The Progress of Osaki CoolGen Project

~ Oxygen-blown Integrated Coal Gasification Fuel Cell Combined Cycle Demonstration Project ~

September, 2017
Osaki CoolGen Corporation
Outline

1. Background and Significance of IGCC Development

2. Gasification Technology

3. Osaki Coolgen Project
   (1) Project Overview
   (2) Overview and Progress of IGCC Demonstration (STEP1)
   (3) Demonstration Plan of IGCC with CO$_2$ Capture (STEP2)
Outline

1. Background and Significance of IGCC Development

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1. Background

Characteristics of coal as energy resource

- Low cost and stable supply compared to other fossil fuels
- Distributed widely all over the world
- Abundance of reserves

![Graph showing fuel price transition with Oil, Gas, and Coal]

Proves reserves

<table>
<thead>
<tr>
<th>Year</th>
<th>Oil</th>
<th>Natural Gas</th>
<th>Coal</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>51</td>
<td>53</td>
<td>153</td>
</tr>
<tr>
<td>barrel</td>
<td>1.70t</td>
<td>185t</td>
<td>11,393t</td>
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</table>

Distribution of Coal resources

- Asia Pacific: 2.8% Oil, 9.4% Natural Gas, 46.5% Coal
- Africa: 7.5% Oil, 7.6% Natural Gas, 1.1% Coal
- Middle East: 47.7% Oil, 42.5% Natural Gas, 46.5% Coal
- Africa: 19.2% Oil, 30.4% Natural Gas, 28.3% Coal
- S&Cent America: 13.3% Oil, 4.1% Natural Gas, 22.8% Coal
- North America: 6.0% Oil, 6.0% Natural Gas, 1.2% Coal

Source: BP statistics 2017
1. Background

**Percentage of each generation resource**

- Coal–fired power generation accounts for about 40% of the world electricity generation
  - The coal–fired power generation is widely used in high energy-consuming countries such as China, India and the US.
  - The proportion of coal–fired power generation is about 30% in Japan.

<table>
<thead>
<tr>
<th>Country</th>
<th>Coal</th>
<th>Oil</th>
<th>Natural Gas</th>
<th>Nuclear</th>
<th>Hydro</th>
<th>Renewable</th>
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</thead>
<tbody>
<tr>
<td>Japan</td>
<td>34%</td>
<td>11%</td>
<td>41%</td>
<td>0%</td>
<td>8%</td>
<td>7%</td>
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<tr>
<td>Russia</td>
<td>15%</td>
<td>1%</td>
<td>50%</td>
<td>16%</td>
<td>17%</td>
<td>0%</td>
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<tr>
<td>OECD Europe</td>
<td>25%</td>
<td>1%</td>
<td>16%</td>
<td>25%</td>
<td>16%</td>
<td>16%</td>
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<tr>
<td>World</td>
<td>41%</td>
<td>4%</td>
<td>22%</td>
<td>11%</td>
<td>16%</td>
<td>6%</td>
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<tr>
<td>Germany</td>
<td>46%</td>
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<td>US</td>
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<td>1%</td>
<td>27%</td>
<td>19%</td>
<td>6%</td>
<td>7%</td>
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<tr>
<td>Denmark</td>
<td>34%</td>
<td>1%</td>
<td>7%</td>
<td>58%</td>
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<tr>
<td>India</td>
<td>75%</td>
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<td>2%</td>
<td>5%</td>
<td>3% 10% 5%</td>
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<tr>
<td>China</td>
<td>73%</td>
<td>0%</td>
<td>2%</td>
<td>2%</td>
<td>18%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Source: Energy balances of OECD countries 2016 (IEA) / Energy balances of non-OECD countries 2016 (IEA)
1. Background

Coal-fired Power Generation
- Current electricity & CO₂ emission and 2040’s prospects -

Electricity from coal-based power generation

- 41% (2014) → 28% (2040)

CO₂ emission from coal-based power generation

- 31% (2014) → 27% (2040)

➢ Coal-fired power generation in the world : about 30%
➢ CO₂ emission from Coal-fired power generation : about 30%

