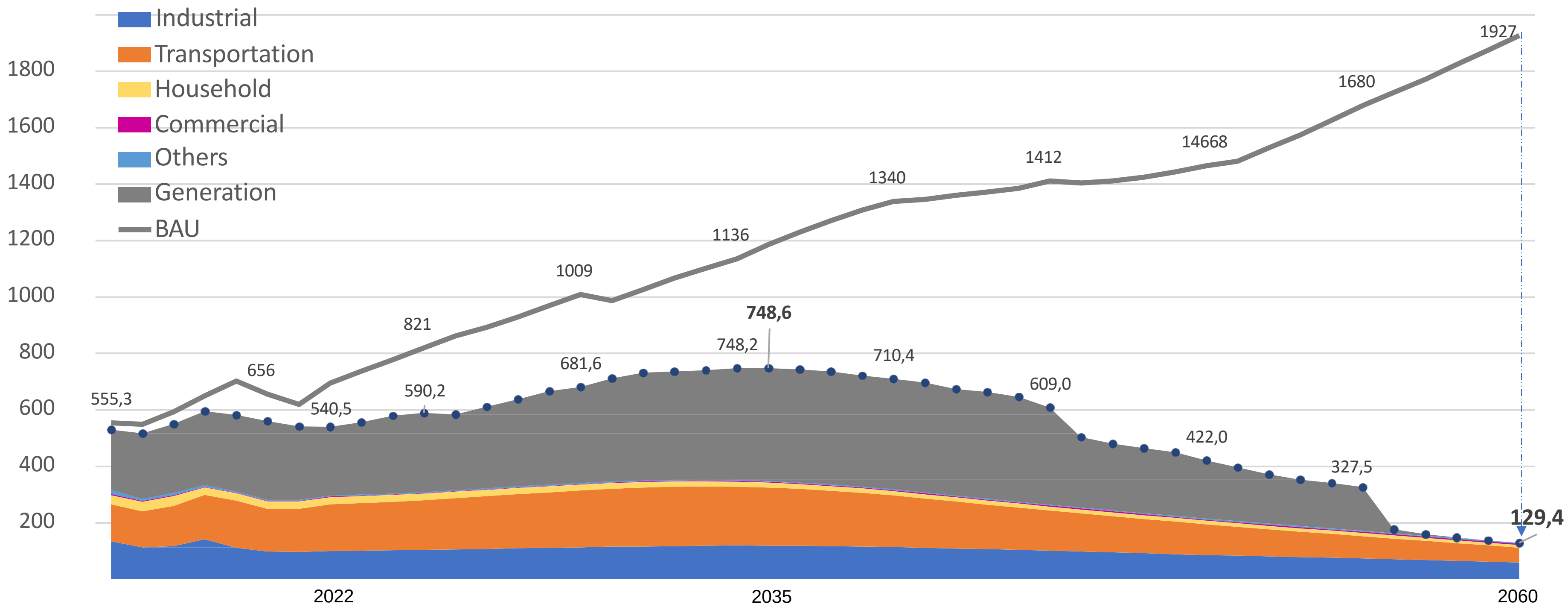
2020 Installed Capacity



2030 Projected



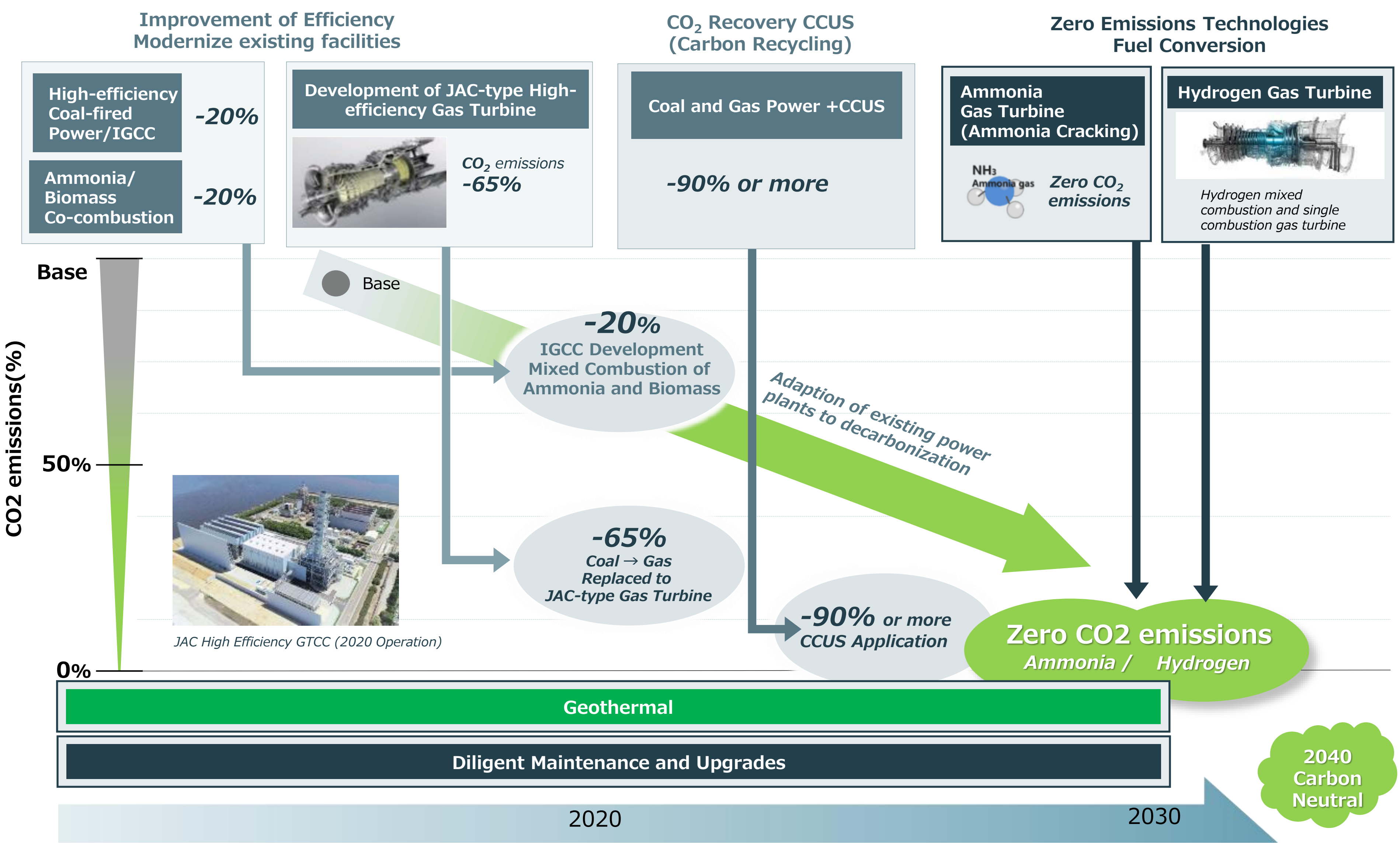
Indonesia's Decarbonization Journey



Decarb Strategies:

