Clean Coal Technology Development in Hitachi

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Engineering Division,
Thermal Power Systems Department,
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Hitachi, Ltd.
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2. Boiler Technology
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5. Future Clean Coal Technology
1. Hitachi Power Systems Company
Hitachi Global Portfolio

Revenues
98.0 billion US$ (FY2012)

- Power Systems
- Information & Telecommunication Systems
- Construction Machinery
- Electronics Systems & Equipment
- Social Infrastructure & Industrial Systems
- Electronics Systems & Equipment
- Financial Services
- Digital Media & Consumer Products
- High Functional Materials & Components
- Automotive Systems
- Others

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Power Business in Hitachi

Thermal Power Business

- Coal-fired Thermal Power Plants
- Gas Turbines

Coal-fired Thermal Power Plants Major Equipment

Steam Turbines
Boilers
Air Quality Control System

Transmission & Distribution (T&D) Systems
Hydroelectric Power Generation Systems, Drive Systems, Smart Grids, Power Semiconductors, etc.

Nuclear Power Business

- Boiling Water Reactor Nuclear Power Plants (ABWR・ESBWR)
- Preventive Maintenance, Nuclear Fuel Cycle, etc.

Nuclear Power Business Major Equipment

Transmission & Distribution, Renewable Energy and Other Businesses

Particle beam therapy systems
Wind Power Generation Systems
Photovoltaic Power Generation Systems

FY2012 Consolidated Revenues 9.0 billion US$ 60% 20% 20%
Total Power System Technology

Integrated supply of BTG + AQCS ⇒ Optimize entire plants

<table>
<thead>
<tr>
<th>Boilers (B)</th>
<th>Turbines (T)</th>
<th>Generators (G)</th>
<th>Air Quality Control System (AQCS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>DeNOx Systems</td>
</tr>
<tr>
<td>O</td>
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<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

- **Steam Turbines and Generators (TG)**
  - Turbines and Generators
  - Low-pressure Turbines

- **Boilers (B)**
  - DeSOx (Spray Type)
  - DeNOx Catalyst

- **Air Quality Control System (AQCS)**
Accelerate Business Development

New Markets
- Expand in emerging markets, particularly in Asia
- Coal-fired systems expand in emerging markets, and gas-fired systems in all regions

Estimation on Thermal Power Generation Capacity

<table>
<thead>
<tr>
<th>Year</th>
<th>GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>3,310</td>
</tr>
<tr>
<td>2020</td>
<td>4,401</td>
</tr>
<tr>
<td>2030</td>
<td>5,142</td>
</tr>
<tr>
<td>2035</td>
<td>5,628</td>
</tr>
</tbody>
</table>

Source: IEA WEO 2011

World Electricity Generation by Energy Source

- Steady growth in coal-fired thermal power plants
- Increasing demand for AQCS due to national regulation
- Accelerated adoption of renewable energy
- Expansion of power transmission and distribution market


(National kWh)
2. Boiler Technology
Total Installed Capacity: 107 GW (Japan: 46 GW)  (As of 2012)
Latest Boiler Supply

**Tokyo Electric Power Co., Ltd (Japan)**
Hitachi Naka Unit 1 and 2

- **Boiler Type**: Once-Through, Benson
- **Generator Output**: 1,000 MW
- **Main Steam Flow**: 2,870 t/h
- **Steam Conditions**: 25.4MPa / 604°C / 602°C
- **Commercial Operation**: 2003 (#1), 2013 (#2)

**MidAmerican Energy Company (USA)**
Walter Scott Jr. Energy Center Unit 4

- **Boiler Type**: Once-Through, Benson
- **Generator Output**: 853 MW
- **Main Steam Flow**: 2,530 t/h
- **Steam Conditions**: 26.2MPa / 570°C / 595°C
- **Commercial Operation**: 2007
4. Steam Turbine Technology
Steam Turbine Supply Record

Total Installed Capacity: 110 GW (Japan: 44 GW) (As of 2012)
# Latest Steam Turbine Supply

## J-Power Co., Ltd. (Japan)  
**Isogo unit No.2**

<table>
<thead>
<tr>
<th>Turbine Type :</th>
<th>Tandem Compound Double Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator Output :</td>
<td>600 MW</td>
</tr>
<tr>
<td>Revolution:</td>
<td>3,000rpm</td>
</tr>
<tr>
<td>Steam Conditions :</td>
<td>25MPa/ 600°C / 620°C</td>
</tr>
<tr>
<td>Commercial Operation :</td>
<td>2009</td>
</tr>
</tbody>
</table>

