Activities and Strategies in Other Countries

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About the IEA CLEAN COAL CENTRE

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- **Reports - 14-16 every year**
- **Technical focus, coal fired power, environment**
- **R & D Facilitation**
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IEA CCC reports related to Pathways

- **Clean coal technologies**
- **Clean coal technologies roadmaps**
- **Toward zero emission coal-fired plants(in progress)**

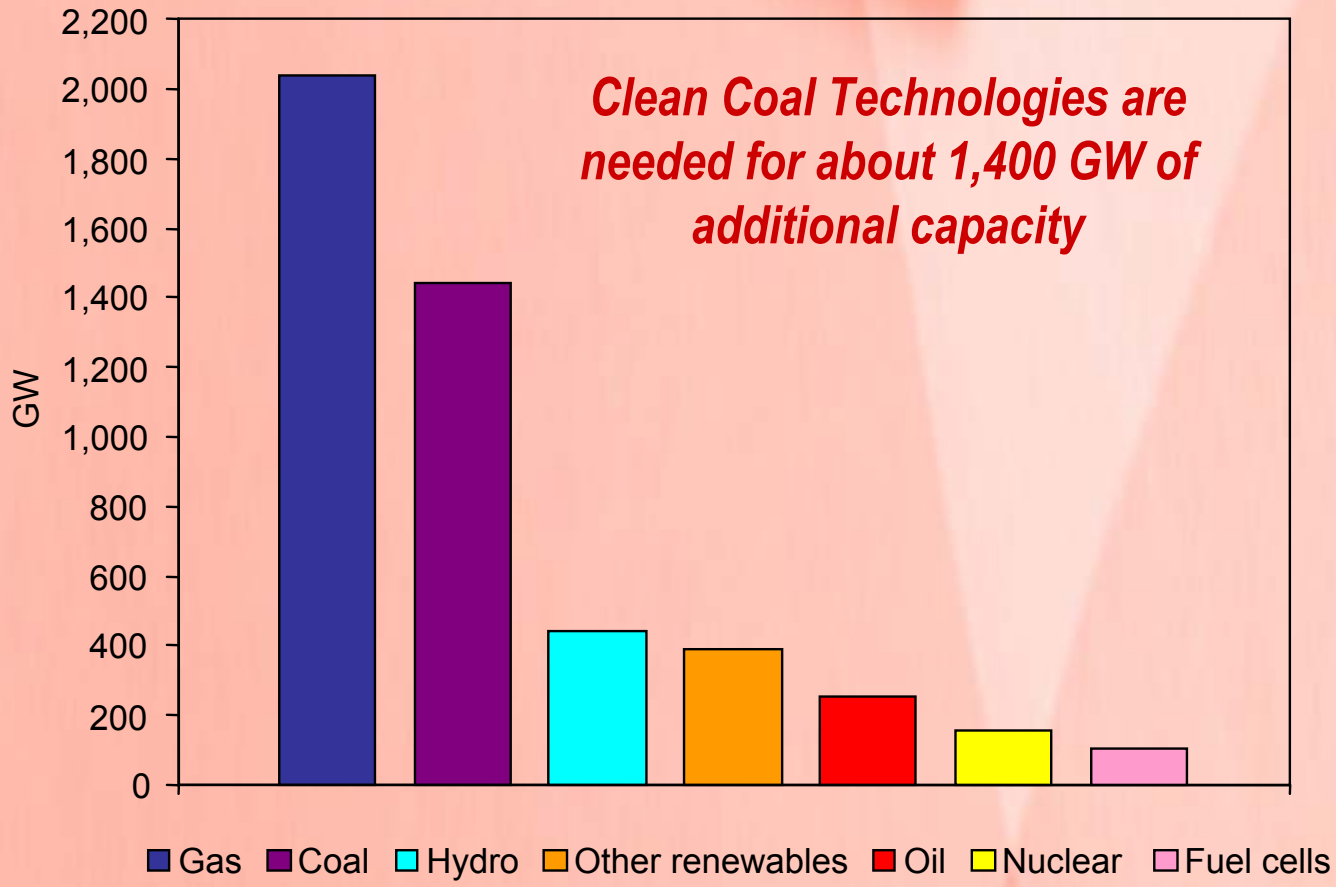
All reports are authored by Dr Colin Henderson. They consider all emissions to air from coal-fired power plant

BIG PICTURE

Why do we care what happens in the rest of the World?

- Carbon emissions a global problem - need global solution – UKs contribution needs to be put into the wider context
- Solutions likely to be expensive – much common interest – points towards cost shared development
- May create or retain export markets for technology suppliers and developers in UK

World Power-Generation Capacity Additions, 2000-2030



Source: IEA WEO, 2002, Business as usual scenario

ROADMAPS and ACTIVITIES

Japan

Australia

Germany

Canada

China

India

Japan (1) - C3 (Clean Coal Cycle) Initiative

- C3 Study Group launched January 2004 by METI to develop new medium- to long-term coal policy
- Interim Report, June 2004:

- All-round perspective from upstream (mines development) to downstream (utilisation)
- Development of technologies for environmentally friendly utilisation
- Infrastructure measures to stabilise coal prices
- International cooperation necessary
- Gasification as core technology but also oxy-coal combustion – Australian co-operation

