Clean coal technologies – Overview of CO_2 abatement activities world wide

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COORETEC workshop, 10-11 March 2005, Leipzig

Elements of this presentation

IEA World Energy Outlook 2004

International Roadmaps and Activities

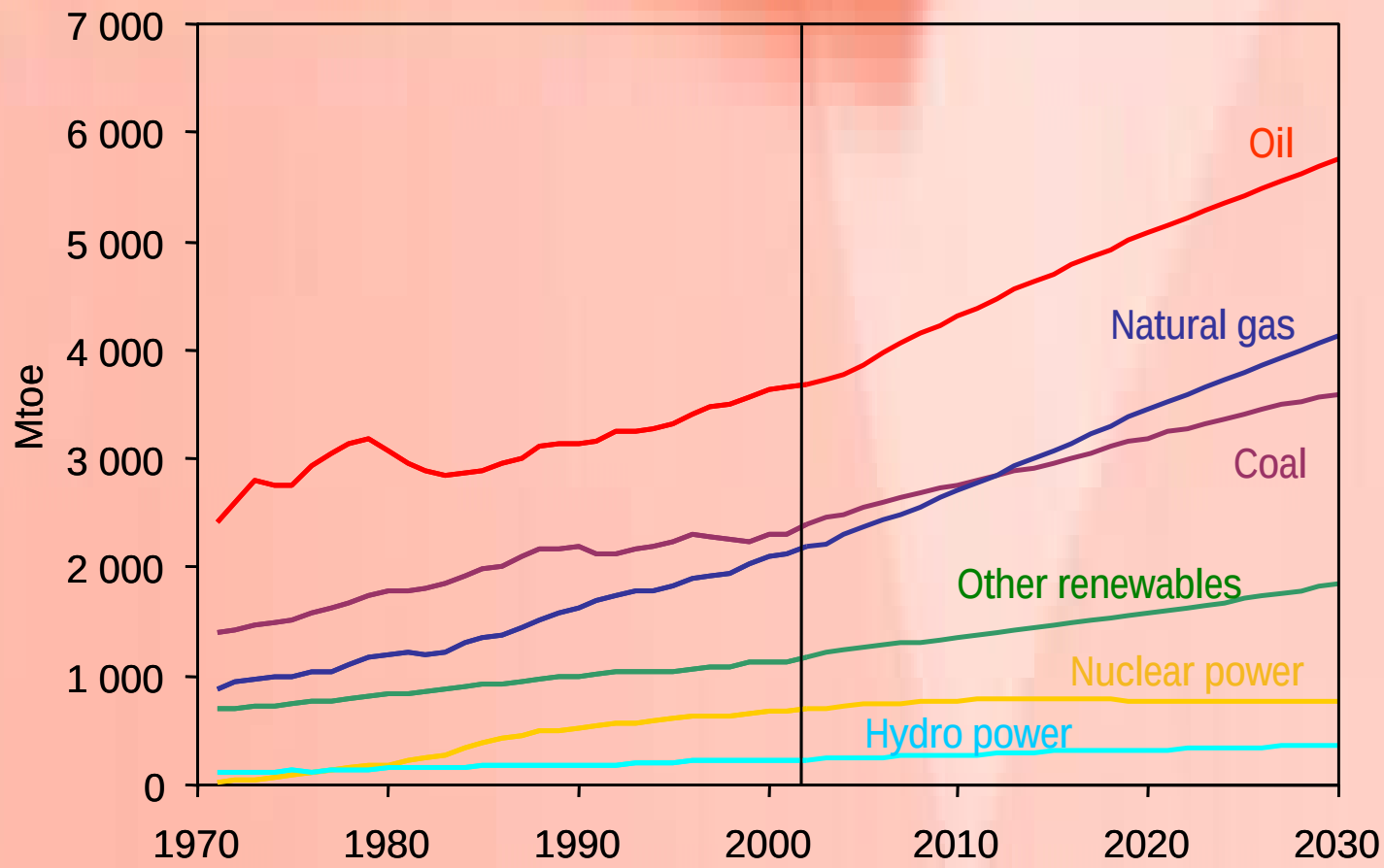
Technology messages

IEA's World Energy Outlook 2004

www.iea.org

World Primary Energy Demand

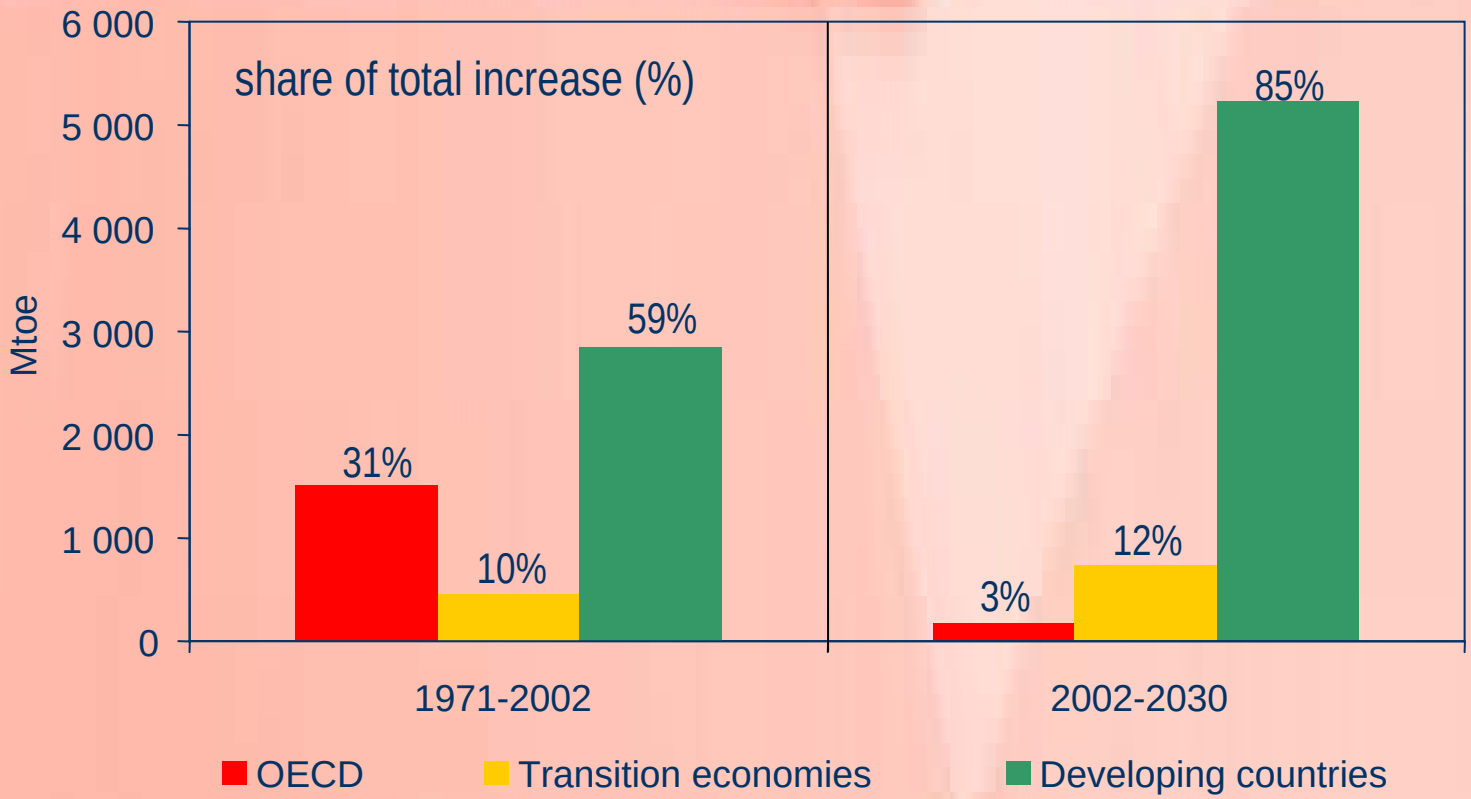
(Source: IEA – World Energy Outlook 2004)



Fossil fuels account for almost 90 % of the growth in energy demand between now and 2030

