Coal power generation technology status and future requirements

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Introduction

Some of the material in this presentation is from work on the IEA CCC's Clean Coal Roadmaps to 2030 study for the WPFF in 2009, updated.

The latter determined R, D & D and commercialisation steps in CCTs and CO_2 capture to 2030 for:

- **Coal-fired power generation and some major industries**
- **OECD and non-OECD countries**

Method used in 2009 study

BASELINE ASSESSMENTS:

- Technologies, programmes, plans and example projects in 2009 were reviewed for USA, Canada, Australia, Europe and Japan

OECD ROADMAPPING:

- Developed a view of coal technologies needed by 2030
- Developed targets for various dates to 2030
- Considering current technologies and known plans, developed the needed R,D&D and commercialisation steps

NON-OECD ROADMAPPING – other priorities and technology statuses may affect timing:

- Reviews identified cooperation areas and technology transfer needs of three example countries (China, India, S Africa)
- Information used as input in developing non-OECD roadmaps

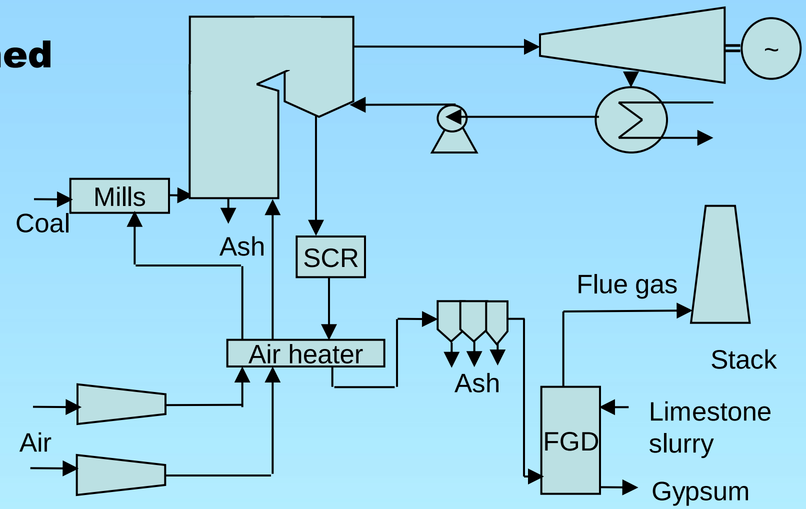
Outline of technologies with prospects

Pulverised coal combustion

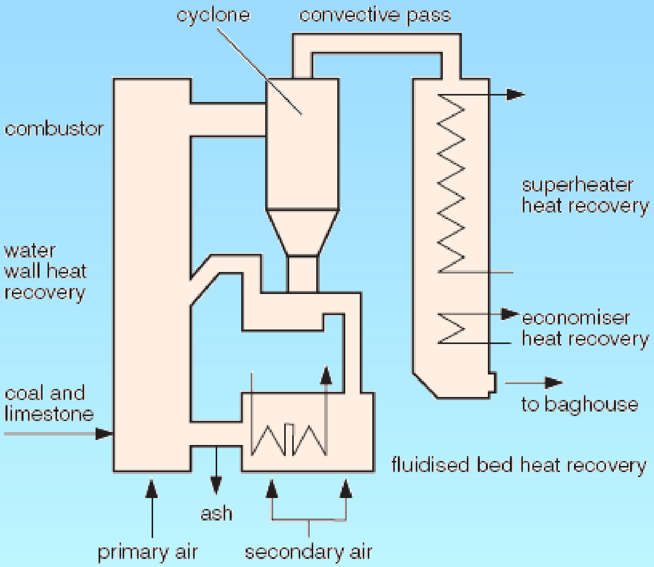
- Hundreds of GWe installed, units to ~1000 MWe
- Efficiency to upper 40s% (LHV) in best locations
- Conventional emissions control well established

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 novel lignite drying and from jump to 35 MPa/700˚C steam
- CCS as integrated technology using flue gas scrubbing or oxygen firing



Circulating fluidised bed combustion



- **Hundreds of units, experience to 460MWe**
- **Suited to low quality coals and other fuels**
- **Emissions control systems well established**

How will it be in 10 or 20 years?

