Status of Coal Fired Power Plants World-Wide

Dr John Topper
Managing Director
IEA Clean Coal Centre

john.topper@iea-coal.org
www.iea-coal.org

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Content

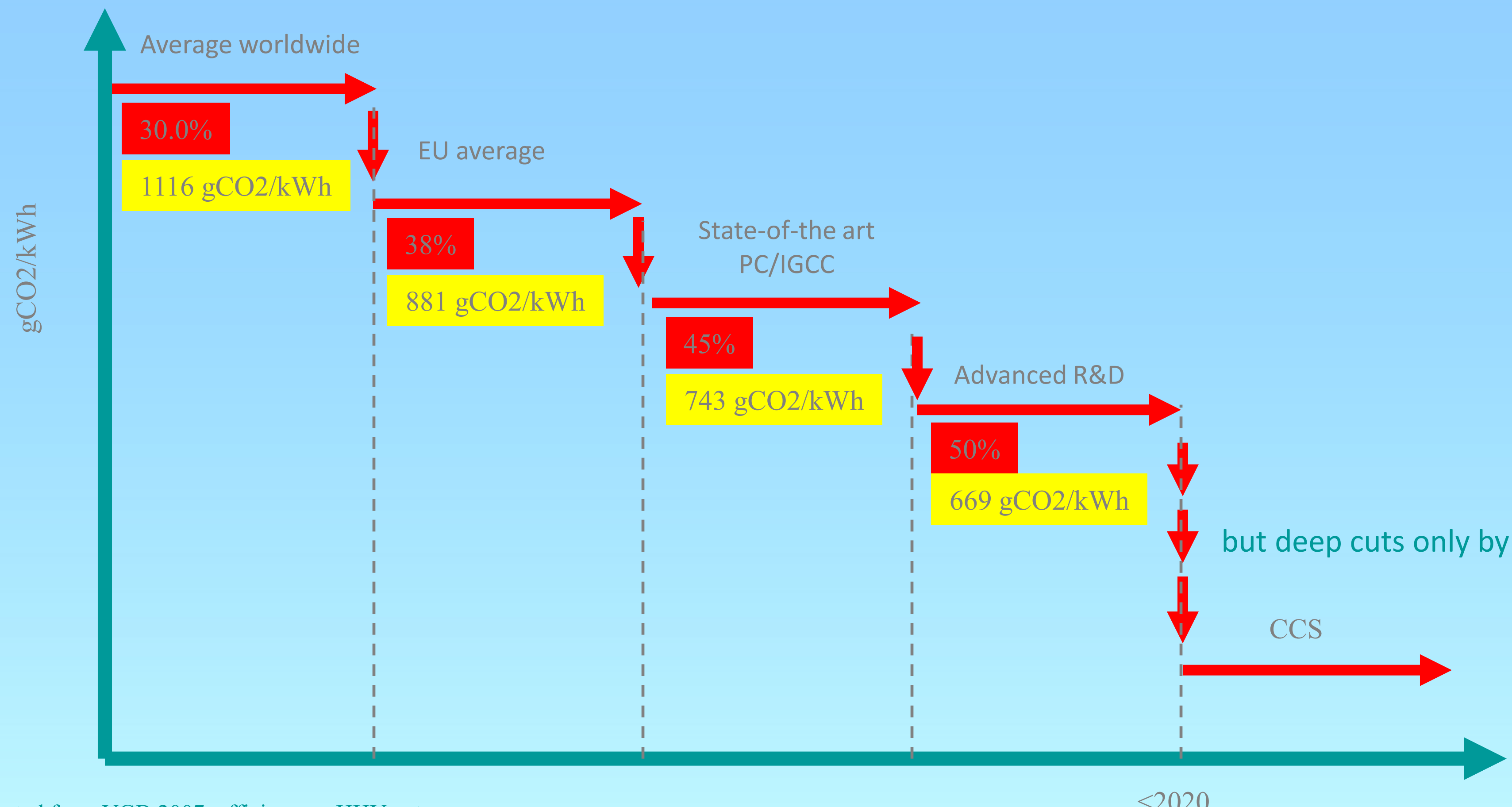
Now and into the Future for

- **Pulverised Coal**
- **Circulating Fluidised Bed Combustion**
- **Integrated Gasification Combined Cycle**

