High Efficiency Low Emissions:

The first way forward for clean coal technology

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IEA Clean Coal Centre
The IEA CCC will disseminate to a wide community objective analysis and information on the efficient, low emissions use of coal worldwide according to a programme agreed by the Membership: In order to achieve this objective, the focus of the IEA CCC activities comprises three broad categories:

- Towards zero emissions – including carbon abatement, emissions and effects, pollution control technology, residues.
- Coal utilisation and analysis – including coal properties, fuel handling, power generation technologies, coal conversion technologies, and industrial uses of coal.
- Economics and markets – including supply, transport and markets development, country studies, capital and operating cost reviews of current and new build technologies, including comparisons with non-coal options.

Services will be delivered through direct advice, review reports, workshops and conferences, facilitation of R&D, provision of networks and web based instruments.
Membership status of the IEA Clean Coal Centre at September 2014

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Scope of the presentation

- Drivers for technology advancement
- Historical improvements in coal power generation technology
- Getting larger and introducing higher efficiency steam cycles
- HELE concept both for CO2 and non-GHG emissions mitigation
- Current examples of HELE coal power plant
- Advanced HELE developments
- Scope to maximise HELE plants in major coal using economies
- Future work for IEACCC
Coal can ensure energy security and economic competitiveness. There are environmental challenges but technologies are available to deal with these.
Role of clean coal technology

High efficiency low emissions technologies are critical to maintain coal based energy security and as a precursor to the longer term deployment of CCS.

Essential to assist developing countries in making this choice as part of their efforts to escape from poverty through access to reliable sources of power.

Lending criteria by multi-lateral donors not overly helpful.
Historical improvements to power cycle efficiencies

- Economies of scale leading to larger units
- Higher temperature steam cycles
- Better integrated operating procedures
Recent plant state of the art conditions

Max SH Steam Temperature, °C

Year

Ultrasupercritical

Supercritical


- Studstrup (DK) 540/540
- Maatsura 1 (J) 538/566
- Esbjerg (DK) 560/560
- Schwarze Pumpe (D) 547/565
- Maatsura 2 (J) 593/593
- Haramachi 2 (J) 600/600
- Nordjylland (DK) 580/580/580
- Boxberg (D) 545/581
- Tachibanawan 1 (J) 600/610
- Avedore (DK) 580/600
- Niederaussem (D) 580/600
- Hekinan (J) 568/593
- Isogo (J) 600/610
- Yunghung 566/576
- Genesee 3 580/570
- Hitachinaka (J) 600/600
- Torrevaldaliga (I) 600/610
- Huan (China)
Application of sc and usc steam cycles
HELE Technologies

Focus on technologies to reduce both GHG and non-GHG (NOx, SO2, PM) emissions.

Technologies for cleaner coal generation

(1) Reducing coal consumption
(2) Reducing non-GHG emissions
(3) Carbon Capture and Storage

Pollutants to be reduced:
- SO2, NOx,
- Particulate matter

CO2 Storage

CO2 Capture

N2, H2O
Waigaoqiao No. 3 power plant in Shanghai is one of the cleanest in the world

Seeing is believing
Coal fired power plant layout showing ESP, FGD and SCR system locations
# Waigaoqiao no. 3 power plant

## Emissions (mg/m³)
- Dust: 11.63
- SO₂: 17.71
- NOₓ: 27.25

<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net efficiency (%)</td>
<td>42.73</td>
<td>43.53</td>
<td>43.97</td>
<td>44.50</td>
<td>44.40</td>
</tr>
<tr>
<td>Specific coal consumption (gce/kWh)</td>
<td>287.4</td>
<td>282.2</td>
<td>279.4</td>
<td>276.0</td>
<td>276.1</td>
</tr>
<tr>
<td>Annual load rate (%)</td>
<td>75</td>
<td>75</td>
<td>74</td>
<td>81</td>
<td>77</td>
</tr>
</tbody>
</table>
Need to limit capital costs as well as increase steam cycle efficiency

Yesterday

Vertical or spiral wound furnace
250 bar, 540°/560° C
\( \eta < 40\% \) (Net, LHV)

Today

600 MW reference design
300 bar, 600°/620° C
Achievable \( \eta = 45 \div 47\% \) (Net, LHV)

COST 522
300 bar, 630°/650° C

Thermie AD700
325 bar, 700° C/700° C
\( \eta = 50 \div 55\% \) (Net, LHV)

2010-2015

soon

Reduced capital costs
Novel layouts

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Towards $\geq 50\%$ cycle efficiency with advanced USC technology