1. Generation: Gradual retirement of coal plants, acceleration of renewable energy development
2. Industrial: CCS, carbon neutral fuels
3. Transportation: electric vehicles, hydrogen
4. Smart grid, new technologies

Mitsubishi Power's Roadmap for Decarbonization



Technology Development for Decarbonization in Indonesia

Collaboration with the Institute Technology of Bandung (ITB)

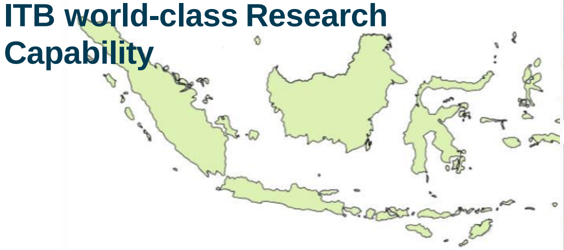
- In 2020, ITB & Mitsubishi Power signed an MOU on Joint Research Collaboration for **new power-generating technologies to reduce greenhouse gases**.
- In 2022, ITB and Mitsubishi Power **extended** the **MOU for 5 more years.** We will deepen this collaboration as platform to consider decarbonization in Indonesia.
- Our activities are well monitored by both governments.


Sciences


Technologies


Engineering

ITB world-class Research Capability



Collaboration for Clean Energy Technologies

Mitsubishi Power state-of-the-art Technologies


Biomass Firing


CCS


H2 Gas Turbine


Geothermal Power Plant


SOFC

Technology Development for Decarbonization in Indonesia

Feasibility Study Themes with ITB

<Detail F/S> GTCC X / Suralaya NH3 Firing
<R&D> Optimization of NH3 Gas Turbine

<Policy Recommendation> Completed
<Realize> Consideration of Supply Chain

<Policy Recommendation & Realize>
Complete F/S and start discussion with counterparts in Indonesia

Hydrogen & Ammonia

Feasibility Sturdy of NH3 GTCC in existing plants “GTCC X”

Biomass Co-firing

Study of Biomass Co-firing in Coal Fired Plant (Suralaya and Paiton)

Air Quality Control System

Analysis of emission gas of BTG plant. (Suralaya / Pelabuhan Ratu)

Micro-Grid

Study of micro-grids in Indonesia and economic calculation.

IGCC / CCUS

Analysis of coal spec from main coal mining in Indonesia.

Big Data for Steam Power Plants

Study of application of boiler smart inspection system.

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Decarbonization of Thermal Power Generation

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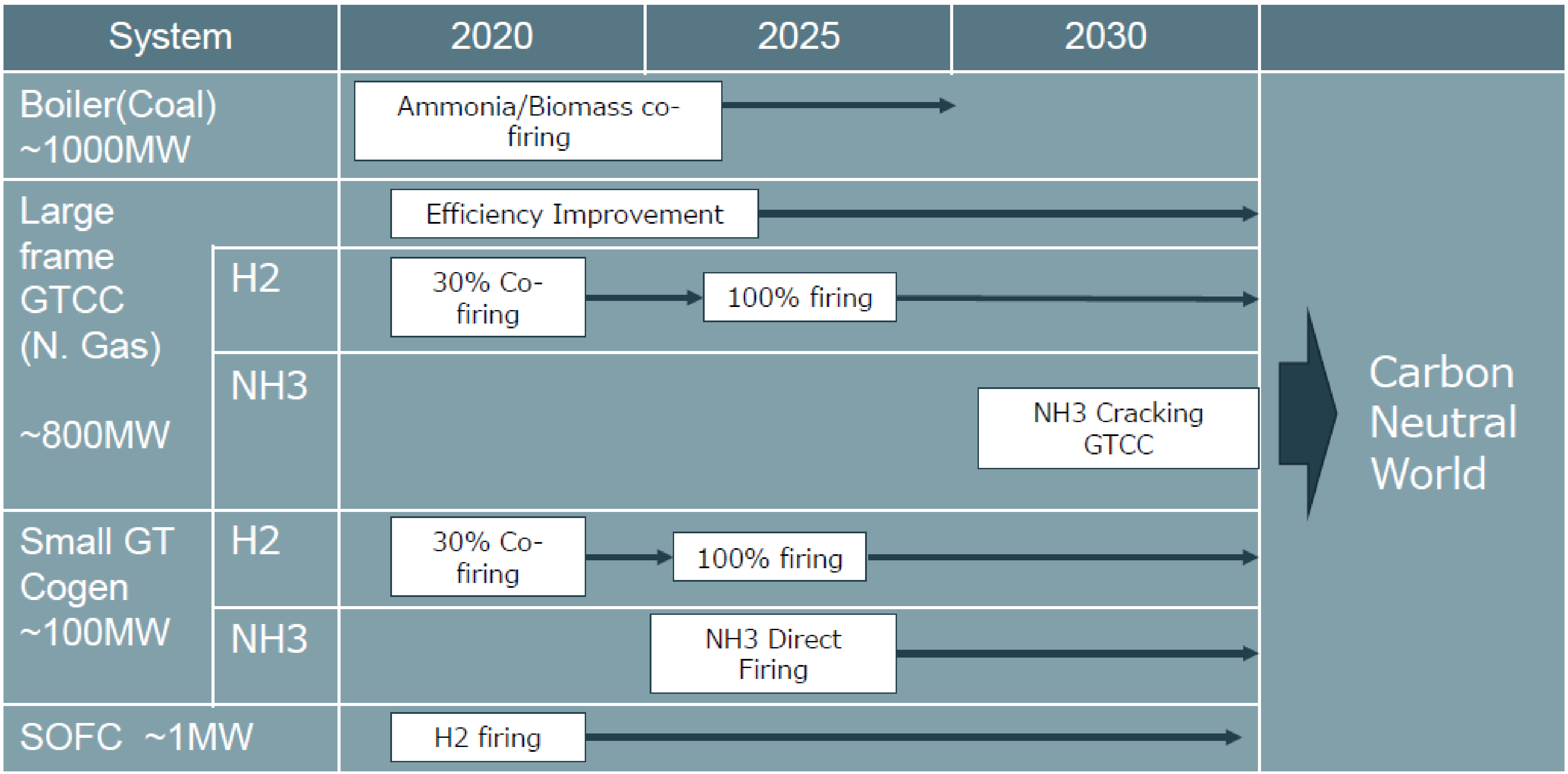
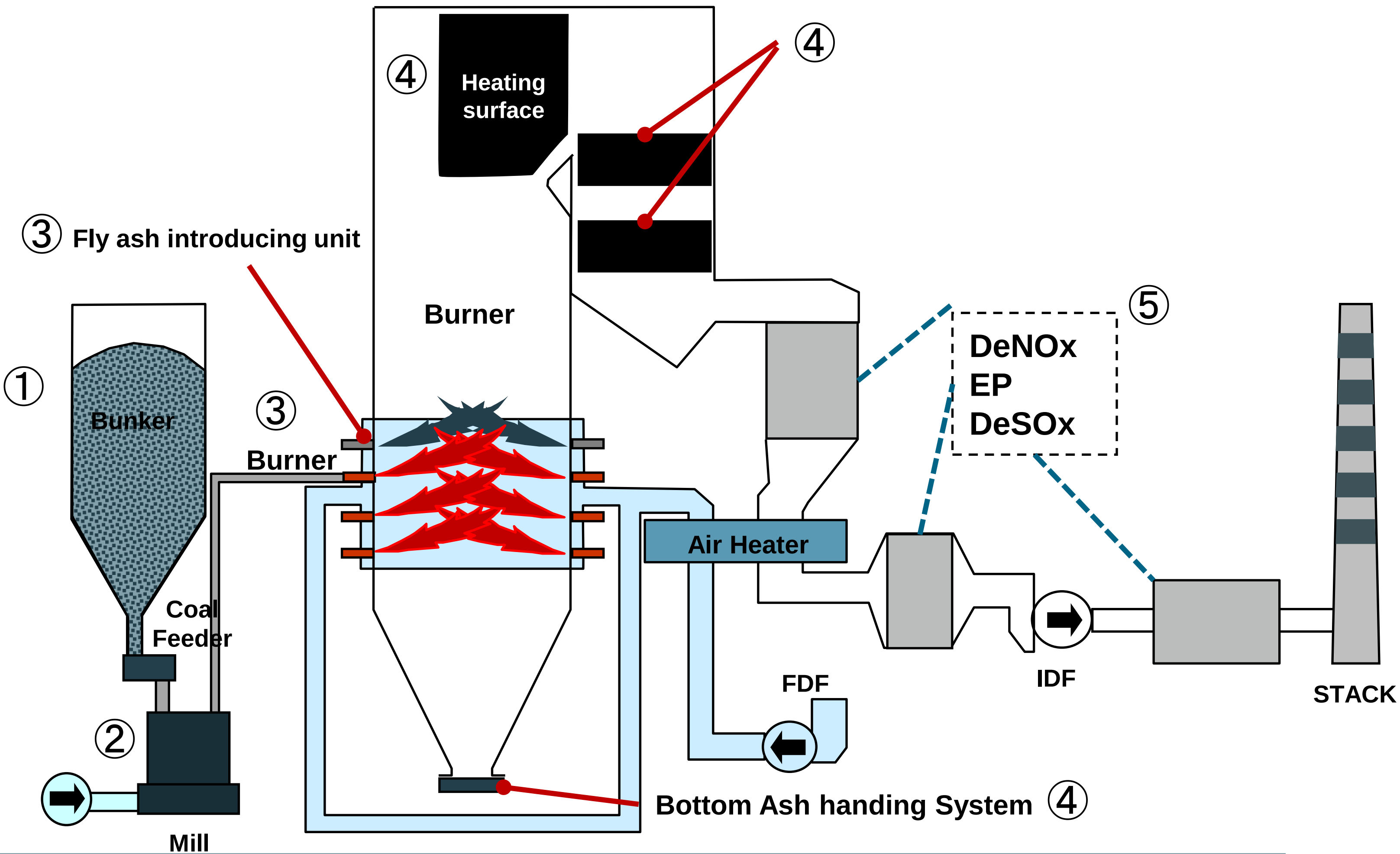
Hydrogen / Ammonia Power Generation