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

Coal-fired Power Generation

- Current generation capacity and 2040’s prospects -

Prospects of the world Coal-fired power generation capacity

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

Coal-fired power generation capacity in the world

⇒ 1,882GW → 2,437GW (555GW)

(2014) (2040)
1. Background

Coal-fired Power Generation
- status in Japan -

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

**Source : Japan’s Energy White Paper 2016
**Source : METI Long-term energy supply-demand outlook(2015.7)
1. Background

Development Road Map of High Efficiency Low Emissions Coal Power Generation Technology in Japan

Fuel Cell (FC) (MCFC) (SOFC)

Integrated coal gasification combined cycle (IGCC)

HRSG

Pulverized coal fired (PCF)

1300°C IGCC → 1500°C IGCC → 1700°C IGCC

55%~
CO₂ reduction about ▲30%

46 ~ 48%
CO₂ reduction about ▲15%

38%

39 ~ 41%

base

Efficiency : Net / Higher heating value
1. Significance

Significance of Osaki Coolgen Project

Global Sustainable Development

We must:
- Efficiently use low cost coal for increased Power Demand
- Drastically reduce CO₂ emissions against Global Warming

In Resources Importing Countries (as Japan)

- Coal is indispensable to achieve sustainable power supply

Development of High Efficient Clean Coal Technology

Osaki Coolgen Demonstration Project

(Step-1) **Oxygen-blown IGCC** with high efficiency, high environmental performance, reliability, coal variety compatibility and controllability

(Step-2) **IGCC + CO₂ Capture**  ➞  **IGFC + CO₂ Capture**

Global Sustainable Development

(Step-3)
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1. Background and Significance of IGCC Development

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2. Gasification Technology

Significance of developing Oxygen blown type “EAGLE” Gasifier

- High efficiency and low carbonization of coal-fired power generation and effective utilization of coal and its byproduct
  - Drastically to improve power generation efficiency and significantly to reduce carbon dioxide emission.
  - Efficiently to capture CO$_2$ by pre-combustion method.
  - To use low-grade coal (sub-bituminous coal and brown coal) and high-grade coal (bituminous coal) for gasification.
  - To re-use coal ash and reduce in volume as slug of glass type

- Multi-purpose uses of coal gasification gas
  - For the gasification gas to be widely used as synthetic fuels and chemical raw materials.
2. Gasification Technology

Development History and Significance of “EAGLE”
Gasifier of Oxygen Blown Type

Coal Energy Application for Gas, Liquid, and Electricity

- **HYCOL Pilot Plant**
  - 50t/d / FY1991~1993 / Sodegaura
  - × 3

- **EAGLE Pilot Plant**
  - 150t/d / FY2002~2013 / Wakamatsu
  - × 8

- **Process Development Unit**
  - 1t/d / FY1981~1985 / Katsuta
  - × 1

- **OCG Demonstration Plant**
  - 1,180t/d / FY2016~
  - 166MW / Osaki
  - × 8

Scale Up
Features of EAGLE Gasifier
Oxygen-blown Two-stage Spiral-flow Gasifier
2. Gasification Technology

Applicable Coal types for the “EAGLE” gasifier

Coals appropriate for Gasification

Sub bituminous Coal area

Bituminous Coal area

Ash Melting Temperature [°C]

Fixed carbon/Volatile matter [-]

EAGLE

Pulverizing Coal Fired

Source: JPOWER EAGLE brochure
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## Project Timeline

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<td>NEDO Research Project</td>
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<tr>
<td><strong>Step-1:</strong> Oxygen Blown IGCC</td>
<td>Feasibility Study</td>
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<tr>
<td><strong>Step-2:</strong> IGCC with CO₂ Capture</td>
<td>IGCC Design, Manufacturing and Construction</td>
<td>Demonstration Operation</td>
<td>CO₂ Capture Design, Manufacturing and Construction</td>
<td>Demonstration Operation</td>
<td>IGFC with CO₂ Capture Design, Manufacturing and Construction</td>
<td>Demonstration Operation</td>
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<td><strong>Step-3:</strong> IGFC with CO₂ Capture</td>
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</table>

