OSAKI CoolGen Project

Demonstration of Integrated Coal Gasification Fuel Cell Combined Cycle

OSAKI CoolGen Corporation

Company Profile

Company name	**OSAKI CoolGen Corporation** This name reflects our desire to realize “CoolGen Project” plan as one of the government’s “clean coal” policies on Osakikamijima Island. **Cool Gen Project** A demonstration project based on “Strategic Technology Roadmap” of the government for realization of innovative low carbon emission coal-fired power generation in which IGCC, IGFC and CCS are combined
Date of incorporation	**July 29, 2009**
Address	6208-1 Nakano, Osakikamijima-town, Toyota-gun, Hiroshima Prefecture (on the premises of The Chugoku Electric’s Osaki Power Station)
Investing companies	The Chugoku Electric Power Co., Inc. 50% Electric Power Development Co., Ltd. (J-POWER) 50%
Business summary	Demonstration and facility construction of oxygen-blown IGCC (Integrated Coal Gasification Combined Cycle), which is the basis for Integrated Coal Gasification Fuel Cell Combined Cycle (IGFC) with ultimately high efficiency, and CO_2 capture technology

※IGCC: Integrated Coal Gasification Combined Cycle
※IGFC: Integrated Coal Gasification Fuel Cell Combined Cycle
※CCS: Carbon Dioxide Capture and Storage

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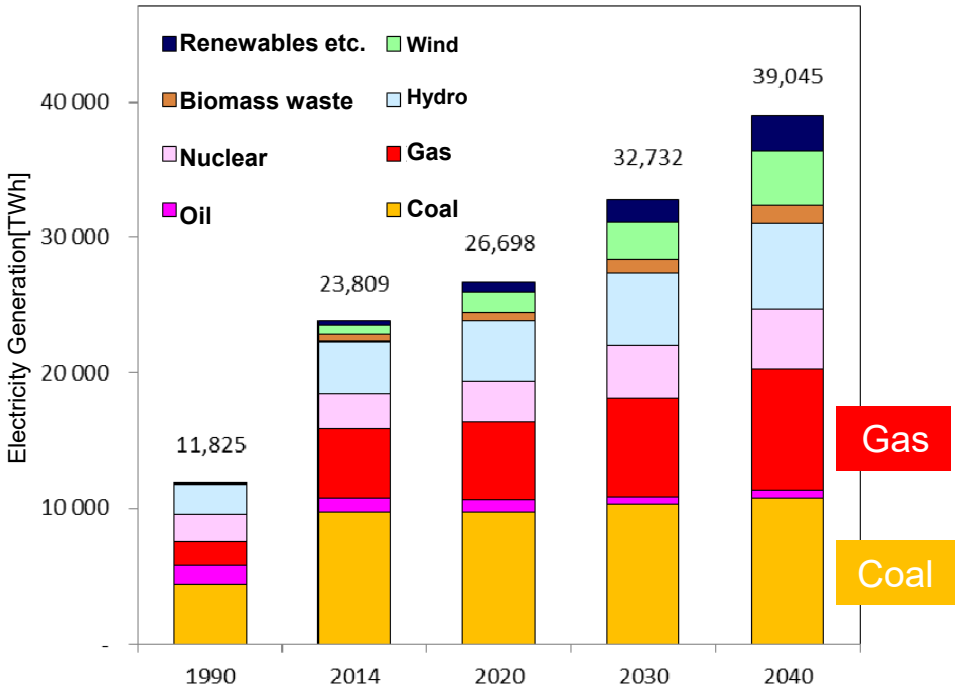
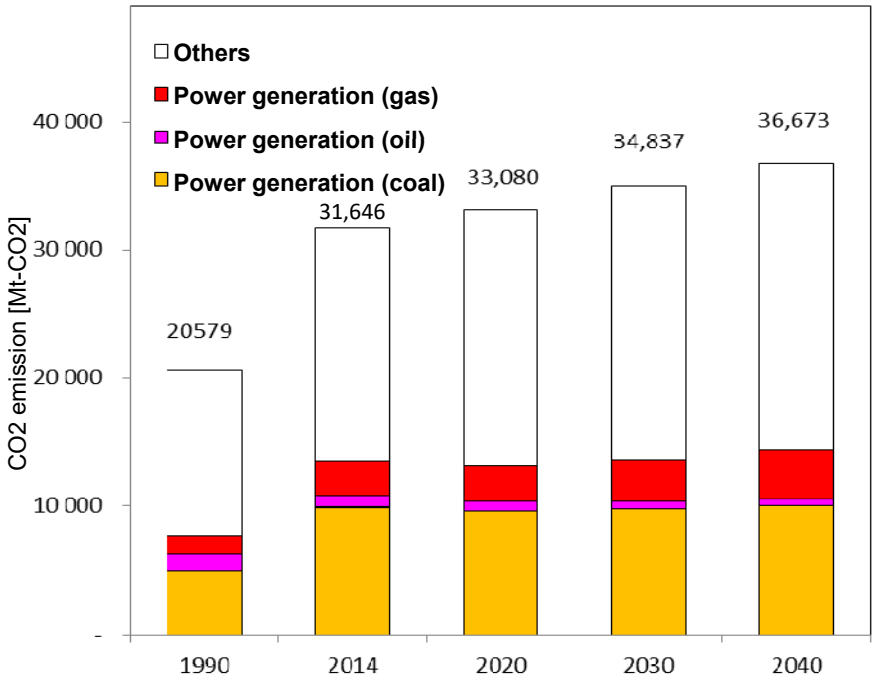
1. Project Background

Outlook on World Power Generation and CO_2 Emission

- About 30% of the world's energy generation will continue to use coal
- About 30% of world's CO_2 emission will be from coal energy generation making the emission reduction a pressing issue