Japan (2) - C3 (Clean Coal Cycle) Initiative

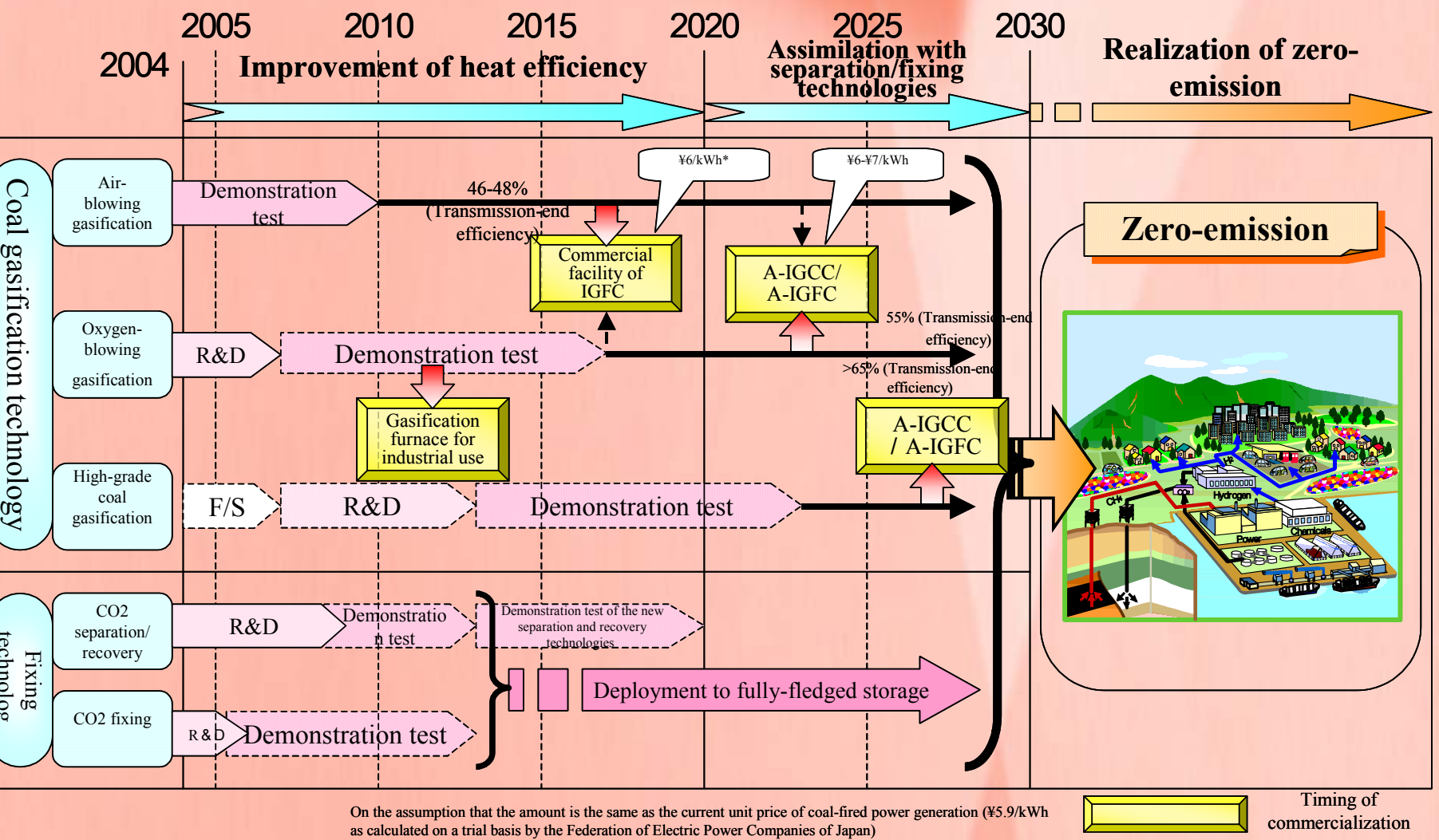
Targets to 2030:

- **reduce environmental impact of coal utilisation**
- **diversify energy sources**
- **secure stable supply of coal.**

Five basic directions:

- **Promotion of high-efficiency in utilisation to reduce emissions, and stimulate economy, sales to Asian countries, establishment of programmes under Kyoto Mechanisms.**
- **Development and deployment of technologies for reduction and utilisation of environmentally harmful byproducts including SO_2, NOx, ash and CO_2 (latter through capture and storage).**
- **New coal uses to improve competitiveness of coal for stability of energy supply through diversity.**
- **Expansion of supply and removal of supply bottlenecks to secure low-cost coal.**
- **Improvement of procurement to preserve cost advantage as coal demand in Asia increases by establishment of a flexible coal-trading environment with transparent price indicators.**

Japan (3) C3 roadmap for realising zero-emission coal utilisation



On the assumption that the amount is the same as the current unit price of coal-fired power generation (¥5.9/kWh as calculated on a trial basis by the Federation of Electric Power Companies of Japan)