Mitsubishi Power is expanding lineup of carbon-free power generation options.



Design Considerations For Biomass Co-Firing

Based on our experience and data, there is a need to consider the following equipment.



Experience in Biomass Co-firing

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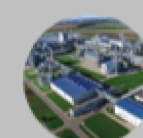
PLANT	Avedore #1	Drax Power Station	Soma Energy Park LLC. *5)
COUNTRY	Denmark	UK	Japan
BOILER OUTPUT	260MW×1	660MW×3 (Unit1 to 3)	112MW×1
STEAM CONDITION	275bar/545/541deg.C	165.5bar/570/564deg.C	16.7MPa/569/569deg.C
BOILER TYPE	One Through Steam Generator	Natural Circulation	Forced Circulation
	Opposite Firing	Opposite Firing	Tangential Firing
OEM	MPW-EDE	Doosan-Babcock	MPW
Biomass Co-Firing Ratio	100cal% Biomass Conversion (White Pellet)	100% Biomass Conversion (White Pellet)	30cal% Biomass Conversion (White Pellet)
Type of project and DOW for equipment	Retrofit (Biomass Conversion in 2017)	Retrofit (Biomass Conversion in 2010-2016)	New (Commercial Operation in 2018)
Storage & Conveyer System	X (Owner Scope)	X (Owner Scope)	X
Mill	X(MPS190→Modified MPS190) (MPW-EDE Scope)	X (Doosan Scope)	X（MVM17RL）
Burner	X(DS burner) (MPW-EDE Scope)	X(DS burner) (MPW-EDE Scope) *1	X(M-PM)
Safety System	X (Mills) (MPW-EDE Scope)	X (Storage & Conveyer System) (Owner Scope)	X
Coal Ash Injection System *2)	X (Owner Scope)	X (Owner Scope)	-
Primary Air Cooler *3)	X (MPW-EDE Scope)	-	-
Ducting *4)	X (MPW-EDE Scope)	-	X

*1) MPW improved burner modified by Doosan
*2) System for reducing ash deposit (Slagging and so on)
*3) Equipment for cooling hot Primary air Temp. to keep PA flow
*4) On Mill inlet duct, To consider inside pressure increase due to explosion
*5) In addition, there are 3 plants (Kamisu Power Cor., Hibikinada Energy Park LLC., Hibikinada Thermal Power Station Co.,Ltd.) with the same performance as Soma

The type of hydrogen varies depending on the process of its production.

Category	Type	Production process	Technology in MHI Group
Carbon Free	**Green**	Electrolysis by renewable electricity $H_2O \rightarrow H_2 + \frac{1}{2}O_2$	Wind Turbine (Vestas) Electrolyser (Hydrogen Pro) 
	Pink	Electrolysis by nuclear energy $H_2O \rightarrow H_2 + \frac{1}{2}O_2$	Nuclear power - PWR 
	Turquoise	Thermal decomposition of fossil fuel CH4 $\rightarrow 2H_2 + C$	Methane pyrolysis (Monolith) 
	Blue	Thermal reforming of fossil fuel w. CCS $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$	Natural gas reforming IGCC CO_2 capture 
Ordinal (emit CO2)	**Gray**	Thermal reforming of fossil fuel $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$	Natural gas reforming IGCC 