Materials Development for High Steam Temperatures

Pre-drying of High Moisture Lignites and Brown Coals

CO2 emission reduction by key technologies



adapted from VGB 2007; efficiency – HHV,net

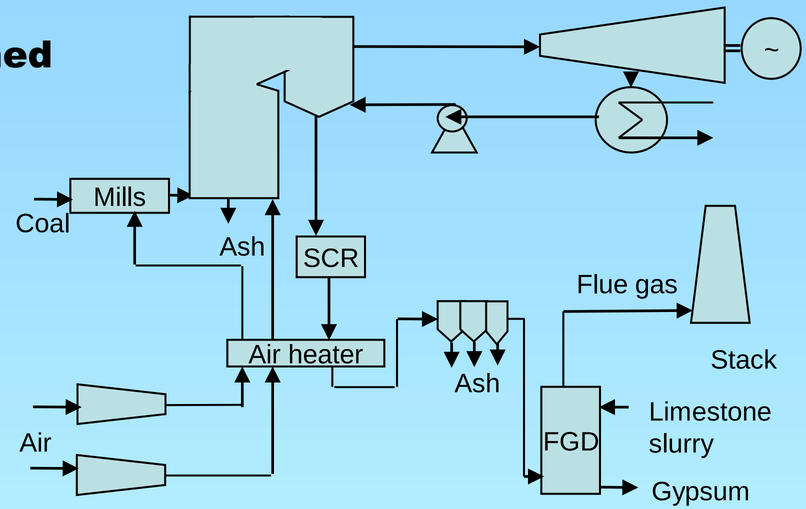
Energy Efficiency makes big change but deep cuts of CO2 emission can be done only by Carbon Capture and Storage (CCS)

Pulverised coal combustion

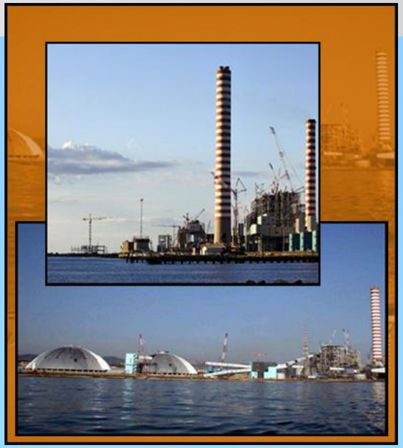
- Hundreds of GWe installed, units to ~1100 MWe
- Efficiency to upper 40s% (LHV) in best locations
- Conventional emissions control well established

How will it be in 10 or 20 years?

- Still the most deployed coal technology
- Advanced emissions control, including dry systems
- Incremental efficiency improvements
- Further efficiency gains from lignite drying and from jump to 35 MPa/700˚C steam (50%+ LHV)
- CCS as integrated technology using flue gas scrubbing or oxygen firing



Torrevaldaliga Nord, Italy



USC, boilers supplied by Babcock Hitachi , using bituminous coal

3 units at 660MWe = 1980MWe station

Very low conventional emissions (NOx <100 mg/m^3, sulphur oxides <100 mg/m^3, particulates 15 mg/m^3, at 6% O_2, dry); full waste utilisation

Highest steam conditions: 604°C/612°C at turbine: 25 MPa

Operating net efficiency >44.7% LHV

Wet scrubber based limestone/gypsum FGD

NOx abatement SCR

Particulates removal Bag filters

New sea port for coal delivery

Solids handling all enclosed

Niederaussem K, Germany

USC, tower boiler, tangential wall firing, lignite of 50-60% moisture, inland

- Most efficient lignite-fired plant
- Operating net efficiency 43.2% LHV/37% HHV
- High steam conditions 27.5 MPa/580°C/600°C at turbine; initial difficulties solved using 27% Cr materials in critical areas
- Unique heat recovery arrangements with heat extraction to low temperatures – complex feedwater circuit
- Low backpressure: 200 m cooling tower, 14.7°C condenser inlet
- Lignite drying demonstration plant being installed to process 25% of fuel feed to enable even higher efficiency