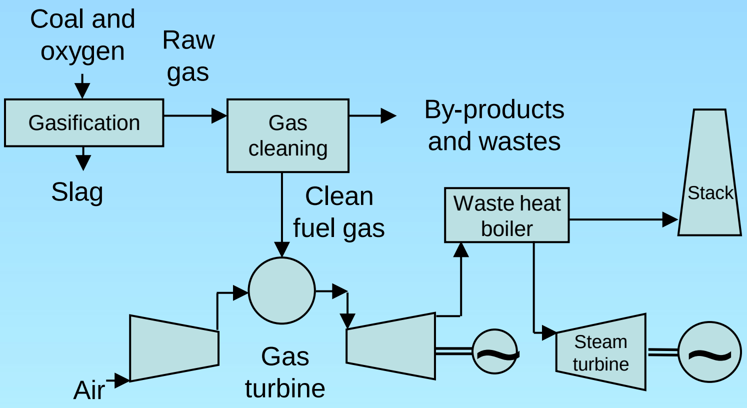
- **Still important, probably burning even more biomass and wastes**
- **Further incremental efficiency improvements**
- **Higher steam conditions (460 MWe S/C unit now operating in Poland – full load achieved Mar 2009)**
- **CCS using flue gas scrubbing, oxygen firing or, in new designs, chemical looping**

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
- Efficiency ~43-45% LHV
- Very low emissions, mercury capture simple

How will it be in 10 or 20 years?

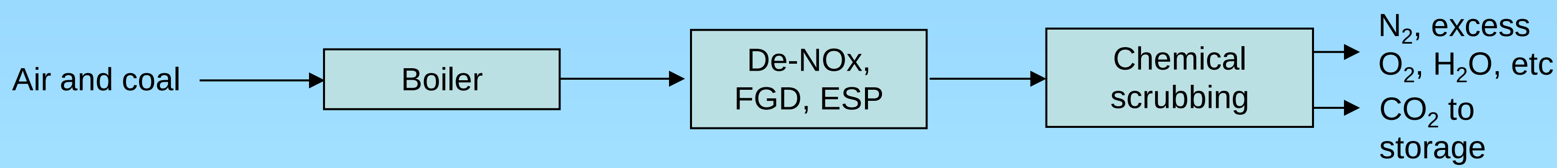
- More widely deployed
- Advancing performance and perhaps reducing cost differential with PCC
- Above from more advanced gas turbines and new gasifier designs, dry gas cleaning
- Polygeneration
- CCS using pre-combustion capture



CO_2 capture - combustion plant

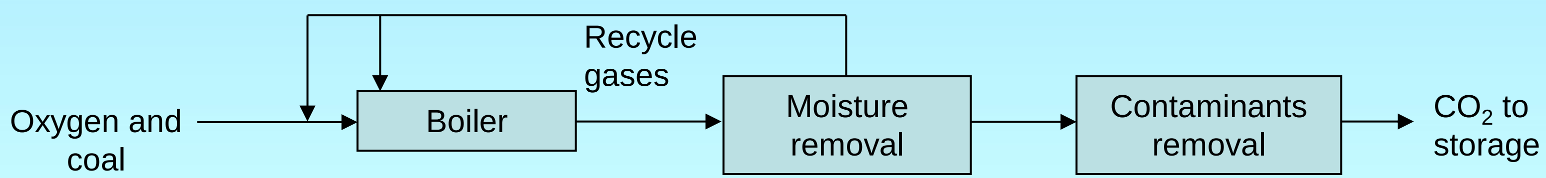
Flue gas scrubbing (amines, ammonia, chilled ammonia):

- Experience to ~20 MWe
- Issues such as corrosion, solvent degradation controllable
- Efficiency penalty high but potential to decrease (~9% points)
- Scrubbing demos to 20 MWe. Larger projects upcoming, e.g. in Canada