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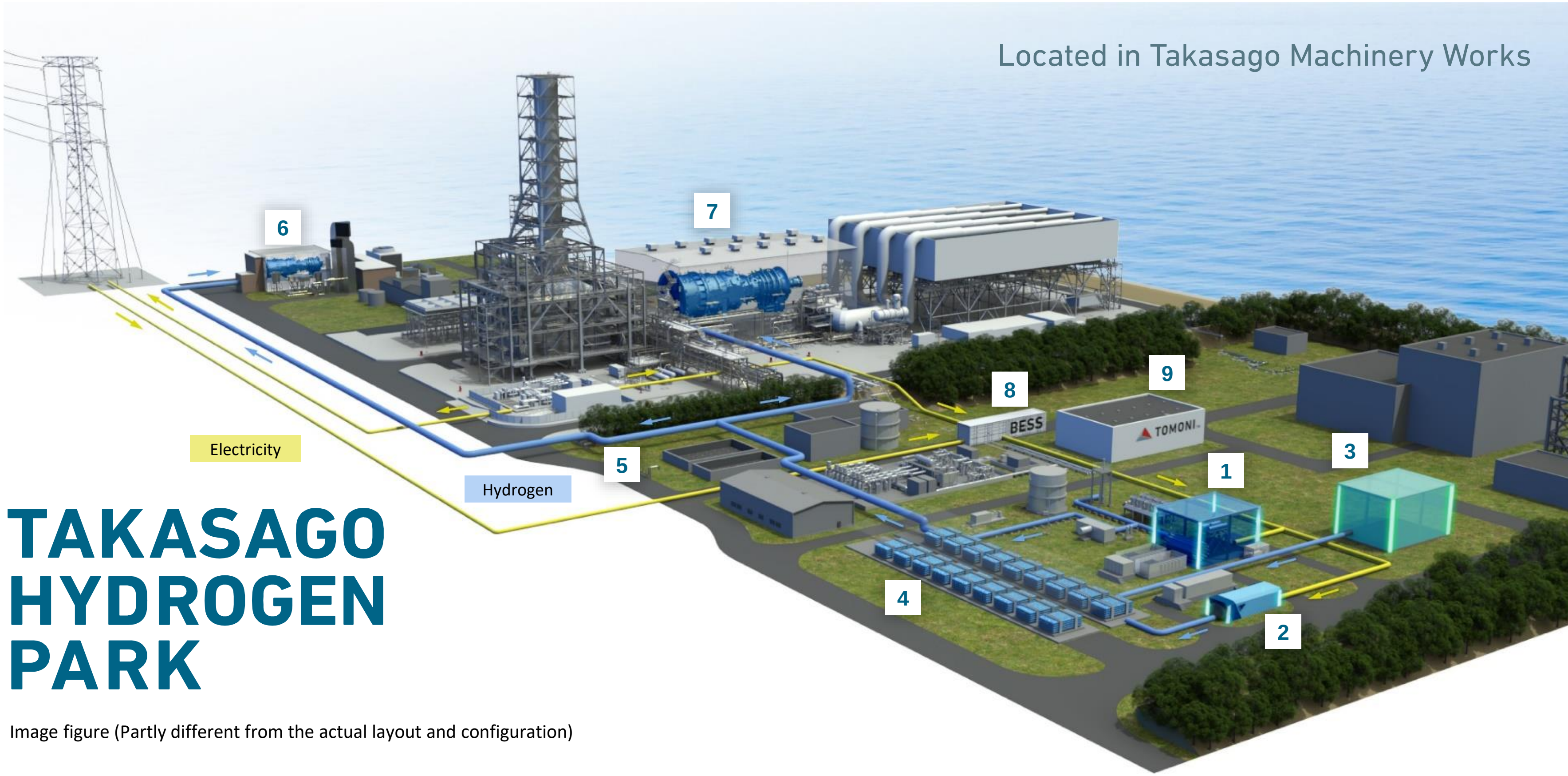


Image figure (Partly different from the actual layout and configuration)

1. Hydrogen Production Facility (Water Electrolysis System)
2. Hydrogen Production Facility SOEC*1
3. Hydrogen Production Facility (Methane Pyrolysis)
4. Hydrogen Storage Facility
5. Hydrogen Piping
6. Hydrogen Power Validation Facility (Small- & Middle-size Gas Turbine) (Combustor for Large-size Gas Turbine)
7. Hydrogen Power Validation Facility (Large-size Gas Turbine)
8. BESS*2
9. Total Energy Management System TOMONI$_{TM}$

*1 SOEC: Solid Oxide Electrolysis Cell
*2 BESS: Battery Energy Storage Systems

Ammonia Co-firing Technology for Coal-fired Plants

- Ammonia is of interest as a carbon-free fuel.
- Ongoing testing and validation of ammonia co-firing with coal by MHI.

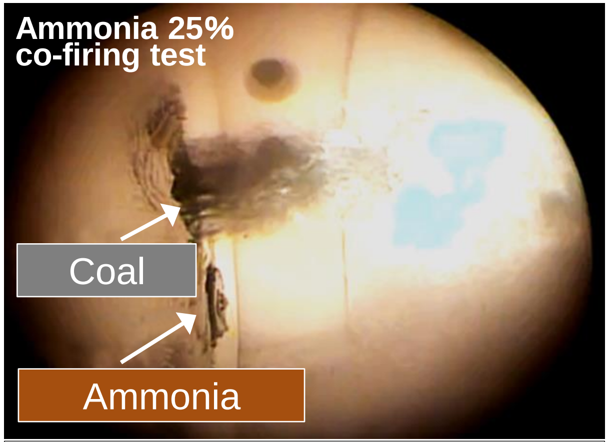
Benefits

- **Reduced CO2 emissions**
- **Easily handling as hydrogen carrier**

(a) High hydrogen content
(b) Suitable for transportation
(Easier to liquefy than H2)
(c) Existing infrastructure technologies for production, transportation, and storage can be used
(d) Can be directly combusted or hydrogenated for use as fuel in boilers, gas turbines, and fuel cells

Challenges

- **Confirmation of applicability of existing combustion technology**
- **Safe handling/operation of Ammonia.**
- **Low-cost and stable supply of CO2-free ammonia**