Increase in World Primary Energy Production by Region

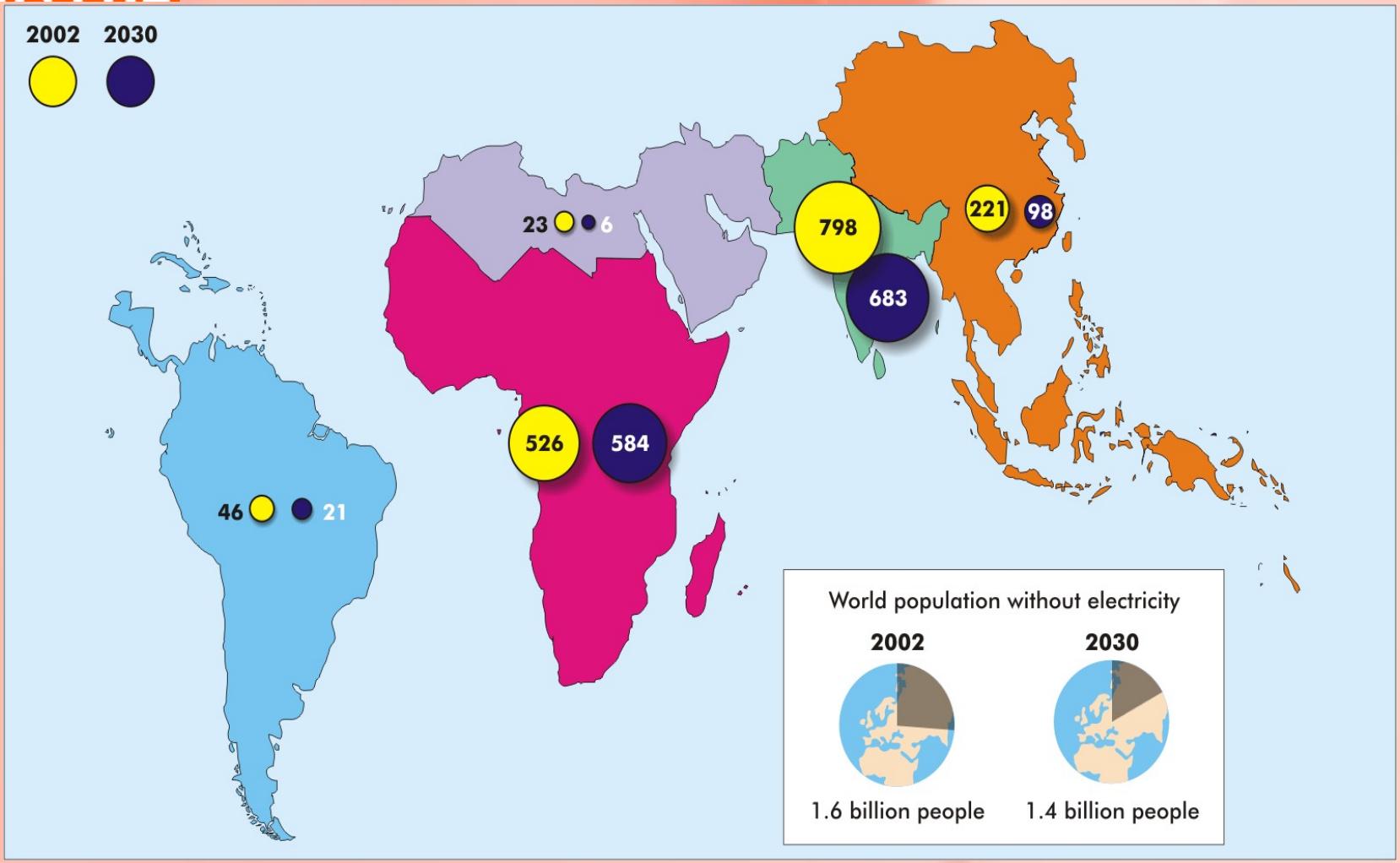
(Source: IEA – World Energy Outlook 2004)



Almost all the increase in production to 2030 occurs outside the OECD

Electricity Deprivation

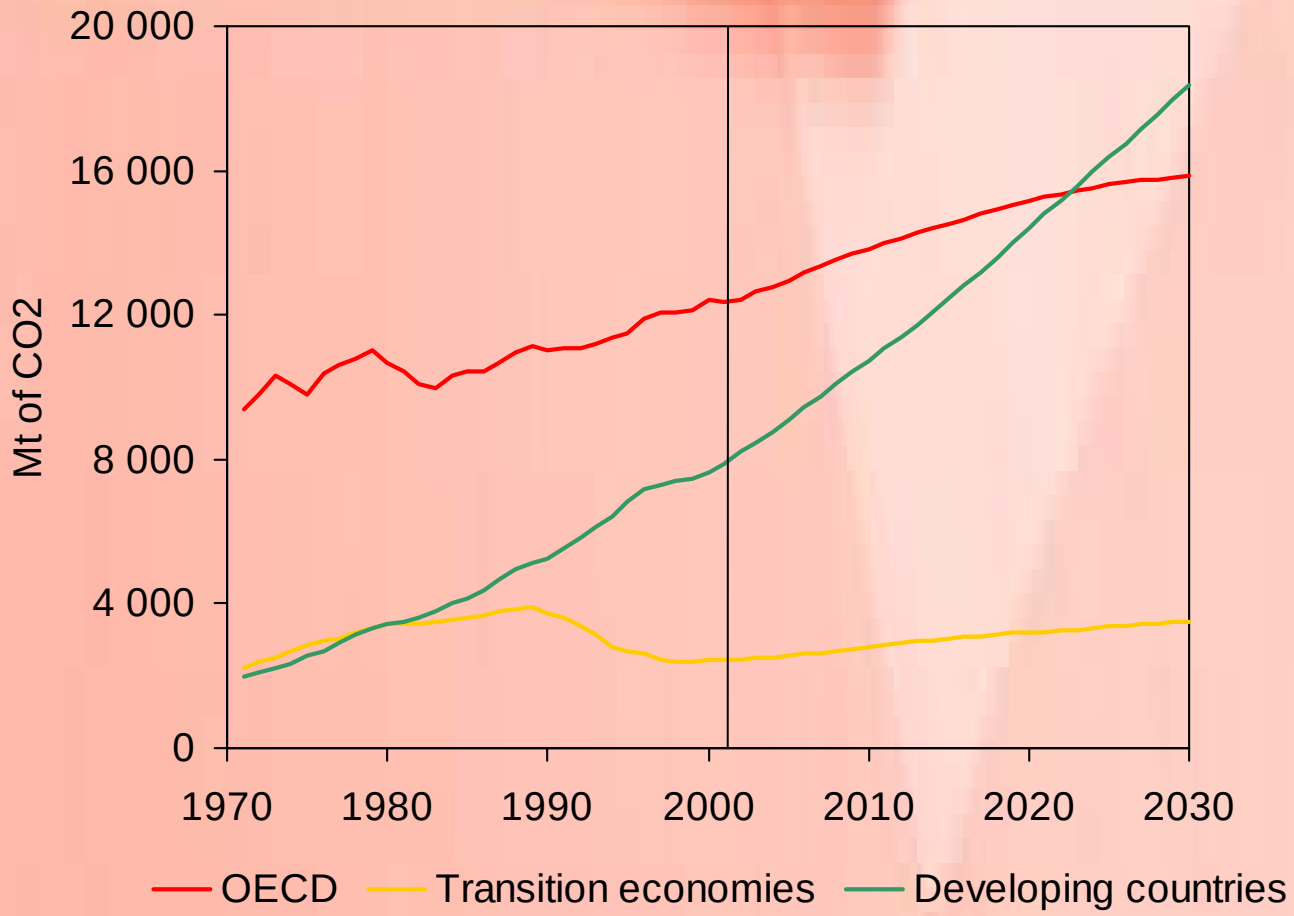
(Source: IEA – World Energy Outlook 2004)



