



MHPS's Activity for Clean Coal Technologies

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Development Department

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1. Corporate Profile

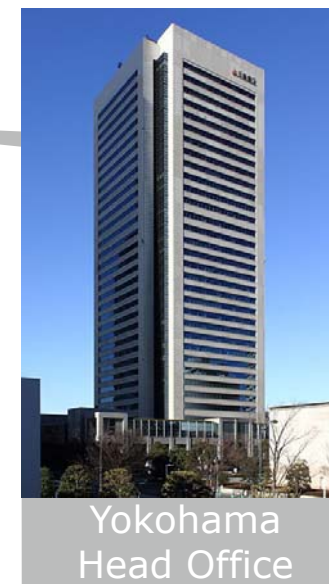
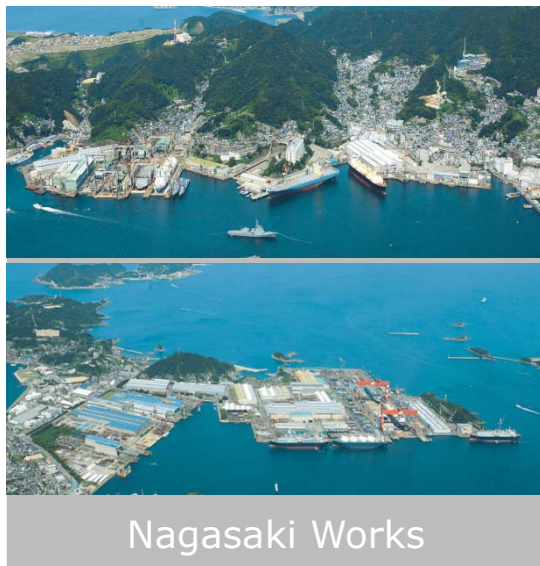
Mitsubishi Hitachi Power Systems, Ltd (MHPS)



Integration in the Thermal
Power Generation Systems
Field

Name	MITSUBISHI HITACHI POWER SYSTEMS, LTD.
Head Office	Yokohama, Kanagawa, JAPAN
Representatives	Koji Tanaka (Chairman of the Board) Kenji Ando (President and CEO)
Capital	100 Billion JPY
Effective Date	February 1, 2014
Employees	21,082 (Consolidated Basis) 10,874 (Non-Consolidated Basis)

Head Office & Main Works in Japan



Global Network of MHPS



MHPS has 56 companies in 23 countries.

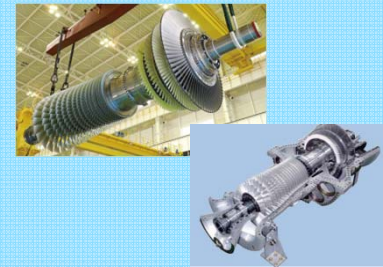
MHPS's Business Field

Products & Services

Gas Turbine Combined(GTCC)
Power Plant



Gas Turbines



Boiler & Turbine Generation
Plants



Environmental Equipment
(SCR/ESP/FGD)



Boilers



Steam Turbines



Integrated coal Gasification
Combined Cycle(IGCC)
Power Plants



Geothermal Power Plants



Generators



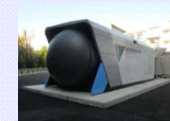
Power Generating Plant
Peripheral Equipment



Plant Control Systems



Fans



Fuel Cells (SOFC)

2. Japan's Energy Policy and Position of Coal Fired Power Plant

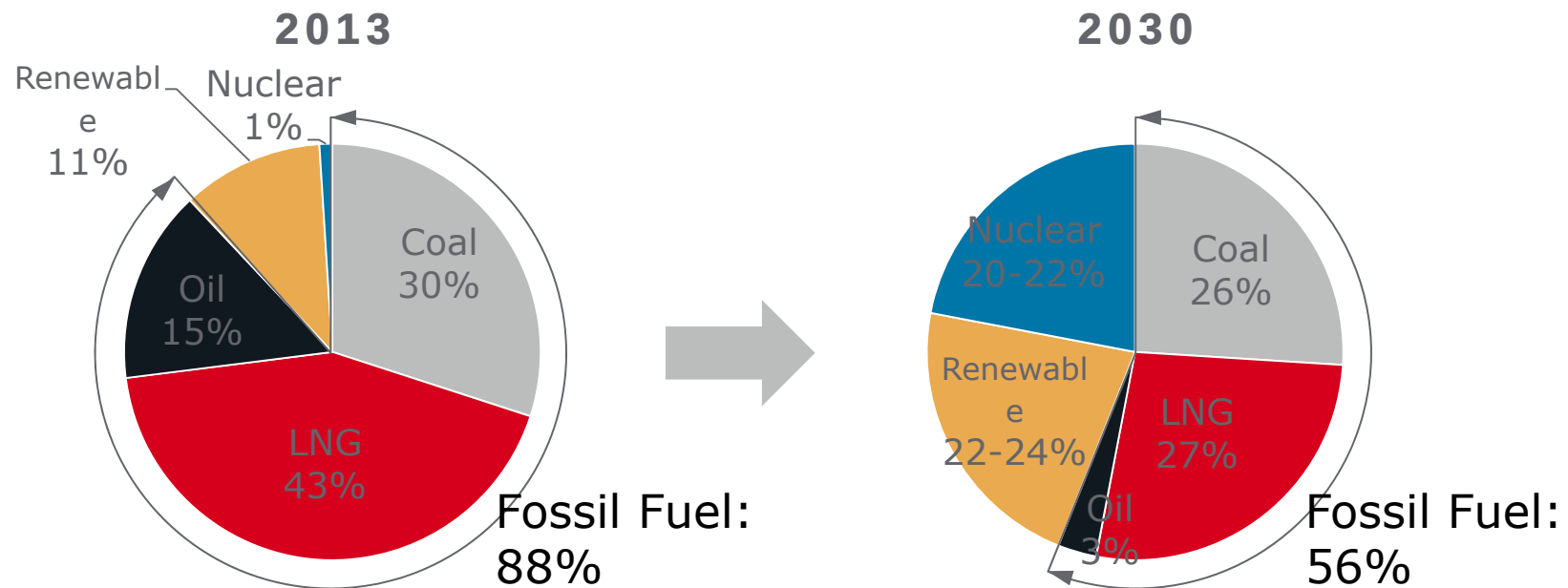
Japan's New Energy policy

Important decisions on Japan's energy policy were made from June to July, 2015

a. Optimum energy mix

Target on power source composition in 2030 was made in line with basic policy of "3E+S" (Energy Security, Economic Efficiency, Environment and Safety).

b. Reduction target of greenhouse gas by 2030: 26% (based on 2013 level)



Position of Coal-Fired Power Plant

Coal fired power plant is positioned as an important baseload electricity source from the viewpoint of basic policy of “3E+S” (Safety, Energy Security, Economic Efficiency and Environment).

[Feature of Coal]

- 1) Affordable (one third compared to oil and natural gas price as of 2014)
- 2) Stably available (not unevenly distributed, lower geopolitical supply risk)
- 3) Easily storable

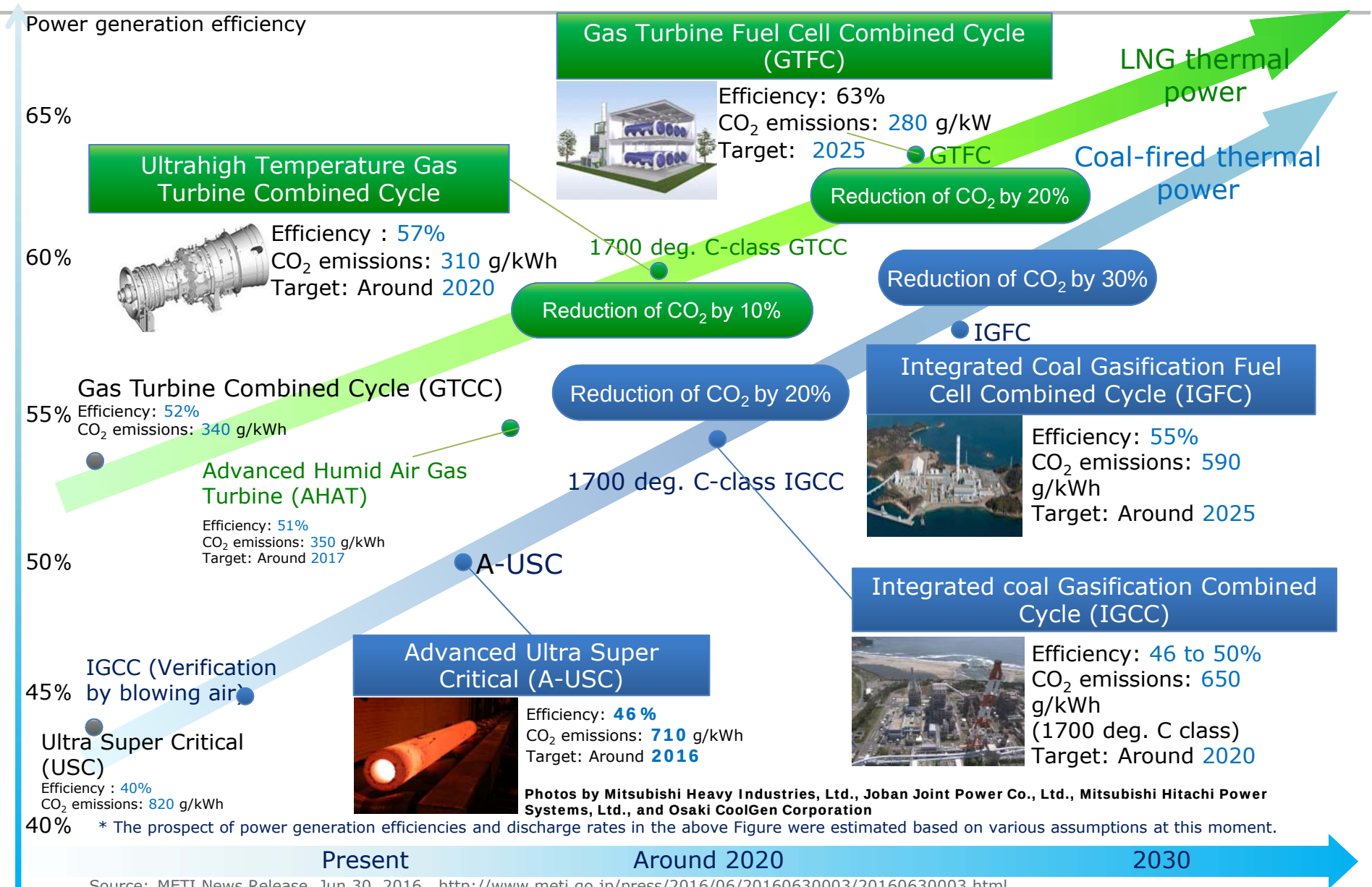
[Concern of Coal-fired power plant]