Timing of commercialization

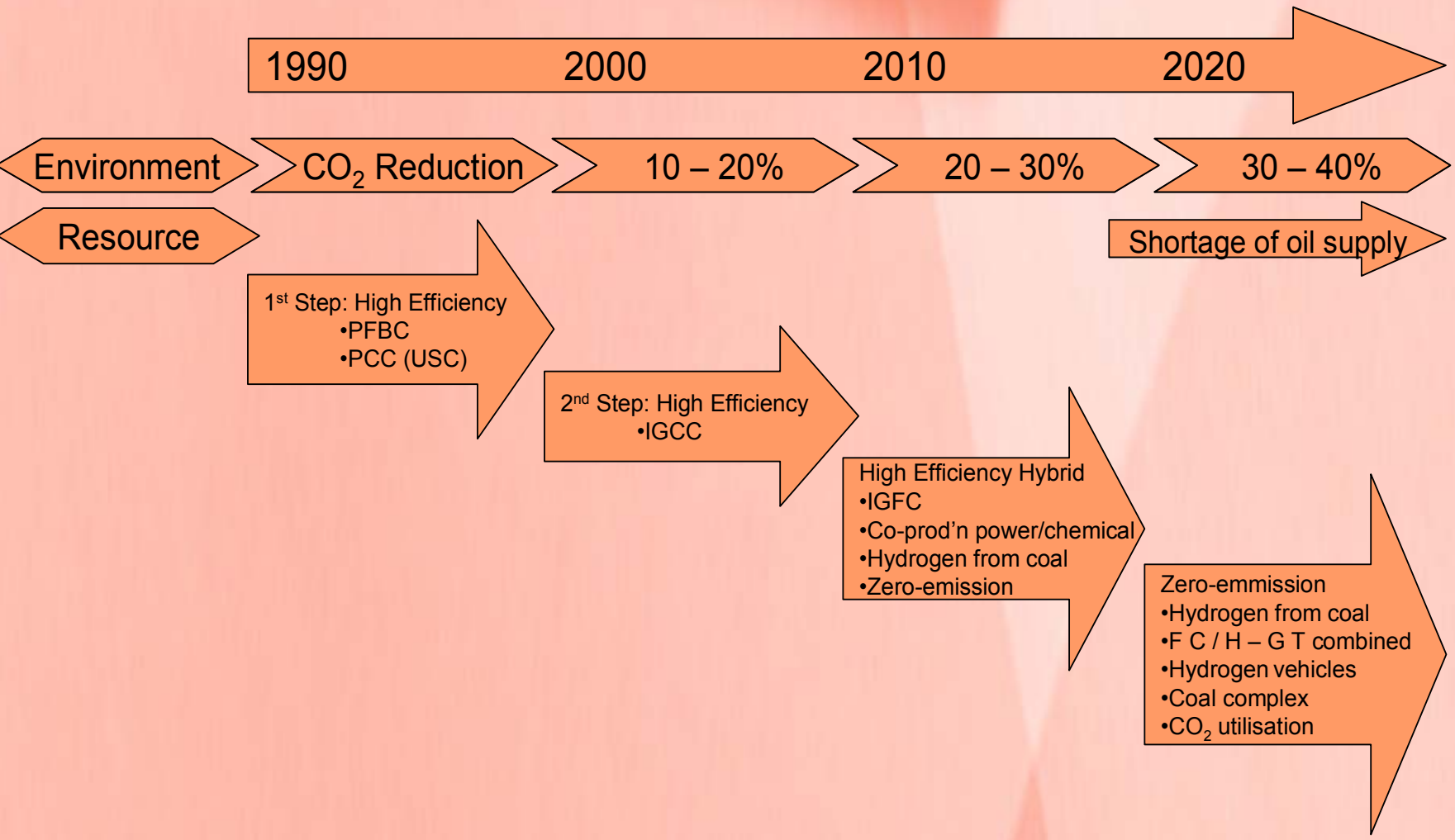
Japan (4) - C3 (Clean Coal Cycle) Initiative

Proposed for realisation of ZETs

- **Feasibility study on next-generation coal gasification technology (This year on) (A-IGCC, A-IGFC) for efficiencies of >=65%**
- **Feasibility study on retrofitting oxy-coal combustion to a PCC plant) (this year on) cooperative research with Australia**
- **Demonstration of integrated coal gasification combined-cycle (IGCC) (continuation)**
- **R&D on integrated gasification fuel cells combined-cycle (EAGLE) (continuation)**
- **R&D on CO_2 capture and storage technologies (Ocean /underground/coal bed sequestration) (continuation)**
- **Demonstration of other CCT systems, such as co-gasification of biomass and waste, co-production of electric power and chemicals, and hydrogen**

The technologies have also featured in a plan drawn up in 2002 by the Centre for Coal Utilisation of Japan (CCUJ) (next slide)

Japan (5) - Coal utilisation technology development strategy for the 21st century (Centre for Coal Utilization Japan, 2003)



Australia (1) – COAL21

Major initiative, involving key stakeholders across industry, government and researchers

Key objectives:

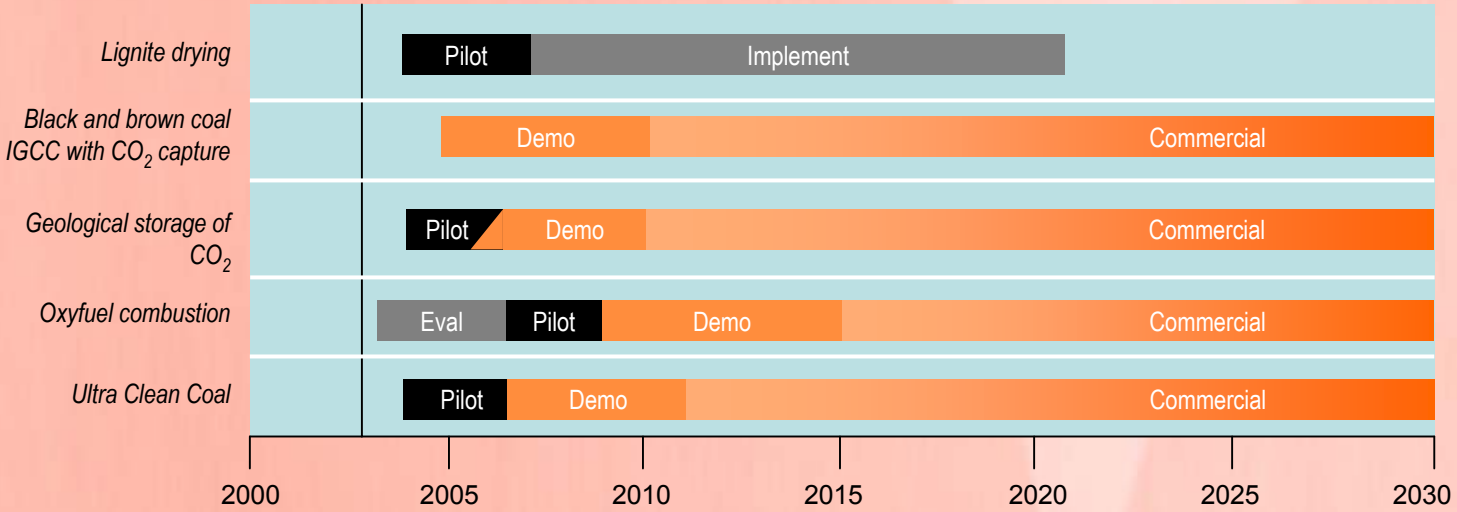
- **to develop a National Clean Coal Strategy**
- **to promote and facilitate the demonstration, commercialisation and early uptake of CCTs in Australia**
- **to promote Australian R&D in CCTs**
- **to foster greater public awareness of the role of coal and the potential for CCTs to significantly reduce or eliminate greenhouse gas emissions and other environmental impacts**