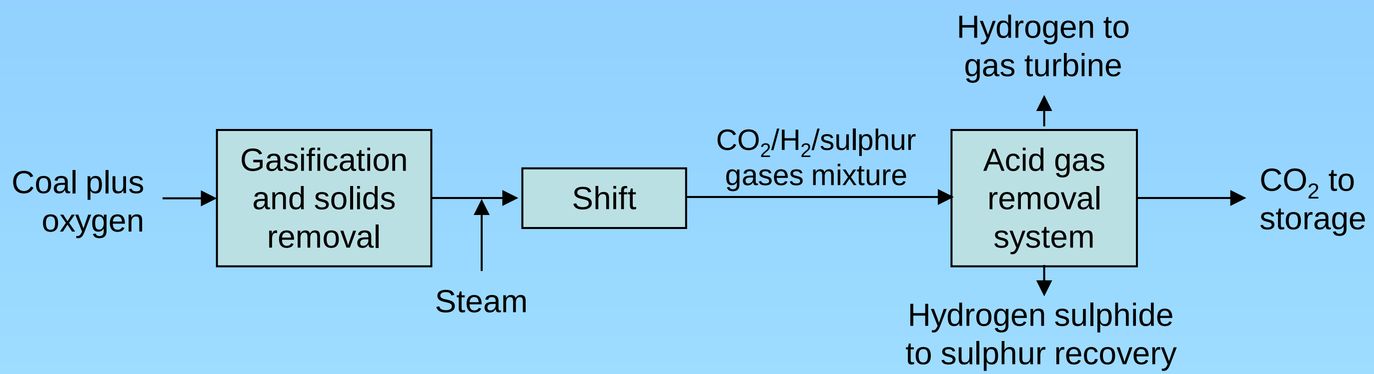


Oxy-coal firing:

- Demonstrated at 30 MWth pilot scale in Germany
- Retrofit in progress at 30 MWe in Australia. Larger projects upcoming EU and USA
- Efficiency penalty appears similar to chemical scrubbing
- New oxygen production technology could reduce penalty if introduced



CO_2 capture: IGCC plants



- **Physical or chemical solvent scrubbing of CO_2 is established in chemical industry**
- **2-5 MWe pilot capture plants at EU IGCC plants (Buggenum and Puertollano)**
- **Lower energy penalty than for PCC**
- **Experience of E-class GTs on 95% H_2**
- **Other methods of separation available**
- **Other schemes without shift**

Coverage of review of some existing OECD programmes and roadmaps in 2009

- **USA:** CCPI CCS demonstrations, Recovery and Reinvestment Act funds; FutureGen (now oxyfuel); Carbon Sequestration Technology R&D Program; CURC-EPRI Coal Roadmap
- **Canada:** Clean Coal Technology and CO_2 Capture and Storage Roadmaps; Clean Energy Fund May 2009, CCS research and demonstrations; Alberta fund for CCS; CCPC
- **Australia:** ACA COAL21 National Action Plan and COAL21 Fund; National Clean Coal Fund; New Clean Energy Initiative, CCS Flagships Program; Programmes of Queensland, NSW and Victoria Governments; GCCSI
- **Europe**: Funding for some CCS projects from budget surplus, others from sale of EUAs; Framework Programme with strong focus on CCS and CCTs; COST, covering basic and pre-competitive research; ZEP Technology Platform
- **Japan: C3 Initiative** CCUJ roadmap; METI Energy Technology Strategy Map and Cool Earth Innovative Energy Technology Program Technology Development Roadmap

Review of projects in 2009

The report described a number of then existing CCT and CCS projects, and four annexes listed many more. Example projects included:

Advanced supercritical pulverised coal plant:

700° C Wilhelmshaven 50+ project, Germany

Post combustion capture:

Vattenfall demonstration project, Nordjyllandsvaerket, Denmark; Latrobe Valley Post Combustion Capture Project, Australia; Alstom chilled ammonia CO_2 capture demonstrations, USA

O*xy-fuel:*

Vattenfall 30 MWth pilot project, Germany; CS Energy Callide A demonstration, Australia; Jamestown CFB oxy-coal combustion demonstration, NY, USA

IGCC (with and without capture):

HRL (Australia) demonstration; Powerfuel project, UK, GreenGen project, China, ZeroGen project, Australia

Conclusions from 2009 survey of international roadmaps and projects … (1)

- Maximising future security of electricity supply and its extension to non-supplied populations was of high priority, so reliance on coal would have to continue
- Accompanying potential CO_2 emissions needed to be addressed
- This required continuing assessment of development barriers and addressing the associated R, D & D to develop CCTs and CCS
- A range of coal technology options needed to be maintained, with provision for breakthrough systems to be explored

Conclusions from 2009 survey of international roadmaps and projects … (2)

- **CCT developments needed to integrate well with CCS**
- **CCS needed to be proven in time for commercial deployment by the mid 2020s**
- **A good line-up of CCS pilot and demonstration projects was in prospect, although a greater sense of urgency was warranted**
- **Two-way technology cooperation between OECD and non-OECD countries was needed to ensure that the above occurred worldwide**
- **Dependence on future advances would not be the sole solution: major CO_2 emissions savings could be achieved by using *current* best CCT designs more widely**

Update since 2009 … (1)