- 1) **Higher amount of carbon dioxide emissions per unit of heat energy**



- ✓ Highly efficient coal fired power plant is necessary
- ✓ Not only CO2 reduction domestically, but also international cooperation, e.g. Joint Crediting Mechanism, is required
- ✓ MHPS will contribute to the environment preservation and energy supply through achievement of the highest and best performance coal fired power plant

Roadmap on next-generation thermal power generation technology



Source: METI News Release, Jun 30, 2016 <http://www.meti.go.jp/press/2016/06/20160630003/20160630003.html>

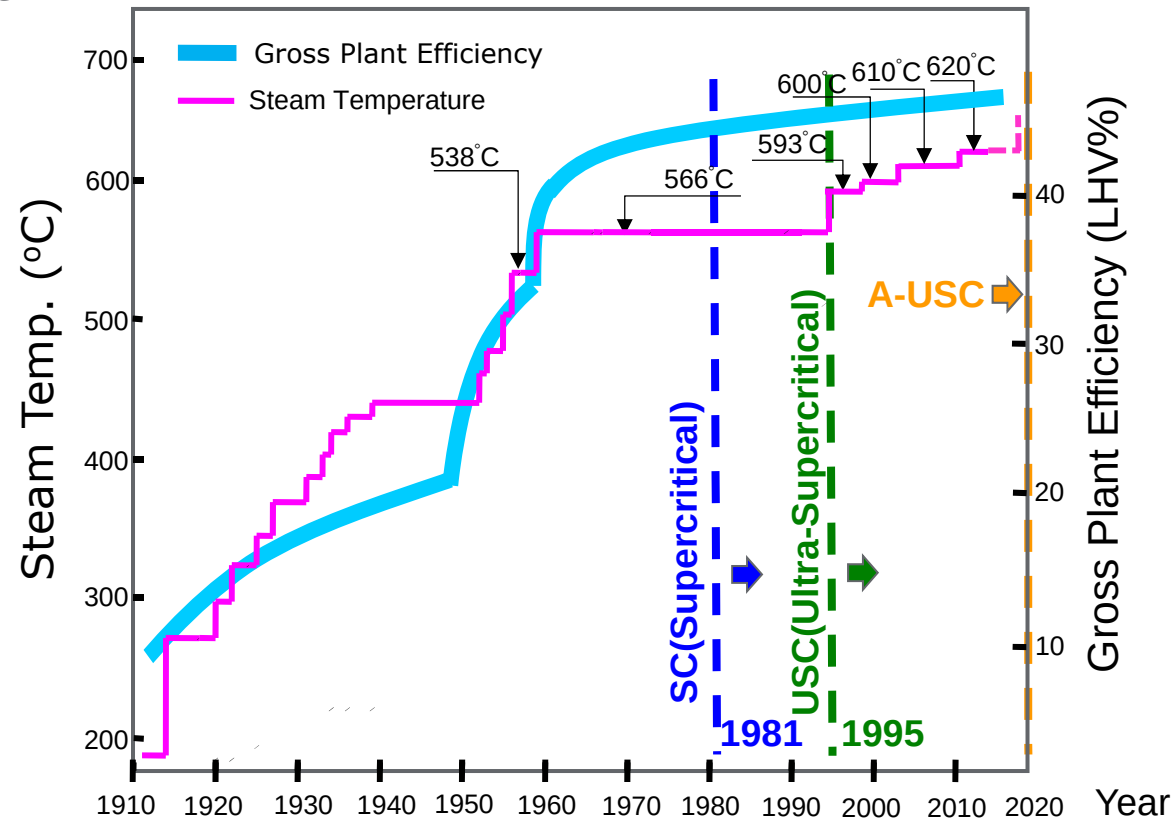
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3. Supercritical / Ultra-Supercritical Power Plant

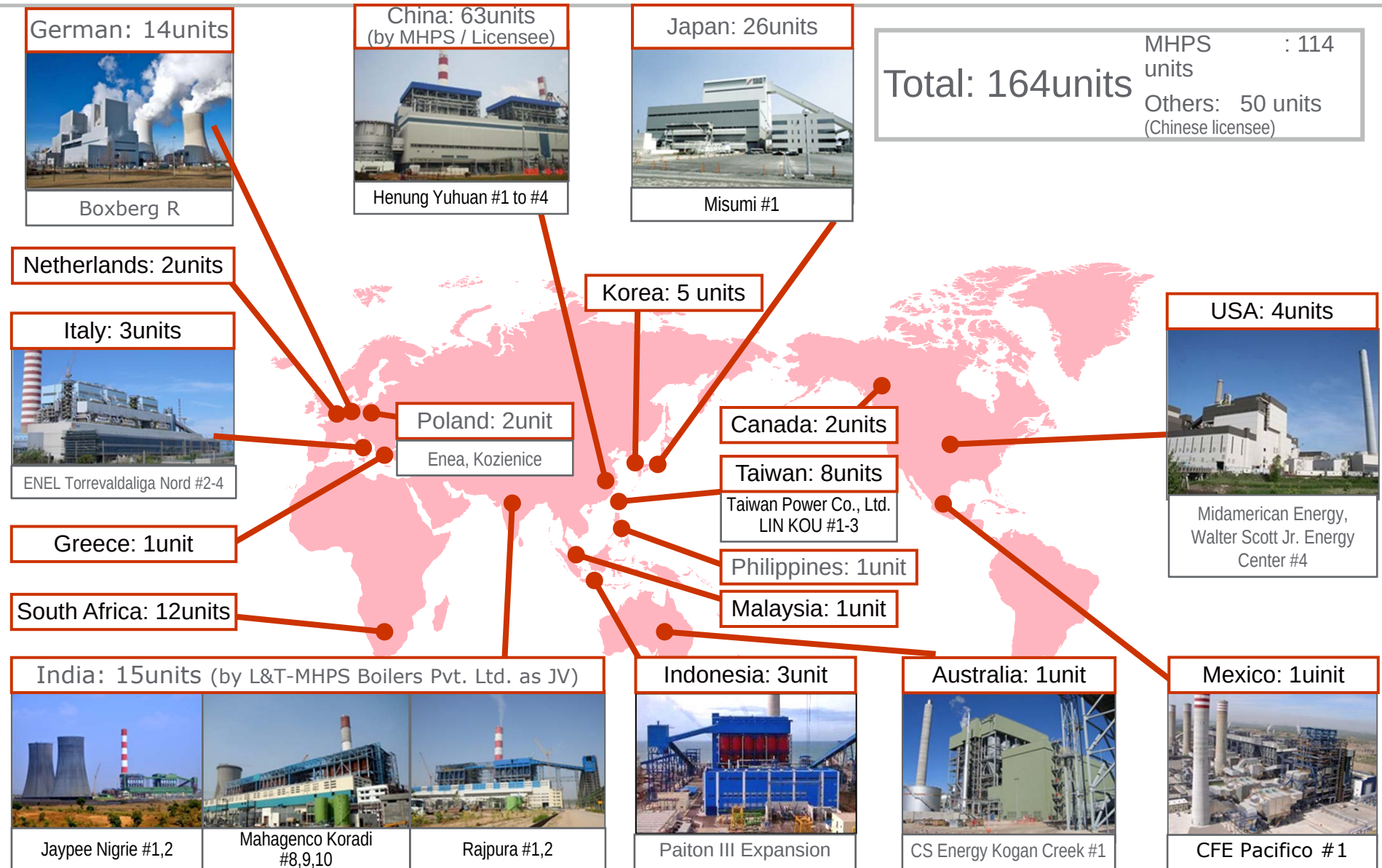
Efficiency vs Steam Condition for Coal Fired Plant

History of steam condition and thermal efficiency in Japanese thermal power plant



- Higher steam temperature and pressure improve thermal plant efficiency
- In other words, SC/USC technology provides economical power production, fuel energy saving, lower carbon emission and environment-friendly

Coal-Fired SC / USC Plant in overseas

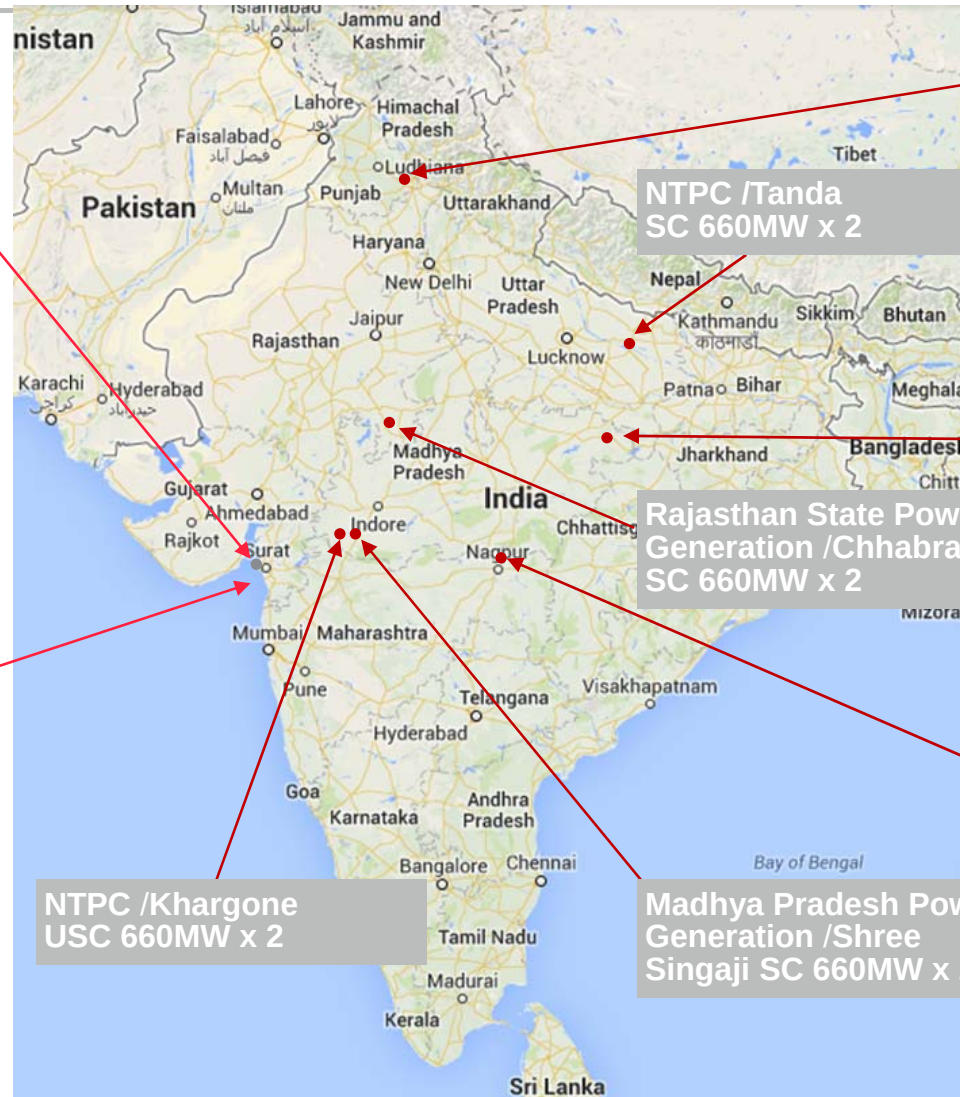


Activities at Indian Market

LMB(L&T-MHPS Boilers Private Ltd.)