<table>
<thead>
<tr>
<th>National programme</th>
<th>Steam temperature</th>
<th>Efficiency (LHV, net)</th>
<th>Programme start date</th>
<th>Demonstration plant operational by (size)</th>
<th>Also includes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>700°C</td>
<td>$&gt;50%$</td>
<td>1998</td>
<td>2021 (500 MWe)</td>
<td>Coatings, biomass co-firing, cycling</td>
</tr>
<tr>
<td>USA</td>
<td>760°C</td>
<td>45-47% (HHV, net)</td>
<td>2000</td>
<td>2021 (600 MWe)</td>
<td>Oxyfuel, coatings, high sulphur coal</td>
</tr>
<tr>
<td>Japan</td>
<td>700°C</td>
<td>$&gt;50%$</td>
<td>2008</td>
<td>2021 (600 MW)</td>
<td>Biomass co-firing</td>
</tr>
<tr>
<td>China</td>
<td>700°C</td>
<td>46-50%</td>
<td>2011</td>
<td>2021 (660 MWe)</td>
<td>-</td>
</tr>
<tr>
<td>India</td>
<td>700°C</td>
<td>$&gt;50%$</td>
<td>2011</td>
<td>2017 (800 MWe)</td>
<td>-</td>
</tr>
</tbody>
</table>

Metals used in boiler and turbine hot spots:
- Steels well proven in USC at 600°C
- Nickel based alloys proving capable in A-USC at 700°C
Raising efficiency significantly reduces the CO$_2$/kWh emitted (source: IEA HELE Roadmap, Dec 2012)
CO₂ emissions reduction by key coal utilisation technologies

Energy Efficiency makes big change but deep cuts of CO₂ emission can be done only by Carbon Capture and Storage (CCS)

Latrobe Valley lignite (Australia)
- 28-29.0%
- 1400 gCO₂/kWh

Average worldwide hard coal
- 30.0%
- 1116 gCO₂/kWh

EU av hard coal
- 38%
- 881 gCO₂/kWh

EU state-of-the-art lignite
- 43-44%
- 930 gCO₂/kWh

State-of-the-art PC/IGCC hard coal
- 45%
- 743 gCO₂/kWh

Advanced R&D Hard coal
- 50%
- 669 gCO₂/kWh

Advanced lignite
- 55%
- 740 gCO₂/kWh

Drax, UK’s most recent 6*660MWe

Torrevaldaliga Nord 3*660MWe

>2030

Data for hard coal-fired power plants from VGB 2007; data for lignite plants from C Henderson, IEA Clean Coal Centre; efficiencies are LHV,net
• Country specific study on the prospects for implementing High Efficiency Low Emissions (HELE) technologies
• Impact of HELE implementation on emissions of CO2
• Look at Australia, China, Germany, India, Japan, Poland, Russia, S Africa, S Korea, USA
• Determine outline costs of deployment, where possible
• Identification of significant trends
**Base Case**
Existing coal fleet with additional USC to meet demand (if required)

**50 year retirement scenario**
Review in 2020, 2030 and 2040. Retire capacity over 50 years old and replace with USC

**25 year retirement scenario**
Review in 2020, 2030 and 2040. Retire capacity over 25 years old and replace with USC in 2020, AUSC in 2030 and 2040
Benefitting from an actively pursued HELE upgrade policy which avoids significant quantities of carbon dioxide. If continued with AUSC, will see emissions level out by 2040.
Fastest growing coal fleet after China. If HELE technology is implemented, significant savings can be made, but current policies on technology may not go far enough.
Japan – 25 year retirement scenario
2015 - 2040

Lower potential savings as coal fleet is already highly efficient and future electricity demand prospects modest. Energy policy under review but high efficiency coal plant an important priority.
Highly dependent on coal and significant emissions savings possible from HELE. Recent and planned new capacity is supercritical not USC. Uncertainties on coal’s place in the future energy mix.
An inefficient coal fleet that would yield significant savings through HELE upgrades. The Russian situation is difficult to research and warrants further study to better quantify the benefits.
This study has provided a valuable insight into country-specific HELE possibilities but deeper analysis for all countries is recommended.

Priority areas for further study are considered to be: India, South Africa, Poland and Russia.

Other coal users need to be researched to complete the world view. A further overview study on HELE prospects is recommended for the “Asian Tiger” economies as a first step.

Plant improvements are significant to achieving efficiency gains and a review of the current best practices is recommended leading to knowledge transfer opportunities.
Dissemination and outreach

- **IEACCC information** is available to all its members and, in due course, non-members.
- **Webinars** are given on key studies, which include the HELE assessment work; all can be accessed via our website.
- **The Centre** is keen to meet with potential stakeholders to discuss the work and to consider specific issues.
- **You can reach us via** [www.iea-coal.org](http://www.iea-coal.org)
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