Australia (2) – COAL21

- CO_2 emissions reduction from coal use in power generation seen as key issue to address to maintain energy security through retention of coal

- Range of CO_2 abatement options were studied, from mining operations and coal preparation through to utilisation (efficiency improvements and CCTs) and CO_2 capture and storage

Australia (3) Summary of technology roadmaps (Australian Coal Association, 2004)



Australia (4) – Oxy-coal project

- **Joint feasibility study with Japan announced September 2004 on oxy-coal retrofitting with CO_2 capture and geological storage**
- **Two stages:**
- **Stage 1 – Detailed engineering feasibility study on the technical requirements and costs to convert an existing PCC boiler (Callide A 30 MWe Unit owned by CS Energy) to oxy-firing.**
- **Stage 2 – Pending the outcome of Stage 1, establishment of an oxy-fired PCC demonstration plant capable of producing up to 150,000 tonnes per year of CO_2 for geological storage over a test period of 3 to 4 years.**

Germany (1)

- Hard coal and lignite significant - over 50% of power generation
- Subsidies for hard coal mining under 1997 Coal Compromise but capacity reductions called for by EC after 2005
- Government working to secure domestic hard-coal via quotas for TPEC from domestic sources and exemption from EU statutes on state aid
- Lignite is competitive

Energy R & D in industry, research institutes, and universities supported by federal Energy Research Programme (energy conservation, energy efficiency and renewables)

On efficiency, focus on coal is:

- materials to permit steam conditions for efficiencies of new stations >50%;
- combined cycle power cycles for 55% efficiency

Germany (2) – COORETEC (CO_2 reduction technologies)

- Government review of R&D needs for realising zero emission plants by working groups from utilities, R&D institutions and academia
- Expected need for>40GWe of new capacity 2010-2020
- Efficient, economic fossil plants needed as well as increased use of renewables and CHP
- Current context of no new nuclear plants and gradual closure of existing ones
- Short term, medium term and long term projects within national and EU research programme
- Short-medium term, R&D to raise efficiency
- Medium term, various combined cycle developments (including IGCC, PPC, advanced PFBC and EFCC
- Long term, combined cycles incorporating fuel cells
- IGCC favoured among combined cycles - potential advantages for CO2 capture
- Demonstration plant called for to show high efficiency, reduced costs, high availability
- Development of CO2 capture and storage important, priority to EGR
- Need for R&D on CO2 injection for ECBM
- Co-operation through international research networks

Canada (1) – Canadian Clean Coal Technology Roadmap

Government policy of energy diversity, security and sustainability

- **Long-term role for coal, stringent environmental requirements**
- **Coal accounts for ~20% electrical generation, from 25 generating stations**
- **Recognition of need for strategy for development and implementation of CCTs**

July 2001, CCTIP set up Clean Coal Technology Roadmap process to accelerate development of cost-effective greenhouse gas and other pollutant mitigation technologies - aims to:

- **identify technologies, energy processes and integration system pathways**
- **provide information on time frames, costs, environmental performance, risk and infrastructure needs**
- **recommend actions**

Management Steering Committee of representatives from industry, R&D organisations and government

- **On-going update of roadmap - workshops to develop**
- **Parallel paths for different technology areas**
- **Environmental and cost targets**

The CCTRM interfaces with the CO2 capture and storage roadmap, which aims to:

- **identify pathways, integration needs and developments needed to capture CO2 from large emitters (various technologies)**
- **to identify CO2 storage opportunities and synergistic opportunities to use for EOR, CBM production and hydrogen production**

Canada (2) – Canadian Clean Power Coalition (CCPC)

Public-private initiative for the R, D&D of CCTs with objective to demonstrate that coal-fired power generation can effectively address all environmental issues projected in the future, including CO2 emissions and mercury

Programme has been investigating feasibility and costs of retrofitting PCC power plant with CO2 capture systems by 2007 and assessing the costs of a green field installation to be commissioned in the year 2010

- **3 Canadian fuels: bituminous coal, sub-bituminous coal and lignite.**
- **Targets for near-ZETs identified**
- **Costs of meeting near-zero emissions without CO2 capture CAN$730-1100/kWe (retrofit); CAN$2700/kWe (new plants)**

Options considered for low-CO_2 generation were amine scrubbing of PCC flue gas, oxy-coal combustion and IGCC with pre-combustion capture.

- **2004 Phase 1 report issued - for greenfield plants, IGCC best option - higher efficiency, ease of emission reduction and lowest energy penalty for CO2 capture.**
- **Costs of the options for PCC plants also evaluated**
- **Retrofits for CO_2 control found not to be attractive**

Canada has many other activities on technologies for CO2 capture and storage

China

Sub-critical PCC

- **Huge existing capacity**
- **Massive numbers of new orders – 87GW in 2003, hundreds of boilers**

Supercritical PCC

- **Policy to rapidly deploy the technology**
- **43GW ordered in 2003, 93% of world supercritical market, ~70 boilers**
- **Ordering pattern continued through 2004**

IGCC

- **Demonstration plant planned at Yantai**

PFBC

- **Exploitation plans suspended**

FBC

- **Numerous industrial scale FBC and CFBC**

India

- BHEL operated 6 MWe fluidised bed gasifier IGCC during the late 1990s. Now seeking partners for 100 MWe demonstration plant
- Lignite-fuelled IGCC also planned
- Interest also in supercritical PCC and PFBC
- CFBC plants in operation since 1995

So what messages can we draw?