## Netherland  
**Rotterdam unit No.1**

<table>
<thead>
<tr>
<th>Turbine Type :</th>
<th>Tandem Compound Four Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator Output :</td>
<td>790 MW</td>
</tr>
<tr>
<td>Revolution:</td>
<td>3,000rpm</td>
</tr>
<tr>
<td>Steam Conditions :</td>
<td>26.3MPa/ 600°C / 620°C</td>
</tr>
<tr>
<td>Commercial Operation :</td>
<td>2013</td>
</tr>
</tbody>
</table>
Latest Steam Turbine Supply in Philippine

**SMC Davao Power Plant Project**

- **Owner**: San Miguel Consolidated Power Corp.
- **Location**: Davao in Mindanao, Philippine
- **Gross Output**: 150MW x 2 units
- **Turbine Type**: Single Flow Exhaust Reheat Condensing Turbine
- **Steam Conditions**: 12.3MPa/538°C / 538°C
- **Commercial Operation**: 2015, 2016

**SMC Limay Power Plant Project**

- **Owner**: SMC Consolidated Power Corp.
- **Location**: Bataan in Luzon, Philippine
- **Gross Output**: 150MW x 2 units
- **Turbine Type**: Single Flow Exhaust Reheat Condensing Turbine
- **Steam Conditions**: 12.3MPa/538°C / 538°C
- **Commercial Operation**: 2016
3. Air Quality Control System Technology
Air Quality Control System

- Boiler
- DeNOx (SCR)
- ESP
- DeSOx (FGD)

Hitachi is one of a few AQCS suppliers for total system

SCR: Selective Catalytic Reduction
ESP: Electrostatic Precipitator
FGD: Flue Gas Desulfurization

(Layout for 1000MW coal fired plant in Japan)
5. Future Clean Coal Technology
Roadmap of Clean Coal Technology

- Hitachi has been developing key technologies of clean coal system
  - Advanced USC (Ultra Super Critical)
  - CCS (CO₂ Capture and Storage)
  - IGCC (Integrated coal Gasification Combined Cycle)

### Road of Development

**2010**
- Capture Ready
- Pilot Testing Plant

**2015**
- Partial Reduction
- Demonstration Plant

**2020**
- Full Reduction
- Commercial Plant

**2025**
- Ultimately-Clean Plant

**2030**
- Advanced USC
  - Efficiency of 46% (HHV)
- Oxy-Combustion
  - Reduce all of CO₂ Emission
- CO₂ Scrubbing
  - Reduce CO₂ Emission by half
- Advanced USC + CCS
  - High Efficiency
  - Zero Emission
- IGCC + CCS
  - Ultimately Clean Coal Technology
The efficiency of the coal fired power plant has been improved by making the steam condition a high temperature.

**Advanced USC (Ultra Super Critical)**

**Next Generation Development Goal**

- Net Efficiency
  - 46-48%

**Average Efficiency in the World**: 32%

**State of the Art**: 600°C/620°C

**USC**: 593°C

**Advanced USC**: 700°C

**Near future**

**Best Practice**

**Development matter**
- Material (Ni-base Alloy)
- Design
- Reliability
Development of Material for Advanced USC

USC141: High Strength Ni-base Alloys (Upper Limit: 720°C)

Application Use; Turbine Moving Blade, Bucket Bolts, Boiler Tube

FENIX700: Fe-Ni-base Alloys for Low Price, Large-scale Production (Upper Limit: 700°C)

12.5 ton Stead Ingot for Turbine Rotor

Application Use; Turbine Rotor

Narrow Gap Hot Wire Technology

Sketch map of HST equipment

Narrow Gap Hot Wire Techinology
Reduction of CO₂ Emission

【Calculation value based on our experiences】

*HHV, Net output base

<table>
<thead>
<tr>
<th></th>
<th>Pressure (MPa)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub: Sub-Critical</td>
<td>16.7</td>
<td>538/538</td>
</tr>
<tr>
<td>SC: Super Critical</td>
<td>24.1</td>
<td>566/566</td>
</tr>
<tr>
<td>USC: Ultra Super Critical</td>
<td>25.0</td>
<td>600/600</td>
</tr>
</tbody>
</table>
Accelerate Commercialization

2005  2010  2015  2020  2025

Pilot Test  →  Demonstration Test  →  Commercialization

Joint Research by Power Companies (To 1995)
Test with Organizations Overseas (2012)
CCTF Project

Conceptual Design of CO₂ Scrubbing (800MW class)