In 2030 there could still be 1.4 billion people without electricity

World Energy-Related CO_2 Emissions

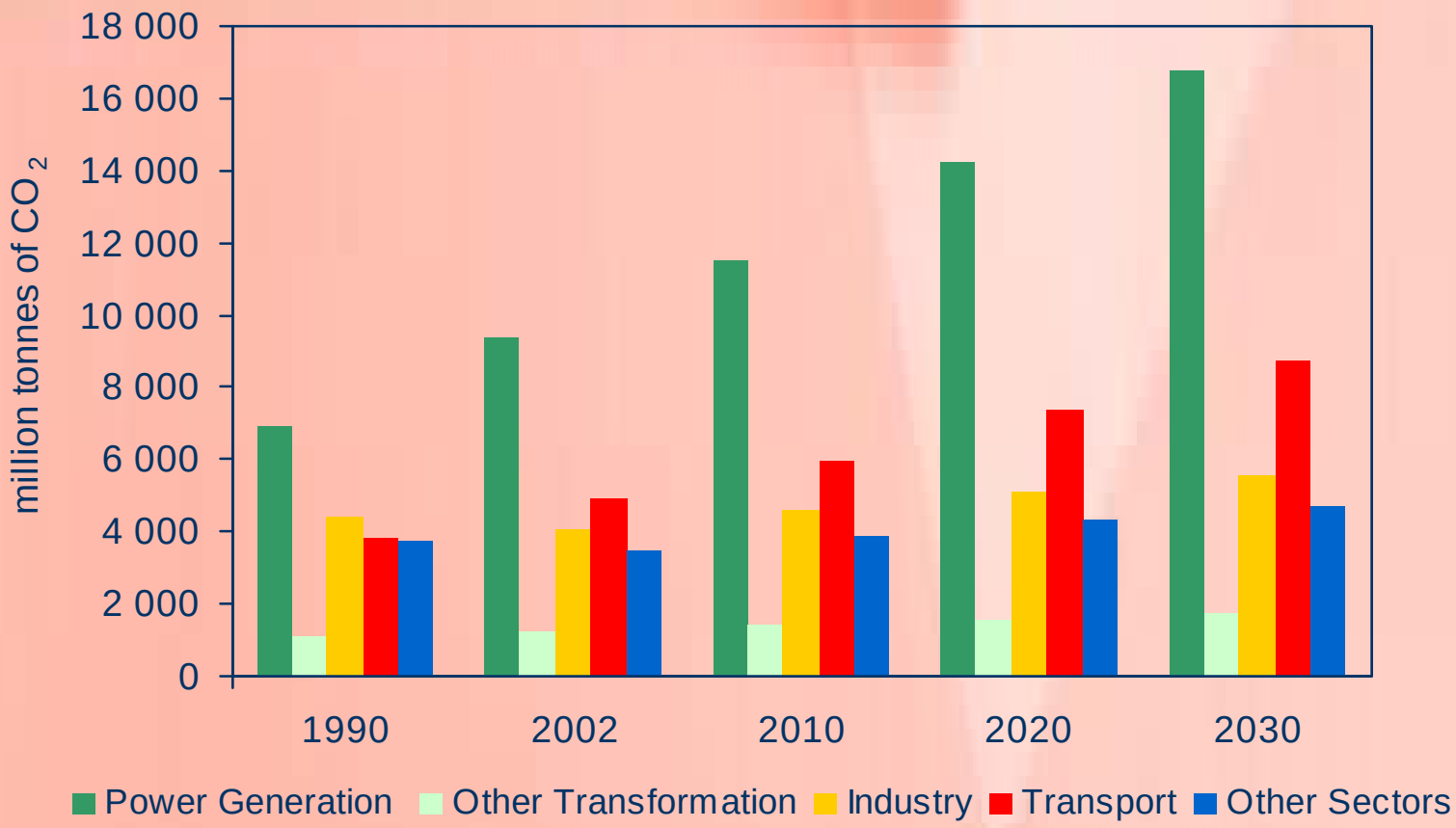
(Source: IEA – World Energy Outlook 2004)



Global emissions grow 62% between 2002 & 2030, and developing countries' emissions will overtake OECD's in the 2020s

CO_2 emissions by sector: 1990-2030

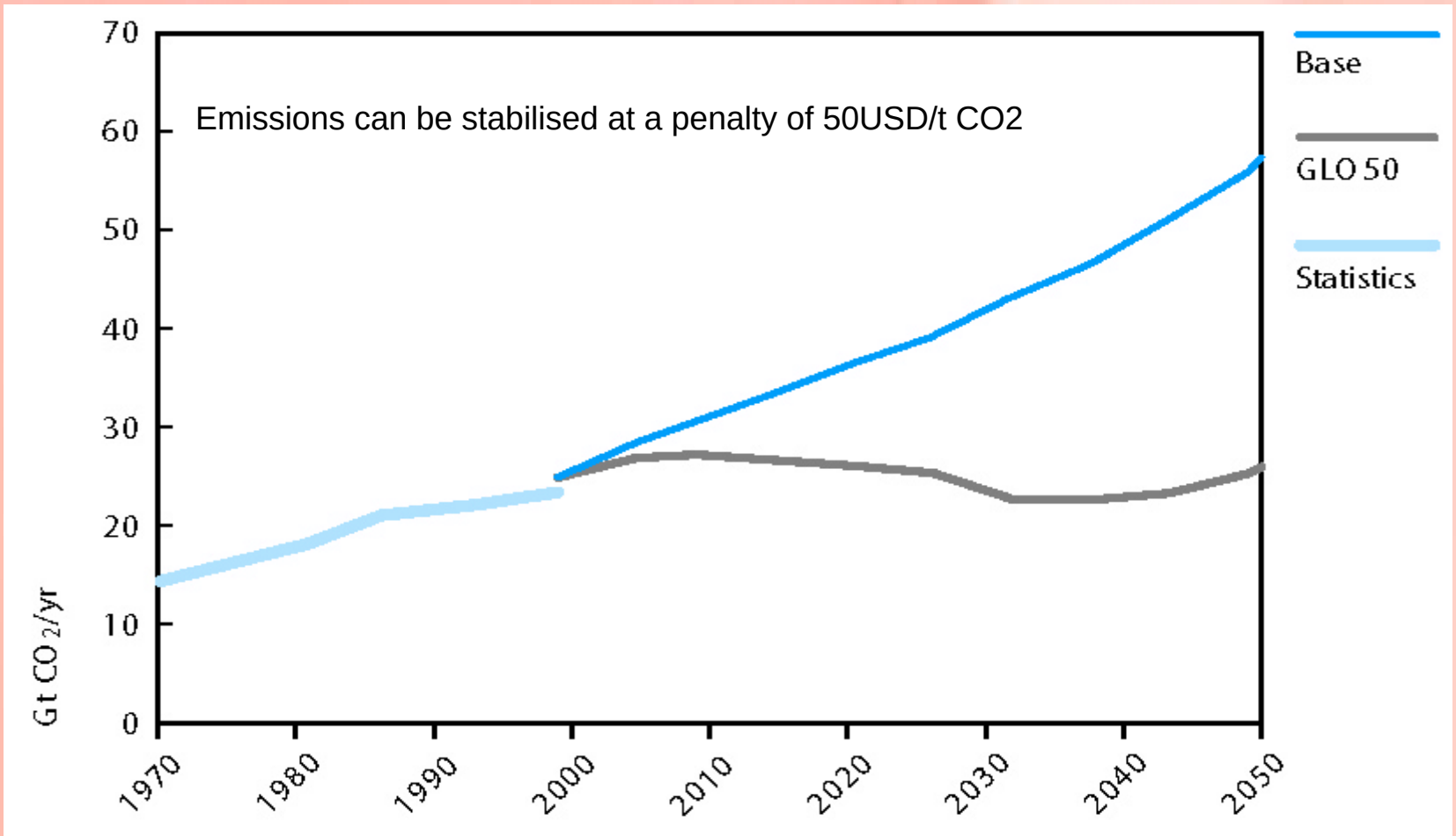
(Source: IEA – World Energy Outlook 2004)



CO_2 emissions in power generation and transport are expected to increase the most

