Upgrading and retrofit efficiency improvements for coal-fired power plants

Dr Andrew Minchener OBE
General Manager
IEA Clean Coal Centre

What is the IEA Clean Coal Centre?

- We are a Technology Cooperation Programme, which is endorsed by the International Energy Agency and funded by various national governments and corporate industrial organisations

- We provide a means for international co-operation on clean coal related issues, and provide objective and independent information on the efficient and sustainable use of coal

- We focus on how to use coal more effectively, efficiently and cleanly, to minimise its environmental impact while providing cost effective energy. This includes the impact of coal related policies and regulations, clean coal use technology developments and deployment, emissions control technologies and global coal markets

What does the IEA Clean Coal Centre specifically do?

- Our output includes:
  - comprehensive assessment reports on all aspects of clean coal technology
  - webinars based primarily on the assessment reports,
  - technical workshops on key clean coal issues,
  - a major Clean Coal Technologies Conference
  - web based dissemination services

- Increasingly, we are implementing various capacity building activities in developing countries and industrialising nations, to support knowledge transfer on a wide range of coal related energy and environmental issues, particularly for power generation

Scope of presentation

- Benefits of upgrading and retrofit
- Global examples of what can be achieved on subcritical units
- Improvements for SC and USC coal power plants

Rationale for upgrading and retrofit

- Efficiencies of coal-fired power plants will decrease gradually over time as components wear
- Such losses may be containable if the best operating and maintenance practices can be followed but eventually efficiency, output and reliability may decrease to the extent that more substantial works (retrofits) are merited to keep the plant economic
- The latter offer opportunities to incorporate technology advances made in the period since the unit was built, which can extend the life of a plant, increase output, improve operational flexibility

Efficiency benefits can be significant

(NETL 2008)

Power Plant Improvements	Potential efficiency increase (percentage points)
Air preheaters (optimise)	0.2 to 1.5
Ash removal system (replace)	0.1
Boiler (increase airheater surface)	2.1
Combustion system (optimise)	0.2 to 0.84
Condenser (optimise)	0.7 to 2.4
Cooling system performance (upgrade)	0.2 to 1.0
Feedwater heaters (optimise)	0.2 to 2.0
Flue gas moisture recovery	0.3 to 0.7
Flue gas heat recovery	0.3 to 1.5
Coal drying (installation)	0.1 to 1.7
Process controls (installation/improvement)	0.2 to 2.0
Reduction of slag and furnace fouling	0.4
Sootblower optimisation	0.1 to 0.7
Steam leaks (reduce)	1.1
Steam turbine (refurbish)	0.8 to 2.6

National and International Support Programmes

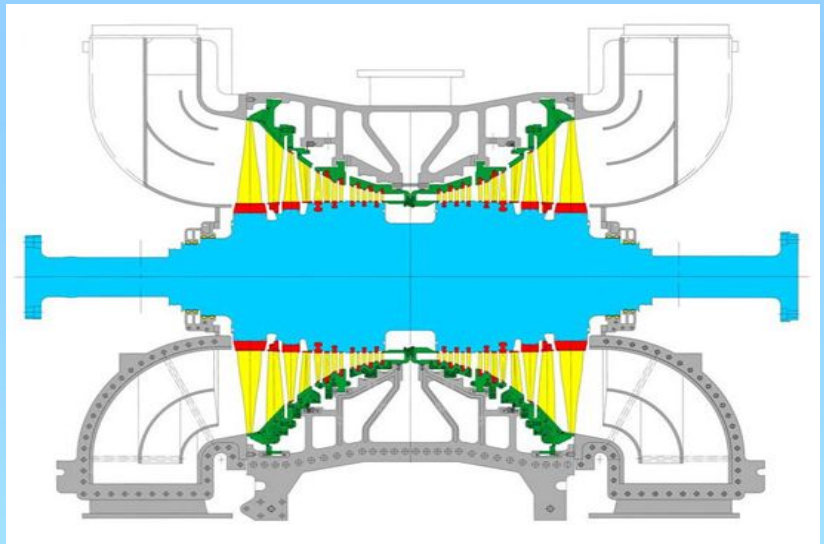
- Australia's Energy Efficiency Opportunities (EEO) Programme
- Plant renovation and modernisation in India: 24 GW of coal-fired units being renovated under the 11th and 12th economic plans (2005-2017). Also Partnership in Excellence (PIE) Programme)
- USAID CenPEEP programme in India: US DOE, utilities and NTPC
- Asia-Pacific Partnership on Clean Development and Climate and the Clean Energy Ministerial Global Superior Energy Performance Partnership
- China's incentive policy on coal power plant upgrading and efficiency improvements