### 1) Project Overview

**Step-1**

- **Gasifier**
  - ASU
  - Coal
  - N₂
  - O₂

**Gas Clean up**

- CO, H₂

**Step-2**

- H₂

**Step-3**

- Fuel Cell
(1) Project Overview

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

**Project Scheme**

Joint Investment

STEP1 EPC contract
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IGCC Process Flow
## Major Specifications

<table>
<thead>
<tr>
<th>Unit</th>
<th>Specification</th>
</tr>
</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>
</tr>
<tr>
<td>Gas Clean-up Unit</td>
<td>Wet Desulfurization Unit : Methyl Di-Ethanol Amine (MDEA) Sulfur Recovery Unit : Limestone Wet Scrubbing</td>
</tr>
<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) Gross Power Output : 166MW (GT+ST)</td>
</tr>
<tr>
<td>Wastewater Treatment Unit</td>
<td>Gas Clean-up Unit Wastewater Treatment</td>
</tr>
</tbody>
</table>
## STEP 1 Demonstration Targets

<table>
<thead>
<tr>
<th>Item</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency</strong></td>
<td>Top class Net Efficiency <strong>40.5% (HHV), 42.7% (LHV)</strong>&lt;br&gt;Equivalent to Net efficiency <strong>46% (HHV), 48% (LHV)</strong>, when applied to 1,500°C class GT (already developed) in a commercial plant (higher output)</td>
</tr>
<tr>
<td><strong>Emission Level</strong></td>
<td>Top class environmental performance&lt;br&gt;SOx : 8ppm&lt;br&gt;NOx : 5ppm&lt;br&gt;Particulate : 3mg/m³N (as 16%O₂ equivalent)</td>
</tr>
<tr>
<td><strong>Coal Variety Compatibility</strong></td>
<td>Applicable to varieties of coal with various ash fusion temperature</td>
</tr>
<tr>
<td><strong>Plant Reliability</strong></td>
<td>Aiming at more than 70%/year availability by 5000hrs operation test.</td>
</tr>
<tr>
<td><strong>Plant Controllability &amp; Operability</strong></td>
<td>Load ramp rate : 1-3%/min.</td>
</tr>
<tr>
<td><strong>Economy</strong></td>
<td>To obtain the prospect that the COE (cost of electricity) of IGCC is the same level as that of USC.</td>
</tr>
</tbody>
</table>
### IGCC Construction Progress

#### Major Events

<table>
<thead>
<tr>
<th>FY</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tbody>
<tr>
<td></td>
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<td>Start of Civil work</td>
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<td>Start of HRSG on site</td>
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<td>Gasifier on site</td>
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<td>Gas cleanup unit on site</td>
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<td>SGC on site</td>
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<td>Operation</td>
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<td></td>
<td>Design, Manufacturing, Construction,</td>
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<td></td>
<td>Pressurization test of piping</td>
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<td></td>
<td>Gas turbine start-up</td>
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<td></td>
<td>Power receiving for commissioning</td>
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<td>Gasifier start-up by coal</td>
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<td>ASU on site</td>
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<td>Start of demonstration</td>
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</tbody>
</table>

- **FY**: Financial Year
- **Operation**: Start of demonstration
- **Major Events**:
  - Start of Civil work
  - Start of HRSG on site
  - Gasifier on site
  - Gas cleanup unit on site
  - SGC on site
  - Operation
  - Design, Manufacturing, Construction, Pressurization test of piping
  - Gas turbine start-up
  - Power receiving for commissioning
  - Gasifier start-up by coal
  - ASU on site
  - Jul
  - May
  - Jan
  - Apr
  - Mar

(2)Overview and Progress (STEP-1)
(2) Overview and Progress (STEP-1)

Mechanical completion

(13th April 2016)
(2) Overview and Progress (STEP-1)

Gas Clean Up Unit

- Regenerator
- Stripper
- Absorber
- COS converter

Images depict various components of the gas clean up unit, including:
- Limestone
- Limestone absorber
- Acid gas furnace
Combined cycle Unit
(2) Overview and Progress (STEP-1)