Percentage of coal power generation in the world **28% (2040)**

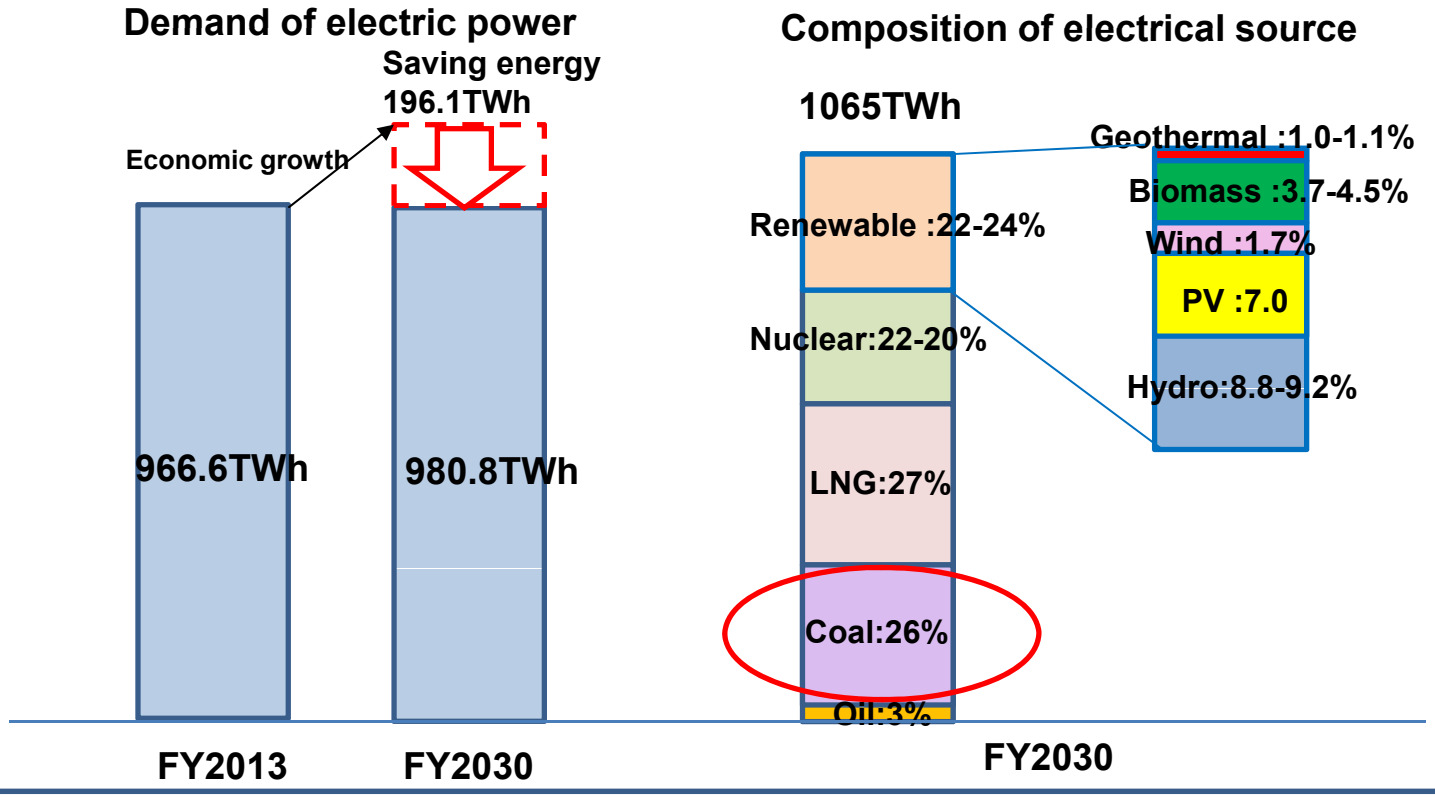
Percentage of CO_2 emission from coal power generation in the world **27% (2040)**

Source: IEA World Energy Outlook 2016 (New Policies Scenario)

Coal-fired Power Generation - status in Japan -

- Energy self-sufficiency in Japan ＝ approx. 6%*
- Coal-fired generation ⇒ Essential for the “Best Mix” energy policy