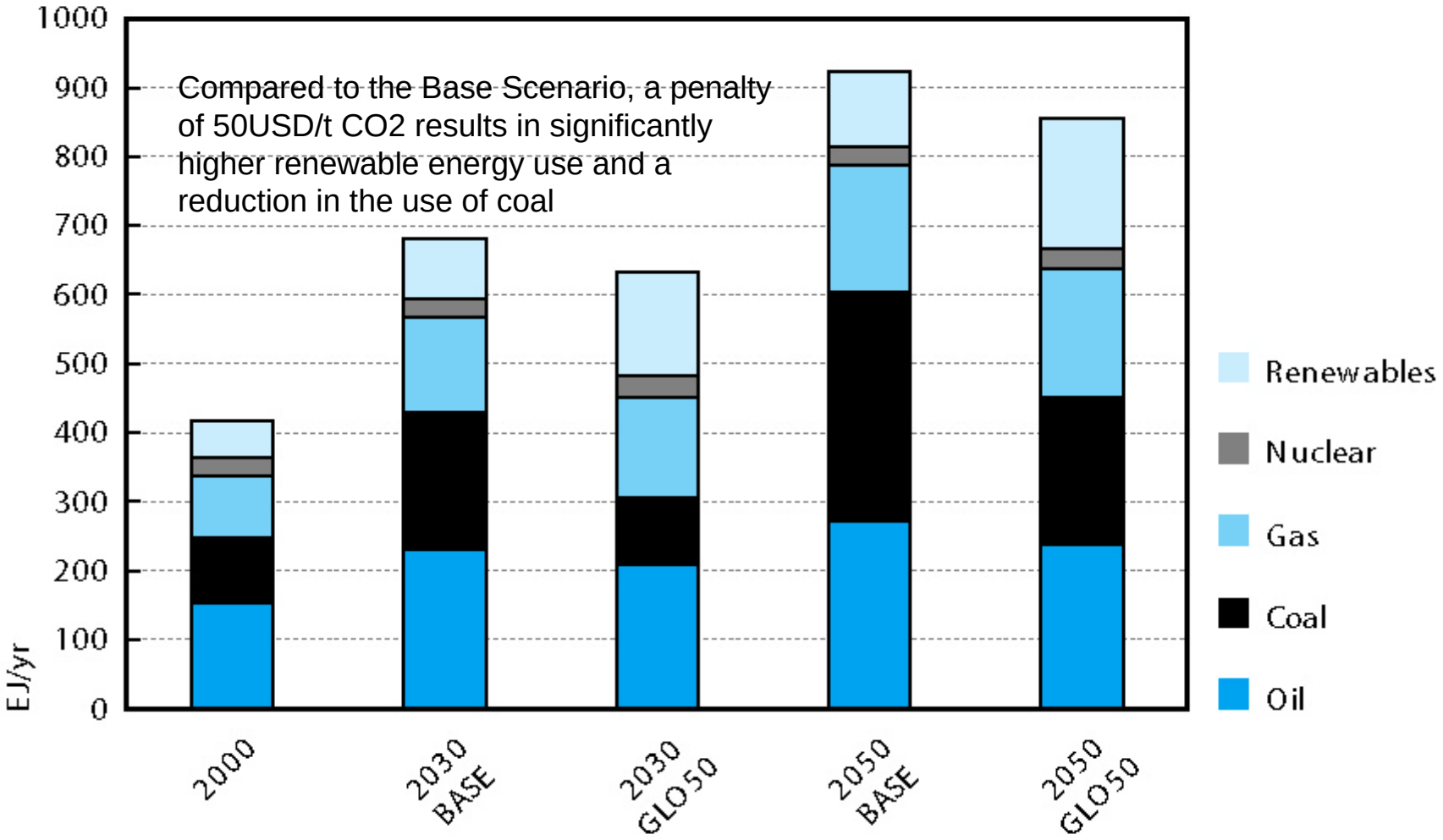
Global CO2 Emissions, Base and GLO50 Scenarios

Source: Prospects for CO2 Capture & Storage IEA 2004



Primary Energy Mix in the GLO50 Scenario

Source: Prospects for CO2 Capture & Storage IEA 2004



ROADMAPS and ACTIVITIES

Canada
USA
Japan
Australia
China
India

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

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

Canada (2) – Canadian Clean Coal Technology Roadmap

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

- **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**

Canada (3) – Canadian Clean Coal Technology Roadmap

The Clean Coal Technology Roadmap 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)**
- **CO2 storage opportunities and synergistic opportunities to use for EOR, CBM production and hydrogen production**

Canada (4) – 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)

Canada (5) – Canadian Clean Power Coalition (CCPC)

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

USA - Strategy and Presidential Initiatives (1)

Source: Phil Sharman, UK DTI

Key initiatives:

"Vision 21" – 21st Century Energy Plant

"Clean Coal Technology" - The President's Coal Research Initiative which includes

The Clean Coal Power Initiative (CCPI)

"FutureGen" – The Integrated Sequestration and H_2 Research Initiative

USA -Strategy and Presidential Initiatives (2)

Source: Phil Sharman, UK DTI

"Vision 21" – 21st Century Energy Plant

- **Set of long-term strategic goals**
- **"Ultimate power plant" by 2015**
- **Fuel flexible, multi-product slate**
- **High efficiency (coal >60% HHV; gas >75% LHV; CHP 85-90%)**
- **Near zero emissions (with CCS)**
- **Energy costs 10-20% lower than now**

USA - Strategy and Presidential Initiatives (3)

Source: Phil Sharman, UK DTI

"Clean Coal Technology" - The President's Coal Research Initiative

- $2 billion over 10 years
- Central power systems focus
- Gasification and advanced combustion
- Hydrogen from coal
- CO_2 capture and storage
- Advanced research
- Power Plant Improvement Initiative (PPII) – 2001 only
- Clean Coal Power Initiative (CCPI) – 2001-2011

USA - Strategy and Presidential Initiatives (4)

Source: Phil Sharman, UK DTI

The Clean Coal Power Initiative (CCPI)

- **The demonstration part of the President's Coal Research Initiative**
- **Co-financing (<50% DOE)**
- **Helping utilities to address targets of CSI and GCCI**
- **CCPI 1 (2003 solicitation) → 8 6 projects ($927m total value; $255m DOE). 4 now in design phase. New techs, high efficiency, coal waste**
- **CCPI 2 (2004) → 4 projects ($1,833m total; $410m DOE). Multi-pollutant control, gasification**

USA - Strategy and Presidential Initiatives (5)

Source: Phil Sharman, UK DTI

"FutureGen" – The Integrated Sequestration and Hydrogen Research Initiative

- Launched February 2003
- $1 billion over 10 years (80% federal)
- 275MW coal gasification-based, high efficiency plant by 2015
- "Polygeneration" - producing H_2/elec.
- Near zero emissions plant with CCS (1Mt/y of CO_2)
- World's 1st prototype "ZE coal" plant
- May incorporate fuel cell hybrid cycle and may use coal/biomass
- Open to non-US participation

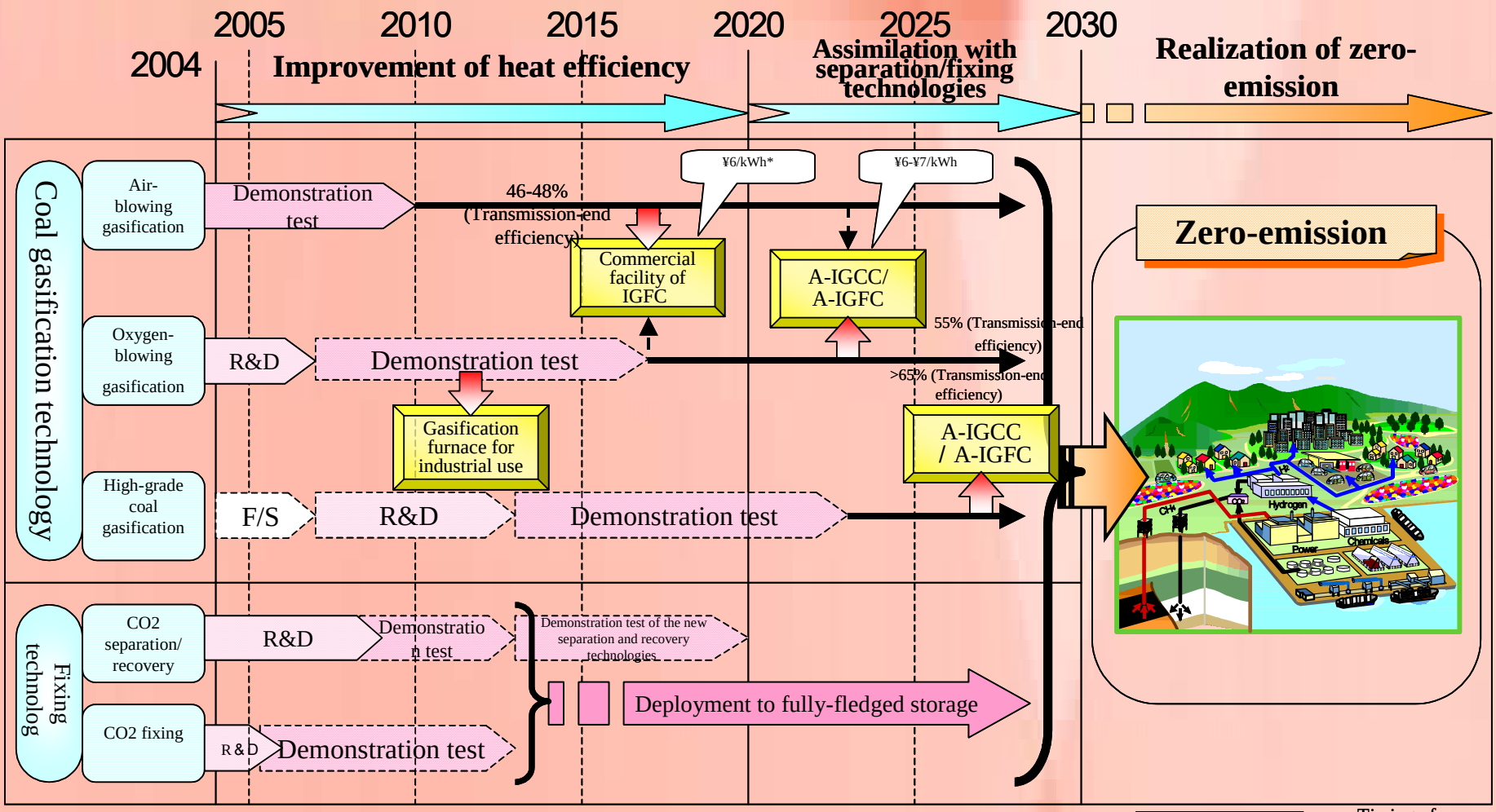
Japan - C3 (Clean Coal Cycle) Initiative