LMTG(L&T MHPS Turbine Generators Private Ltd.)



NTPC /Tanda
SC 660MW x 2

IPP L&T Rajpura
SC 700MW x 2
25.12MPag/568/596°C



IPP Jaypee Nigrie
SC 660MW x 2
25.12MPag/568/596°C



Rajasthan State Power Generation /Chhabra
SC 660MW x 2

Maharashtra State Power Generation /Koradi
SC 660MW x 3
25.0MPag/569/595°C



NTPC /Khargone
USC 660MW x 2

Madhya Pradesh Power Generation /Shree Singaji
SC 660MW x 2

MHPS has contributed to Indian power generation by CCT originated in Japan through the JV with Indian company, Larsen & Toubro, Ltd.

Global Activity with SC/USC Technology

USC steam condition (600 °C steam temp) was first applied in Taiwan and Korea

■ Taiwan Linkou #1

Output :	800 MW
Main Steam Flow :	2,404 t/h
Main Steam :	604 °C / 25.38 MPag
Reheat Steam :	602 °C
Commercial Operation :	2016/6
Fuel :	Bituminous Coal, Sub-bituminous coal



■ Korea Taeon #9

Output :	1050 MW
Main Steam Flow :	3,145 t/h
Main Steam :	603 °C / 25.94 MPag
Reheat Steam :	613 °C
Commercial Operation :	Under commissioning
Fuel :	Bituminous Coal, Sub-bituminous coal



Successful Test of Automated Combustion Tuning System Using AI Technology

- Yokohama, January 10, 2017 -- A newly developed system from Mitsubishi Hitachi Power Systems, Ltd. (MHPS) which aims to automate combustion tuning in boilers using artificial intelligence (AI) has undergone verification testing in Taiwan, and demonstrated results that are comparable to those that could be achieved by a highly experienced engineer.



Taiwan Power Company's Linkou Thermal Power Plant

 MITSUBISHI HITACHI POWER SYSTEMS

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Products	Technology	About Company
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[HOME](#) [News](#) [Successful Test of Automated Combustion Tuning System Using AI Technology -- Verification Testing Performed at Coal-fired Power Plant, Operated by the Taiwan Power Company --](#)

Successful Test of Automated Combustion Tuning System Using AI Technology

-- Verification Testing Performed at Coal-fired Power Plant, Operated by the Taiwan Power Company --

No. 090

Yokohama, January 10, 2017 -- A newly developed system from Mitsubishi Hitachi Power Systems, Ltd. (MHPS) which aims to automate combustion tuning in boilers using artificial intelligence (AI) has undergone verification testing in Taiwan, and demonstrated results that are comparable to those that could be achieved by a highly experienced engineer. The system was installed at Taiwan Power Company's Linkou Thermal Power Plant, and verification was carried out on-site. The new automated boiler combustion adjustment system is a core element of a comprehensive system, currently under development, that will eventually enable AI-controlled operation of thermal power plants. The latest test results mean development can now proceed toward further advances, including improvements to the system's precision and expansion of its applicable functions.

MHPS is developing AI-based boiler control systems to support power companies globally. By analyzing the large volumes of complex digital data acquired during boiler operation, these systems can provide a range of functions such as cost optimization (operating costs, maintenance management costs, etc.) and early detection of anomalies.

Prior to the current verification testing program, MHPS had provided power generation equipment to the Linkou Thermal Power Plant, overseeing delivery of three sets of coal-fired supercritical-pressure boilers and steam turbines with outputs of 800 megawatts (MW) each. The first set has already started commercial operation, and the second is scheduled to go into service in spring 2017.

In conventional combustion tuning testing, a variety of processes are optimized by adjusting parameters -- such as flue-gas emission characteristics, combustion balance, steam temperature characteristics, and boiler efficiency -- set by an experienced engineer. During the recently completed verification testing in Taiwan, an AI system that had learned changes in process values was called on to propose the optimal parameters. The results confirmed that the AI system proposed parameters essentially no different from those set by an experienced engineer, and the various process values were well-balanced.

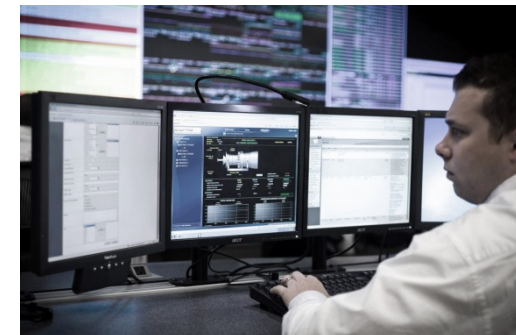
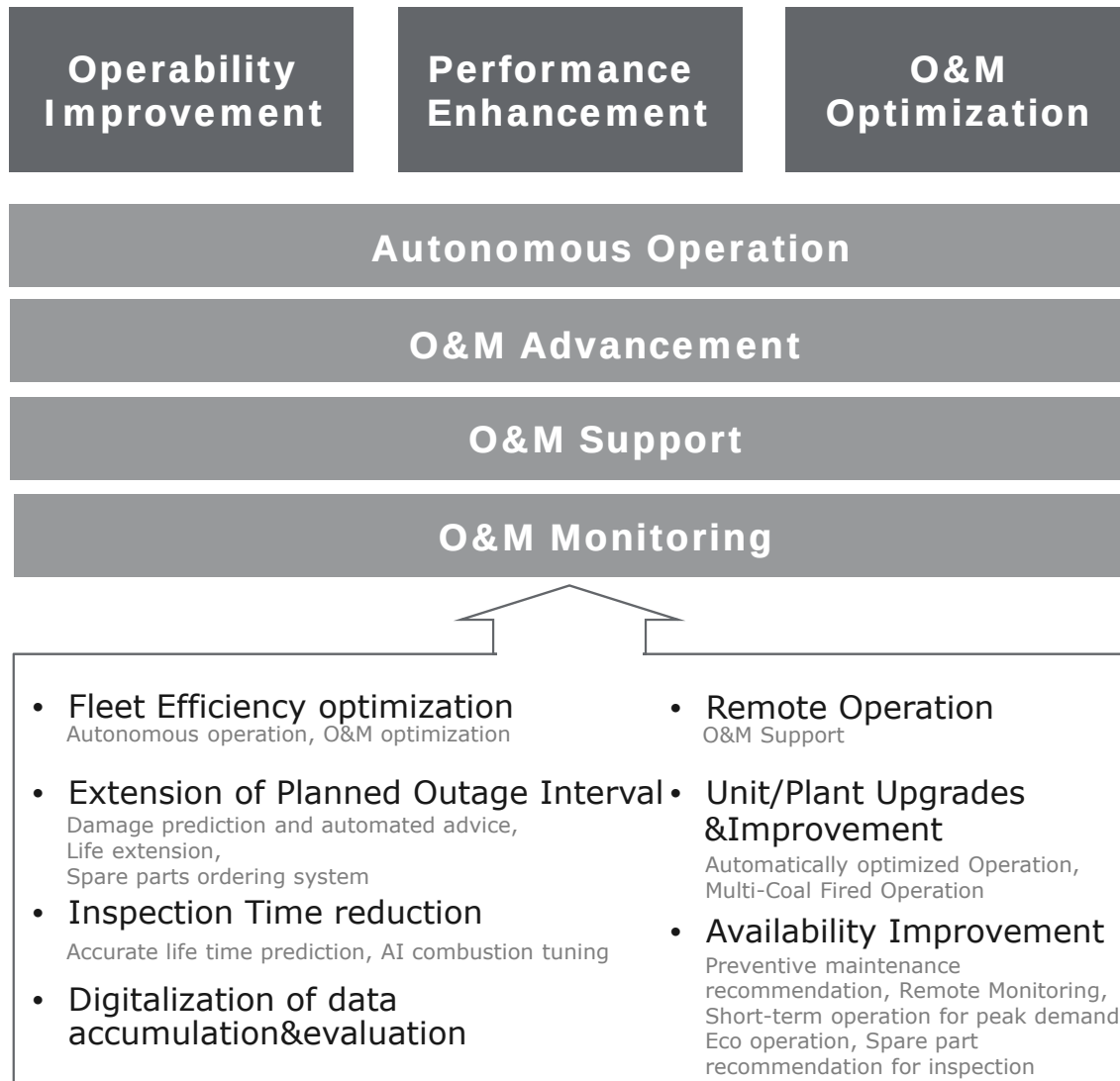
MHPS will continue to enhance the AI-based combustion tuning system at the Linkou Thermal Power Plant. It will also apply the results obtained through the verification testing program in Taiwan to MHPS digital solutions portfolio, for future proposals to other potential users.



Taiwan Power Company's Linkou Thermal Power Plant

MHPS-TOMONI ICT Solution

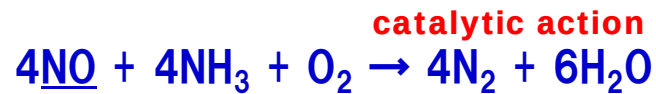
Through partnership, we ensure customer satisfaction throughout strategic development to expand mutual benefits in a sustainable way.