Energy Mix in Japan**

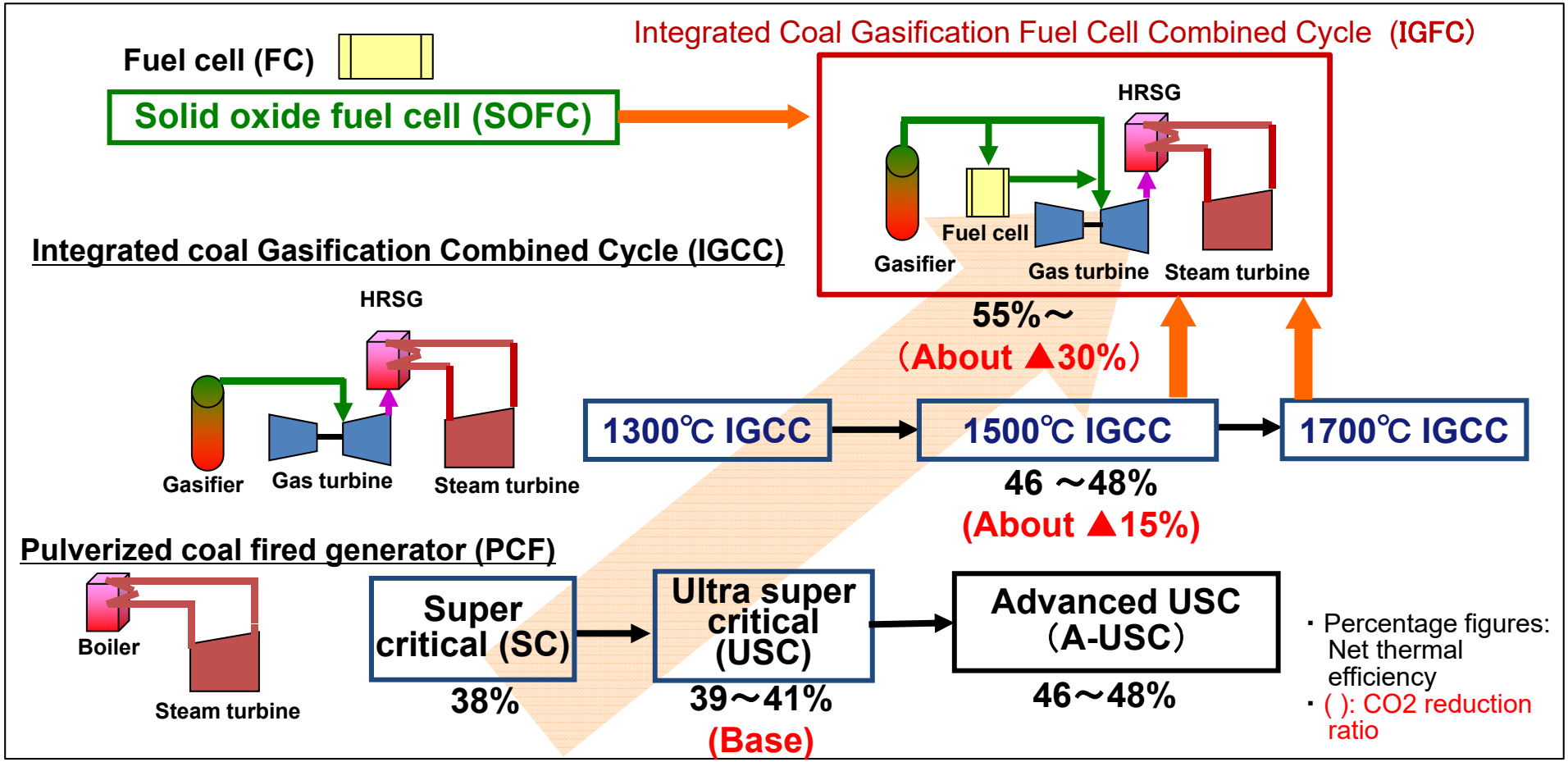


*Source : Japan’s Energy White Paper 2016

**Source : METI Long-term energy supply-demand outlook(2015.7)

Strategic Technology Roadmap of Highly Efficient Coal-fired Power Generation

- Currently in Japan, pulverized coal fired (PCF) plants with ultra super critical (USC) steam generators with only steam turbines are primarily in use, but combined cycle power plants with different types of turbines are being developed for thermal efficiency improvement.
- When the ultimate technology of IGFC will be commercialized, improvement of efficiency by 14pt or above will be achieved. As a result, about 30% CO_2 emission will be reduced.



Reasons for Development of Highly Efficient Coal-fired Power Generation and Carbon Emission Reduction Technology

For the world's sustainable development

- Efficient use of economically advantaged coal to meet increasing demand for power
- Climate change mitigation by substantial reduction of CO_2 emission

For Japan that heavily depends on imported resources

- Coal is vital in energy mix for its abundance, widespread reserve areas and stable cost

Technology must be developed for highly efficient coal-fired power generation and reduction of carbon emission

(First step)

OSAKI CoolGen Project

Integrated Coal Gasification Combined Cycle (IGCC)

High plant efficiency, environmental performance, facility reliability, coal types compatibility and plant operability will be verified

(Second step) **IGCC + CO_2 capture** ➡ (Third step) **IGFC + CO_2 capture**

2. Oxygen-blown Coal Gasification Technology

Oxygen-blown Coal Gasification Technology Development

The OSAKI CoolGen Project will leverage knowledge and expertise gained from the EAGLE Project ※

For commercial use

OSAKI CoolGen Demonstration plant 166MW (1,180t/d)
(FY 2016- at Osakikamijima)

EAGLE pilot plant (150t/d)
(FY 2002 - 2013 at Kitakyushu)

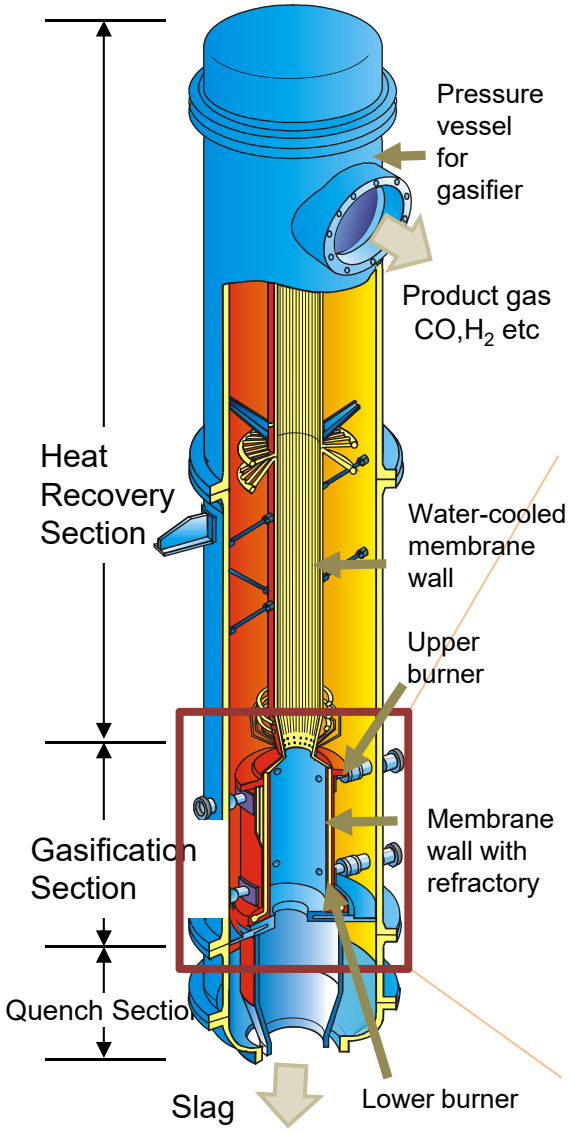
HYCOL pilot plant (50t/d)
(FY 1991-1993 at Sodegaura)

Process Development Unit (1t/d)
(FY 1981-1985 at Katsuta)

※Multi Purpose Coal Gasification Technology Development (FY1998-2009)
（Joint project of NEDO/J-Power）
Innovative CCS Combined with Coal Gasification Technology Development (FY 2010-2013)
(Joint project of NEDO / J-Power / Hitachi)

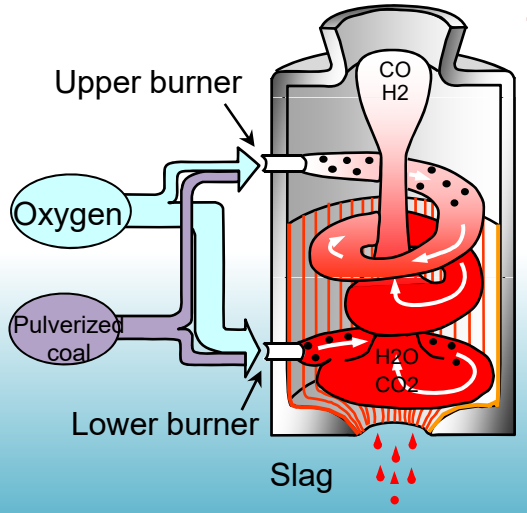
Feature of EAGLE Gasifier (1) High Gasification Efficiency