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

Considers

- **Full production, use and disposal chain**
- **Technologies for environmentally friendly utilisation**
- **Infrastructure measures to stabilise coal prices**
- **International co-operation necessary**
- **Gasification as core technology but also oxy-coal combustion – Australian co-operation**

Japan 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

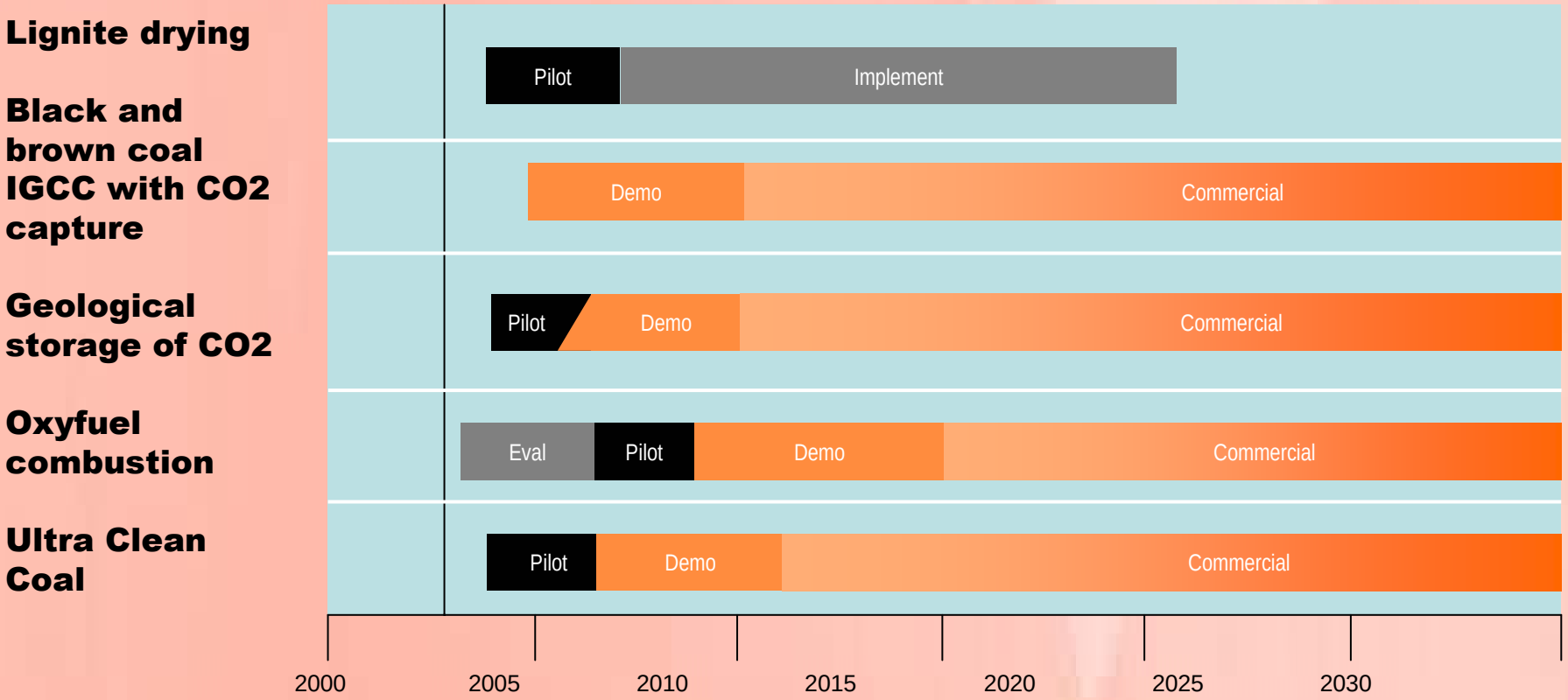
Australia – COAL21

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

Objectives/Issues/Activities

- **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**

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



Australia – 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 30 MWe PCC boiler to oxy-firing.

Stage 2 – 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.

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**
- **26GW large boilers ordered in 2003, 93% of world supercritical market, ~43 boilers**
- **Ordering pattern continued through 2004 -2005**