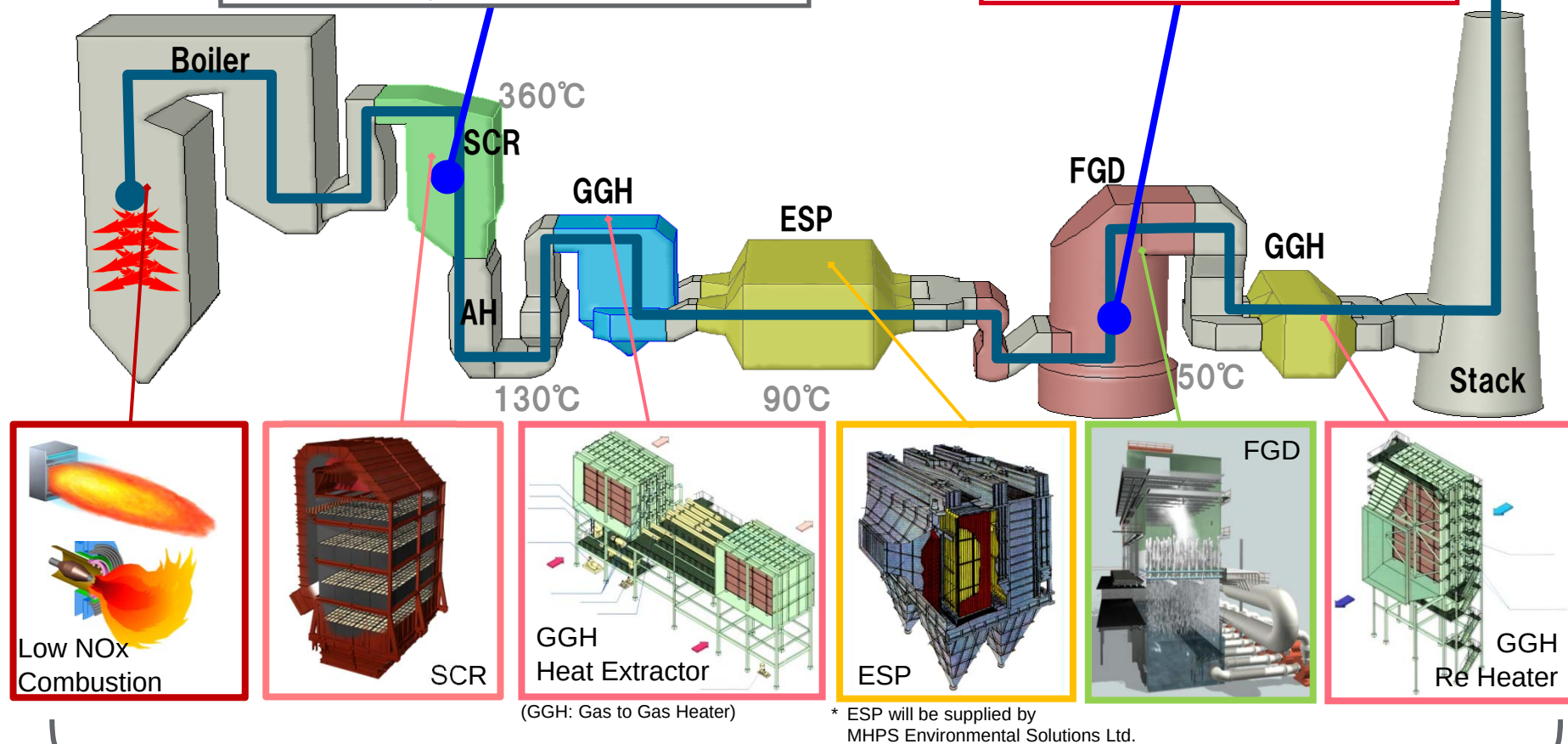
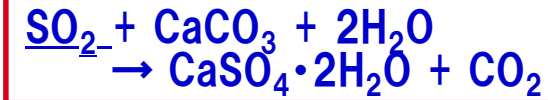
4. Air Quality Control System

Air Quality Control System (AQCS) for Coal Fired Plant

Harmful NO is decomposed into harmless N₂ and H₂O by **catalytic**



Harmful SO₂ is recovered as harmless gypsum(CaSO₄)



One-stop AQCS solution by MHPS

World lowest level emission (SO_x, NO_x, PM) can be achieved by applying the integrated AQCS system

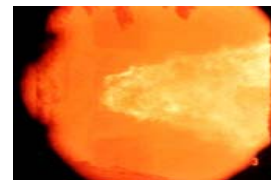
World-class Combustion Test Facility

- Combustion test facility upgraded in October 2014 with More sophisticated instrumentation equipment to evaluate combustion and fluid characteristics.
- Development of high efficiency low NOx combustion (burners and systems) for both of tangential and opposed firing boilers.
- Advanced and speedy developments by integration of combustion test and CFD simulation.
- Accommodation of various fuels - coal, cokes, biomass, oil, residual oil, vacuumed residue (VR), solvent de-asphalting (SDA), and so on.

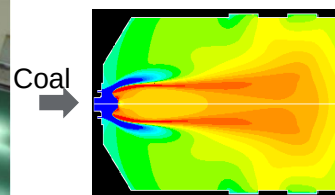
CFD: Computational Fluid Dynamics



Combustion test furnace (4 t/h)



Actual flame



CFD simulation

Combustion test
- Detailed measurement
- Verification of combustion performance



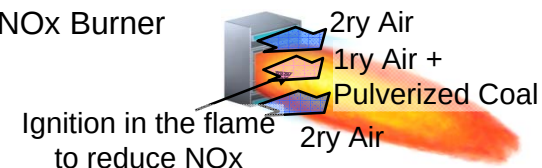
Upgrade
of CFD



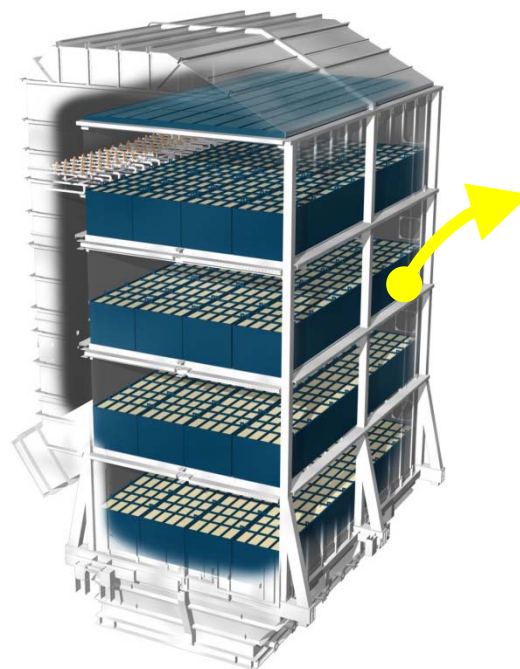
Advanced and
Speedy test

CFD simulation
- Case study of test in advance
- Selection of optimum conditions
- Evaluation of actual boiler performance

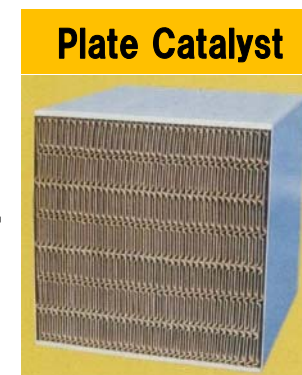
Low NOx Burner



SCR (Selective Catalytic Reduction) System



or

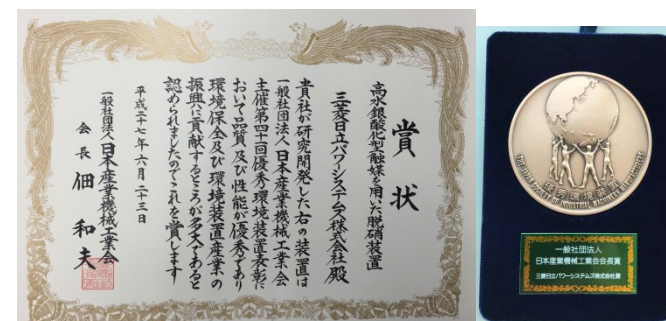


SCR Performance

Approx. **90% NO_x removal efficiency** can be achievable.

SCR System

MHPS is a pioneer of SCR technology and is producing & distributing both honeycomb and plate catalyst. Either type of MHPS catalyst is the largest market share in the world and we contribute to global environmental conservation.



MHPS won the chairman prize of JSIM* for developing a new high mercury oxidation catalyst.

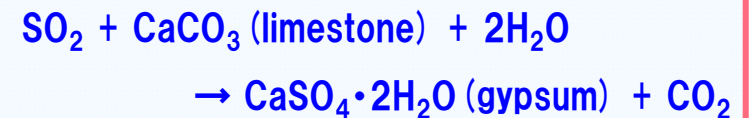
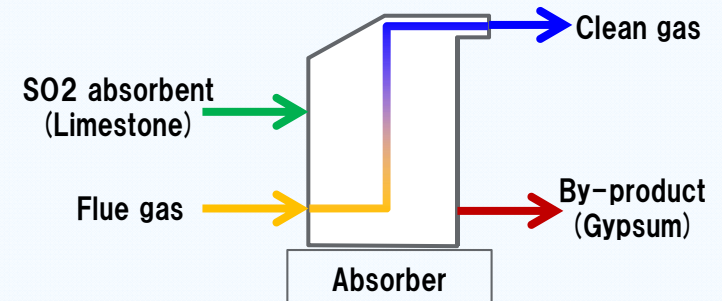
* The Japan Society of Industrial Machinery Manufacturers

Wet FGD (Flue Gas Desulfurization) System

FGD Absorber



Chemical Reaction in Absorber



FGD Performance

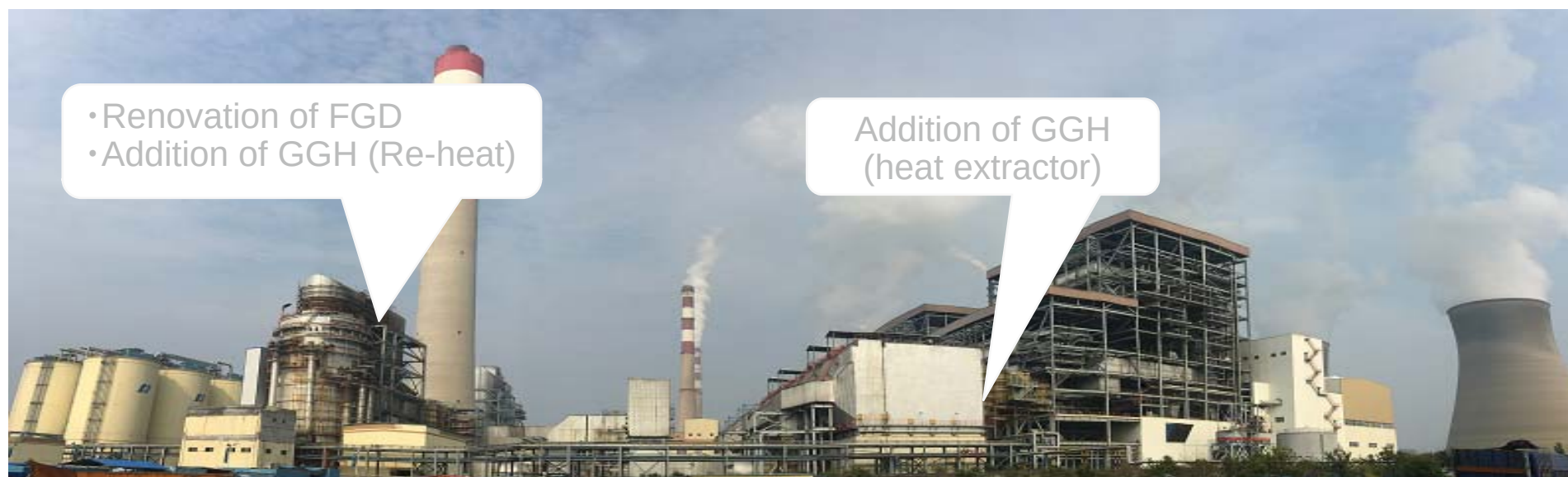
More than **95% SO2 removal efficiency** can be achievable.

