Clean Coal Technology for the Future Power Generation

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1. Coal Now
World Coal Status

2014 Production

- Bituminous Coal: 80%
- Anthracite: 9%
- Lignite: 10%
- Sub-bituminous Coal: 1%

2014 Consumption

- Bituminous Coal: 80%
- Anthracite: 9%
- Lignite: 10%
- Sub-bituminous Coal: 1%

2014 Import

- Bituminous Coal: 86%
- Anthracite: 0%
- Lignite: 4%
- Sub-bituminous Coal: 10%

IEA Coal Information 2015

High rank coal: 45%
Low rank coal: 55%

WEC
Energy Mix in Major Countries

Comparison of Fuel for Power Generation

Coal and coal products
Crude, NGL and feedstocks
Oil products
Natural gas
Nuclear
Hydro
Solar/wind/other
Biofuels and waste
Oil shale and oil sands
Natural gas
Geothermal

Comparison of Fuels for Power Generation in the Area

Coal and coal products
Oil products
Natural gas
Nuclear
Hydro
Oil shale and oil sands
Geothermal

IEA Energy Statistics 2014
Coal and Electricity Demand

From 1990 to 2040


Source: IEA World Energy Outlook 2014
Electricity Generation Mix of Japan

- July 2015, Japan’s New Energy Mix towards 2030 was decided.
- The basic policy of “Energy Mix” is to realize a balanced power source composition, while achieving 3E+S (Safety, Energy Security, Economic efficiency and Environment).
- Coal is positioned as the important energy source to be used while the environmental burden.

Electricity Generation Mix:

- **2013**
  - Oil: 12%
  - Coal: 30%
  - LNG: 43%
- **2030**
  - Oil: 3%
  - Coal: 26%
  - LNG: 27%
  - Renewable Energy: 22-24%

METI Website
2. What is Clean Coal Technology?
Clean Coal Technology

Environmental Protection
- Low NOx Combustion
  - De-SOx
  - De-NOx
  - Dust Removal
- Flue-gas Treatment

Global Warming
- High Efficiency
  - PF Combustion
    - SC, USC, A-USC
  - Gasification
    - IGCC, IGFC
- CO₂ Capture
- Biomass Co-combustion
- CCS
3. Environmental Protection
Environmental Protection of Coal Fired Power Station

- Low NOx Furnace and Burners
- De-NOx
- De-SOx
- EP
- Ash treatment facility
- Ash recovery
- Coal unloader
- Condenser
- Mill
- Generator
- Turbine
- Boiler
Facilities of Environmental Protection

- **De-NOx Catalyst**
- **De-NOx Reactor**
- **Low NOx Burner**
- **Low NOx Furnace**
- **De-Sulphur Facility**
- **Electrostatic Precipitator**
4. Global Warming
# 4.1 High Efficiency

## High-Efficient Coal Fired Power Generation

**Efficiency: HHV Basis**

<table>
<thead>
<tr>
<th>Pulverized Coal (USC)</th>
<th>IGCC (1500C Class Gas Turbine)</th>
<th>IGFC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Steam Temp: 620°C</strong></td>
<td><strong>Gasifier</strong></td>
<td><strong>Gasifier</strong></td>
</tr>
<tr>
<td>Boiler</td>
<td>Gas Turbine</td>
<td>Fuel Cell</td>
</tr>
<tr>
<td>Steam Turbine</td>
<td>Steam Turbine</td>
<td>Gas Turbine</td>
</tr>
<tr>
<td><strong>Gross Efficiency</strong></td>
<td><strong>Gross Efficiency</strong></td>
<td><strong>Gross Efficiency</strong></td>
</tr>
<tr>
<td>44%</td>
<td>49%</td>
<td>60%</td>
</tr>
<tr>
<td><strong>Net Efficiency</strong></td>
<td><strong>Net Efficiency</strong></td>
<td><strong>Net Efficiency</strong></td>
</tr>
<tr>
<td>41%</td>
<td>46%</td>
<td>54%</td>
</tr>
<tr>
<td><strong>Commercialized</strong></td>
<td><strong>Commercialized</strong></td>
<td><strong>Under Development</strong></td>
</tr>
</tbody>
</table>
Steam Temperature Increase of Boiler (Japanese Ultra Super Critical Units)

Steam Temperature

- Temperature/Pressure
- Steam Pressure
- Year of operation

- Hekinan No.1
- Isogo No.1
- Tachibanawan No.1
- Isogo No.2
- USC

- Steam Temperature
- Steam Pressure
- Year of operation

- 450
- 483
- 538
- 566
- 593
- 610
- 620

- (4.1)
- (16.6)
- (24.1)
- (31.0)

- 1955
- 1960
- 1965
- 1970
- 1980
- 1990
- 1995
- 2000
Coal-fired Power Generation Capacity in Japan (2013)