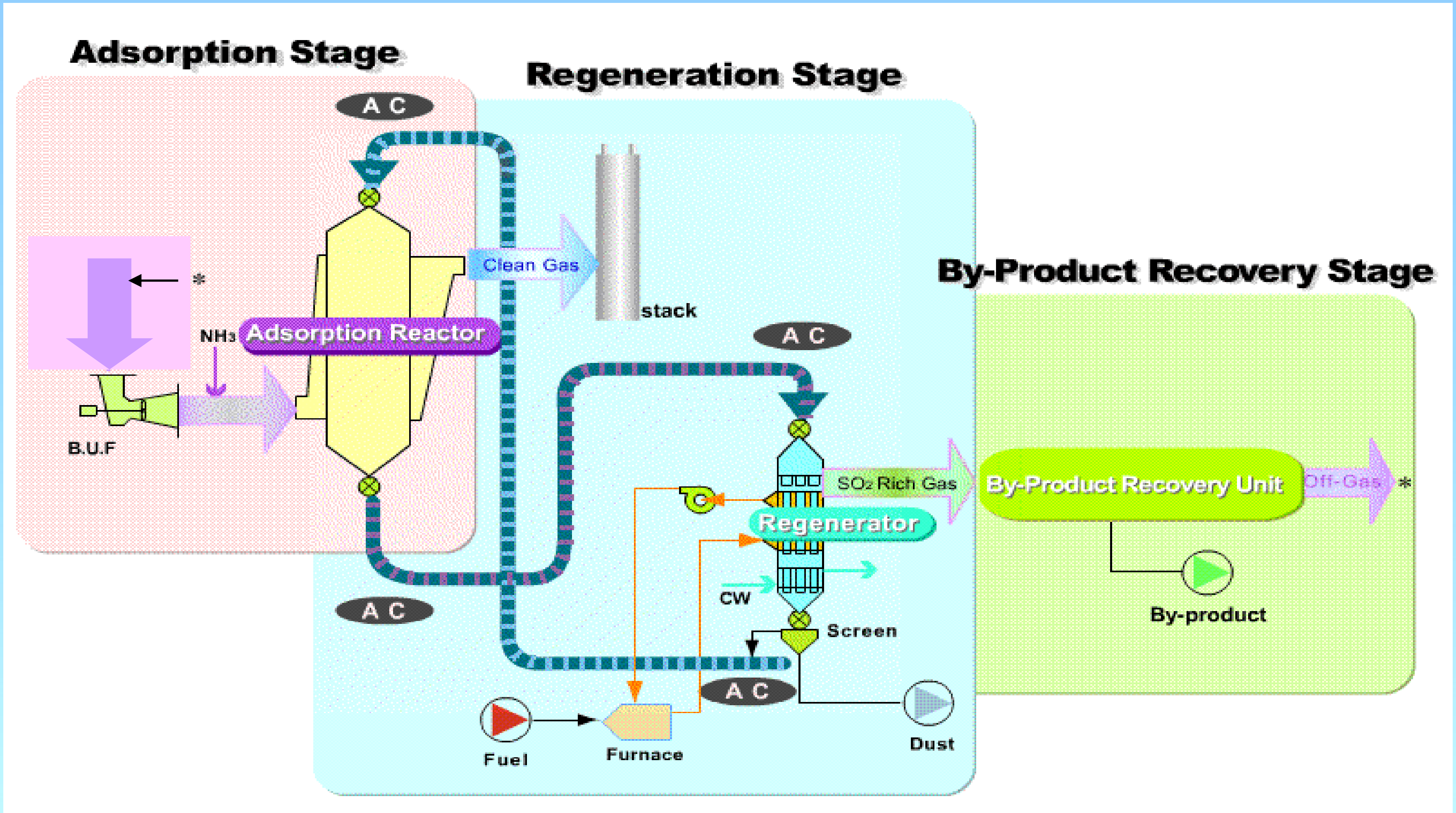
NOx abatement	Combustion measures
Particulates removal	ESP
Desulphurisation	Wet FGD

Isogo New Units 1 & 2, Japan

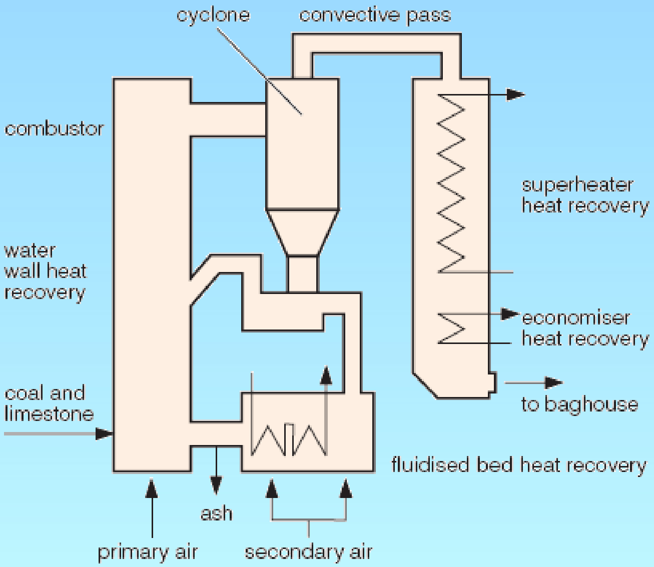
USC, tower boiler, opposed wall firing, international bituminous coal and Japanese coals, warm sea water

- Near zero conventional emissions (NOx 20 mg/m^3, sulphur oxides 6 mg/m^3, particulates 1 mg/m^3, at 6% O_2, dry); full waste utilisation
- Highest steam conditions: 25.0 MPa/600°C/610°C at turbine: ASME CC 2328 steels in S/H; P122 for main steam pipework
- Operating net efficiency >42% LHV/40.6% HHV
- Efficiency tempered slightly by 21°C CW, fewer FW heating stages
- Dry regenerable activated coke FGD (ReACT)
- NOx abatement: Combustion measures and SCR
- Particulates removal: ESP
- Isogo New Unit 2 uses ReACT specifically for multi-pollutant control, including mercury

ReACT process flow, *courtesy JPower*



Circulating fluidised bed combustion



Hundreds of units, experience to 460MWe – latter is SC; 330 MWe SC plant being installed in Russia; 600 MWe SC unit being constructed in China – local supplier

Suited to low quality coals and other fuels

Emissions control systems well established

How will it be in 10 or 20 years?