Zouxian Power Station AQCS Renovation Project in China

- Dust removal efficiency and SOx removal efficiency were drastically improved through the package contract of AQCS renovation.

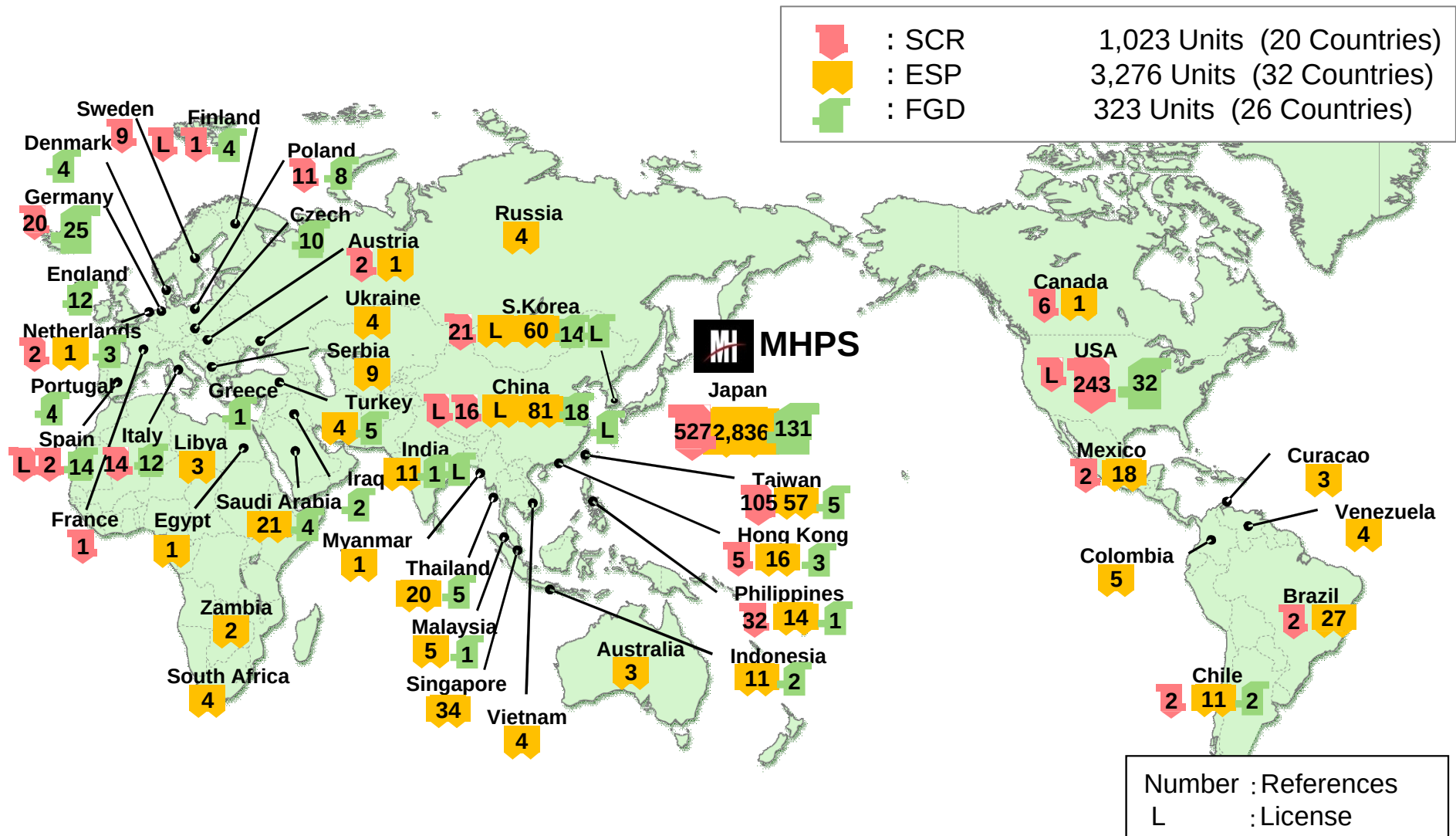
Output:	1000 MW
Site:	the province of Shangtung
Fuel:	Bituminous Coal
SOx removal efficiency	98.8%