- **Although there have been some lost projects and delays, a significant number have survived**
- **New projects have emerged, both CCTs and CCS**
- **CO_2 capture has been demonstrated on coal systems at pilot (up to 20MWe) scale and FEED studies are in progress for demonstrations at 100-200 MWe for combustion technologies**
- **CO_2 capture is now being operated on IGCC slipstreams at 2-5 MWe pilot scale at two EU plants; a larger demonstration (about 50 MWe equivalent) is planned in the USA**

Update since 2009 ... (2)

- IGCC projects include new plants under construction in the USA and China, with plans for addition of at least partial CCS. One or two other new IGCC projects including CCS look fairly likely to proceed
- Unfortunately, the 50+ plant at Wilhelmshaven is indefinitely suspended
- There are possible signs of a lessening commitment to coal by some governments, prompted by adverse public reactions as well as financial tightening

Suggested post-2030 targets – for discussion

- 90% CO_2 capture part of standard equipment, various systems, and other emissions at virtually zero levels
- Availability >90% combustion-based systems; >85% gasification-based systems
- Efficiency of power generation approaching as far as possible that of current non-capture systems (40-45%, net, LHV)
- Substantial reduction in CO_2 abatement cost (40-50 US$/t predicted in 2009)

Technical milestones from the 2009 report

- The following slides include diagrams from the 2009 report. They are simplified in the tables following them, where recent developments are also highlighted

OECD roadmapping – PCC

Current position (2009)	2009-2015	2015-2017	2017-2020	2020-2025	2025-2030	Post-2030
COMMERCIAL USC TO 25-30 MPa/600°C/620°C 46% NET, LHV, BITUM COALS, INLAND, EU, EVAP TOWER COOLING, (44%, HHV). ON HIGH MOISTURE LIGNITE 43% NET, LHV, SIMILAR CONDITIONS (37%, HHV)	COMMERCIAL USC TO 25-30 MPa/600°C/620°C	COMMERCIAL USC TO 25-30 MPa/600°C/620°C	COMMERCIAL USC TO 650°C+	COMMERCIAL CCS USC TO 35 MPa/700°C/720°C (scrubbing only for 700°C; oxy-coal to 600°C)	COMMERCIAL CCS USC TO 35 MPa/700°C/720°C RANGE OF CAPTURE SYSTEMS (oxy-coal to 650°C only)	COMMERCIAL CCS USC ROUTINELY BEYOND 35MPa/700°C/720°C ALL CAPTURE SYSTEMS ALL COALS, ALL FIRING CONFIGURATIONS. EFFICIENCIES 40-45%, NET, LHV, INCL. CO_2 CAPTURE, DEPENDING ON CONDITIONS AND SYSTEMS USED
	R&D, PILOT TESTS FOR HIGHER TEMPS FIRST 700°C DEMO BEGINS OPS 2014	700°C DEMOS R&D materials Side-stream CCS	R&D: Materials, Novel steam cycles novel post-comb, oxy-coal materials 650-700°C	R&D Studies supporting commercial plants. OXY-COAL PILOT 650-700°C	>700°C/720°C DEMOS, ALL WITH CCS, VARIOUS TYPES R&D materials	
	CCS R&D, PILOTS AND DEMOS	FULL FLOW CCS DEMOS ON USC 600°C PLANTS	ADVANCED FULL FLOW CCS DEMOS (scrubbing only for 700°C technology)			
Emissions on bitum coals: Particulates 5-10 mg/m^3 SO_2 <20 mg/m^3 NOx 50-100 mg/m^3 dry systems can give lower emissions		Full environmental controls at at least 2009 state-of-the-art emissions		Emissions on all coals: Particulates 1 mg/m^3 SO_2 10 mg/m^3 NOx 10 mg/m^3 90% mercury removal		Near-zero emissions all coals: Particulates <1 mg/m^3 SO_2 <10 mg/m^3 NOx <10 mg/m^3 99% mercury removal 90% CO_2 capture

Notes on PCC

- **500 MWe 700C+ PCC demonstration in Europe indefinitely suspended. Alternative demonstrations should be considered elsewhere. Sidestream CO_2 capture needs to be included**
- **The associated R&D and pilot plant work is continuing**
- **By 2020, such plants need to be offered commercially, supported by continuing materials development and testing**
- **Consideration should be given to including full flow CO_2 scrubbing as part of a 700C demonstration**
- **Other emissions decreasing**
- **Development and deployment of dry gas cleaning and novel lignite drying should probably be specifically included in roadmap; also mercury capture as normal commercial option**