Small scale test furnace

Scale up

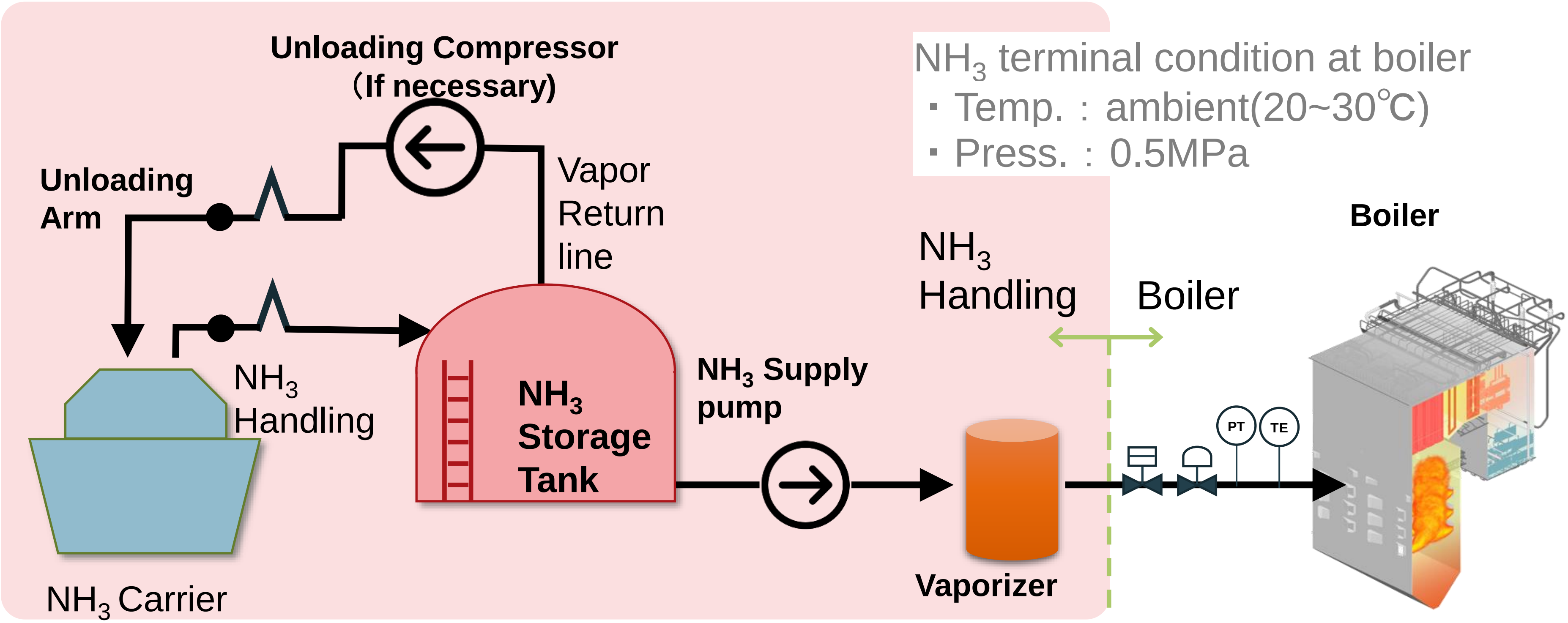
4t/h Comb. Test Facility

※Commercial size of burner will be tested at this facility

Basic Concept of Ammonia Co-firing

Typical System for Ammonia Supply

- Ammonia unloading, storage and supply system is expected to be Ammonia in liquid phase which is pressurized or at low temperature (under -33deg.C) will be necessary.
- In addition to the modification of the boiler itself, several hundred millions US$ of Ammonia handling systems may be necessary.



For Decarbonization Society (Application of Catalyst Technology)

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Fuel

LNG

↓

Ammonia →

Flue Gas Characteristics

NOx "Increase" →

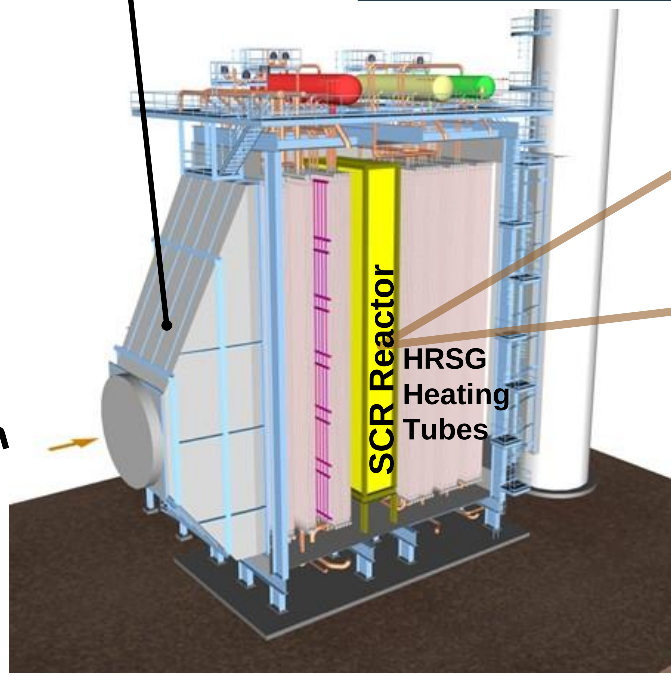
Technology Applied

"Ultra" High Efficiency DeNOx →

Retrofit

Equip. Reinforcement
(Catalyst & Ammonia Facility)
HRSG Evaporator Tubes:
-Modification
-Replacement

Flue Gas from Gas Turbine



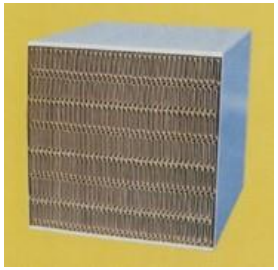
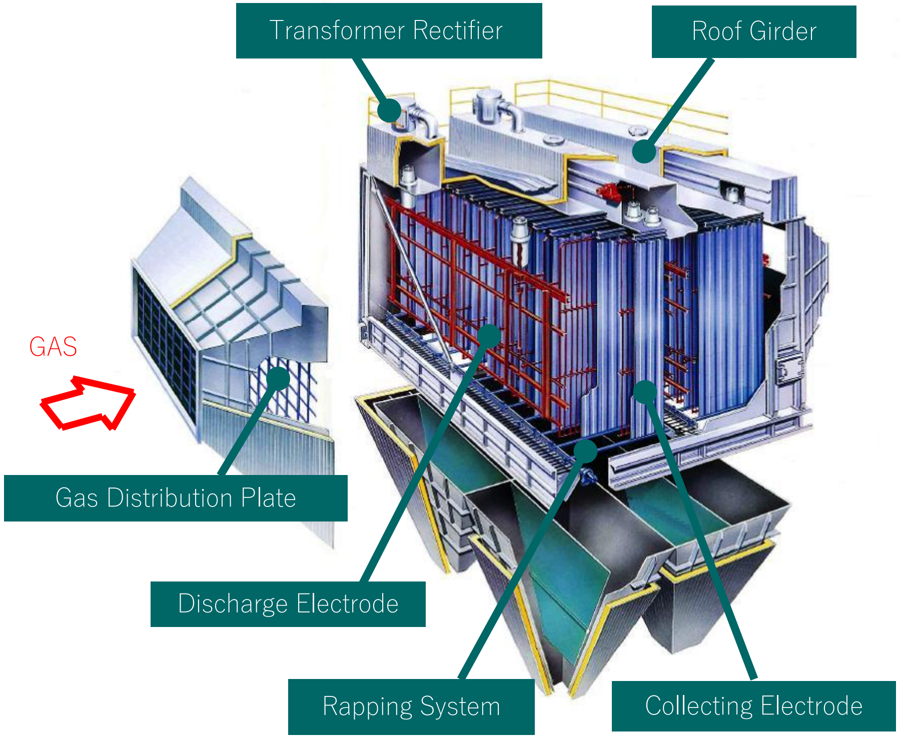
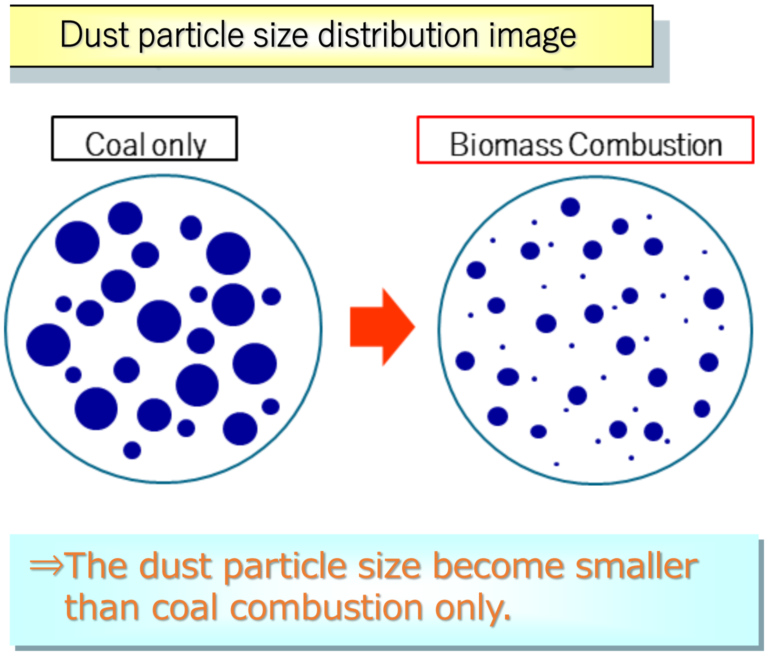