EAGLE gasifier structure

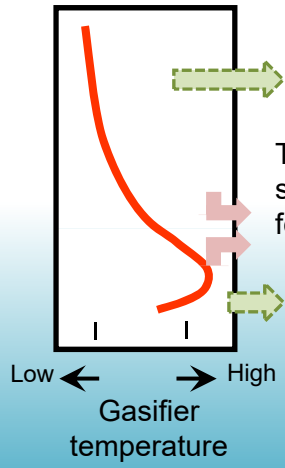


- **"Single section 2 stage spiral flow gasifier" has been implemented with upper and lower coal burners**
- **Adjustment of oxygen supply from upper and lower burners makes high gasification (generation) efficiency and steady slag discharge possible. This will also enable highly efficient gasification of ash with high melting point, not only ash with low melting point**
- **Product gas contains little N_2 because the gasifier is oxygen-blown. Compared to air-blown type, it contains higher ratio of CO and H_2 that are raw material for fuel, which makes the heat value higher**

Conceptual flow in gasifier



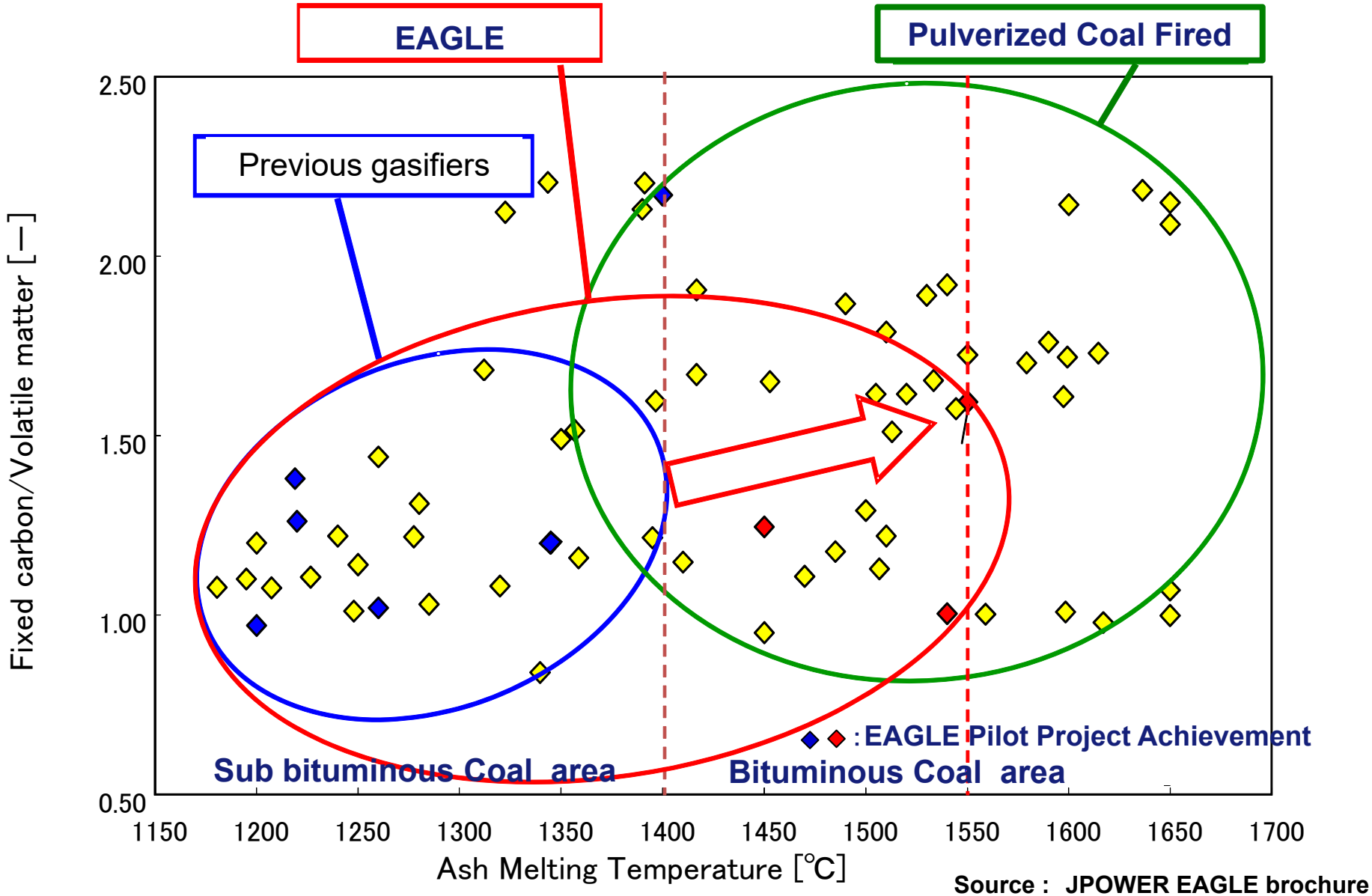
Temperature distribution



Upper burner: Lean oxygen
High efficiency gasification
The spiral flow prolongs and secures the residence time needed for gasification of coal particulate

Lower burner: Rich oxygen
Temperature above ash melting point is maintained for stable discharge of slag