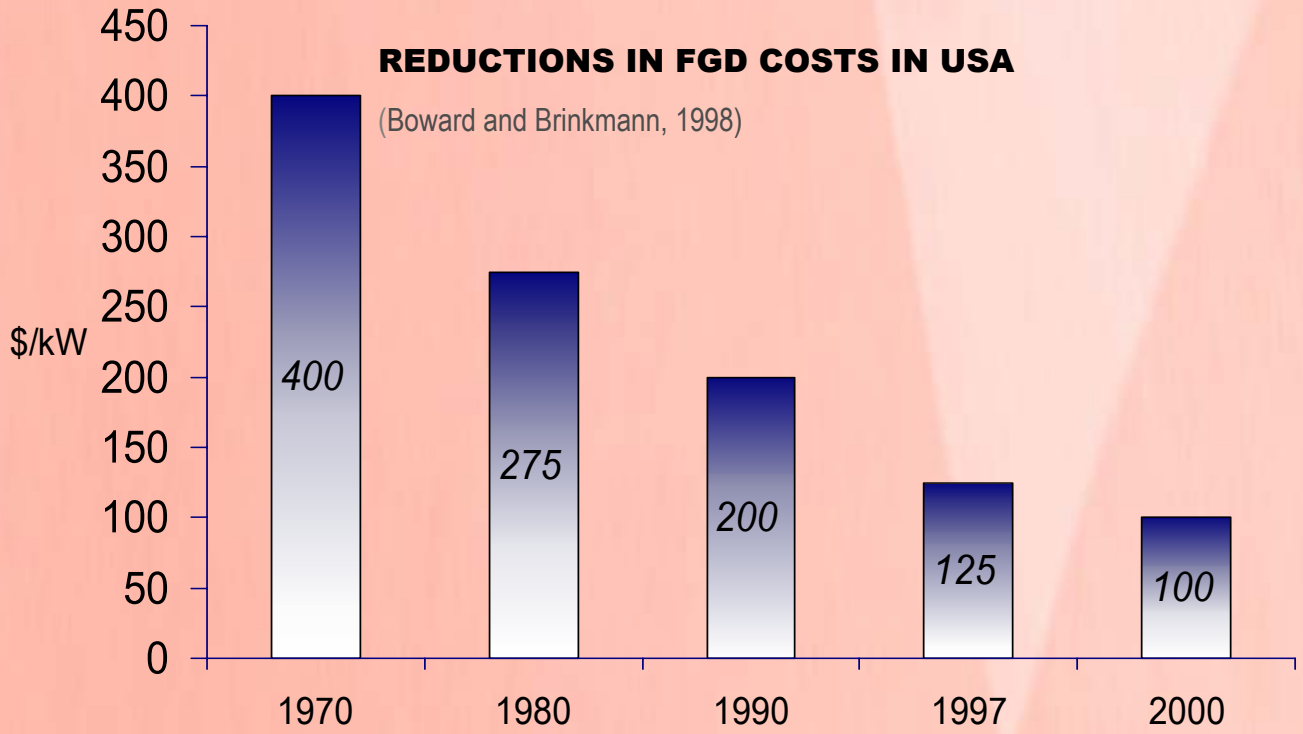
The two principal technology options

- **Supercritical pulverised coal leading to ultra-supercritcal steam conditions (>650C and >30 MPa), offering net efficiencies of 50% and above on an LHV basis over the next ten – twenty years.**
- **In the longer term, IGCC could become the leading technology *based on present knowledge* as CO_2 capture and storage becomes the norm.**
- **NOTE that there is predicted to be no significant difference between efficiencies of PCC and IGCC as they develop. HOWEVER, there is expected to be a lower efficiency penalty associated with IGCC where CO_2 capture and storage are required.**

Why we need both technologies!

- **Uncertainty in R & D – not sure of outcomes and associated costs for USC and IGCC**
- **Time to deploy IGCC – will take 15-20+ years to see market penetration**
- **Construction policy in China and India – where most "new build" will occur**

Potential for Cost Reduction



Carbon Abatement Strategies only make sense as part of a Zero Emissions Strategy!

The headline is true if we want to keep a coal component in our power supply options as

- **There will be downward pressure on SOx, NOx and particulates emissions and possibly Hg at the same time as on carbon**
- **There are possible interactions to consider between the technologies especially in post combustion capture is pursued**