OECD roadmapping – IGCC

Current position (2009)	2009-2015	2015-2017	2017-2020	2020-2025	2025-2030	Post-2030
5 DEMOS/EX- DEMOS OPERATE, 250-300MWe VARIOUS ENTRAINED GASIFIERS ON VARIOUS COALS 600 MWe COMMERCIAL PLANTS UNDER CONSTRUCTION. HIGHER CAP. COST THAN PCC BUT COST W. CAPTURE COMPETITIVE. 40-43% NET, LHV, 46% NEW PLANTS (LATEST F-TURBINES) ON BITUMINOUS COALS. AVAILABILITY ~80%	CONSTRUCT, OPERATE COMMERCIAL PLANTS WITH LATEST F AND W TURBINES	COMMERCIAL PLANTS WITH LATEST F- AND W-CLASS GTs. SOME WITH CAPTURE COMMERCIAL OP OF NEW WATER QUENCH GASIFIERS	COMMERCIAL PLANTS OPERATING WITH LATEST F- AND W-CLASS GTs VARIOUS GASIFIER TYPES	COMMERCIAL PLANTS OPERATING WITH H- OR J-GTs ABLE TO BURN HIGH HYDROGEN. FULL CO_2 CAPTURE AVAILABLE CAPITAL COST COMPARABLE WITH PCC FOR NON-CAPTURE SYSTEMS	COMMERCIAL IGCC WITH H- OR J-CLASS GTSs WITH ULTRA-LOW NOx ON HYDROGEN FUEL. FULL CO_2 CAPTURE	ADVANCED IGCC WITH CO_2 CAPTURE AS STANDARD USING GAS SEPARATION MEMBRANES AND SHIFT MEMBRANE REACTORS CAPITAL COST LOWER THAN PCC WITH CCS EFFICIENCY 40-45%, LHV, INCL. CO_2 CAPTURE, DEPENDING ON TECHNOLOGY, COAL TYPE, CONDITIONS ITM OXYGEN AS OPTION WITH ITM-OPTIMISED H_2 GT DRY GAS CU INCL. MERCURY FUEL CELLS IN SOME PLANTS EVENTUALLY OTHER SYSTEMS WITH CO_2 GTs CO_2/H_2O GTs
	R&D: Reduce capital cost, increase availability, extend range of coals. Gas turbine developments. Dry syngas cleaning Cryogenic air separation, e.g. ITM. Modelling to optimise IGCC blocks	R&D: Reduce cost, extend range of coals, increase availability. GT developments. Dry syngas cleaning. Slipstream gas polishing for fuel cells ITM PILOT (stand-alone)	R&D: Develop H-class IGCC GT Develop GT for ITM cycles. Novel gasifiers, new power cycles. Pilot dry gas cleaning, fuel cells tests DEMONSTRATE ITM (stand-alone)	R&D: Studies supporting commercial plants	R&D: Studies supporting commercial plants. Develop CO_2 GTs	
	PRE-COMB CCS R&D, PILOTS AND DEMOS			PILOT OF FUEL CELL ON ULTRA-CLEAN SYNGAS SLIPSTREAM DEMONSTRATE ITM OXYGEN SUPPLY IN IGCC	COMMERCIAL SCALE DEMO OF DRY GAS CLEANUP DEMONSTRATE ITM O_2 IN IGCC WITH ITM-OPTIMISED GT AND CCS DEMONSTRATE ULTRA-DEEP SYNGAS CLEANING WITH FUEL CELLS	
		FULL FLOW PRE-COMB CCS DEMOS USING SCRUBBING. Supporting R&D	ADVANCED CCS DEMOS			
Emissions: Particulates <1 mg/m^3 SO_2 <20 mg/m^3 NOx <50 mg/m^3; SCR will allow lower levels Mercury capture demonstrated		Full emissions controls at at least 2009 state-of-the-art		Emissions: Particulates 0.1 mg/m^3 Emissions of SO_2 and NOx <10 mg/m^3 90% mercury removal		Near-zero emissions, all coals: Particulates 0.1 mg/m^3 SO_2 <10 mg/m^3 NOx <10 mg/m^3 99% mercury removal

Notes on IGCC

- Construction of commercial demos in some number, operating 2010-2017, needed to extend experience with the technology
- As many as possible should include CO_2 capture demonstrations
- 2 new IGCCs in USA, 1 in China, will be operating within the next year or two, so some progress. Other still in prospect but experience with firing IGCC syngas turbines on hydrogen, hoped for in this period, may come a little slower than hoped
- Over period to 2030, movement to higher specification gas turbines and other developments is needed to keep efficiency progressing upwards; novel systems could play a major role; decreasing emissions
- Proving that high availability is maintainable will remain very important