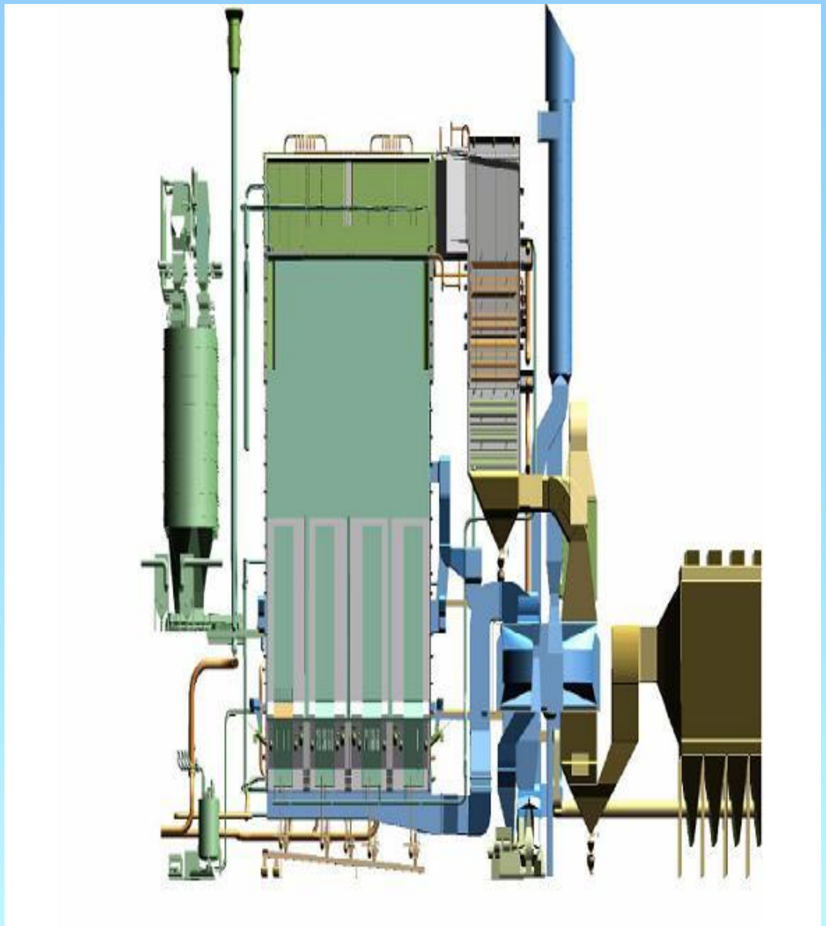
Still important where low grade coal, biomass and wastes need firing, but increasing number sold as utility boilers as alternative to PCC on steam coals

Further incremental efficiency improvements – USC steam conditions now offered; future move to 700˚C steam conditions would take advantage of materials developments for A-USC PCC

CCS using flue gas scrubbing, oxygen firing or, in new related systems, chemical looping

Lagisza Supercritical CFBC

- The world's first CFBC unit with supercritical steam conditions
- Largest CFBC; 460 MWe
- First electricity in February 2009
- Emissions of SOx, NOx and particulates lower than required by latest EU LCPD limits.
- Located to NE of Katowice, Poland



Integrated gasification combined cycle (IGCC)

Commercial demonstrations in USA and Europe and Japan. Shortly in China, another in USA. Others at FEED stage

Cost and availability concerns have held back orders in past; still expensive

Efficiency ~43-46% LHV

Very low emissions, mercury capture simple

How will it be in 10 or 20 years?

More widely deployed

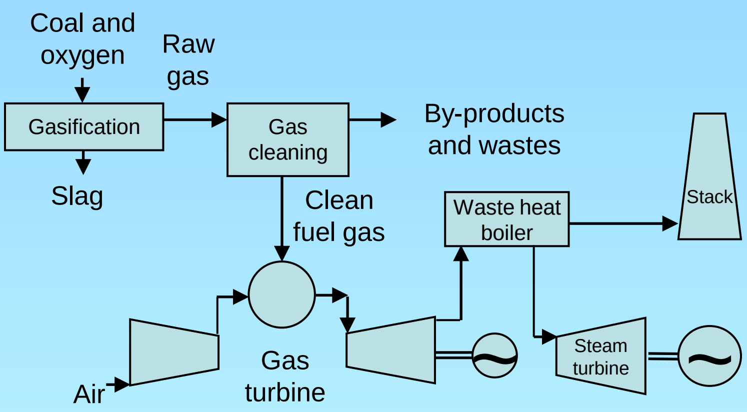
Availability up to 85%

Advancing performance to 50%+ LHV, perhaps reducing cost differential with PCC

Above from more advanced GTs and new gasifier designs, dry gas cleaning, other new systems