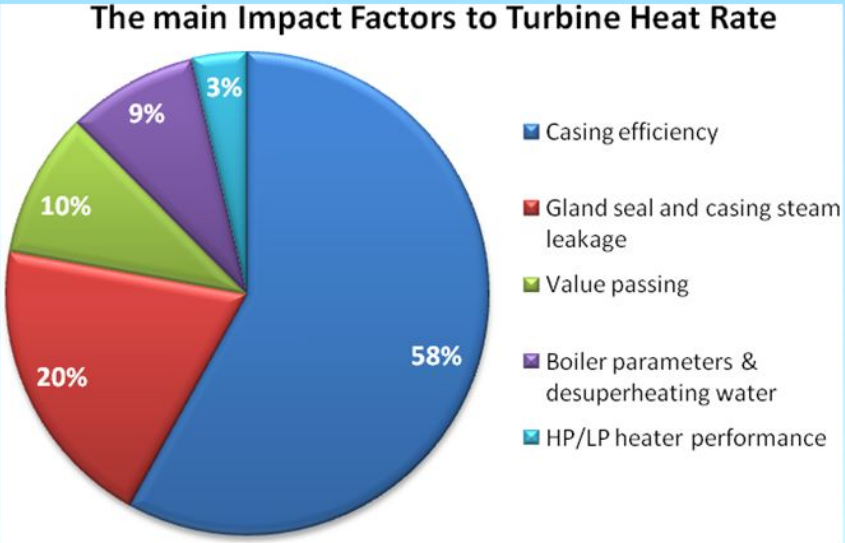
Efficiency improvement initiatives

- Efficiency improvement activities have been given a high priority to minimise fuel costs and emissions. Factors include inadequate maintenance due to inadequate resources, use of older and smaller plant, pressure to operate, and use of lower grade coals

- Turbine retrofits are especially worthwhile – advanced design features can be incorporated

- Boiler improvements can also be needed, especially where there has been a major change in the coal type