Before	SO ₂	Dust
	>50mg/Nm ³	14mg/Nm ³
↓		
After	SO ₂	Dust
	≤35mg/Nm ³	≤5mg/Nm ³



MHPS's AQCS Global Activities

MHPS Delivered AQCS units all over the world



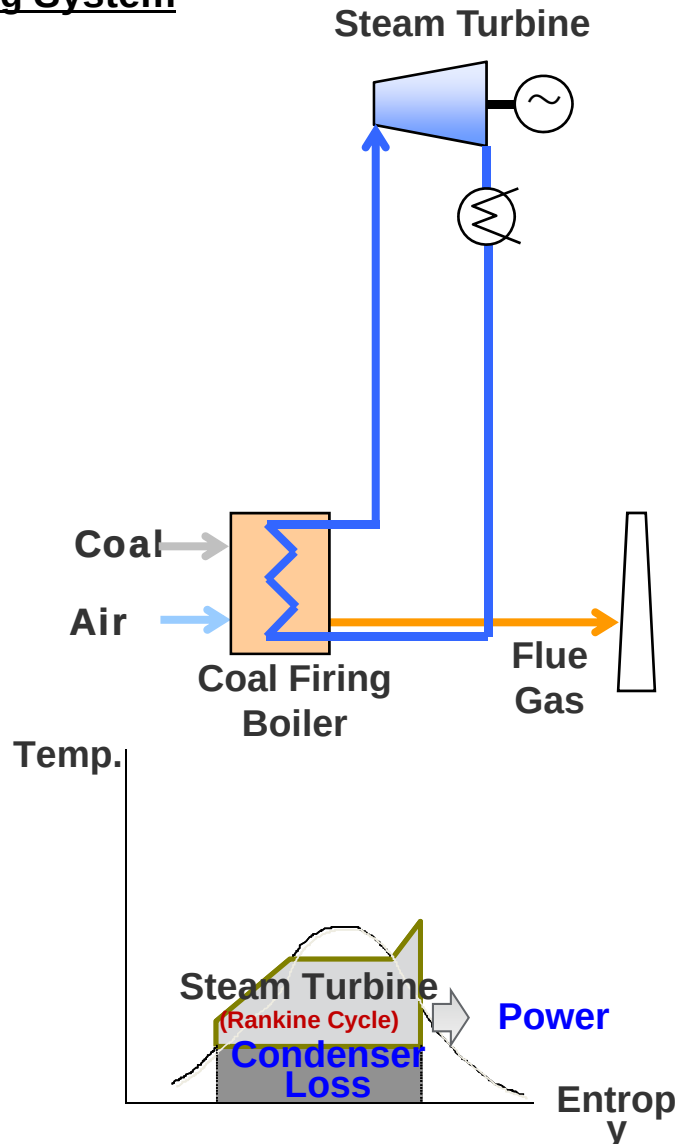
5. Advanced Clean Coal Technology

5-1. IGCC

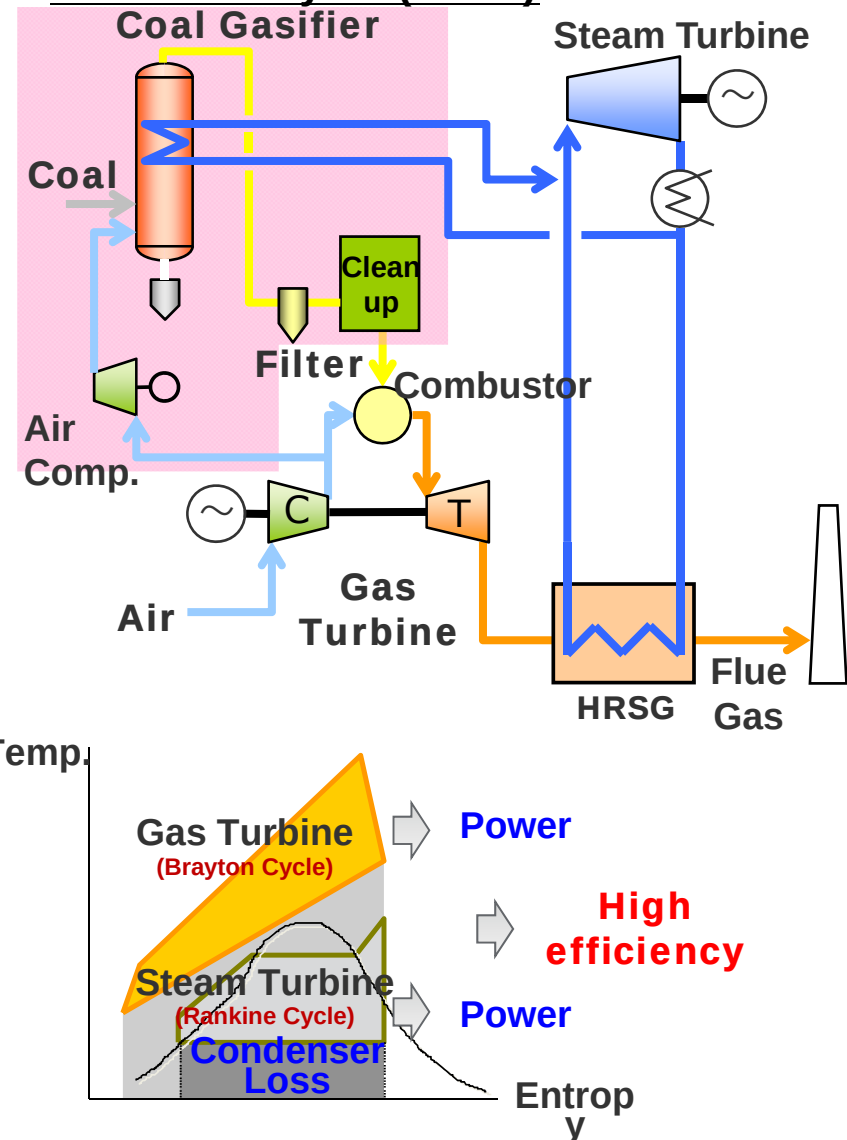
Outline of IGCC System

*Integrated coal Gasification Combined Cycle

① Conventional Coal Firing System

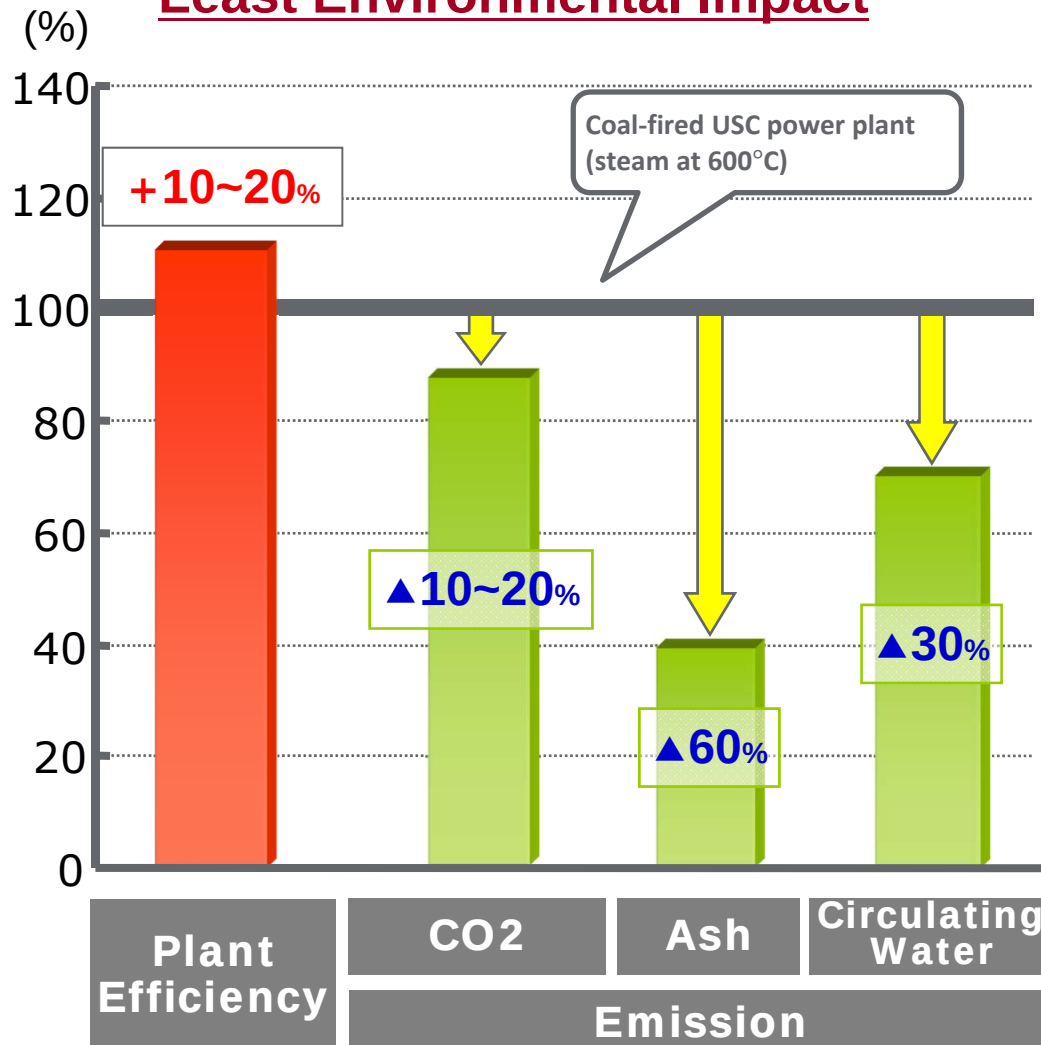


② Integrated Coal Gasification Combined Cycle (IGCC)



Features of IGCC system (Environmental Performance)

Higher Efficiency and Least Environmental Impact



Fly-ash
(Conventional Boiler)

Grassy Molten Slag
(IGCC)

Approx. 60% decrease in volume



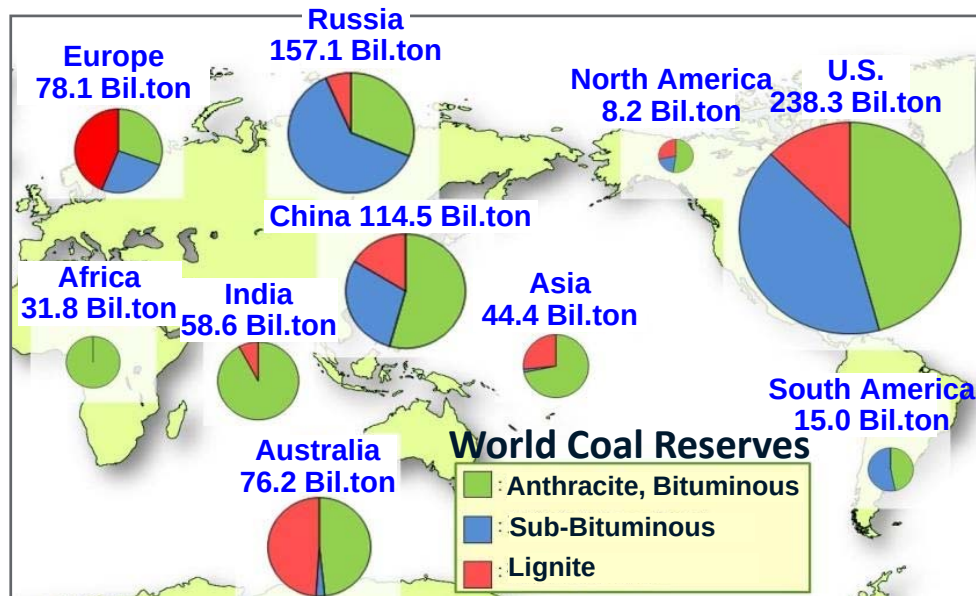
Utilization as a
pavement material

Utilization as a
concrete aggregate

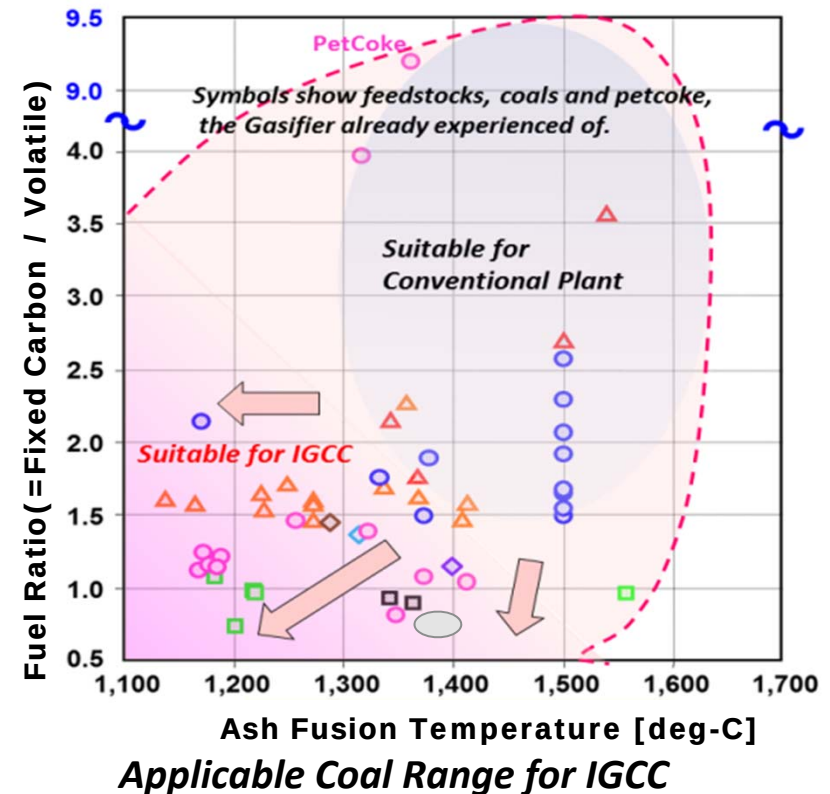
are possible.

Features of IGCC system (Fuel Flexibility)

Flexibility to “Variety of Coal”

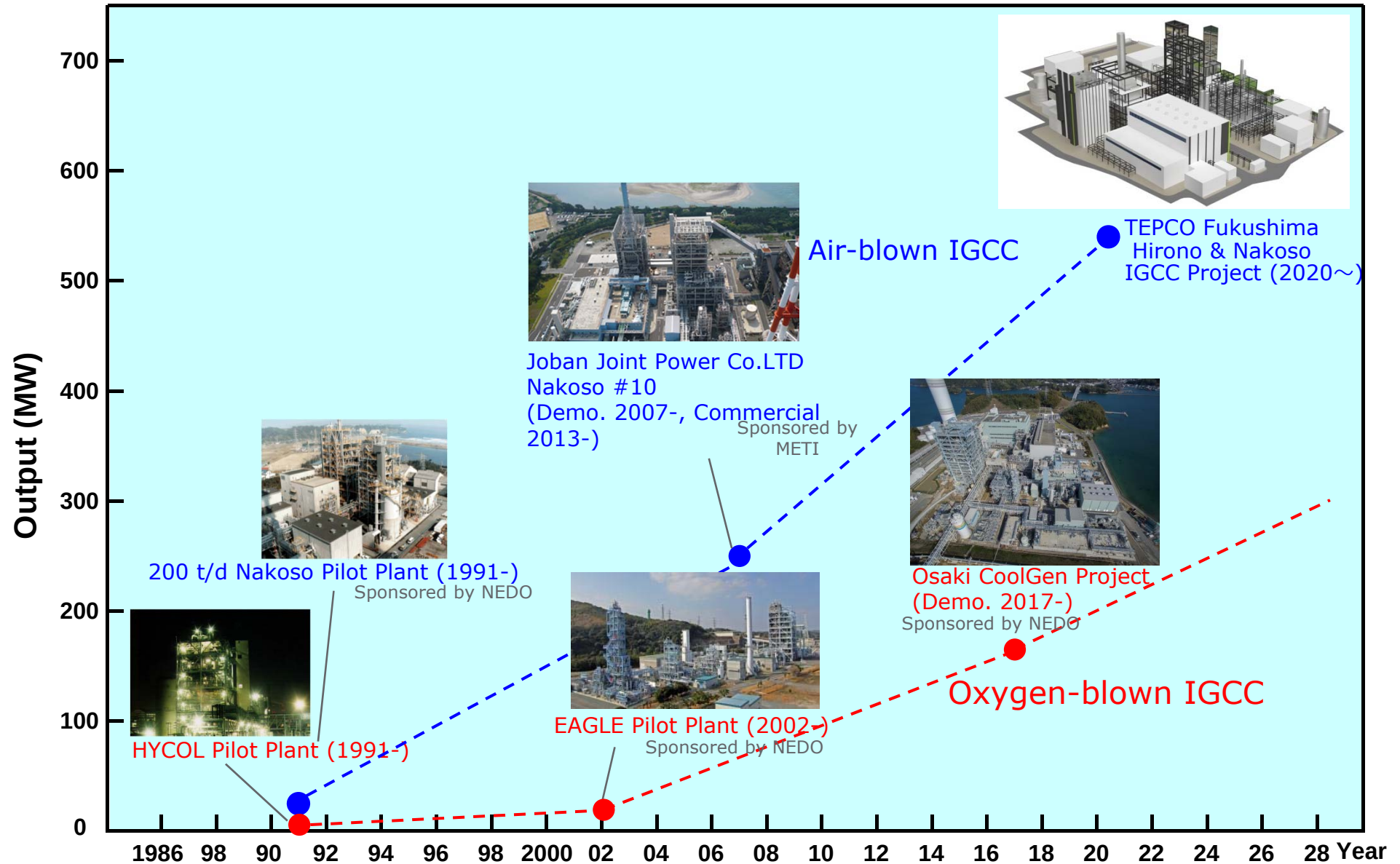


- Anthracite, Bituminous: 413.0 Bil. ton
- Sub-Bituminous : 264.0 Bil. ton
- Lignite : 152.0 Bil. ton