Total 37.7 GW
(excl. off-grid plants)

- **USC**: 20.0 GW (53%)
- **SC**: 11.4 GW (30%)
- **Sub-critical, etc.**: 6.3 GW

Note:
- Sub-critical: steam pressure < 22.1MPa
- SC: Super Critical: steam pressure ≥ 22.1MPa, steam temperature ≤ 566°C
- USC: Ultra Super Critical: steam pressure ≥ 22.1MPa, steam temperature ≥ 593°C

※ None adapting steam temperature between 566°C < and < 593°C

Source: "Demand and Supply of Electricity", Ministry of Economy, Trade and Industry
World Highest Efficient Coal fired Power Station

---Isogo No.2 600MW  600/620C  USC (Japan)---
Installation of USC in the World

- Installed capacity of coal fired power generation is 100–110GW/year by 2014.
- First Ultra Super Critical Unit (USC) was installed in Japan in 1993. Since then, USC is increasing. But super critical and Sub critical units are decreasing.
- 60% of recent installation is USC in the world. SC is less than 10%.
- Recent installation is almost USC in China.
Number of USC installed in the World

- Japan installed first USC unit in 1993. Since then, units for utility use are all USC.
- In 2006, first USC unit was put into operation in China. Since then, 30–35 units have been installed in China every year. Now total number of Chinese USC is largest in the world.
- USC units were operated in more than ten countries at present. Recent USC units are Malaysia in 2015 and Taiwan in 2016.
Efficiency of Coal Power Generation of Various Countries (HHV, Gross)

IEA Electricity Information 2013: Calculated by JCOAL
Advanced USC (A-USC)

- Japan
  - 35MPa, 700°C
  - A-USC
  - Net efficiency 46-48% (HHV Basis)

- EU
  - 700 degree C, 540MW

- USA
  - 760 degree C, 35MPa Developed by NETL

- China
  - 700 degree C, Double Reheat
Development of IGCC

Japanese IGCC

- Nakoso NO.10 : 250MW
  Commercial Operation : April 2013

- Osaki CoolGen : 170MW
  Operation: 2017

New IGCC plan(Website of Nakoso and Hirono)

- Nakoso  About 540MW :
  Start of construction : 2016(Planned)
  Start of operation  : Early 2020(Planned)

- Hirono  About 540MW :
  Start of construction : 2016(Planned)
  Start of operation  : Early 2020(Planned)

Existing Commercial IGCC:
  Puertollano(335MW), Wabash River(296MW), Tampa(322MW), Nakoso(250MW), Edwardsport(630MW), Tianjing(250MW)
No less important is “High Efficient Power Generation + CCS”
4.3 Biomass Co-combustion

SEM
Pulverization coal/biomass

Cedar bark

Pine tree bark

Newlands coal

Cedar chip

Saw dust of pine tree
Reduction of Coal Consumption with Biomass mixing

Coal technology conference (Shikoku Power)
5. Coal Ash Utilization
Amount and Utilization of Ash from Boiler in Japan

Utilization of Ash from Power Stations

- Total ash
- Utilized ash
- Percent of utilization

Utilization of Ash (2013)

- Cement: 67%
- Civil: 14%
- Building: 4%
- Agriculture, Fishery: 1%

Utilization of Ash (2013)
6. Japanese Roadmap of Clean Coal Technology

**High efficiency and low carbon**

**CO2 capture**

- A-USC
- IGFC
- A-IGCC
- ABC
- Ferro Coke
- COURSE50
- CO2 recycle IGCC
- Chemical Looping
- Oxy-fuel combustion
- Post combustion
- CO2 Conversion

**Power generation**

- Commercial (700°C)
- Demonstration (Osaki)
- Commercial (GT1700°C)
- Commercial (<10%)
- Blast furnace demo.
- Commercial
- Commercial
- Commercial
- Commercial
- Pilot scale test

**Upgrading**

- Brown coal carbonization
- High efficiency fluidized bed drying
- Hyper Coal
- IGCC with renewable energy
- TIGAR
- ECOPRO
- Low environmental burden (B, Se)

**Steel Industry**

- Commercial (800°C)
- IGCC demo. (Osaki)
- Commercial
- Commercial
- Commercial
- Commercial
- Commercial
- Commercial

**Low rank coal utilization**

- Commercial
- Commercial
- Commercial
- Commercial
- Commercial
- R&D of reducing tech.

**Industrial use**

- Mid-long term R&D
7. Lastly----------------

• Coal should be used as a main fuel in the future. Non-OECD countries will use much more coal than OECD countries in the future.

• However, consideration should be paid to reduce air pollution and GHG emission in order to continue using coals.

• Now, Clean Coal Technology is essential.
Thank you for your attention.