Feature of EAGLE Gasifier (2) Compatibility of Multiple Coal Types



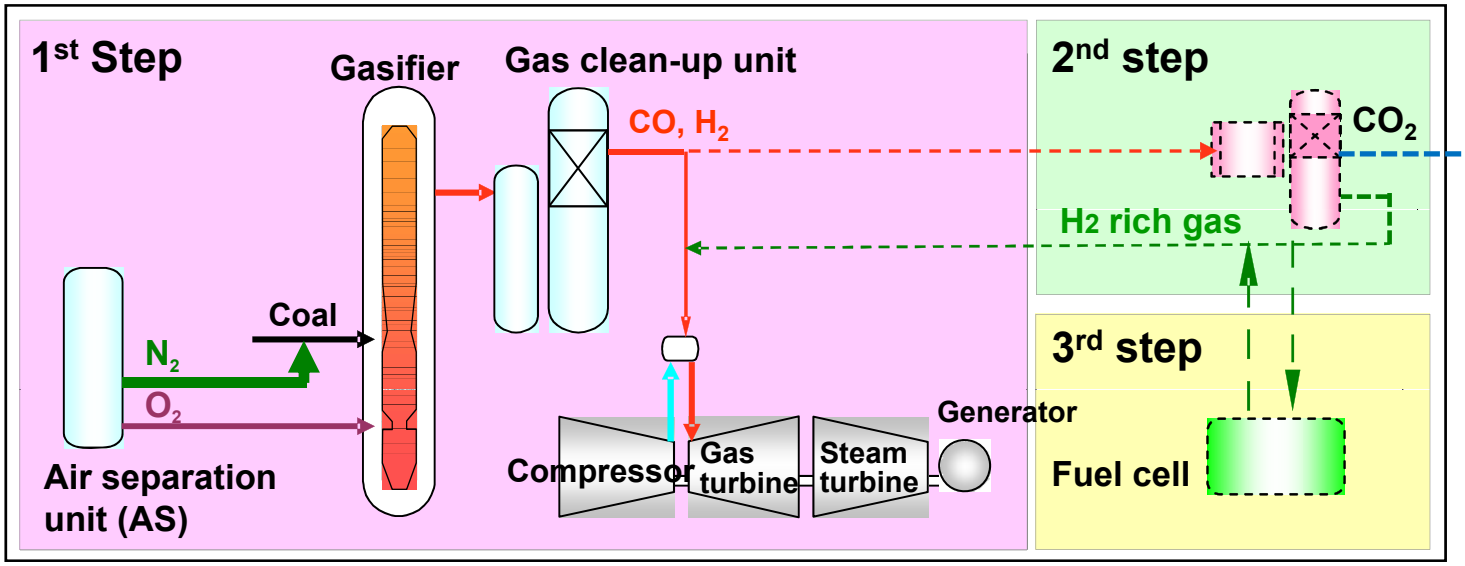
Source : JPOWER EAGLE brochure

3. Outline of OSAKI CoolGen Project

Outline of Osaki CoolGen Project

- This project is aiming at a large reduction of CO_2 emission by the innovative low carbon emission technology in coal-fired power generation in which ultimately efficient IGFC is combined with a CO_2 capture system.
- The project consists of 3 steps. The first step subsidized by METI started in fiscal 2012 and the second and third steps, which started in 2016, are supported by grants from NEDO.

Fiscal	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Environmental assessment													
Feasibility study		Feasibility Study				Feasibility Study		Feasibility Study					
1st step Oxygen-blown IGCC				Design, manufacturing, construction					Demonstration				
2nd step IGCC with CO_2 capture unit								Design, manufacturing, construction		Demonstr-ation			
3rd step IGFC with CO_2 capture unit										Design, manufacturing, construction		Demon-stration	



Project Scheme

METI (~FY2015): Ministry of Economy, Trade and Industry
NEDO (FY2016~):
New Energy and Industrial Technology Development Organization

Subsidy

The Chugoku Electric Power Co., Inc. (Energia)
Electric Power Development Co., Ltd. (J-POWER)

Joint Investment

OSAKI CoolGen Corporation

STEP1 EPC contract

Mitsubishi Hitachi Power Systems, LTD.

Coal gasifier unit
Combined cycle unit
Coordinate all units

JGC Corporation

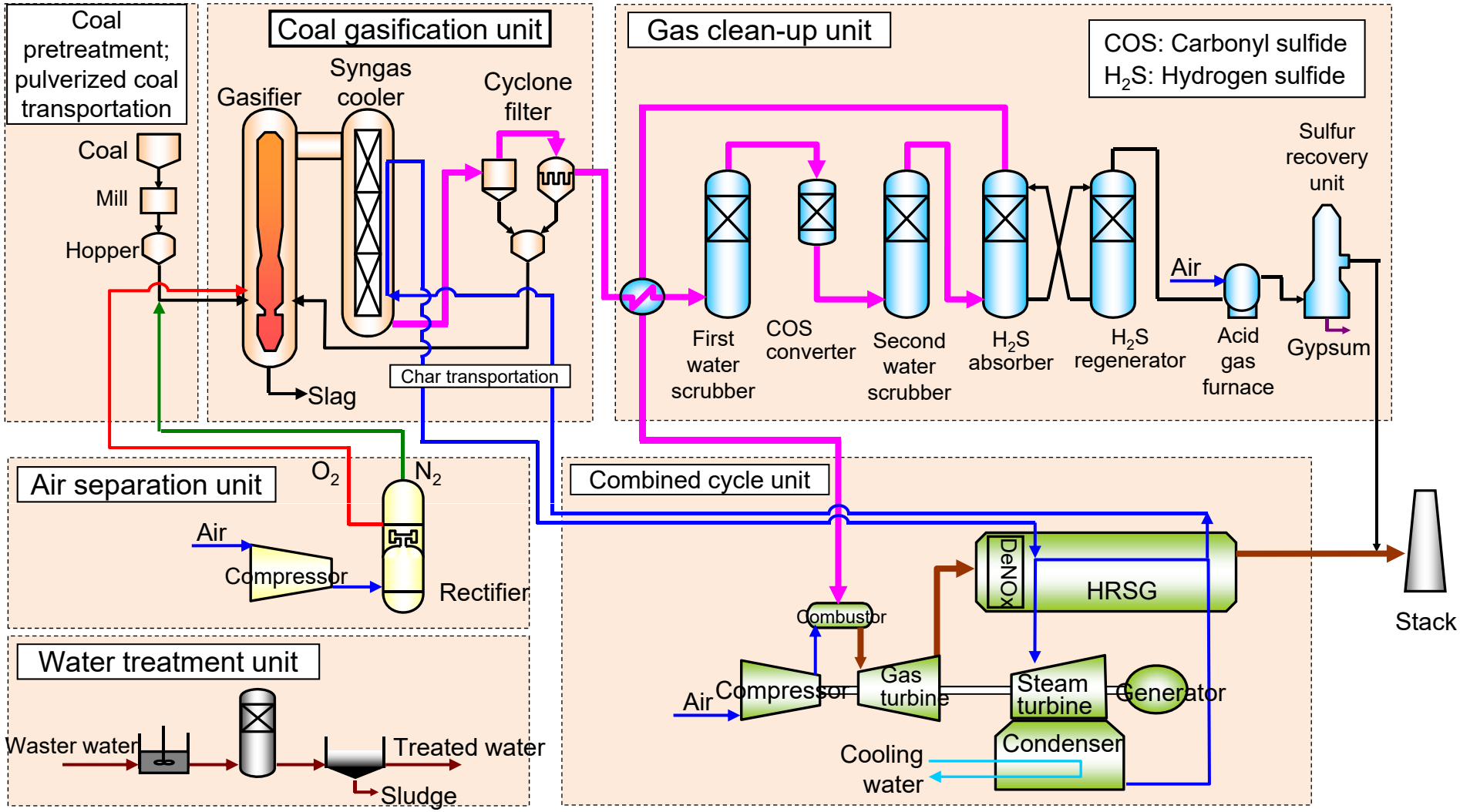
Gas clean up unit
Wastewater treatment
Air separation unit