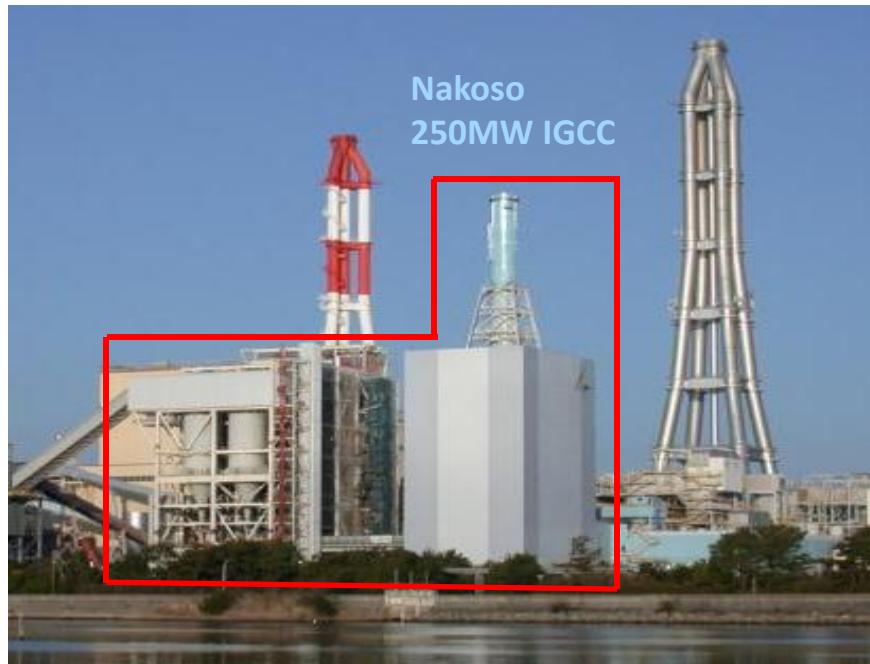


- *LRC (Low-Rank coals), that have low ash fusion temperatures, are not suitable for conventional boiler due to causing ash slagging problem and limiting operation of the plants, but IGCC can use wider range of coals including LRC.*
- *The Air-blown IGCC System already verified its flexibility and capability to many brands of coal sourced in the world.*

IGCC/Gasification Technology Development



Nakoso 250MW IGCC Plant



Major Specification

Output	250 MW (gross)
Gasifier	Air-blown Dry Feed
Gas Clean-Up	MDEA (Methyl diethanol amine)
Gas Turbine	M701DA GT (1 on 1)
Plant Efficiency	42% (LHV, net)

Project Schedule

Operation Started	Sep. 2007
Commercial Operation	July. 2013

Nakoso 250MW IGCC Demonstration Plant achieved all the following targets.

- ✓ Excellent Performance (**Highest Efficiency**, Less Environmental impact)
- ✓ Higher Reliability (**World record of continuous operation 3,917hr**)
- ✓ Fine Operability (Load change rate >3%/min)
- ✓ Fuel Flexibility (Verified applicability for low-rank coal, **10 kinds coals**)



Converted to **the First Commercial IGCC Plant** in Japan.
(Total operating hours are approx. **36,400 hrs.**)

JSME* Medal for Technology
(2013) Awarded



This project was sponsored by METI

* Japan Society of Mechanical Engineering)

Achievements of Nakoso 250MW IGCC Plant

		Targets	Achievements	Note
Performance	Output (Gross) (Net)	250MW 220MW	250MW 225MW	
	Efficiency (Net, LHV)	> 42.0%	42.9%	
	Carbon Conversion	> 99.9%	> 99.9%	
Emission (@dry, 16%O ₂)	SO _x NO _x Dust	< 8 ppm < 5 ppm < 4 mg/m ³ N	1.0 ppm 3.4 ppm < 0.1 mg/m ³ N	
Operational Flexibility	Coal Kinds	Bituminous Sub-bituminous	Chinese, Canadian 2 US (including PRB) 3 Indonesian (Adaro , etc.) Colombian, 2 Russian	10 kinds of coal in total 6 Sub-bituminous 4 Bituminous have been used.
	Start-up Time	< 18 hr	15 hr	
	Minimum Load	50%	36%	
	Ramping Rate	3%/min	3%/min	
Reliability	Long-term Continuous Operation	2,000 hr	3,917 hr	Cumulative operating hours : > 36,400 hrs.

Osaki CoolGen Project

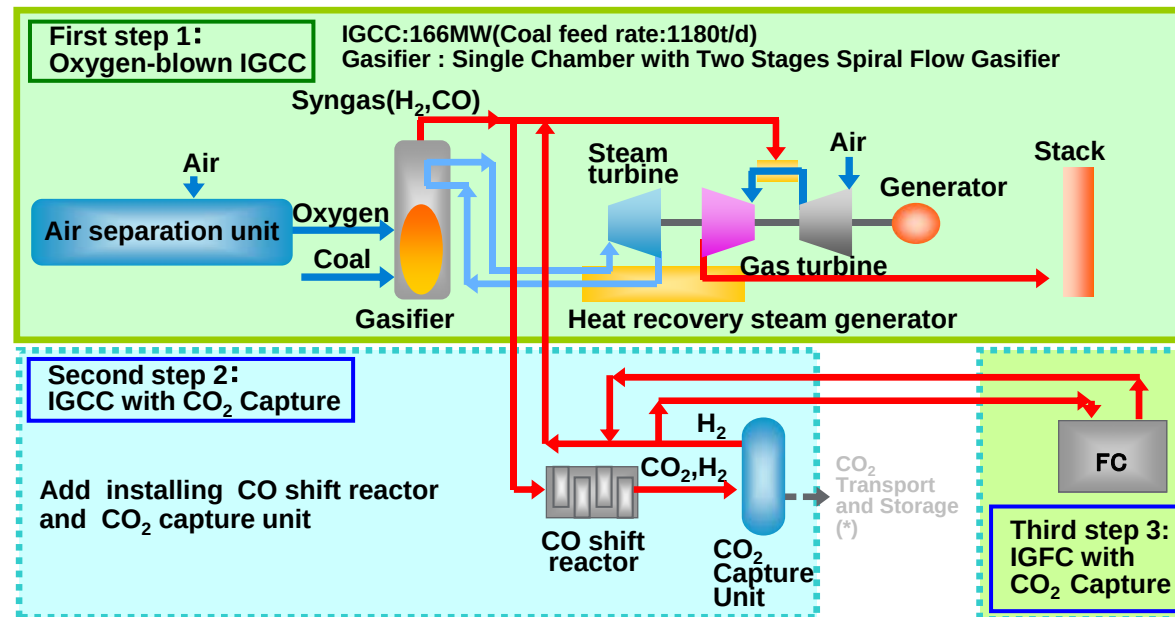


Major Specification

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	40.5% (HHV, net) (42.7%(LHV, net))

Project Schedule

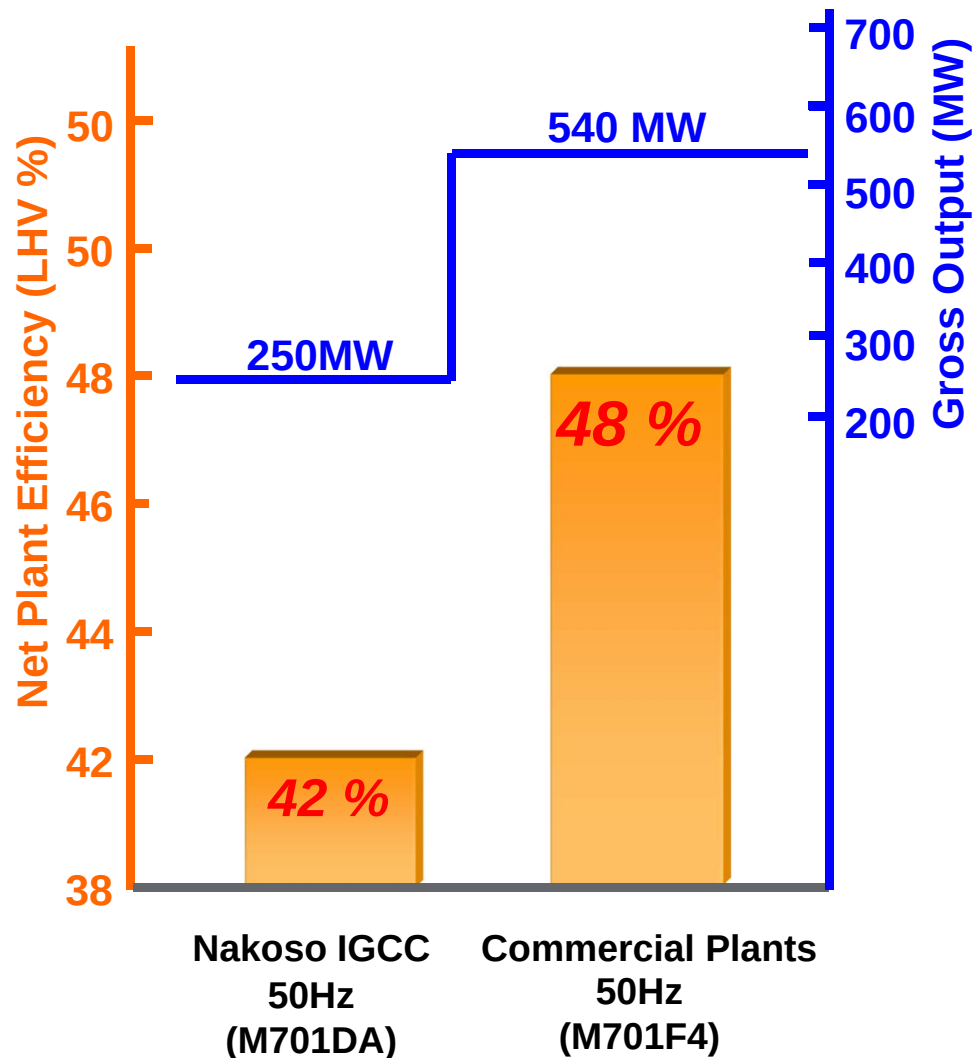
Construction Started	March 2013
Demo. Operation Start	March 2017
Coml. Operation Start	April 2019



(*) CO₂ Transportation and Storage are outside of the Osaki CoolGen Project.