IGCC

- **Demonstration plant planned at Yantai**

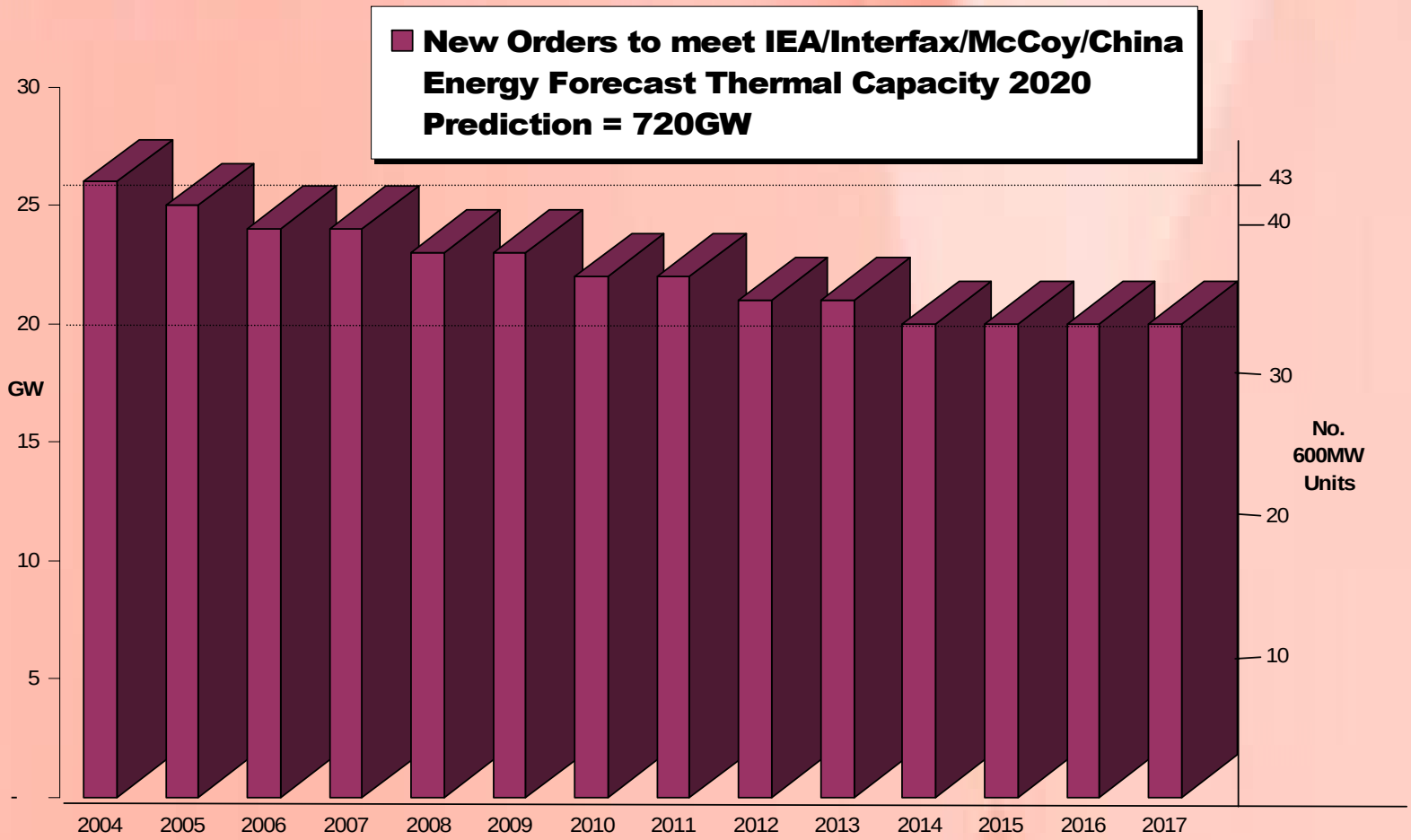
PFBC

- **Exploitation plans suspended**

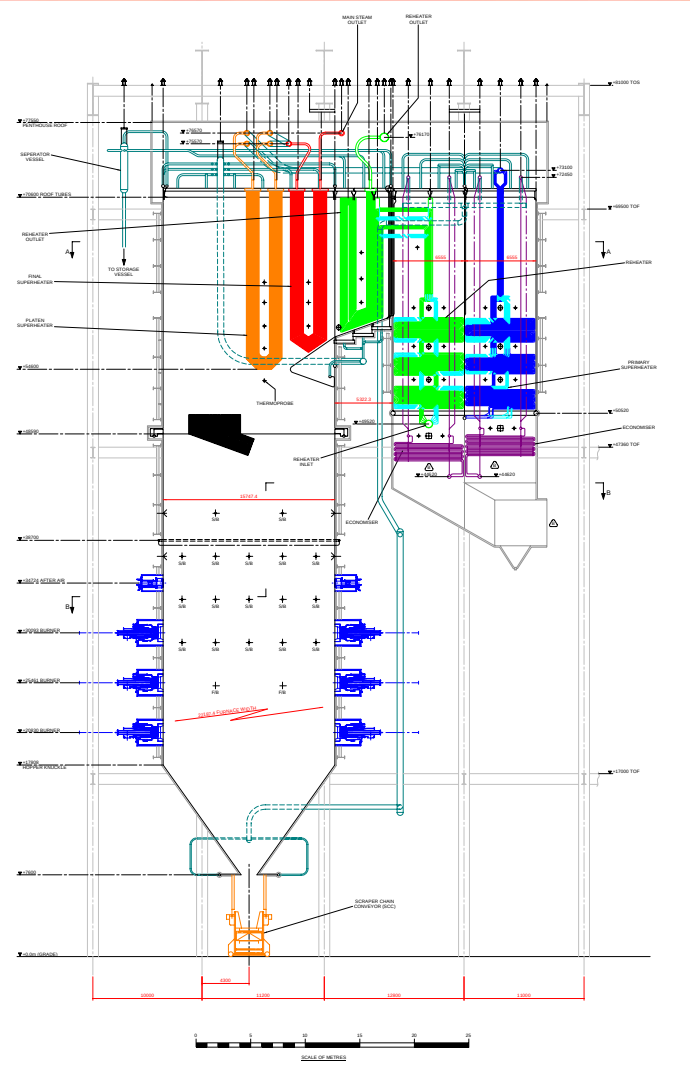
FBC

- **Numerous industrial scale FBC and CFBC**

China – future ordering patterns of supercritical plant



A Typical Project Award



WANGQU 2x600MW, PRC

- Project funded through JBIC loan to Chinese Government
- Contract awarded on 15 September 2003
- Boiler and Auxiliary equipment including Mills, Fans, Airheater, ESP
- International Bidding competition amongst Babcock Hitachi, IHI, Mitsubishi Heavy Industries, Mitsui-Babcock (winner)

Chinese Perceptions – Challenges Faced in the 21 Century

(Courtesy of Beijing Research Institute of Coal Chemistry)

Main Tasks

- **Reduce Pollutants & Greenhouse Gases Emission**
- **Reduce Dependence on Imported Oil**
- **Increase Efficiency**

Chinese Perceptions
-Highlights of CCTs of China
Advanced Power Generation Technology

(Courtesy of Beijing Research Institute of Coal Chemistry)

- **Ultra Supercritical Power Generation**
- **Pollution Control Technology**
- **IGCC**
- **Poly-generation~Vision 21**

India

- Government and NTPC stating intentions to build supercritical PCC plant, but also showing interest in developing a gasification route
- 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
- CFBC plants in operation since 1995

Characteristics of Indian Coals

Ash Content:	**35 - 45 per cent**
Sulphur:	**<1 per cent**
Reactivity:	**moderately high**
Ash fusion temp:	**>1500 deg C**
Ash Chemistry:	**high in Silica**
	high in Alumina
	highly abrasive
	medium slagging

BHEL's Approach to IGCC

Fixed bed gasifier :

6.2 MWe IGCC Commissioned in 1989

Fed about 1,000,000 units of Power to TNEB grid

Fluidized bed gasifier :

18 TPD PFBG - BHEL CORP. R&D, Hyderabad, Commissioned in 1993

168 TPD PFBG - BHEL – CCDP, Tiruchy, Commissioned in 1997

Series of trial operations being conducted since 1997

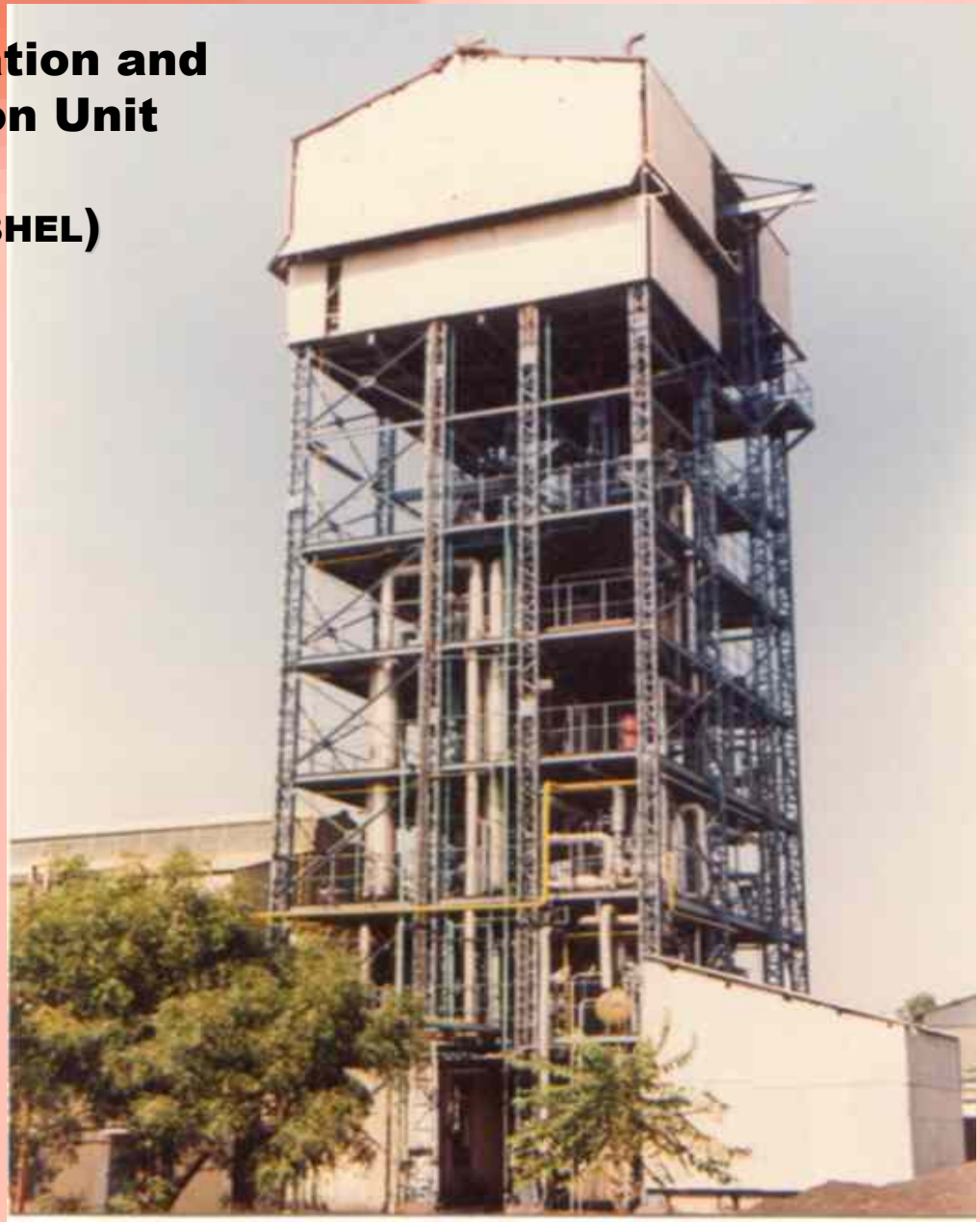
IGCC Mode power generation demonstrated in March , 1998

Commercial scale 100 MW IGCC - PFBG capacity : 1500 TPD

Process Evaluation and Demonstration Unit (PEDU)

(Courtesy of BHEL)

Coal throughput	**18 t/day**
Gasifier diameter	**450 mm**
Gasification media mix	**air / steam**
Gasification temp.	**1000°C**
Gasification pr.	**11 kg / cm^2**
Gas calorific value (HCV) $kcal/m^3$	**1050**
Coal size	**1 to 4 mm**



Technology messages

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.