Likely steam turbine and boiler upgrades

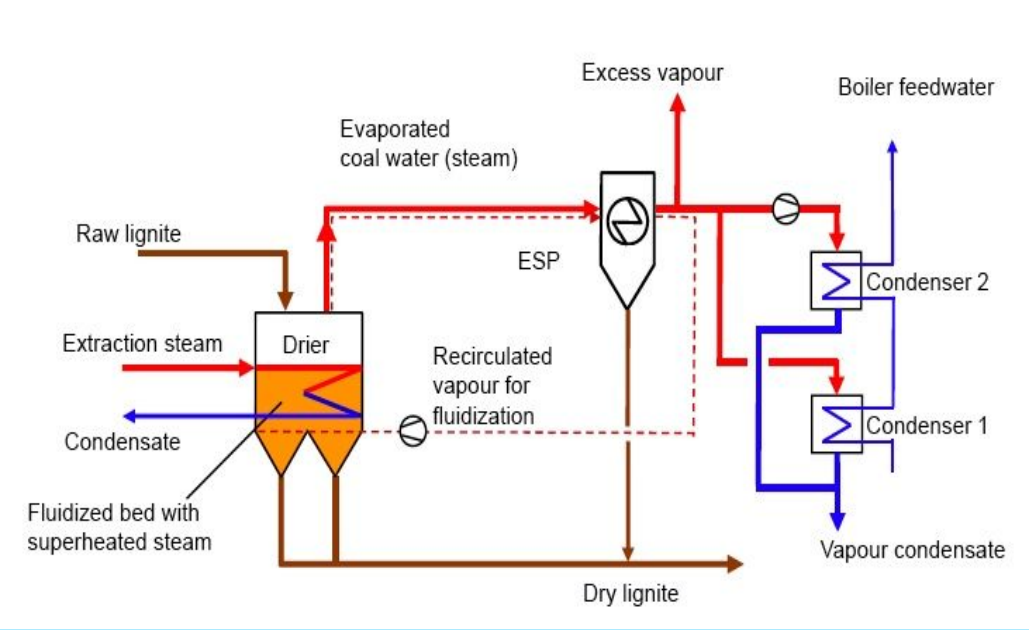
Turbine and related technical measures

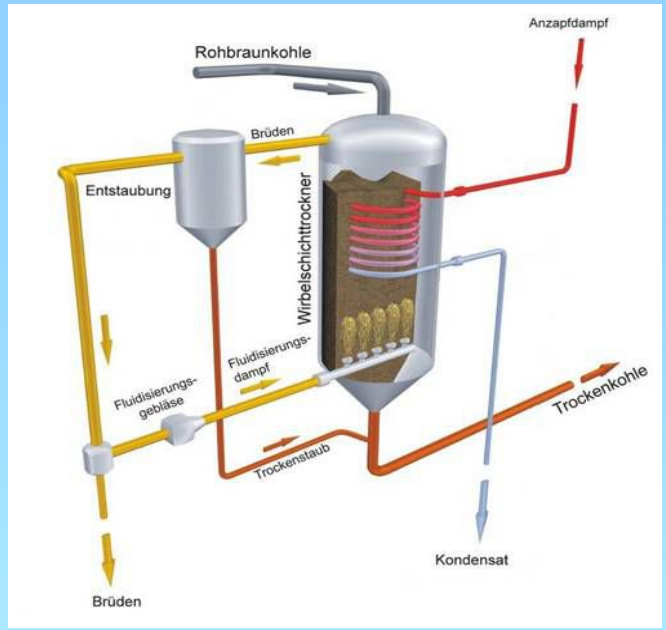
- New rotors, modern blading, more stages
- Replacement inner casings with new stators, better sealing
- Valves, feedwater heaters, condenser refurbishments

Boiler and related technical measures

- Improved coal and air flow management, more advanced monitoring, reduction of air in-leakage
- Modern burner designs
- Upgrading of fuel milling (quality and flow)
- Redesign of heat transfer surfaces, additional area, better materials; air heater improvements; smart sootblowing

Lignite drying as a route to higher efficiency





RWE's WTA lignite drying process **Vattenfall's PFBD process**

- **Pre-drying high moisture lignite and use of a revised boiler configuration would raise efficiency by 4% points**
- **Existing lignite boilers firing 50-60% moisture lignite could replace 25-30% with dried fuel, increasing efficiency by 1% point**
- **RWE's technology is available now**

Diagrams from RWE Power and Vattenfall

Several IEA CCC studies undertaken on coal power plant upgrade and retrofit

Most recent report is '**Upgrading and efficiency improvement in coal-fired power plants**' by Dr Colin Henderson **(CCC/221 August 2013)**

This includes over twenty case studies from USA, EU, Australia, South Africa, Indonesia and India

The following slides show a few of these, together with some complementary Chinese examples from work by the IEA and from local sources

Arnot, South Africa – upgrade of 350 MWe units to 400 MWe capacity

- **The six units began original operation in the 1970s**
- Upgrade project, undertaken by Alstom, covered the boiler, HP, IP and part of the LP turbines, the condensers and other components
- Project implemented over three-year period to 2010
- Demonstrated the importance of an initial comprehensive feasibility study covering the whole plant
- Generous original furnace size facilitated the large increase in output
- Power output above target, e.g. 406 MWe for Unit 3 and 409 MWe for Unit 2
- Some 15 MWe of the additional power from each unit due to increased efficiency
- NOx significantly reduced
- Life extension of 20 years achieved

(Davies and others, 212)