Air separation Unit
## (2) Overview and Progress (STEP-1)

### STEP 1: Commissioning results and demonstration plan

<table>
<thead>
<tr>
<th>FY</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tbody>
<tr>
<td>Individual machinery and system test</td>
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<tr>
<td>GT no load test</td>
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<tr>
<td>Coal gasification test</td>
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<tr>
<td>load dump test</td>
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<tr>
<td>load dump test, Relief valve test</td>
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<tr>
<td>Gasifier/GT characteristic test</td>
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<tr>
<td>Automatic plant control adjustment</td>
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<tr>
<td>Test of heat run and performance</td>
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<tr>
<td>Test of automatic plant start-up/shut down</td>
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</table>

- **Integrated Commissioning**
- **Demonstration**
  - Verification of basic performance and reliability
  - Verification of compatibility of coal variety
  - Verification of controllability

### Operating data (AS of July, 2017)

<table>
<thead>
<tr>
<th>Power generation Gross output</th>
<th>Gasifier Operating hours</th>
<th>Continuous Operating hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>300,638 MWh</td>
<td>2,415 h</td>
<td>514 h</td>
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</table>
3. Osaki Coolgen Project (2) Overview and Progress (STEP-1)

Commissioning

April-2016
Gas turbine start up
June
Parallel in power grid

July
Gasifier start up by coal

August
Start of power generation by coal
3. Osaki Coolgen Project (2) Overview and Progress (STEP-1)

Commissioning

November Achievement
Gasifier load : 100%
Power generation : 166MW (100%)

March-2017
Start of Demonstration

August-2017
Completion Ceremony
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(3) Demonstration Plan of IGCC with CO₂ Capture (STEP-2)

STEP2 / CO₂ Capture test (FY 2016-2020)

**CO₂ Capture test**

<table>
<thead>
<tr>
<th>Feed Gas</th>
<th>17% slipstream syngas equivalent to 15% of total CO₂ volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ Capture method</td>
<td>Physical absorption</td>
</tr>
<tr>
<td>CO shift section</td>
<td>Sweet Shift (Downstream of desulfurization)</td>
</tr>
</tbody>
</table>

**Sour Shift Catalyst pilot test**

<table>
<thead>
<tr>
<th>Feed Gas</th>
<th>Sour Shift (Upstream of desulfurization)</th>
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</thead>
</table>

**Diagram**

- **CO₂ Capture unit**
  - Sweet Shift Reactors: CO + \( \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2 
  - CO₂, \( \text{H}_2 \)
  - Steam
  - CO, \( \text{H}_2 \)

- **IGCC**
  - Gasifier
  - Scrubber
  - MDEA
  - GT
  - ST
  - G

- **Air Separation unit**
  - N₂
  - O₂
  - Coal

- **Steam**
  - Sour Shift Reactor (Low temperature)
  - Gas Clean-up unit

- **Sour Shift Catalyst Pilot Test unit**

- **Physical absorption**
  - CO₂ Flash Drums
  - Absorber

- **CO₂ Capture unit (17% slipstream test)**

- **CO₂ Capture method**

- **CO shift section**

- **Gas Clean-up unit**

- **Feed Gas Sour Shift** (Upstream of desulfurization)
### 3) Demonstration Plan of IGCC with CO₂ Capture (STEP-2)

#### STEP2 Demonstration Targets

<table>
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<tr>
<th>Item</th>
<th>Targets</th>
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</table>
| **Basic Performance (CO₂ capture)**            | **CO₂ Capture rate**: more than 90%  
|                                                | **CO₂ Purity**: more than 99%                                                                                                                                                                         |
| **Generating Plant Efficiency**                | To obtain a prospect of 40% (net, HHV) power generation efficiency while 90% of CO₂ volume is captured in newly-installed commercial IGCC with 1,500°C class GT.                                           |
| **Operability & Reliability**                  | To establish operation procedures with load change and verify the reliability for IGCC system combined with CO₂ Capture                                                                                   |
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.

http://www.osaki-coolgen.jp