Plate-type SCR Catalyst

For Decarbonization Society (DeDusting System)

Potential effect for ESP performance by **biomass combustion**





- The dust particles in the exhaust gas become **small, making it difficult to collect**.
- Same as above reason, there is a high possibility that collected dust is **re-entrainment** by rapping.

Smoke with High Dust Concentration

Not moisture but dust

Periodical maintenance of ESP is mandatory for proper plant operation.

MHI ICT Solution TOMONI: Concept for Geothermal

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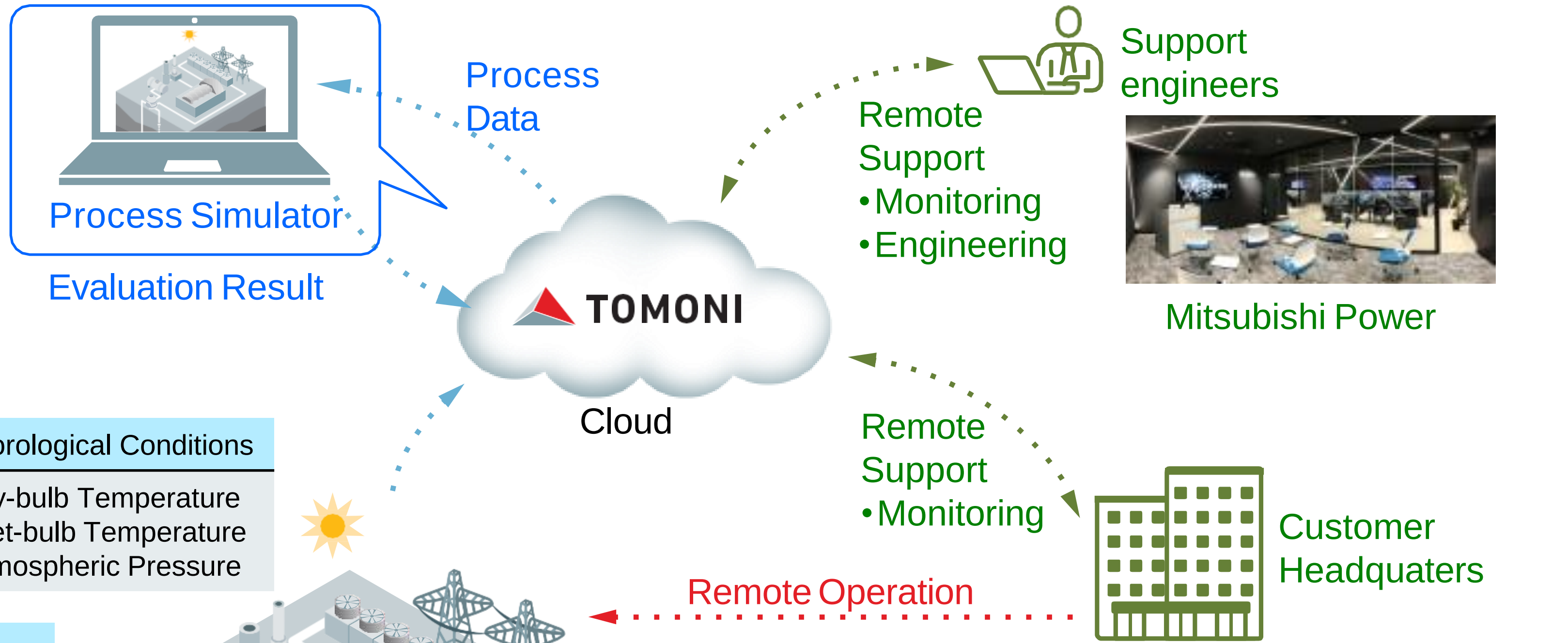