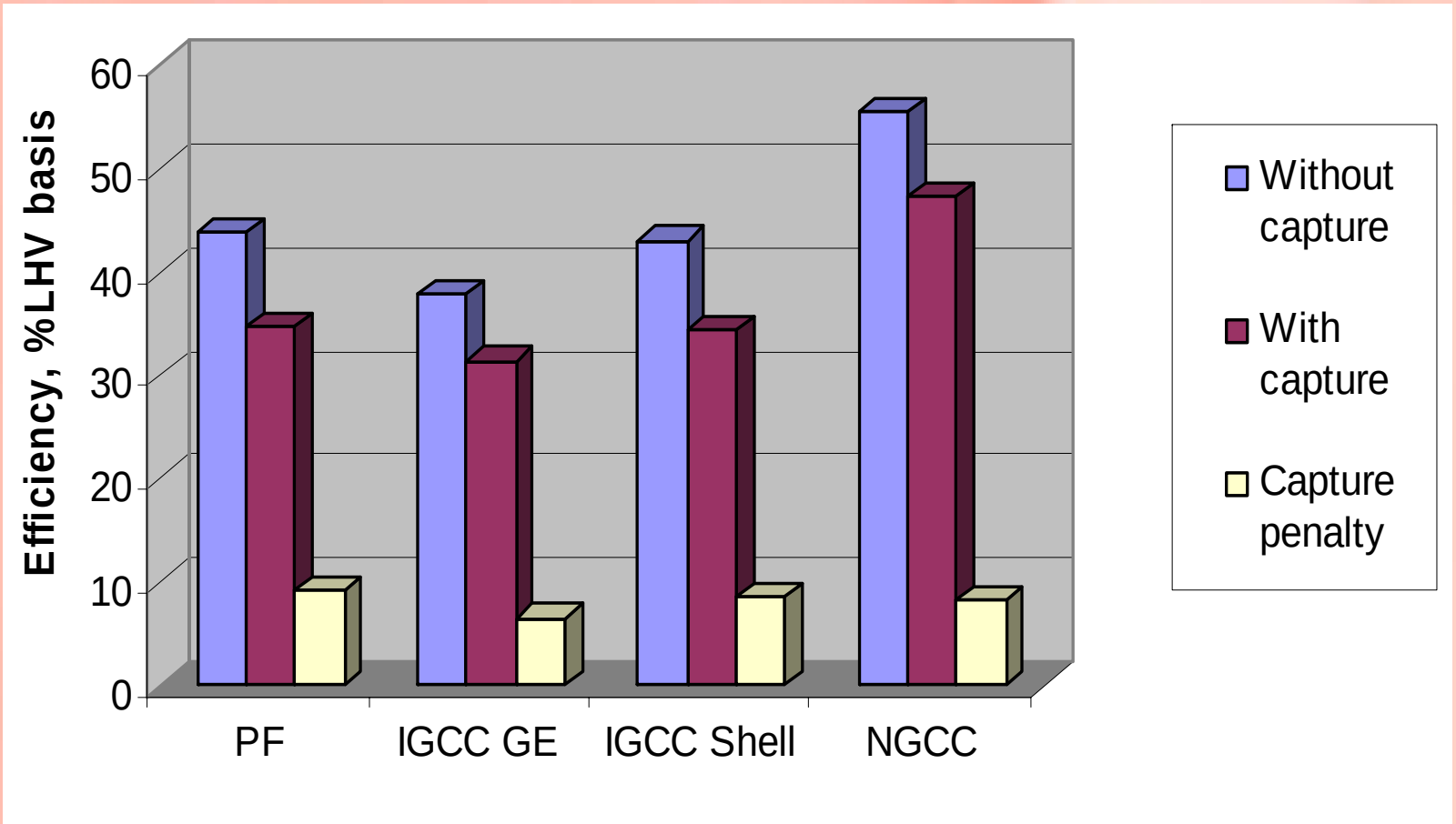
Why we need both technologies!

Uncertainty in R & D – not sure of outcomes and associated costs for USC and IGCC

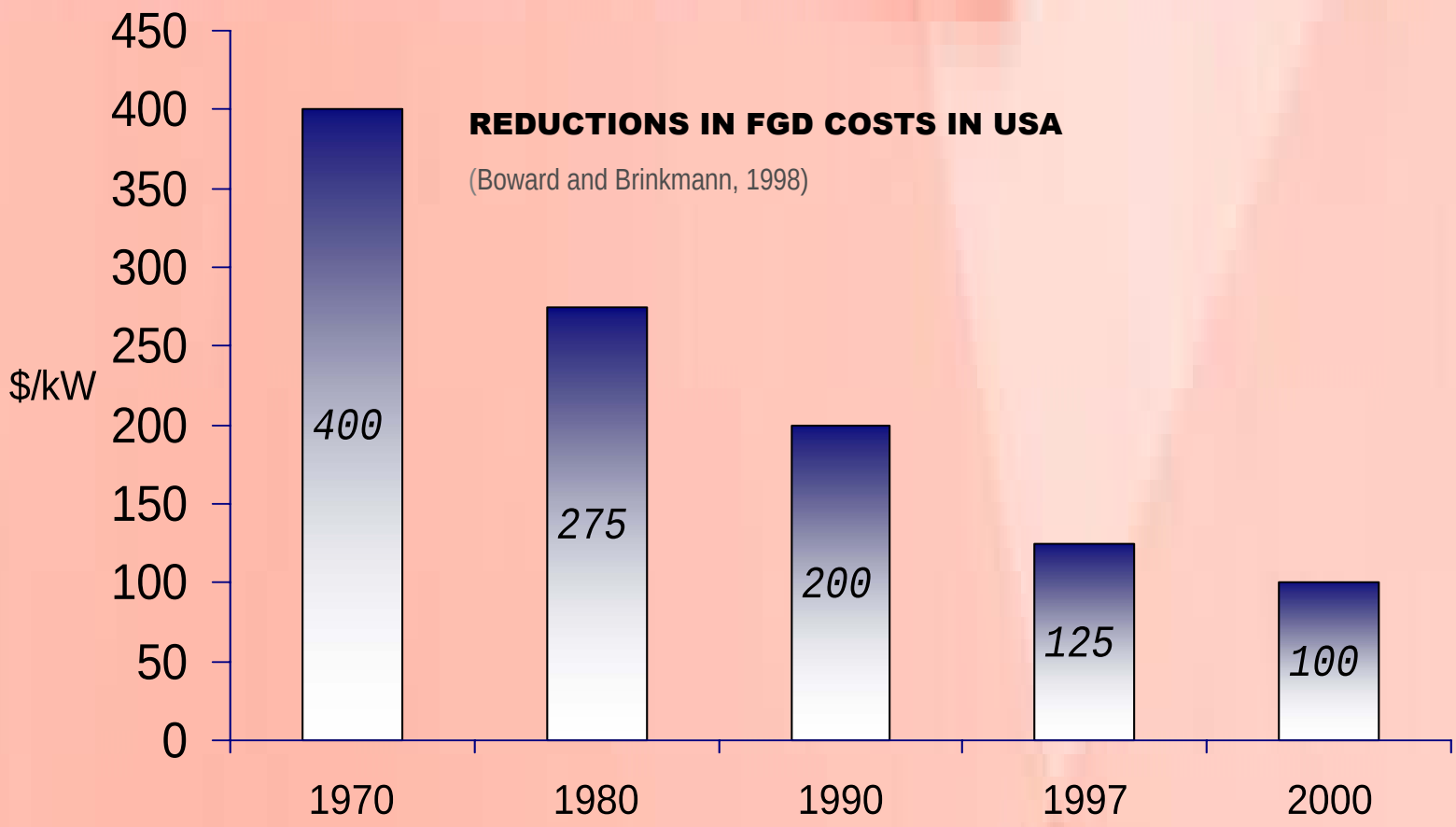
Time to deploy IGCC – will take 15-20+ years to see market penetration

Construction policy in China and India – where most "new build" will occur

Efficiency of power generation
(IEA GHG Data 2004)