Diamond Engineering Co . Ltd.

Coal preparation & supply unit

4. Overview and Progress of IGCC Demonstration(STEP1)

Oxygen-blown IGCC Demonstration Facilities



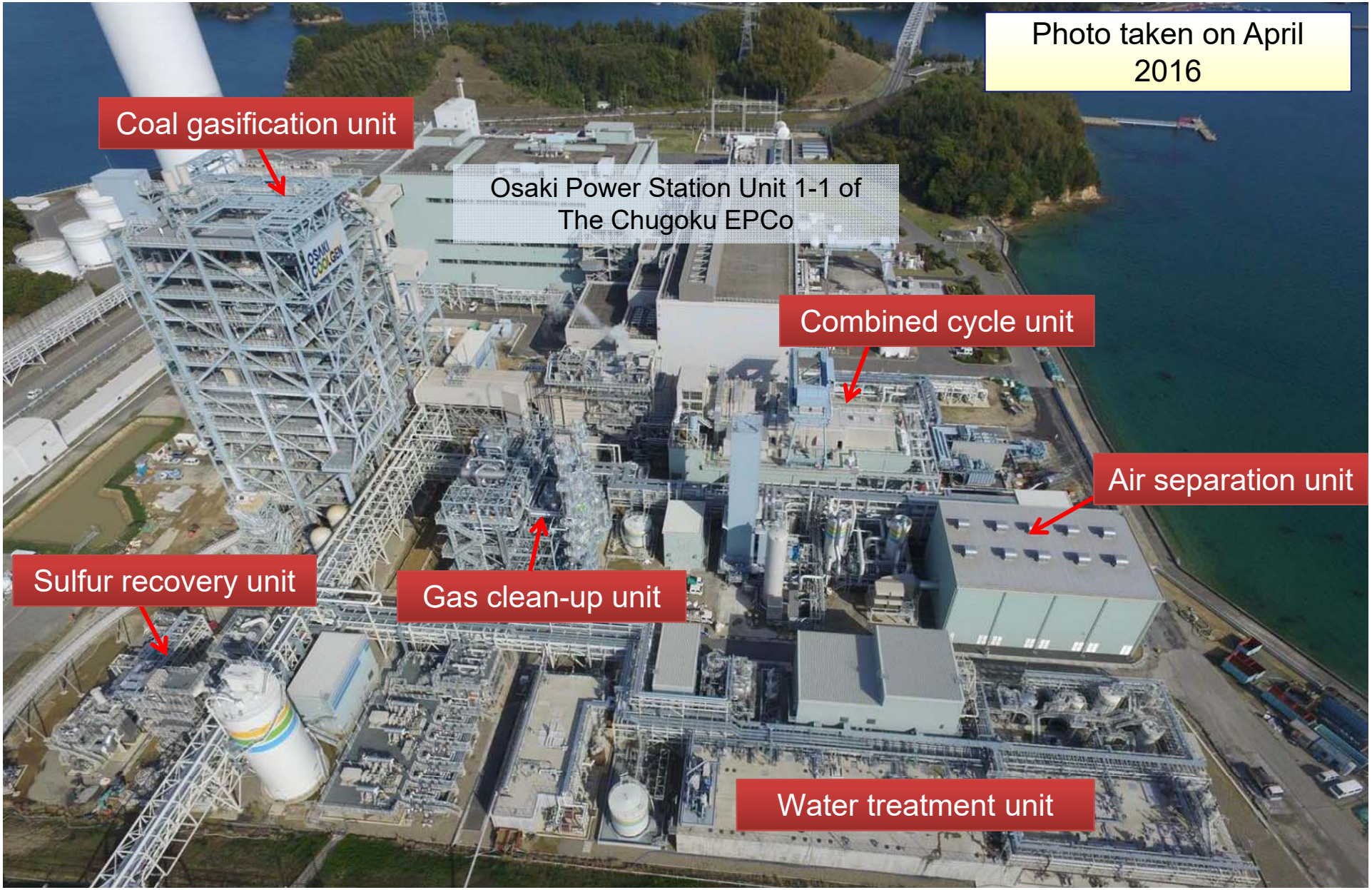
Major Specifications

	Specification
Coal Gasification Unit	Oxygen-Blown Single-Chamber Two-Staged Spiral-Flow Entrained Bed Coal feed：1,180 ton/day
Gas Clean-up Unit	Wet Desulfurization Unit：Methyl Di-Ethanol Amine (MDEA) Sulfur Recovery Unit：Limestone Wet Scrubbing
Air Separation Unit	Pressurized Cryogenic Separation
Combined Cycle Unit	GT (MHPS：H100 TIT=1300°C class, adopted Multi-Cluster burner) Gross Power Output：166MW (GT+ST)
Wastewater Treatment Unit	Gas Clean-up Unit Wastewater Treatment