Polygeneration

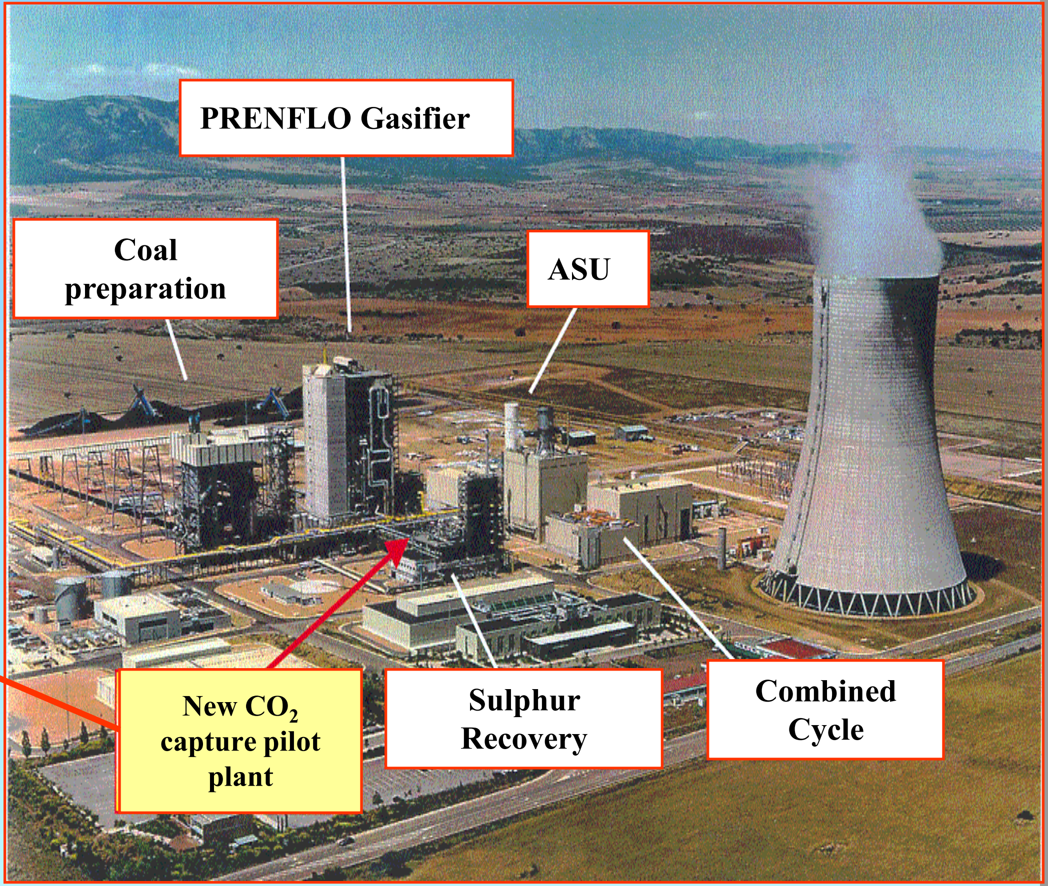
CCS using pre-combustion capture and later innovative systems



Puertollano IGCC power plant and pilot plant location

CO2 capture pilot plant general view

Courtesy of Elcogas



IGCC power plant general view

IGCC – Market Issues

IGCC market breakthrough still looks as far away as ever

This requires:

- **Reversing the alarming rise in costs that appears to have happened based on FEED studies in USA, Canada, Australia**
- **Proving availability really can be 85%**
- **Proving that large FB or W turbines do work reliably on hydrogen/nitrogen mixtures, with only combustion chamber modifications**

Future Developments in conventional technology

A-USC technology

Lignite Drying

A-USC technology

- Work is being undertaken in EU, Japan, USA, India and China to develop these high temperature (700˚C plus) systems to increase the efficiency of generation to around 50%, LHV basis, and so reduce CO_2 emissions
- We have no details of the China project
- in India, an ambitious date has been set for operation of an 800MW demonstration plant. Work is in its initial stages
- All envisage using advanced alloys based on nickel (superalloys) to cope with the high temperature, high pressure steam. Nickel-iron superalloys are also under consideration
- The USA programme is currently aimed more immediately at higher temperatures than the EU and Japanese programmes,
- The USA also has an aim to develop oxy-fired A-USC technology

A-USC technology

- Existing superalloys used in high temperature gas turbines are potentially suitable for some areas. However, component sizes and pressure stresses present new challenges
- Superalloys are much more expensive than steels, so steels will still be used for cooler parts of the boiler and turbine; developments and tests on these to operate at 650˚C are part of the activities
- The fabrication techniques needed to successfully produce plant components including reliable welding of thick sections is part of the development
- There have been successes reported but full scale demonstration is still some years away