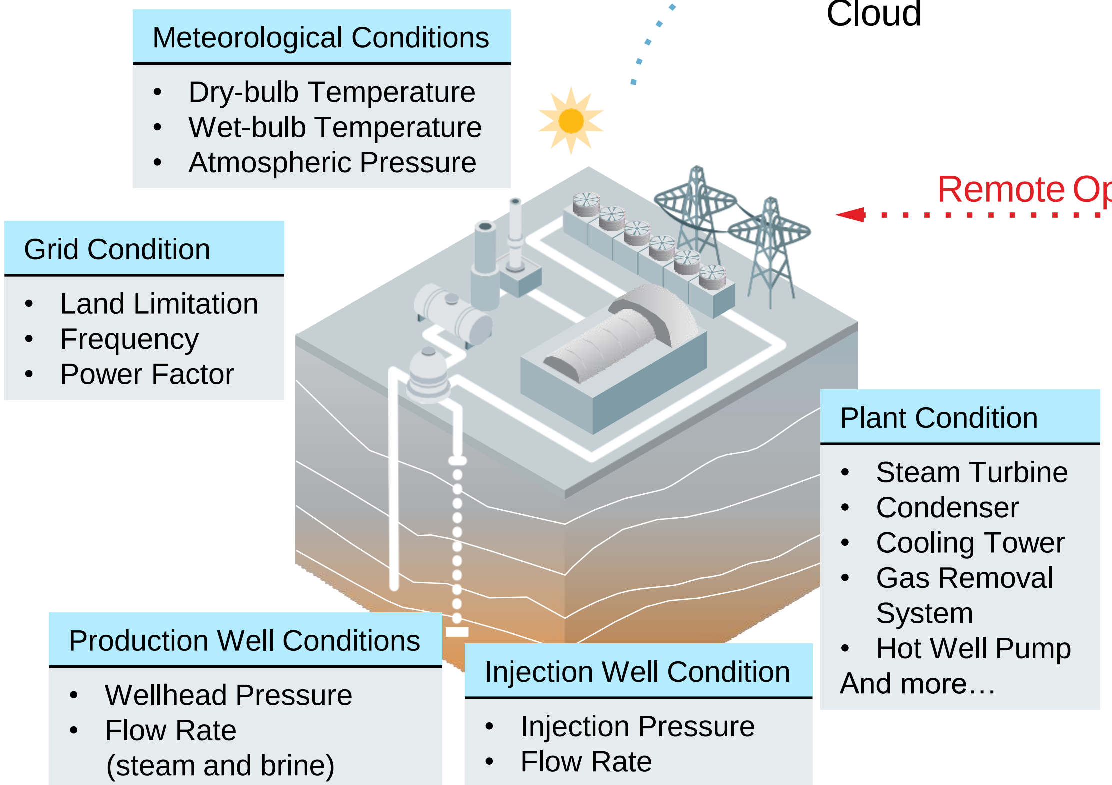

Benefits for Geothermal

1.Improved administrative work efficiency with “real time data sharing anytime, anywhere.”

2.Capacity factor improvement with “remote support service” with Mitsubishi Power experts.

3.Outage interval optimization with “real-time plant performance and scaling condition visualization.”

4.Plant performance and reliability improvement with “periodical plant diagnosis.”

5.Optimization of management resources with “remote operation.”

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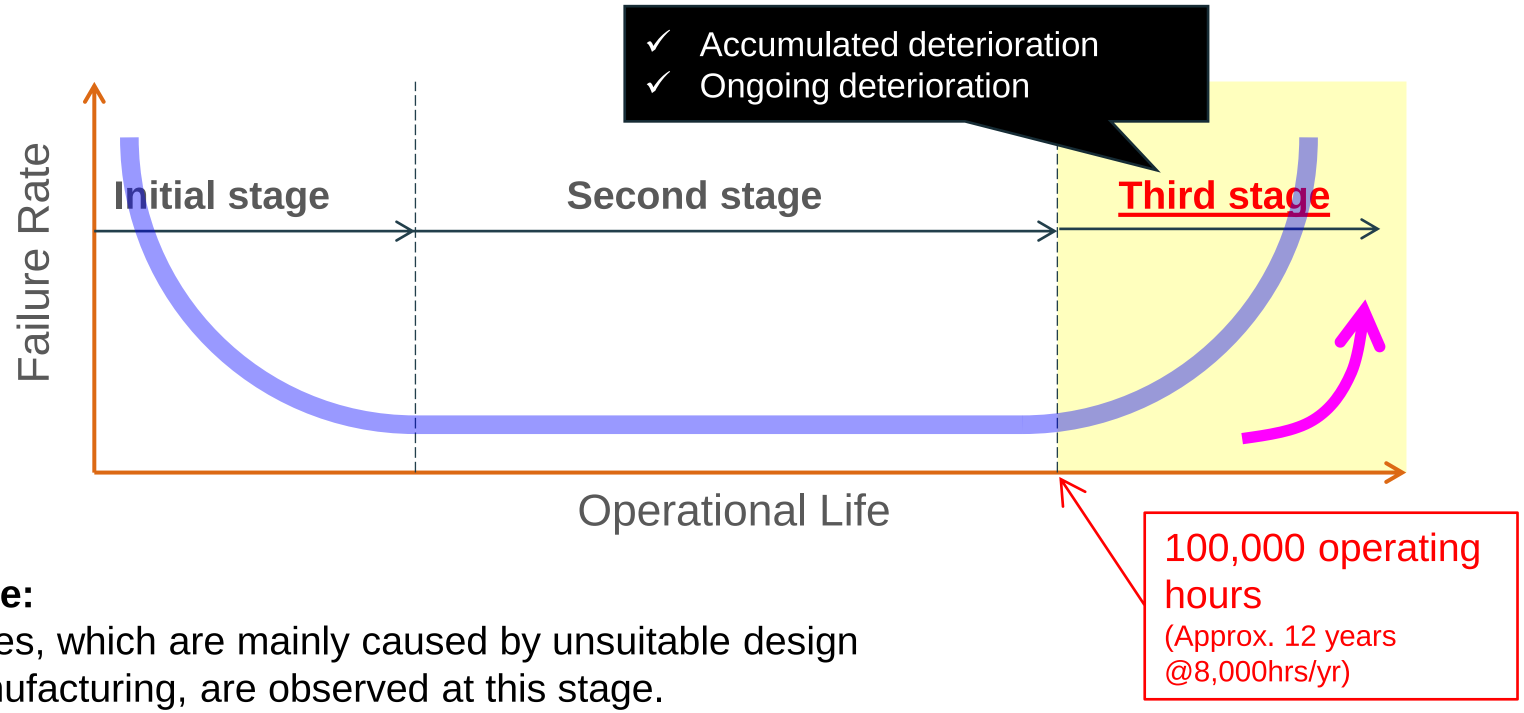
Importance of Periodical Maintenance

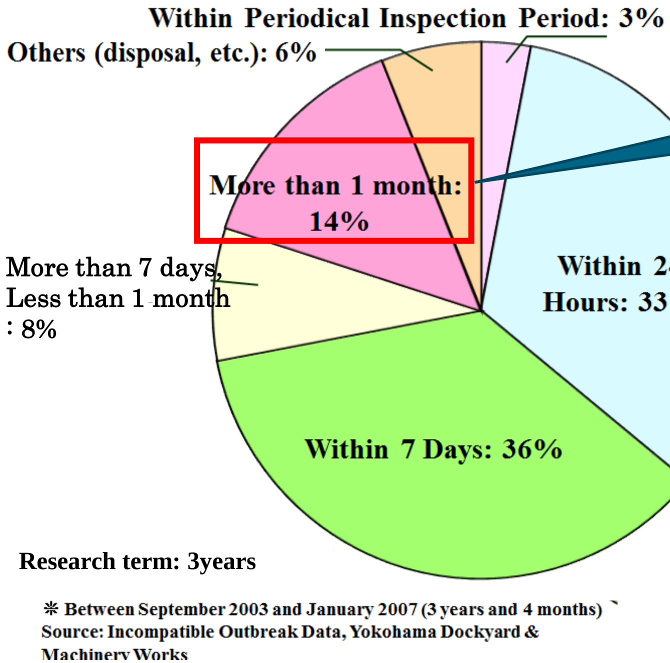
- The graph shows the generalized failure rate curve for equipment, as a function of its operational life. It is called a ‘Bath Tub Curve’ because its gradient looks like a bath tub.