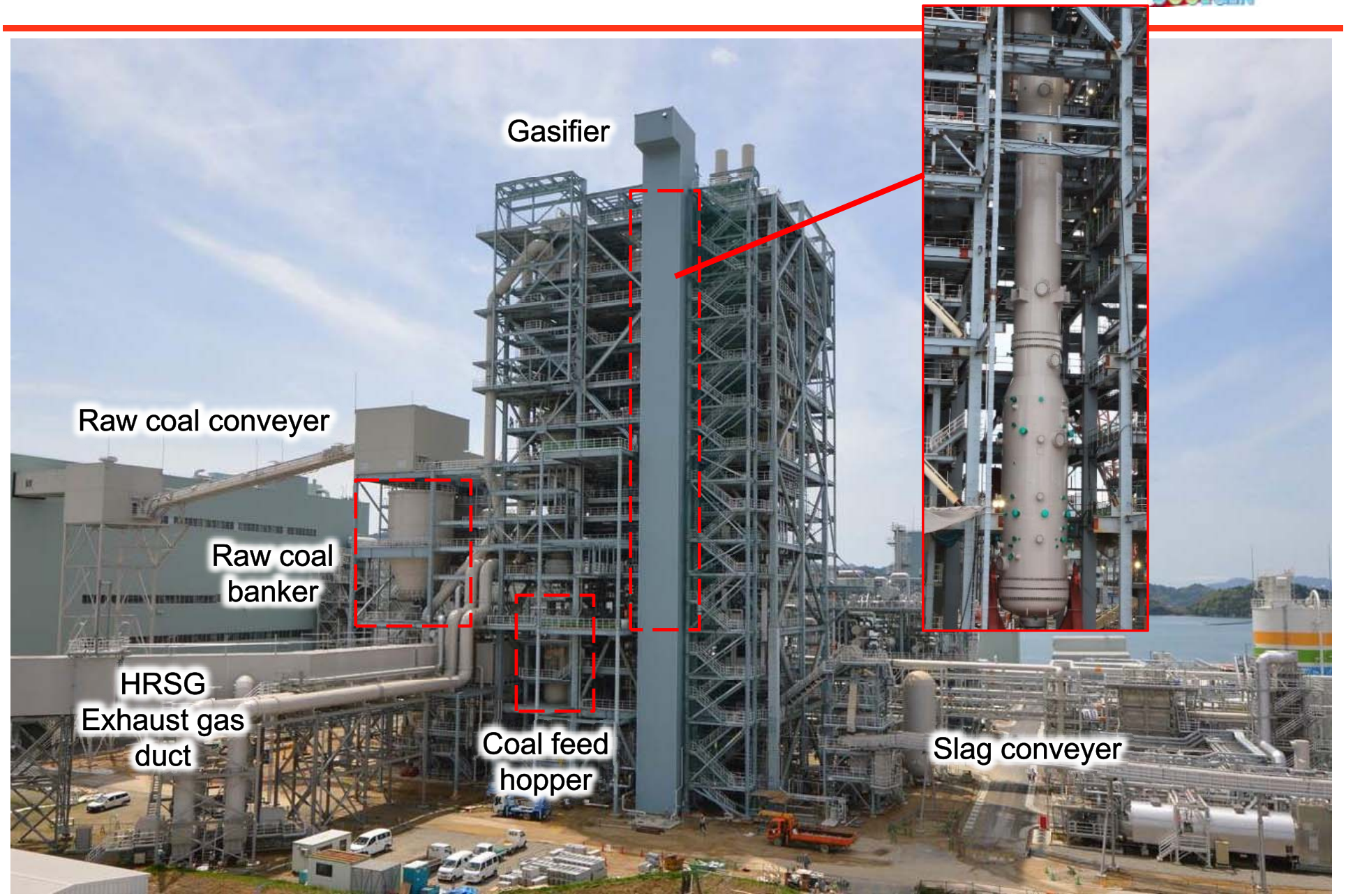
Project Outline and Targets

Verification test items	Oxygen-blown IGCC Demonstration Targets
Plant efficiency	IGCC net efficiency: 40.5% (Highest level in world's 170MW class plants) Obtain prospect of 46% (HHV) and 48% (LHV) for commercial plants with 1,500 degree centigrade class Gas turbine
Environmental performance	Environmental targets (O_2 equivalent 16%) SO_X: 8ppm, NO_X: 5ppm, Particulate: 3mg/m^3N
Coal types compatibility	Determination of a compatible range of coal types (to be expanded from low ash melt-point coals, which are poorly compatible with PCF plants, to coals that are compatible with PCF plants)
Plant reliability	Commercial-level annual plant availability of 70% or higher in 5,000-hour prolonged endurance tests
Plant controllability & operability	Operating characteristics, controllability, load change rate of 1 to 3% and so on that are necessary for commercial thermal power plant
Economic performance	Obtain prospect of the equivalent or less generating cost with USC

Oxygen-blown IGCC Demonstration Facilities



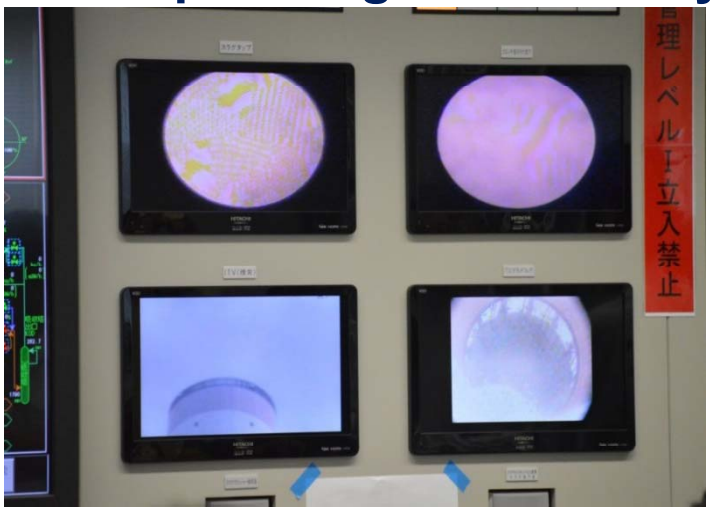
Coal Gasification Unit



Commissioning

April-2016
Gas turbine start up

August
Start of power generation by coal



November
Achievement Power generation
: 166MW (100%)

March-2017
Start of Demonstration

Primary Testing Items and Schedule

Fiscal Year		2015	2016	2017	2018
Individual facility & sysem tests					
Comprehensive trial operation	GT operation test				
	Gasifier coal feeding test				
	Minimum output to 50% load rejection test; Blackout test				
	75～100% load rejection test etc.				
	Gasifier/GT characteristic test Automatic plant control adjustment				
	Operation and performance confirmation				
Demonstration	・Verification of basic performance and reliability ・Verification of compatibility of coal variety ・Verification of controllability				