A-USC technology in the EU

- R&D on materials development and components design, fabrication and testing in AD700 programme started in 1998, including the COMTES700 and complementary VGB E-max tests
- Boiler: superalloy superheater section, headers and steam valves have been tested at 700˚C (up to 725˚C at SH outlet)
- Turbine: welds of 10% Cr steel to superalloys produced and blades cast; turbine inlet valve casing in superalloy tested at 705˚C
- Work on fabrication and testing of thick-walled components continues within COMTES+ at power plants in Germany and Italy. A 500 MWe demonstration is expected operating in 2021

E On's 50% efficient plant

… 50 plus by using new nickel alloy superheater tubing at 700C

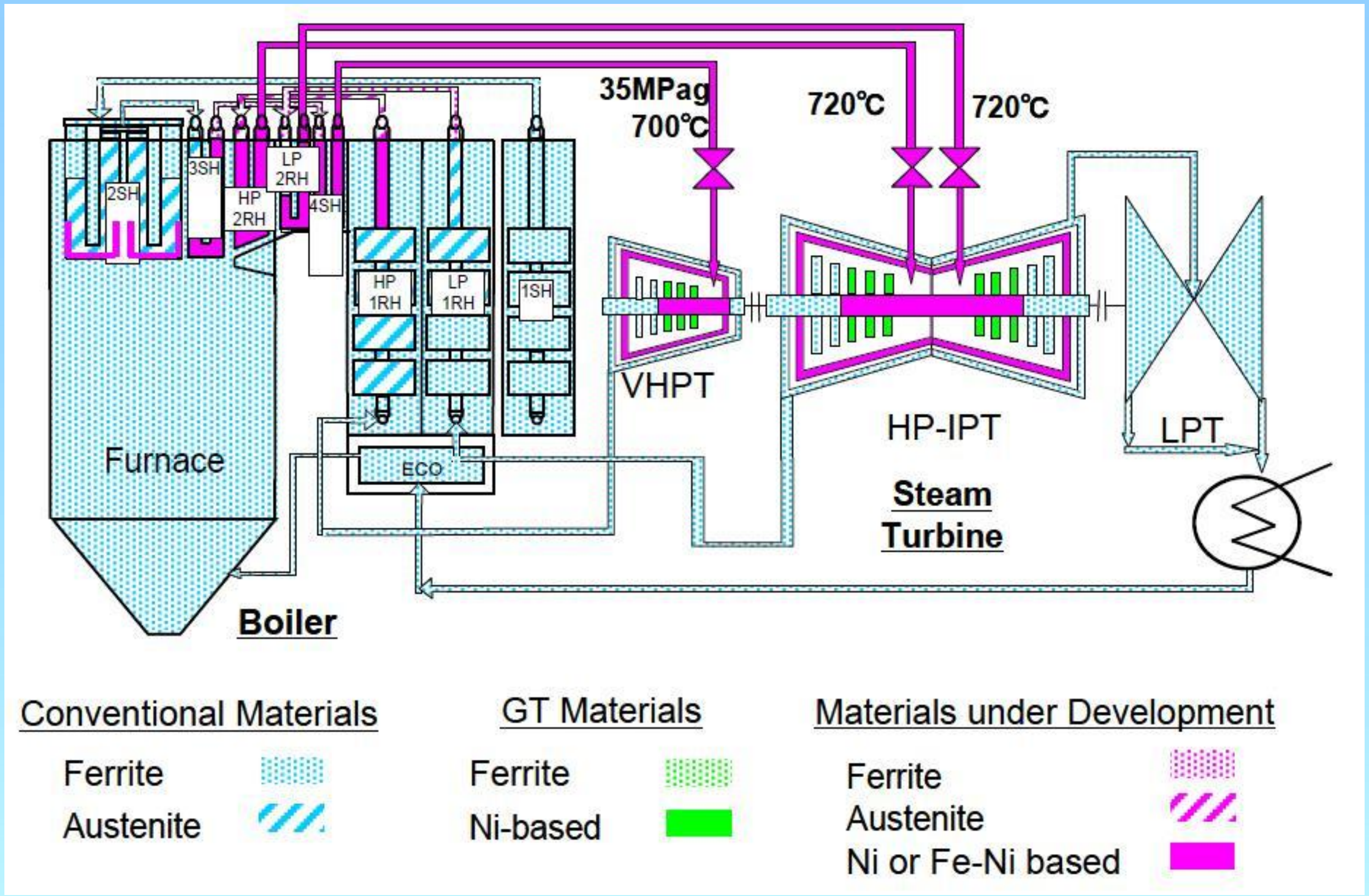
Location	**Wilhelmshaven**
Efficiency	50 %
Capacity	500 MW_e

Postponed/Cancelled in 2010
Looked very expensive; technical problems with welding and post weld heat treatment

