OSAKI CoolGen Project

Demonstration of Integrated Coal Gasification Fuel Cell Combined Cycle

OSAKI CoolGen Corporation
### Company Profile

<table>
<thead>
<tr>
<th>Company name</th>
<th>OSAKI CoolGen Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This name reflects our desire to realize “CoolGen Project” plan as one of the government’s “clean coal” policies on Osakikamijima Island.</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Date of incorporation</th>
<th>July 29, 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>6208-1 Nakano, Osakikamijima-town, Toyota-gun, Hiroshima Prefecture (on the premises of The Chugoku Electric’s Osaki Power Station)</td>
</tr>
<tr>
<td>Investing companies</td>
<td>The Chugoku Electric Power Co., Inc. 50% Electric Power Development Co., Ltd. (J-POWER) 50%</td>
</tr>
<tr>
<td>Business summary</td>
<td>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 CO₂ capture technology</td>
</tr>
</tbody>
</table>

※IGCC: Integrated Coal Gasification Combined Cycle  
※IGFC: Integrated Coal Gasification Fuel Cell Combined Cycle  
※CCS: Carbon Dioxide Capture and Storage
1. Project Background
2. Oxygen-blown Coal Gasification Technology
3. Outline of OSAKI CoolGen Project
4. Overview and Progress of IGCC Demonstration (STEP1)
5. Plans for IGCC with CO$_2$ Capture Technology (STEP2)
1. Project Background
Outlook on World Power Generation and CO₂ Emission

- About 30% of the world’s energy generation will continue to use coal
- About 30% of world’s CO₂ 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 CO₂ emission from coal power generation in the world: 27% (2040)

Source: IEA World Energy Outlook 2016 (New Policies Scenario)
- Energy self-sufficiency in Japan = approx. 6%*
- Coal-fired generation ⇒ Essential for the “Best Mix” energy policy

**Energy Mix in Japan**

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>FY2013 (966.6TWh)</th>
<th>FY2030 (980.8TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic growth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saving energy 196.1TWh</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>FY2030 (980.8TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand of electric power 1065TWh</td>
<td>980.8TWh</td>
</tr>
</tbody>
</table>

**Composition of electrical source**

- LNG: 27%
- Nuclear: 22-20%
- Renewable: 22-24%
- Coal: 26%
- Hydro: 8.8-9.2%
- Biomass: 3.7-4.5%
- Wind: 1.7%
- PV: 7.0%
- Geothermal: 1.0-1.1%

**Source:**
- Japan’s Energy White Paper 2016
- 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% CO₂ 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 CO₂ 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) (Third step)
IGCC + CO₂ capture → IGFC + CO₂ capture
2. Oxygen-blown Coal Gasification Technology
The OSAKI CoolGen Project will leverage knowledge and expertise gained from the EAGLE Project.

- **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

- “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\textsubscript{2} because the gasifier is oxygen-blown. Compared to air-blown type, it contains higher ratio of CO and H\textsubscript{2} that are raw material for fuel, which makes the heat value higher

EAGLE gasifier structure

- Pressure vessel for gasifier
- Water-cooled membrane wall
- Upper burner
- 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

Heat Recovery Section

Gasification Section

Quench Section

Slag

Conceptual flow in gasifier

Temperature distribution

Upper burner: Lean oxygen
High efficiency gasification

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

Product gas CO, H\textsubscript{2} etc

Compared to air-blown type, it contains higher ratio of CO and H\textsubscript{2} that are raw material for fuel, which makes the heat value higher

Product gas contains little N\textsubscript{2} because the gasifier is oxygen-blown.
Feature of EAGLE Gasifier (2) Compatibility of Multiple Coal Types

- **EAGLE**
- **Pulverized Coal Fired**
- **Previous gasifiers**

**Fixed carbon/Volatile matter [−]**

**Ash Melting Temperature [℃]**

- Source: JPOWER EAGLE brochure
3. Outline of OSAKI CoolGen Project
This project is aiming at a large reduction of CO₂ emission by the innovative low carbon emission technology in coal-fired power generation in which ultimately efficient IGFC is combined with a CO₂ 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.
**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

Coal pretreatment; pulverized coal transportation

Coal gasification unit
- Gasifier
- Syngas cooler
- Cyclone filter
- Char transportation
- Slag

Gas clean-up unit
- First water scrubber
- COS converter
- Second water scrubber
- H₂S absorber
- H₂S regenerator
- Acid gas furnace

Air separation unit
- Air
- Compressor
- Rectifier

Water treatment unit
- Waster water
- Treated water
- Sludge

Combined cycle unit
- HRSG
- DeNOx
- Combustor
- Steam turbine
- Generator
- Cooling water
- Condenser