These points are not made in the DTIs consultation on CATs

OECD country CCTs roadmap

Increasing efficiency, lower emissions, lower costs

Now → 2020

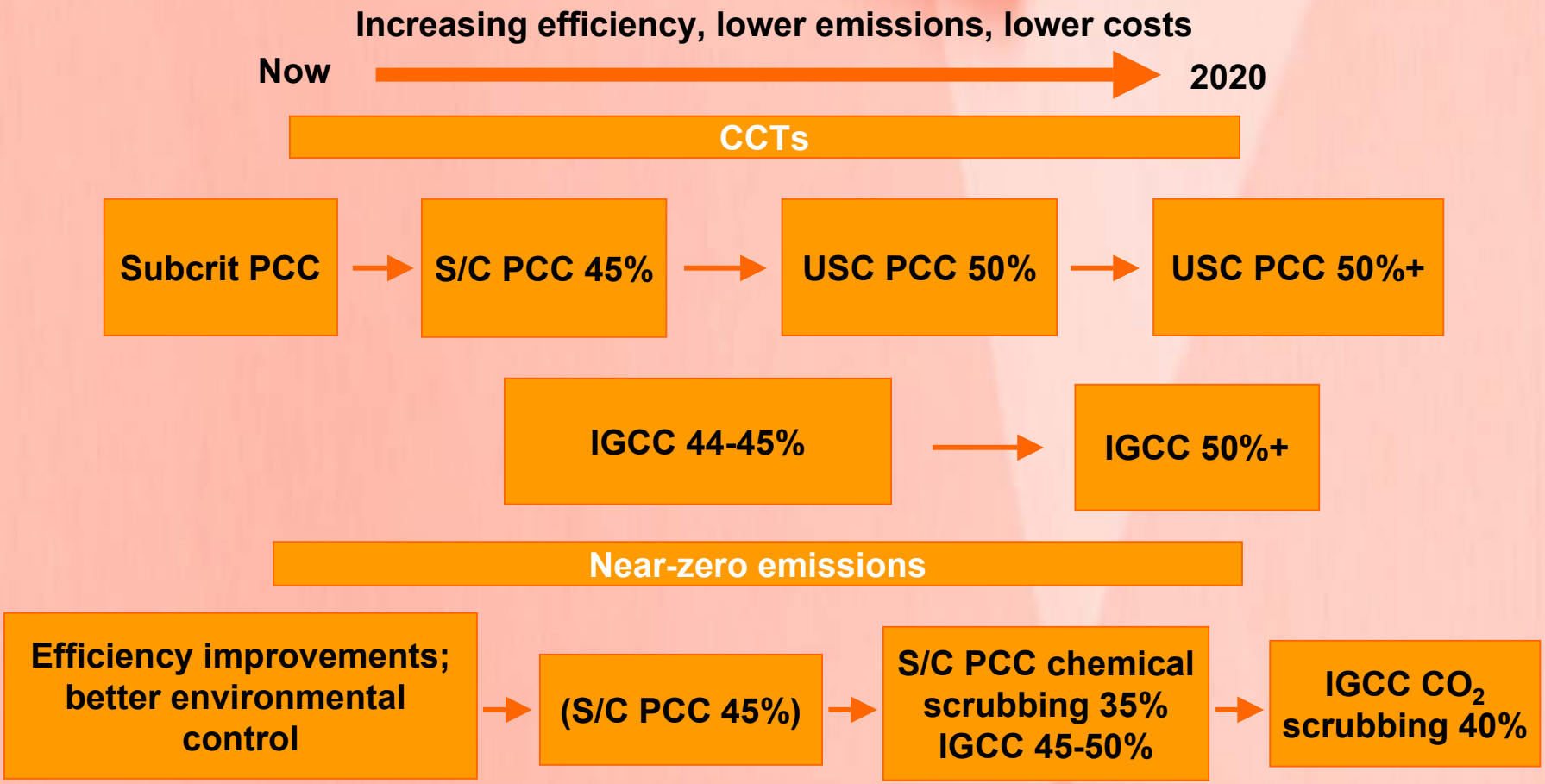
CCTs

- S/C PCC 40-45% → S/C PCC 47%
USC PCC demo 50% → USC PCC 50-55% → USC PCC 50-55%
- IGCC demo 45% → IGCC 47% → IGCC 50%
IGCC-FC demo → IGCC 50%+
(IGCC-FC below)

Path to near-zero emissions

- Efficiency improvements;
better environmental control
Retrofit S/C PCC
chemical scrubbing 30% → S/C PCC+
scrubbing 35%
Retrofit IGCC +
scrubbing 35% → PCC Oxy-coal 40%
IGCC scrubbing 40% → IGCC membrane
techs 45%
IGCC-FC 55-60%
IGCC for H_2
and chemicals