A-USC technology in Japan

- METI Cool Earth calling for the main A-USC programme – started in 2008
- Started with materials development and evaluation for boiler components. Tensile, creep and welding properties of superalloy materials are being determined, and large and small diameter pipes have been fabricated in superalloy
- Turbine: rotors and casings have been forged and cast and are undergoing testing. Rotor welding tests are also being carried out. Valve materials are also being tested; almost all tests have been proceeding within expectations
- Boiler components and small turbine test scheduled for operation 2015-2016
- Commercialisation at 48% (LHV basis) efficiency is expected around 2020

A-USC technology in Japan



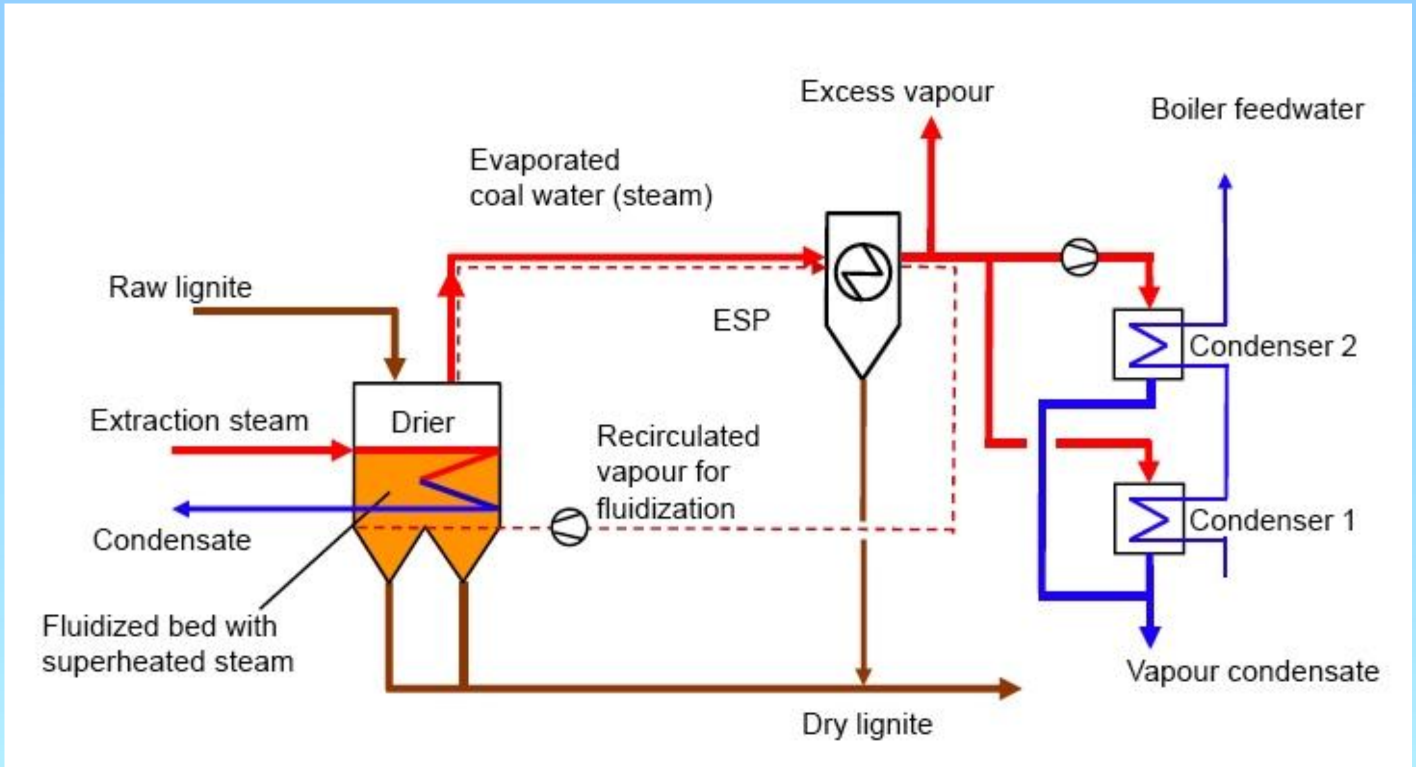
Materials in Japanese double-reheat A-USC design *(Fukuda M, 9th Liege Conference: Materials for Advanced Power Engineering, 2010)*

A-USC technology in the USA

- 760˚C steam temperature envisaged; focus currently on developing superalloys, fabrication and welding
- Boiler: superalloy tests in coal combustion products showed good corrosion resistance. Successfully welded in 75 mm thicknesses
- Component test facility planned for operation from 2014. A-USC oxy-coal combustion systems also being designed.
- Turbine: superalloys had acceptable properties for rotor, blade, and bolting components; there is on-going effort on welding of turbine casings and other cast components
- A 600 MWe demonstration is planned for operation from 2021