OECD roadmapping – CO_2 capture

Current position (2009)	2009-2015	2015-2017	2017-2020	2020-2025	2025-2030	Post-2030
4 LARGE SCALE CAPTURE DEMONSTRATIONS ON NON-POWER PLANTS CAPTURE EXPERIENCE IN CERTAIN INDUSTRIES AND FOR FOOD PROCESSING NUMBER OF PILOT CAPTURE PLANTS	POST-COMB CAPTURE: LARGE DEMOS 85% CAPTURE INCLUDING RETROFITS USING SCRUBBING R&D & PILOTS ON PCC AND CFBC: develop/improve chemical solvents; laboratory work on post comb capture using dry systems	POST-COMB CAPTURE: LARGE DEMOS 85% CAPTURE INCLUDING RETROFITS USING SCRUBBING R&D & PILOTS: test advanced solvents, dry systems. Capture slipstream on 35MPa/700°C/720°C unit.	POST-COMB CAPTURE: ADVANCED DEMOS >85% CAPTURE INC RETROFITS. R&D: advanced solvents membrane contactors dry absorption, adsorption	FIRST COMMERCIAL SYSTEMS, >85% CAPTURE, ALL 3 MAIN METHODS OF CAPTURE, NEW PLANTS AND RETROFITS POST-COMB CAPTURE: Supporting R&D: new solvents, membrane contacting systems with novel solvents, solid absorbents or adsorbents	COMMERCIAL SYSTEMS 90%+ CAPTURE. POST-COMB CAPTURE: NEW SOLVENTS; MEMB CONTACTING; SOLID ABSORBENTS, ADSORBENTS OXY-COAL 650˚C STEAM SYSTEMS. PRE-COMB CAPTURE WITH H-CLASS GTs WITH ULTRA-LOW NOx ON H_2 GENERAL: REDUCED ENERGY USE OF CO_2 CAPTURE AND COMPRESSION	COMMERCIALLY AVAILABLE SYSTEMS, 90%+ CO_2 CAPTURE, EFFICIENCIES 40-45%, NET, LHV. POST COMBUSTION CAPTURE: GREATLY REDUCED WATER CONSUMPTION FROM VARIOUS SYSTEMS. OXY-COAL: VARIOUS SYSTEMS UP TO 700˚C STEAM; INTEGRATED ITM. PRE-COMB CAPTURE: HIGH SPEC GTs WITH ULTRA-LOW NO_X ON H_2; MEMBRANES; SHIFT MEMBRANE REACTORS; ADVANCED IGCC CYCLES WITH ITM; IG FUEL CELLS. CHEMICAL LOOPING SYSTEMS
	OXY-COAL: LARGE AND MEDIUM DEMOS AND PILOTS. R&D: process modelling, combustion studies, materials studies; characteris'n NOx, SO_2, mercury removal; low gas recycle rate with CFBC	OXY-COAL: LARGE DEMOS INCLUDING RETROFITS. R&D: process modelling, heat transfer modelling; materials for higher temp systems. Pilot low recycle CFBC	OXY-COAL: SUPERCRITICAL FULL FLOW DEMOS. R&D: test boiler sections 650-700˚C steam; concepts for ITM incorporation; improved boiler geometries	OXY-COAL: PILOT 650-700˚C steam. PILOT oxy-coal with ITM in two reactors. R&D: supporting studies	OXY-COAL: 650-700˚C STEAM DEMO; ITM OXY-COAL PILOT USING INTEGRATED MEMBRANE BOILER.	
	PRE-COMB CAPTURE: LARGE DEMOS. R&D: new solvents, membranes, adsorption systems	PRE-COMB CAPTURE: LARGE DEMOS 85% CAPTURE PHYSICAL AND CHEMICAL SCRUBBING R&D: H_2 combusting GTs, slipstream tests on memb separation, lab test membranes and membrane reactors, advanced gasifiers	PRE-COMB CAPTURE: ADVANCED SOLVENTS >85% CAPTURE FULL FLOW DEMOS R&D: air-extracting GTS for hydrogen, shift with low steam requ't, pilot membranes, membrane reactors, gasification fuel cell cycles, advanced gasifiers, novel IGCC cycles	PRE-COMB CAPTURE R&D: H-class GTs for high H_2 fuels, pilot shift membrane reactors, novel IGCC cycles, pilot ITM IGCC	PRE-COMB CAPTURE: DEMO SHIFT MEMBRANE REACTORS; DEMO GASIFICATION FUEL CELL CYCLES FOR CCS; DEMO NOVEL GASIFICATION-BASED CYCLES; DEMO ITM IGCC CCS Supporting R&D	
	CHEMICAL LOOPING: SMALL PILOT TESTS, R&D on O_2 carriers. All CCS: energy efficient compressors	CHEMICAL LOOPING: lab tests on O_2 carriers. All CCS: energy efficient compressors	CHEMICAL LOOPING: small pilot tests and supporting R&D. All CCS: energy efficient comps	CHEMICAL LOOPING: PILOT TESTS and supporting R&D	CHEMICAL LOOPING: DEMOS and supporting R&D	