Initial stage:
Initial failures, which are mainly caused by unsuitable design and/or manufacturing, are observed at this stage.
Second stage:
The failure rate is kept low with proper maintenance.
Third stage:
The failure rate during this stage tends to **rise** because of the accumulated deterioration during the previous stages and ongoing deterioration.

Importance of Periodical Maintenance

Time required to recover from failures



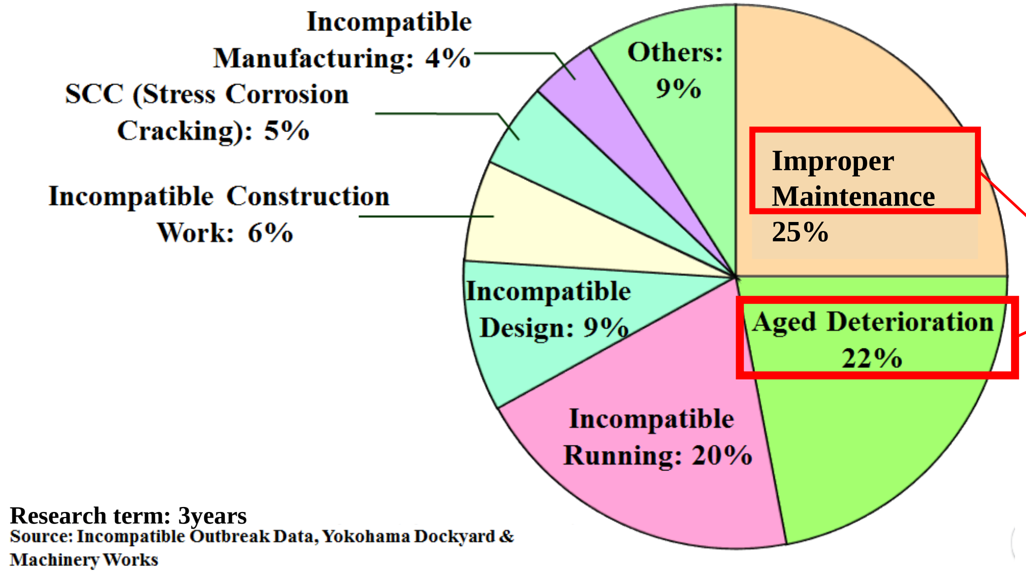
Steam Turbine downtime was more than 1 month

Steam turbine failures can have serious financial consequences for the owner.

Huge financial impact is incurred during turbine operation downtime as the owner has to purchase electricity from the grid to compensate for electricity usually generated by the turbine.

Steam turbine operation downtime must be minimized.
The owner should make every effort to avoid serious failures.

Steam Turbine failures and Their Causes



These account for approx. 50% of Turbine failures

Counter measures

①Periodical inspection
②Replacement of deteriorated parts
⇒ Required to avoid serious failures

③Preparing spare parts ⇒ For rapid recovery from failures

Mitsubishi Power Turbine Life Assessment Program

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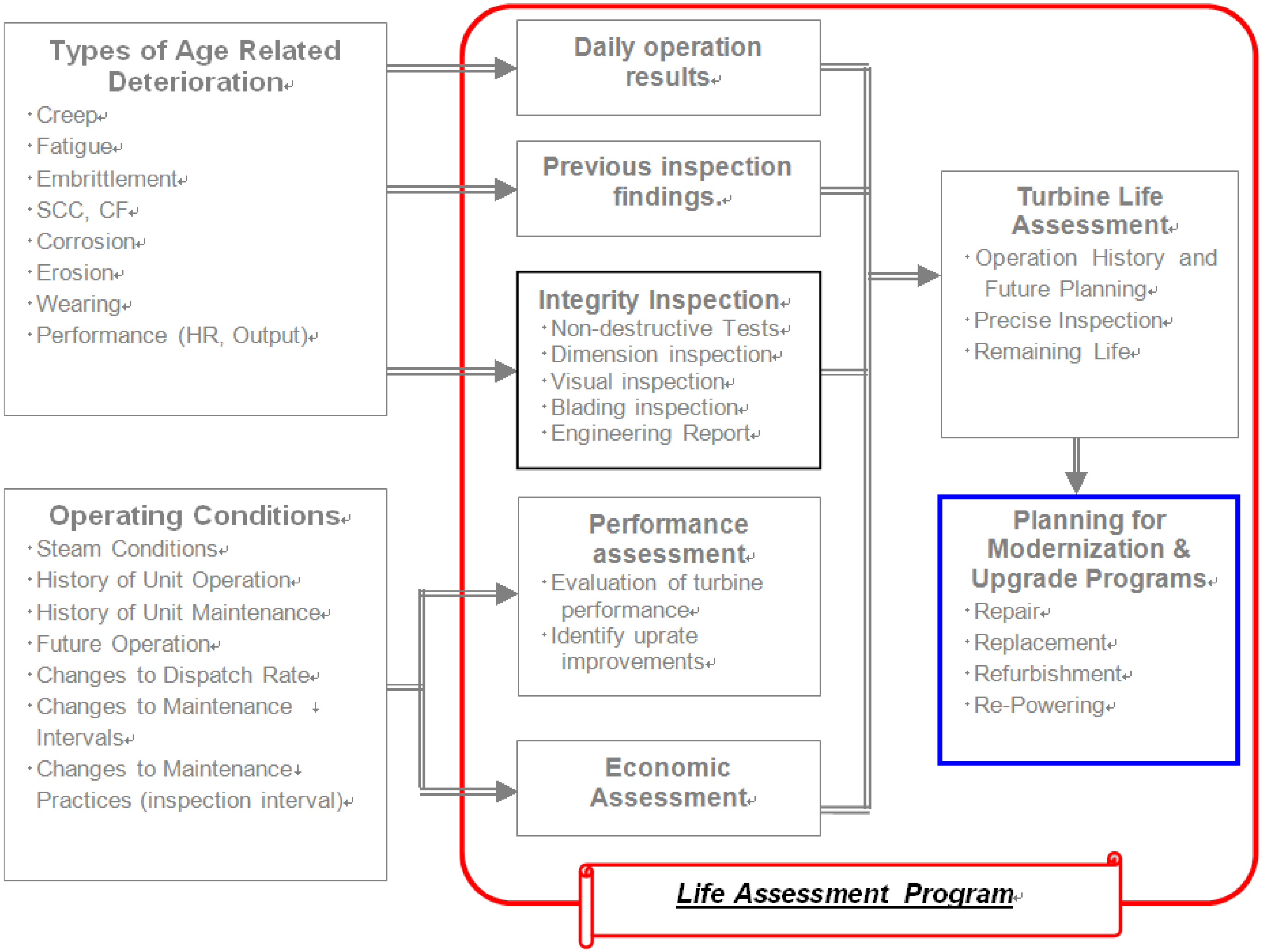
Concept of the Turbine Life Assessment Program



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