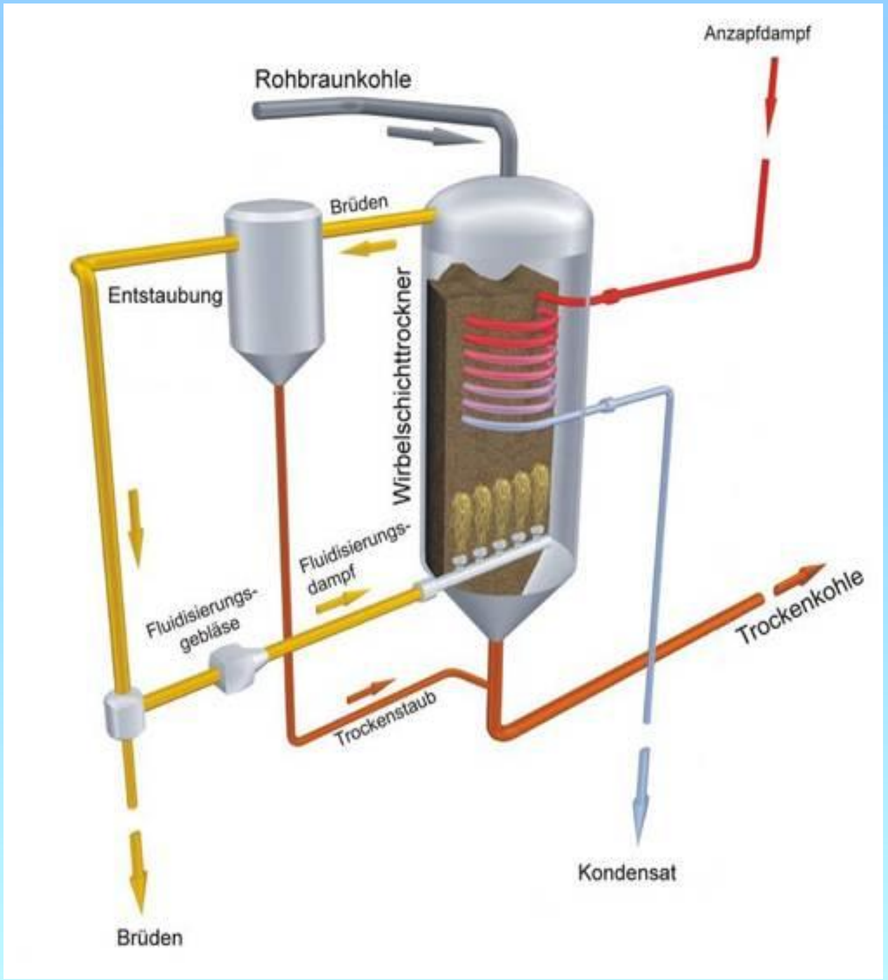
Lignite drying

Lignite drying



RWE's WTA lignite drying process

Lignite drying



Vattenfall's PFBD process

Lignite drying

- Removing a lot of moisture from the system will cause the heat balances in the boiler to be changed
- More heat will need to be removed from the combustion zone and cooled flue gas recirculation may be needed
- There should be cost savings in a new boiler that will largely offset the cost of the drier (including elimination of beater mills and hot furnace gas recycle systems, smaller flue gas volume). It will also allow plants to have greater turndown

Suggested targets

Date ranges for technical developments

Technology	2012-2020	2021-2025	2026-2030	2031-2050
PCC – bituminous coals	Commercial supercritical and USC plants; oxyfuel demos; R&D on A-USC	Commercial USC plants; commercial scale A-USC demo with CCS; supporting R&D; oxyfuel A-USC pilot/demo	A-USC commercial plants; oxyfuel A-USC demo	A-USC with full CCS commercially available, including oxyfuel
PCC – lignite	Commercial supercritical and USC plants; lignite drying: 100% dry feed boiler demo and first commercial orders; oxyfuel demo; R&D on A-USC	Commercial USC plants with 100% fuel drying; A-USC lignite plant demos with lignite drying; oxyfuel A-USC pilot/demo	Commercial A-USC plants with 100% fuel drying; oxyfuel A-USC demo	Lignite A-USC incorp drying fully commercially available with full CCS, including oxyfuel
CFBC	Sales of commercial supercritical then USC CFBC boilers	Commercial USC CFBC	A-USC CFBC commercial demo; A-USC oxyfuel demo; first A-USC commercial orders	A-USC CFBC with full CCS commercially available, including oxyfuel
IGCC	Commercial plants with 1400°C-1500°C turbines; R&D on availability, low grade coals; pilot dry gas cleaning, non-cryogenic oxygen; dev of GTs	Commercial plants with 1600°C turbines for high hydrogen fuel for CCS capability; dry syngas cleaning; some non-cryogenic oxygen; supporting R&D	Commercial plants with 1700°C turbines for high hydrogen fuel for CCS capability; some non-cryogenic oxygen; supporting R&D	Commercial plants with 1700°C+ turbines for high hydrogen fuel with full CCS; non-cryogenic oxygen option

THE END

THANK YOU FOR LISTENING

john.topper@iea-coal.org

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