	Power generation Gross output	Gasifier operation hours
Operating data **（As end of September 30, 2017）**	**464,157MWh**	**3,878h**

Commissioning results: basic performance

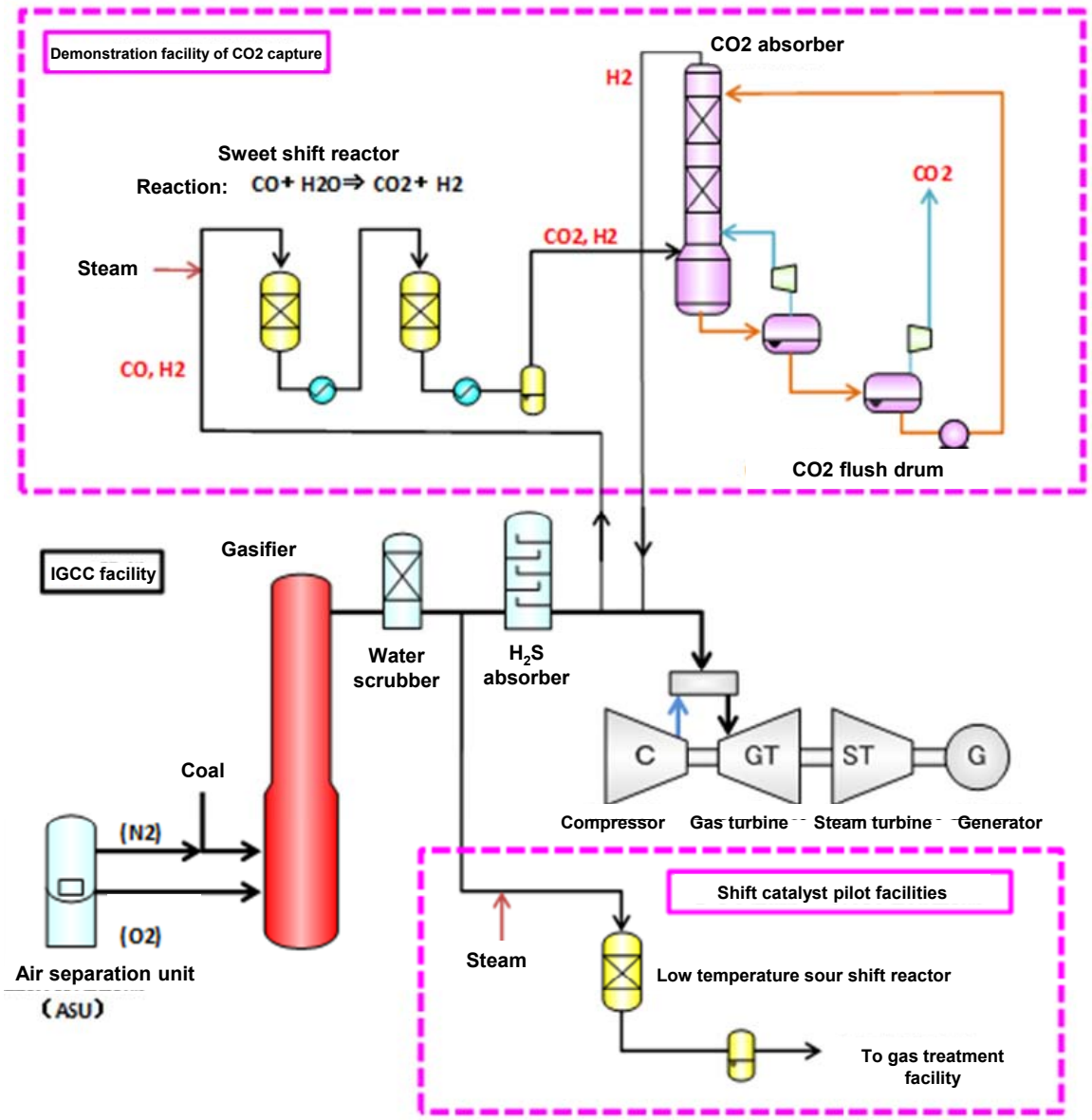
- **Efficiency**
  - Target: Net efficiency 40.5% (HHV)
  - Result: Net efficiency 40.8% (HHV)

- **Emission Level** (as 16% O_2 equivalent)
  - Target: SOx 8ppm
    NOx 5ppm
    Particulate 3mg/m^{3}N
  - Result: SOx < 8ppm
    NOx < 5ppm
    Particulate < 3mg/m^{3}N

- **Load change rate**
  - Target: 1～3%/min
  - Result: 1～5 %/min

5. Plans for IGCC with CO_2 Capture Technology (STEP2)

Outline of CO_2 Capture Technology Demonstration Project



Outline of CO_2 capture technology demonstration	
Demonstration scale	Equivalent to 15% CO_2 capture ratio from IGCC exhaust gas
CO_2 absorption and regeneration method	Physical absorption
CO shift method	Sweet shift (extraction from desulfurized gas)

Shift catalyst pilot facility	
CO shift method	Low temperature sour shift (gas extraction before desulfurization)

Goal of CO_2 Capture Technology Demonstration Project

	Target
Basic performance (Plant efficiency)	Obtain prospect of 90% CO_2 recovery and 40% (HHV*) net thermal efficiency for new commercial plant with 1,500 degree centigrade class GT *Higher Heating Value
Basic performance (Recovery efficiency and purity)	CO_2 recovery ratio of 90% or above Purity of recovered CO_2 to be 99% or above
Plant controllability & operability	Establish operation methods of IGCC combined with CO_2 capture technology; verify reliability
Economic performance	Evaluate cost per unit of CO_2 capture on the basis of the cost per unit shown in “Strategic Technology Roadmap” of the government as the benchmark.

Thank you for your kind attention.

We would like to express our gratitude to the Ministry of Economy, Trade and Industry (METI), and the New Energy and Industrial Technology Development Organization (NEDO) for continuous support to the Osaki CoolGen Project.

We will carry on design, construction and demonstration steadily and safety, and make our best effort to achieve successful completion of the Osaki CoolGen Project.

OSAKI COOLGEN