Guru Nanak Dev TP, PSEB Bathinda, Punjab, India

- NASL, a joint venture of NTPC, India, and Alstom Power Systems GmbH, is carrying out a number of projects in India
- Guru Nanak Dev has four units dating from the 1970s firing a bituminous coal of HHV ~17,000 MJ/kg
- R&M and up-rating from 110 MWe to 120 MWe
- Units 1 and 2 were to be restored to their 110 MWe rating and units 3 and 4 to be uprated to 120 MWe through mill and airheater upgrades, reblading HP and LP turbines, new HP heaters and new DCS
- Units 1, 2 and 3 are now running at close to full capacity, with Unit 4 believed to be operational

AECO Sabarmati D Station, India

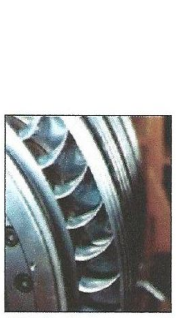
- Up-rating from 110 MWe to 120 MWe
- Sabarmati has four units. Unit D is the oldest one, opened in 1978
- The project, carried out by NASL in 2003, included a turbine retrofit with new HP/IP/LP rotors, redesign of the reheater to match the retrofitted turbine and installation of new distributed control systems
- As a result, the unit has successfully operated for 5 years at 120 MWe, at better than guaranteed heat rate and an average PLF of some 95%

Better control of sootblowers as a route to improved operation

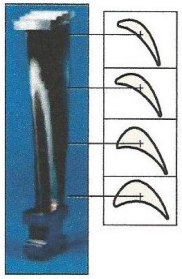
- Jeffrey Energy Center in the USA includes a 780 MWe subcritical unit, which opened in 1983, firing subbituminous coal, and had suffered serious slagging and fouling, giving derates and outages
- SmartClean™ System installed in February 2009
- System monitors the condition of key areas of the boiler and controls sootblower operation; blowers have variable intensity
- There is continuous monitoring of ash accumulation using strain gauges
- There is also continuous monitoring of the thermodynamic efficiency of each heat exchanger by an energy balance
- The system has prevented the derates and outages and improved the plant heat rate by 0.87%

Upgrades can be justified for older supercritical plants that are sufficiently below current new performance

- Farge 350 MWe bituminous coal-fired supercritical unit in Germany started operation in 1967
- Steam turbine and condenser modernised and retrofitted by Siemens in 2004
- This included replacement of rotors, with modern profile blading for the earlier stages, new inner casings for HP and IP, together with condenser modernisation
- Output increased by 22 MWe while efficiency increased from 39.4% to 42.3%, LHV net


3DS blading


diagonal impulse stage with admission ring


twisted blades with shrouds


free-standing last stage blade

Waigaoqiao No. 3 USC power plant in China

Full load calcualated design efficiency 46.5%

Emissions (mg/m^3)

Dust: 0.7

SO_2 : 15.1

NOx : 17.2

Year	2008	2009	2010	2011	2012	2013	2014	2015 to date
Net efficiency (%, LHV basis)	42.7	43.4	42.7	43.5	44.0	43.9	44.4	44.5
Specific coal consumption (gce/kWh)	287.4	282.8	287.4	279.2	282.2	279.4	276.1	276.8
Annual load rate (%)	75	75	75	74	75	81	74	77

Year Year 2008 2009 2008 2010 2009 2011 2010 2012 2012 2013 2014 2015 2015 to date

Net efficiency (%, LHV basis) 42.7 43.4 42.7 43.5 44.0 43.9 44.4 44.5

Specific coal consumption (gce/kWh) 287.4 282.8 287.4 279.2 282.2 276.0 279.4 276.1 276.8 276.1 276.8

Annual load rate (%) 75 75 75 74 75 81 74 77 81 78 77 78

Final thoughts

- Increasingly, there are drivers to ensure higher efficiency and lower environmental impact for coal fired power plants. These challenges are being met by various equipment suppliers and utility companies.
- Modernisation and retrofit offers opportunities for cost effective improvements to units of all sizes
- National and international support can be available through various routes although such opportunities have been squeezed recently.
- Ultimately, providing the necessary infrastructure is in place, the introduction of large scale high efficiency low emissions coal power plants offers the cleaner way forward.
- Asia is the leading exponent of this coal based option, and is establishing designs that offer very attractive ways forward.

andrew.minchener@iea-coal.org

Thank you for listening