Notes on CO_2 capture with update

- CO_2 capture technologies need rapid demonstration at 100 MWe plus to become commercially deployable in the 2020s
- All 3 main types of CO_2 capture need pursuing: a number of North American and EU publicly funded demonstration projects are likely to construct soon, with FEED studies begun
- Later demonstrations will allow performance and cost to be improved so that first commercial systems, from 2020, would use such systems
- During the 2020s, breakthrough systems need to be demonstrated (e.g. chemical looping, integrated ITM oxy-coal, membrane reactors, fuel cells) to provide bases of advanced post 2030 plants
- Supporting R&D will be needed throughout

Non-OECD roadmaps

- **Other priorities and technology statuses may affect timing of R,D&D and commercialisation**
- **Reviews carried out to identify cooperation areas and technology transfer needs of three example countries (China, India, S Africa)**
- **Information used as input in developing non-OECD roadmaps**

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Coal use in China, India and South Africa
Power generation

Shanghai, 900 MW SC units

Sipat power plant, India

Fuyang Huaren, 660 MW SC units

China power technologies roadmap including CO_2 capture

Current position (2009)	2009-2015	2015-2020	2020-2030	Post-2030
PCC: SUBCRIT, SC AND USC END 2009: 24% PLANTS SC/USC UP TO 600°C NUMEROUS FBC UNITS	CLOSE SMALL SUBCRIT DEPLOY MORE SC AND USC	CLOSE SMALL SUBCRIT DEPLOY MORE SC AND USC	DEPLOY USC TO 700°C FIRST COMMERCIAL CCS PLANTS	COMMERCIAL CCS USC PCC AND CFBC ROUTINELY BEYOND 35MPa/700°C/720°C ALL CAPTURE SYSTEMS ALL COALS, ALL FIRING CONFIGURATIONS EFFICIENCIES 40-45%, NET, LHV, INC CO_2 CAPTURE, DEPENDING ON CONDITIONS AND SYSTEMS USED
	KNOWLEDGE SHARING: EMISSIONS CONTROL SYSTEMS SC CFBC POST-COMB CO_2 CAPTURE	KNOWLEDGE SHARING AND TECHNOLOGY TRANSFER: PARTICIPATE IN 700°C DEMO. POST-COMB CO_2 CAPTURE OXY-COAL CO_2 CAPTURE	KNOWLEDGE SHARING: ADVANCED EMISSIONS CONTROL ADVANCED POST-COMB CO_2 CAPTURE OXY-COAL CO_2 CAPTURE	
	POST-COMB CO_2 CAPTURE PILOTS	POST-COMB CO_2 CAPTURE DEMOS OXY-COAL PILOTS AND FIRST DEMOS	ADVANCED POST-COMB CO_2 CAPTURE DEMOS OXY-COAL DEMOS	
IGCC DEMOS UNDER CONSTRUCTION	CONSTRUCT AND OPERATE IGCCs (GREENGEN STAGE I AND OMB) OVERSEAS IGCC PROJECTS	COMMERCIAL IGCC	COMMERCIAL IGCC WITH CO_2 CAPTURE	IGCC CO_2 CAPTURE AS STANDARD SOME USING MEMBRANES EFFICIENCY 40- 45%, LHV, INC CO_2 CAPTURE, DEPENDING ON TECHNOLOGY, COAL TYPE, CONDITIONS ITM OXYGEN AS OPTION WITH ITM-OPTIMISED H_2 GT DRY GAS CU INCL MERCURY FUEL CELLS IN SOME PLANTS EVENTUALLY OTHER SYSTEMS WITH CO_2 GTs CO_2/H_2O GTs
	KNOWLEDGE SHARING AND TECHNOLOGY TRANSFER: GASIFICATION, GAS TURBINES	KNOWLEDGE SHARING AND TECHNOLOGY TRANSFER: PRE-COMB CO_2 CAPTURE, GAS TURBINES	TECHNOLOGY TRANSFER AND KNOWLEDGE SHARING: ADVANCED GAS TURBINES DRY GAS CLEANING DRY CO_2 CAPTURE	
	GREENGEN IGCC STAGE II: 25% FLOW PRE-COMB CCS DEMO	GREENGEN IGCC STAGE III: PRE-COMB CCS DEMO 400MW	ADVANCED PRE-COMB CO_2 CAPTURE DEMOS	
EMISSIONS FROM COMB PLANTS: WIDE RANGE BUT SOME PLANTS HAVE EFFECTIVE DUST, SO_2, NOx CONTROLS				NEAR-ZERO EMISSIONS, ALL COALS: PARTICULATES 0.1 mg/m^3 SO_2 <10 mg/m^3 NOx <10 mg/m^3 99% MERCURY REMOVAL