This project is sponsored by NEDO

Expected Performance of IGCC Plants



Item		Specifications
		50Hz
Coal		Bituminous
Output	Gross	540 MW
	Net	480 MW
Gasifier	Oxidizer	Air-blown (O2 Enriched)
	Coal Feed	Dry Feed
Gas Clean-Up		MDEA (Methyl Di-ethanol Amine)
Gas Turbine		M701F4 ×1 (1 on 1)
Net Plant Eff. (LHV)		48 %

Note: Plant performance like output and efficiency depends on site conditions including coal properties.

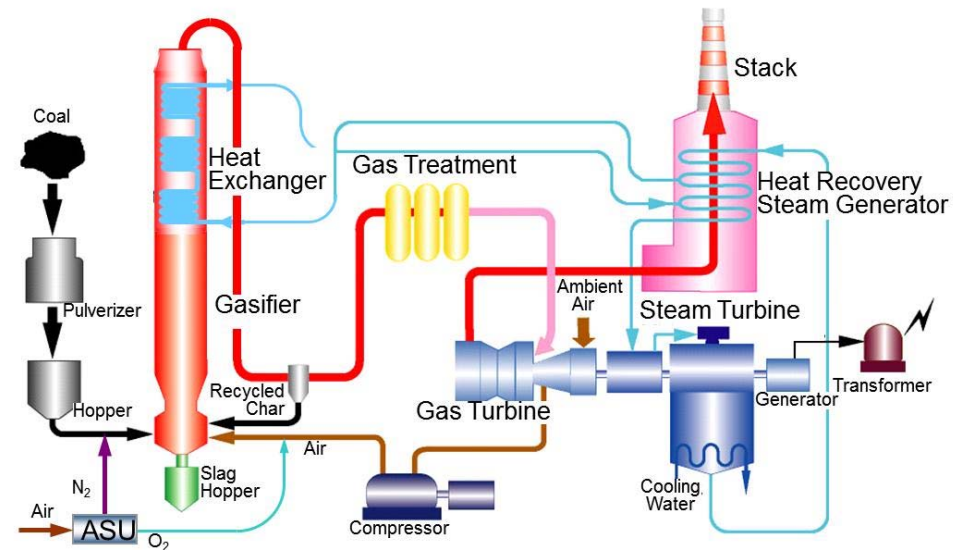
Fukushima Revitalization Power IGCC Project



Major Specification

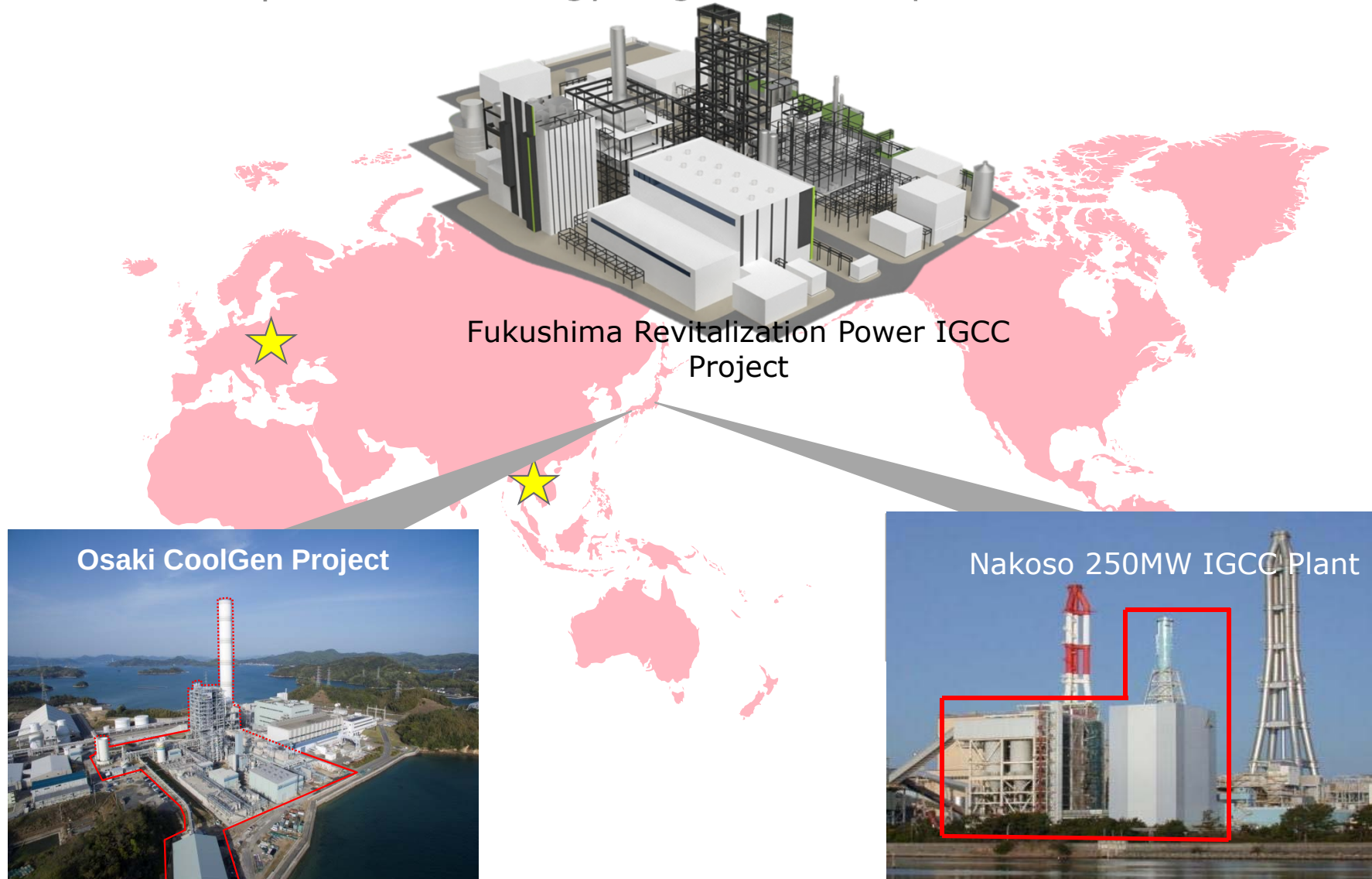
Output	540 MW (gross) 480 MW (net)
Gasifier	Air-blown Dry Feed
Gas Clean-Up	MDEA
Gas Turbine	M701F GT (1 on 1)
Project Schedule	
Operation Start	2020 (Nakoso site) 2021 (Hirono site)

- High Efficiency by using state of the art Gas Turbine
- Lower CO₂ emission intensity than the latest USC coal fired power plant.
- Fuel Flexibility for high moisture Low Rank Coal
- Highly Reliable system verified in Nakoso 250MW IGCC plant



IGCC Projects around the world

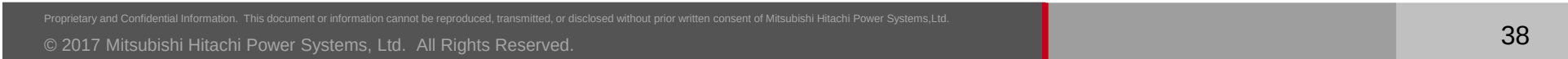
MHPS develop IGCC technology originated in Japan to around the world



5. Advanced Technology

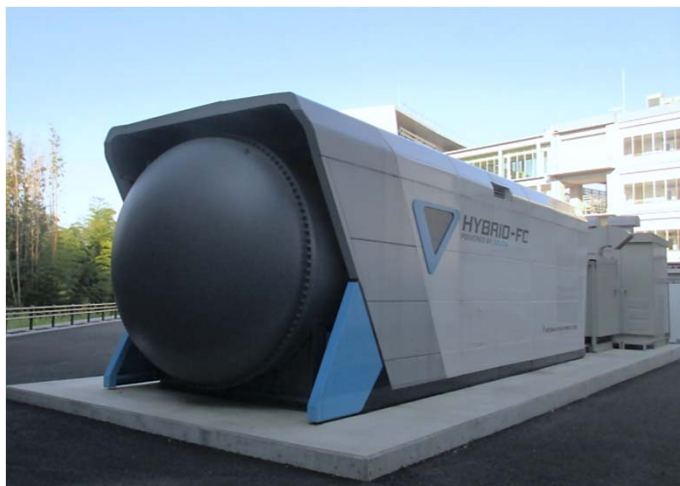
5-2. SOFC

SOFC and Micro Gas Turbine Hybrid System



SOFC-MGT Hybrid System Line-up

250kW class Demonstration system



Planned Specifications

Model	HYBRID-FC
Rated output	250 kW
Efficiency at sending end	55 %LHV
Outside dimension (m)	[W]3.2 [L]9.5

1,000kW class Hybrid System (image)



Planned Specifications

Model	HYBRID-FC
Rated Output	1200 kW
Efficiency at sending end	57 %LHV
Outside dimension (m)	[W]9.5 [L]18 [H]3.8

SOFC-MGT Hybrid System Projects in Japan

- The demonstration 250kW class system started operation from March 2015 in Kyushu university and has been performed up to now.
- 6 demonstration projects will be conducted to verify performance under each operation condition.



Total:
7 systems

- Finished, 1 system, 2012~2013
- In operation, 2 system, 2015~
- In preparation, 4 systems, 2016~



Technical development of SOFC is sponsored by NEDO

Conclusion

- ◆ **MHPS shall be continuously developing clean coal technology to improve plant efficiency and reduce carbon emission**
- ◆ **MHPS shall contribute to environmental conservation and carbon emission reduction to provide Japanese clean coal technology worldwide**
- ◆ **MHPS shall work to promote IGCC and SOFC as highly efficient power generation technologies in addition to conventional clean coal technology**



**MITSUBISHI HITACHI
POWER SYSTEMS**