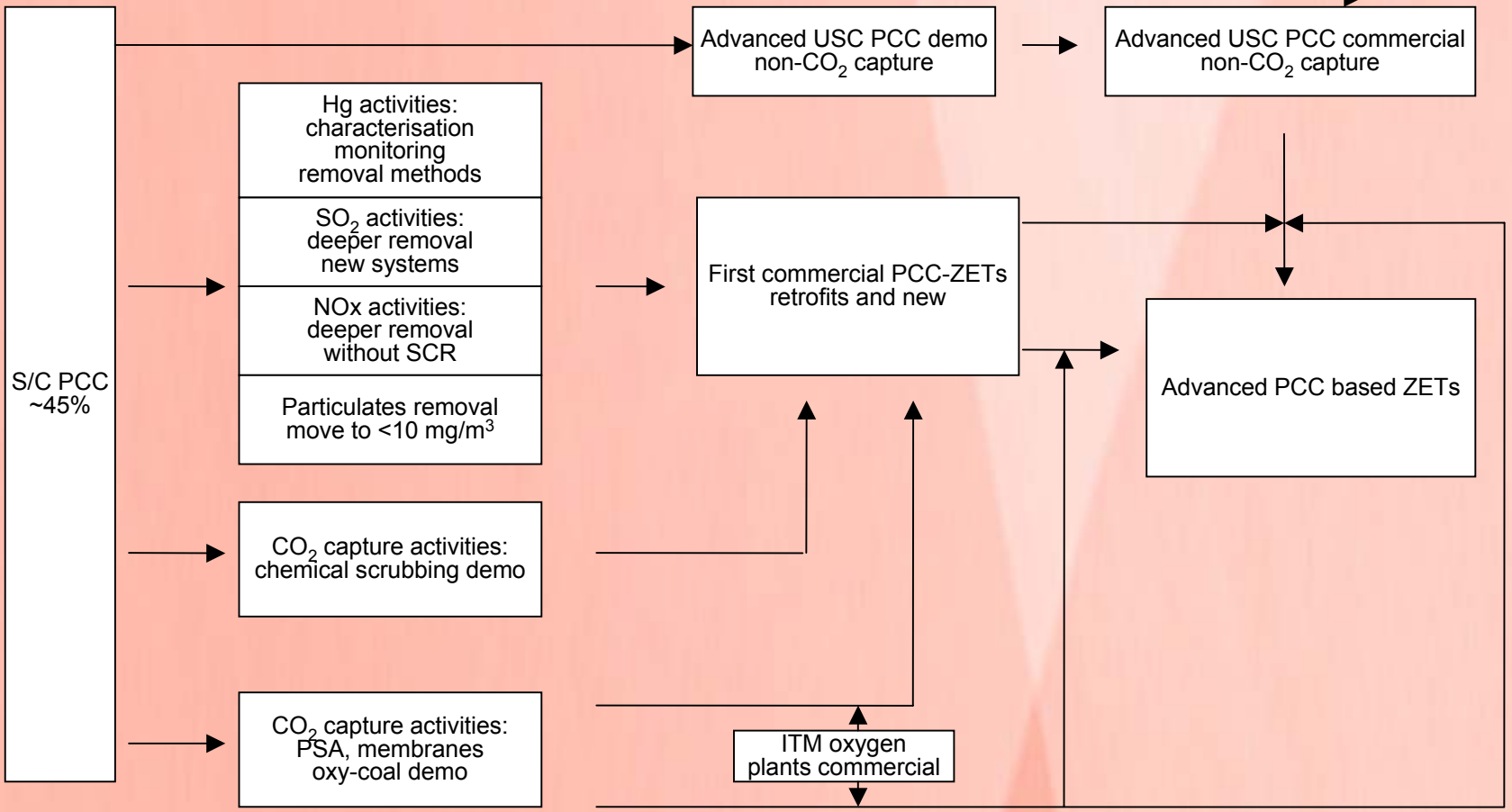
Non-OECD country CCTs roadmap



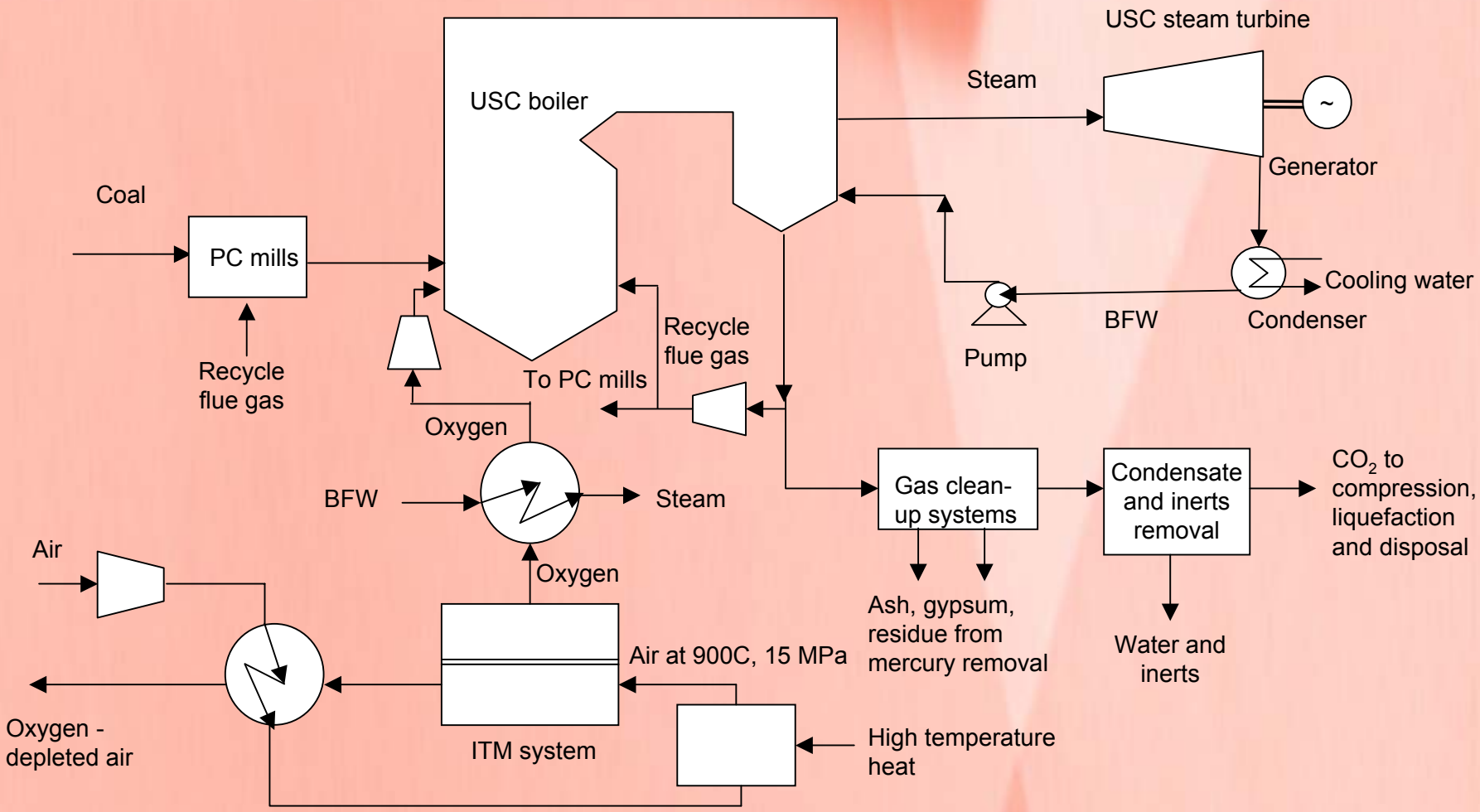
Path to zero emissions for PCC

Now → 2005-10 → 2010-15 → 2015 on

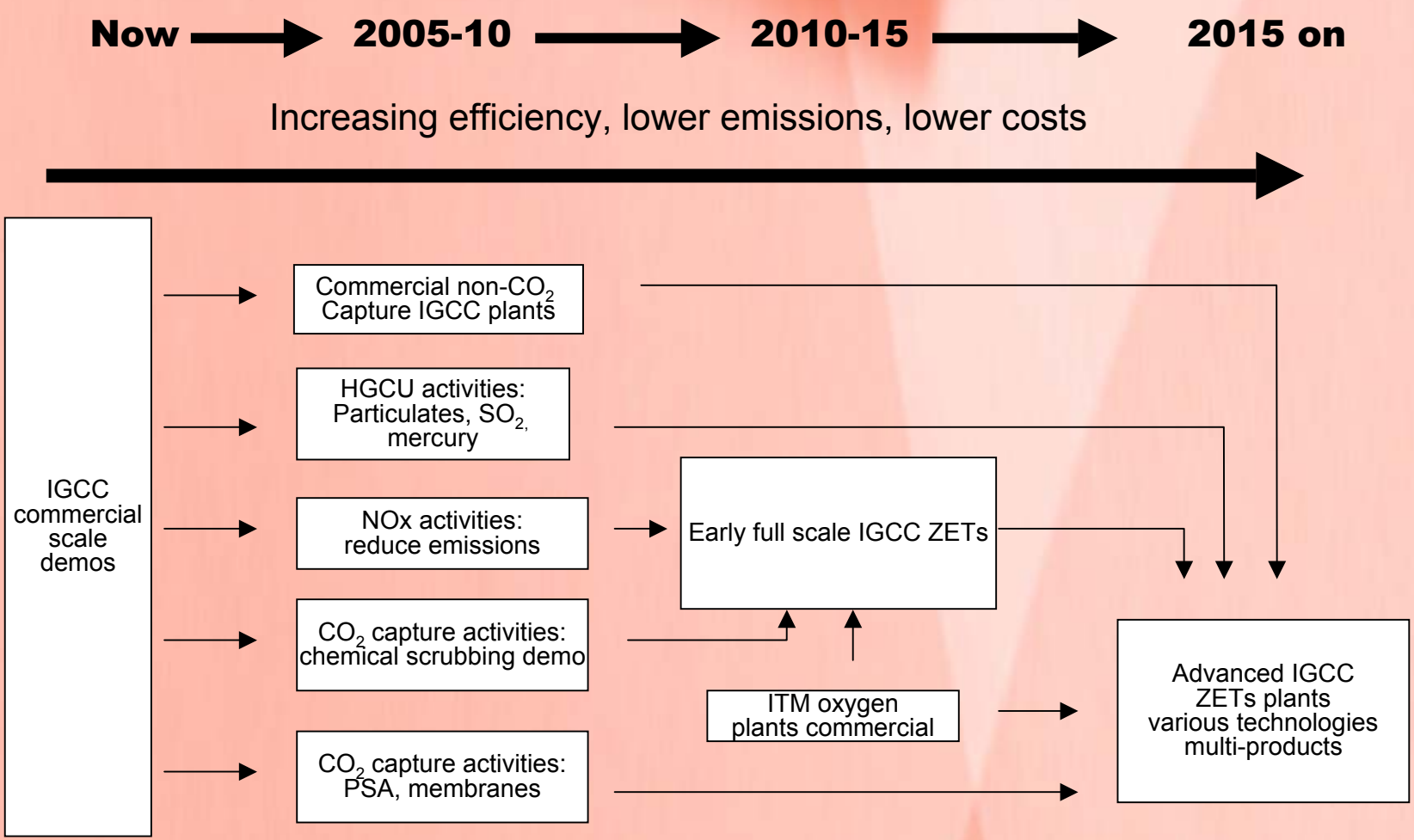
Increasing efficiency, lower emissions, lower costs



A possible schematic for the ultimate PCC using oxy-coal combustion, with USC and ITM



Path to zero emissions for IGCC



R & D towards zero emissions (PCC)

- Improve FGD, NOx reduction systems
- Develop mercury and other trace metals removal and measurement systems
- Develop ferritic materials and nickel-based superalloys for higher steam conditions (boilers and turbines)
- Develop USC systems as basis of ZETs
- CO_2 capture by flue gas scrubbing – new chemical and physical solvents
- CO_2 capture from flue gas using membranes and adsorption techniques
- Minimise energy use of CO_2 capture
- Oxycoal combustion
- SO_2, NOx, mercury removal from CO_2 disposal stream from oxy-coal
- Ion transport membranes for oxygen production for oxy-coal

R & D towards zero emissions (IGCC)

- Better refractories, gas coolers, coal feeding to increase reliability and availability
- Improved coal conversion
- Hot gas clean-up
- Developing mercury and other trace metals removal and measurement systems
- Tests of new turbine designs as they emerge on syngas
- CO_2 separation technologies for shifted syngas (physical solvents, membranes, adsorption)
- Minimising energy use of potential CO_2 capture systems
- Ion transport membranes for O_2 production
- Hydrogen turbine demonstrations
- Cycle optimisation studies
- Co-production plant concept optimisation
- Eventual incorporation of high temperature fuel cells

Capture ready plant?

QUESTIONS for us all

If it will take 15-30years to see serious deployment of IGCC what do we do to get deep cuts beyond efficiency gains in CO_2 emissions in the meantime?

Remember that most (but not all) new build coal plant will be PCC based in developing countries and it will operate for 40+years

We still have to sort out how to incentivise CO_2 CCS in OECD countries and yet we urgently need to persuade developing countries to at least build their new plant "Capture Ready" for later retrofit

How do we do that?

CONCLUSIONS

- Globally we see pursuit of both gasification and combustion based technologies with greater efficiency the immediate goal and CCS in the medium-long term
- Too early to pick a single winning technology
- Carbon Abatement has to be a part of a ZETs approach for coal
- Capture ready - a big issue in the big coal using developing countries