COS: Carbonyl sulfide
H₂S: Hydrogen sulfide

Sulfur recovery unit
Gypsum

Stack
# Major Specifications

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

<table>
<thead>
<tr>
<th>Verification test items</th>
<th>Oxygen-blown IGCC Demonstration Targets</th>
</tr>
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<tbody>
<tr>
<td><strong>Plant efficiency</strong></td>
<td>IGCC net efficiency: 40.5% (Highest level in world’s 170MW class plants)</td>
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<tr>
<td></td>
<td>Obtain prospect of 46% (HHV) and 48% (LHV) for commercial plants with 1,500 degree centigrade class Gas turbine</td>
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<tr>
<td><strong>Environmental performance</strong></td>
<td>Environmental targets (O&lt;sub&gt;2&lt;/sub&gt; equivalent 16%)</td>
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<tr>
<td></td>
<td>SO&lt;sub&gt;X&lt;/sub&gt;: 8ppm, NO&lt;sub&gt;X&lt;/sub&gt;: 5ppm, Particulate: 3mg/m&lt;sup&gt;3&lt;/sup&gt;N</td>
</tr>
<tr>
<td><strong>Coal types compatibility</strong></td>
<td>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)</td>
</tr>
<tr>
<td><strong>Plant reliability</strong></td>
<td>Commercial-level annual plant availability of 70% or higher in 5,000-hour prolonged endurance tests</td>
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<tr>
<td><strong>Plant controllability &amp; operability</strong></td>
<td>Operating characteristics, controllability, load change rate of 1 to 3% and so on that are necessary for commercial thermal power plant</td>
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<tr>
<td><strong>Economic performance</strong></td>
<td>Obtain prospect of the equivalent or less generating cost with USC</td>
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</table>
Oxygen-blown IGCC Demonstration Facilities

Photo taken on April 2016

- Coal gasification unit
- Combined cycle unit
- Air separation unit
- Sulfur recovery unit
- Gas clean-up unit
- Water treatment unit

Osaki Power Station Unit 1-1 of The Chugoku EPCo
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

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tbody>
<tr>
<td>Individual facility &amp; system tests</td>
<td></td>
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<tr>
<td>Comprehensive trial operation</td>
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<tr>
<td>GT operation test</td>
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<tr>
<td>Gasifier coal feeding test</td>
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<tr>
<td>Minimum output to 50% load rejection test; Blackout test</td>
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<tr>
<td>75~100% load rejection test etc.</td>
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<tr>
<td>Gasifier/GT characteristic test</td>
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<tr>
<td>Automatic plant control adjustment</td>
<td></td>
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<tr>
<td>Operation and performance confirmation</td>
<td></td>
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<td></td>
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<tr>
<td>Demonstration</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>• Verification of basic performance and reliability</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>• Verification of compatibility of coal variety</td>
<td></td>
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<td></td>
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<tr>
<td>• Verification of controllability</td>
<td></td>
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</tbody>
</table>

### Power generation Gross output

<table>
<thead>
<tr>
<th>Operating data (As end of September 30, 2017)</th>
<th>464,157MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasifier operation hours</td>
<td>3,878h</td>
</tr>
</tbody>
</table>

### Legend

- Past test
- Future test
Commissioning results: basic performance

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

- **Emission Level** (as 16% O₂ equivalent)
  - Target: SOx 8 ppm
    NOx 5 ppm
    Particulate 3 mg/m³N
  - Result: SOx < 8 ppm
    NOx < 5 ppm
    Particulate < 3 mg/m³N

- **Load change rate**
  - Target: 1～3% / min
  - Result: 1～5 % / min
5. Plans for IGCC with CO$_2$ Capture Technology (STEP2)
### Outline of CO₂ Capture Technology Demonstration Project

#### Outline of CO₂ capture technology demonstration

<table>
<thead>
<tr>
<th>Demonstration scale</th>
<th>Equivalent to 15% CO₂ capture ratio from IGCC exhaust gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ absorption and regeneration method</td>
<td>Physical absorption</td>
</tr>
<tr>
<td>CO shift method</td>
<td>Sweet shift (extraction from desulfurized gas)</td>
</tr>
</tbody>
</table>

#### Shift catalyst pilot facility

| CO shift method | Low temperature sour shift (gas extraction before desulfurization) |
### Goal of CO₂ Capture Technology Demonstration Project

| Basic performance (Plant efficiency) | Obtain prospect of 90% CO₂ 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) | CO₂ recovery ratio of 90% or above  
Purity of recovered CO₂ to be 99% or above |
| Plant controllability & operability | Establish operation methods of IGCC combined with CO₂ capture technology; verify reliability |
| Economic performance | Evaluate cost per unit of CO₂ 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 safely, and make our best effort to achieve successful completion of the Osaki CoolGen Project.