Non-OECD roadmapping: notes on power technologies with update

- **In China, USC parameters reach close to world highest now**
- **Generation plants in India and South Africa now reaching supercritical – need to move quickly toward higher conditions through continuing external collaborations**
- **In 2009, there were two IGCC projects in China with timescales close to many OECD projects, and technology collaboration projects with overseas gas turbine manufacturers were in place. The GreenGen project is the only one currently under construction**

Non-OECD roadmapping: notes on CO_2 capture

- **China has many initiatives and activities on CO_2 capture, e.g. GreenGen IGCC project, post-combustion CO_2 capture plants of Huaneng, EOR using CO_2 from Shenhua CTL plant planned**

- **CCS activities have started in South Africa and a demonstration is planned. India interested in CCS for future but currently focused on efficiency improvement**

Finally …

Two general conclusions slides, followed by two more giving suggested pointers to discussion items

Conclusions … (1)

- **CCTs need further development to improve efficiencies and reduce emissions to near zero by 2030. Current application of best coal technologies needs to spread much further**
- **Demonstration of PCC at very high parameters has stalled but needs to be revived and if possible include CO_2 capture**
- **Commercial demonstrations of novel lignite drying systems are needed for higher efficiency with such fuel on PCC and IGCC**
- **IGCC orders are still disappointing**
- **CO_2 capture technologies on coal systems, now at up to 20 MWe, needs larger demonstrations to achieve commercial CCS in the 2020s. This process is occurring, with FEED studies and finance**

Conclusions … (2)

- **All 3 main types of CO_2 capture need progressing rapidly as well as potential breakthrough capture technologies**
- **Rapidly rising countries such as Brazil and Indonesia need to be encouraged through co-operations to use best available technology**
- ***Two-way* knowledge sharing between OECD and non-OECD will be increasingly important for CCT and CCS deployment**
- **CCS is beginning to worry some of the public: this perceptual issue needs solving before it becomes a real limitation on projects**

Some initial pointers for this discussion ... (1)

- **Need to fit with IEA CCS roadmap**
- **Need to look forward to 2050** – breakthrough technologies may be important
- **Metrics for roadmap to feature in report need to be agreed** – e.g. Extent of deployment of different types of plant, efficiency/heat rate, specific CO_2 emissions; other emissions; plant flexibility, water consumption, capital requirements, cost per MWh, cost per tonne of CO_2 avoided/captured
- **Targets for selected metrics need to be agreed**
- **Is a target date for no further non-capture plants needed?**
- **Growing interest in use of low rank coals – what are the best technologies for maximum efficiency?**
- **Dry cooling and reduced water usage for CO_2 capture need to be accommodated while keeping CO_2 emissions low**

Some initial pointers for this discussion … (2)

- **Technical development gaps identification** – e.g. proving commercial scale demonstration 700C PCC; establishing low energy consuming lignite drying; proving commercial scale IGCC with CCS and low NOx; achieving G and H-class gas turbines in a commercial IGCC, and gas turbine optimised for ITM oxygen; dry gas cleaning for PCC and IGCC; reducing costs and speeding development of breakthrough technologies such as chemical looping ...
- **IGCC still slow to take off but CCS was supposed to improve the relative prospects for IGCC because of a lower capture cost: is cost now increasing compared with PCC-CCS? Cost of some IGCC-CCS projects has caused deferments/cancellations**
- **Many IGCC-CCS projects are starting as NGCC for declared economic reasons. Is this the best way? Will they proceed beyond gas?**
- **Support for stable carbon price needed everywhere**