NCCC Test Result

Hitachi has participated in SaskPower CCS Project

- Hitachi and SaskPower*4 have collaborated to design and built Carbon Capture Test Facility (CCTF, 120 t-CO₂/day) at Shand Power Station.
- Hitachi supplies the newly-designed steam turbine and generator for Boundary Dam CCS Project. (3000 t-CO₂/day)

Boundary Dam Power Station

*1 NCCC: National Carbon Capture Center  *2 MEA: Standard Solvent
*3 H3-1: Hitachi Solvent  *4 SaskPower: Utility company in Saskatchewan, Canada
**CCS (CO₂ Capture and Storage) - Oxy-fuel Combustion**

*Fundamental Study*
- Laboratory Test
- Basic Combustion Test (0.4MWth Test Facility)

*Verification Study*
- Large Scale Combustion Test (4MWth Test Facility)
- Total System Check (1.5MWth Test Facility)

*Demonstration Test*
- Feasibility Study
  - Trial Design of Actual Plant (500MW class)
  - Cost Evaluation

*0.4MWth Test Facility*

*30MWth Test Plant *1*

*Conceptual Design of Oxy-combustion (500MW class)*

*1: Schwarze Pumpe (Vattenfall):*
Hitachi has conducted burner combustion test.
IGCC (Integrated coal Gasification Combined Cycle)

1st Stage: IGCC (Oxygen-brown)

- Fuel Gas (CO, H₂)
- O₂
- Coal

- Gas Turbine
- Steam Turbine
- HRSG*
- Gasifier

- Shift Reactor (※)
  - CO + H₂O → CO₂ + H₂

2nd Stage: CO₂ Capture

- Fuel Cell
- H₂

3rd Stage: IGCC/IGFC + CO₂ Capture

- Shift Reactor (※)
- CO₂, H₂
- CO₂ Capture

※HRSG: Heat Recovery Steam Generator

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**IGCC Pilot Plant (Nakoso, Fukushima)**

<table>
<thead>
<tr>
<th>Gasifier</th>
<th>O$_2$-blown Entrained Flow Gasifier (2-stage Spiral Flow Type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Feed Rate</td>
<td>150 t/day</td>
</tr>
<tr>
<td>Gasification Pressure</td>
<td>2.5 MPa</td>
</tr>
<tr>
<td>Syngas Volume</td>
<td>14,800m$^3$/N/h</td>
</tr>
<tr>
<td>Gas Clean-up</td>
<td>Absorption with MDEA</td>
</tr>
<tr>
<td>Sulfur Recovery</td>
<td>Limestone-Gypsum</td>
</tr>
<tr>
<td>CO$_2$ Capture Unit Capacity</td>
<td>1,000m$^3$/N/h</td>
</tr>
<tr>
<td>GT Output</td>
<td>8,000kW</td>
</tr>
</tbody>
</table>

Other units:
- Air Separation Unit
- Gasifier and Char Recycle Unit
- Gas Clean-up Unit
- Sulfur Recovery Unit
- Gas Turbine
- CO$_2$ Capture Unit (Sweet Shift + Chemical Absorption)
IGCC Demonstration Plant (Osaki Kami-jima, Hiroshima)

Early Commercialization with Accelerated Demonstration Test

<table>
<thead>
<tr>
<th>2012</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGCC (Oxygen-blown)</td>
<td>Carbon Capture</td>
<td>IGCC (Oxygen-blown)/IGFC + Carbon Capture</td>
<td>Osaki CoolGen Project (Ministry of Economy, Trade and Industry Subsidy Project)</td>
</tr>
<tr>
<td>IGCC (Oxygen-blown) Commercial System</td>
<td>IGCC (Oxygen-blown) + CCS Commercial System</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Osaki CoolGen Project

- Gasifier: 1,100 tons/day
- Combined cycle: 170 MW class

Stared the Construction in March 2013

Demonstration Test Area
Cooperation with Integrated Thermal Power Systems Company

MH Power Systems
(Joint Stock Company with Mitsubishi Heavy Industries)
- Gas turbines
- Steam turbines & Generators
- Boilers and AQCS
- Control equipment
- Maintenance services

Hitachi Group

Power Systems Company
- Nuclear power systems
- Power transmission and distribution
- Electric control systems
- Renewable energy

Hitachi Capital, Ltd
- Finance
- Leasing

Hitachi Transport System, Ltd
- Logistics

Hitachi Power Solutions, Ltd.
- Monitoring
- Facility diagnosis

Information & Telecommunication Systems Company
- Big Data utilization
- Cloud computing

Infrastructure Systems Company
- Compressors
- Inverters
- Demand Side Management (DSM)
- Smart cities

T&D: Transmission & Distribution
DSM: Demand Side Management
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