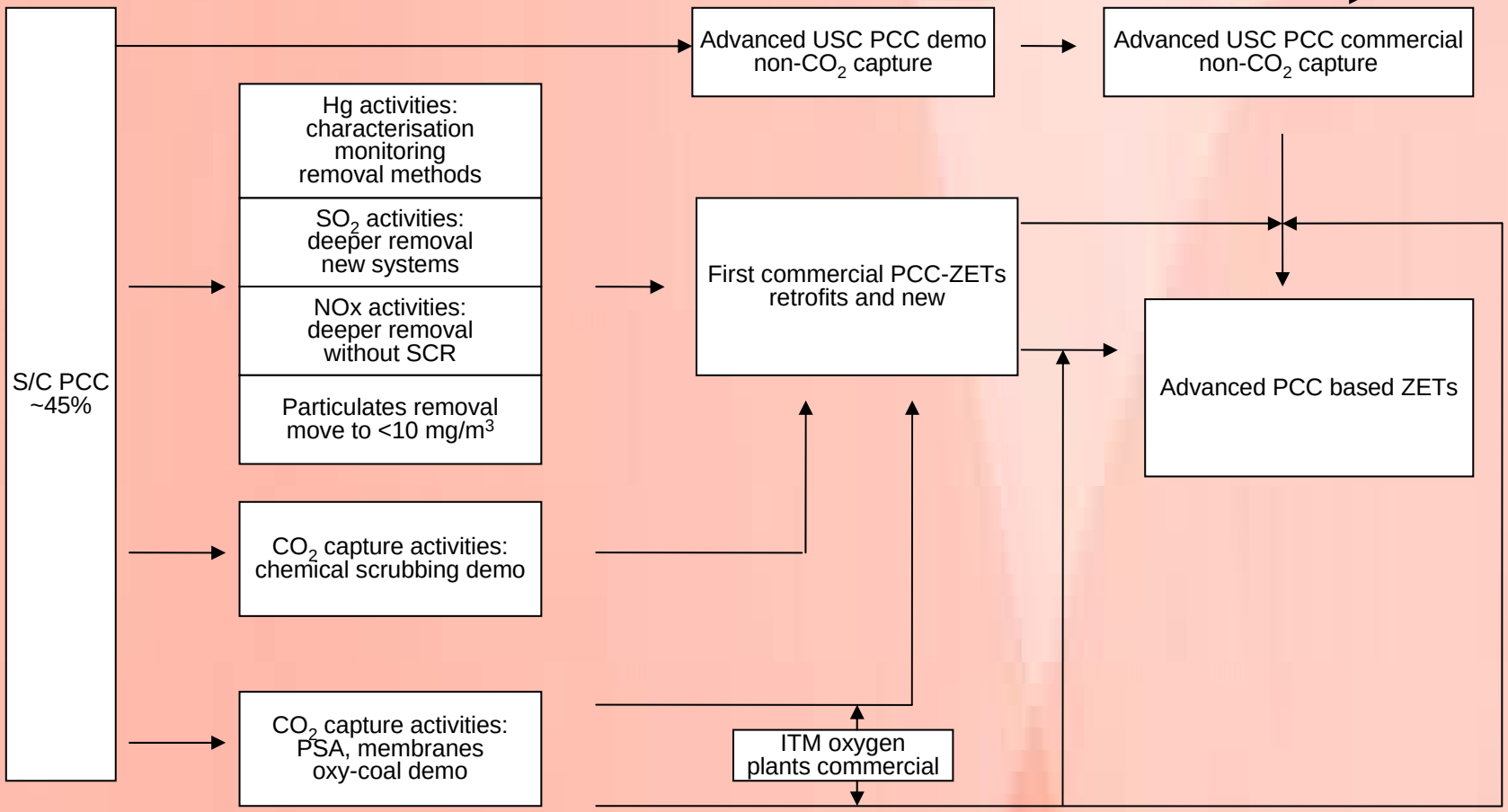
Potential for cost reduction



Path to zero emissions for PCC

Now → 2005-10 → 2010-15 → 2015 on

Increasing efficiency, lower emissions, lower costs



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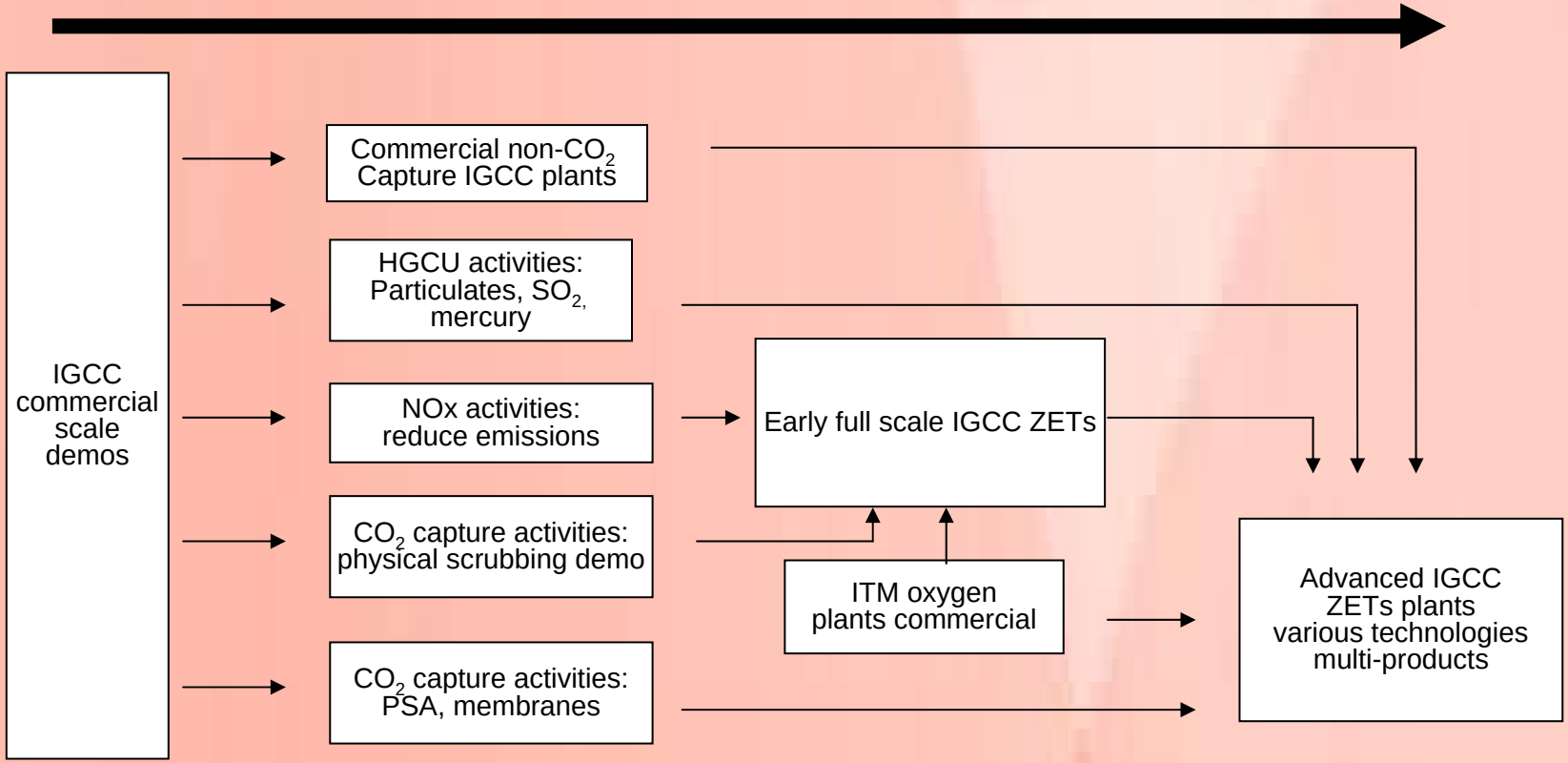

R & D needs towards Zero Emissions

PCC

- Improve FGD, NOx reduction systems
- Develop mercury and other trace metals removal and measurement systems
- Develop ferrous alloys and nickel-based superalloys for higher steam conditions
- Steam turbine developments
- CO2 scrubbing – new chemical and physical solvents
- CO2 separation using membranes and adsorption techniques
- Oxycoal combustion
- Minimise energy use of CO2 capture

IGCC

- Better refractories, gas coolers, coal feeding to increase reliability and availability
- Improved coal conversion
- Co-gasification
- Dry gas clean-up
- Tests of new turbine designs as they emerge on syngas
- CO2 separation technologies for shifted syngas (physical solvents, membranes, adsorption)
- ITMs for O2 production
- Hydrogen turbine demonstrations
- Fuel cell improvements, scale-up, demonstration on hydrogen from syngas

CO_2 storage

- Storage integrity, environmental effects, legal issues, verification

Conclusions

- The route to very low CO_2 emissions will require technologies for coal use in both OECD and developing countries
- The favoured technologies are IGCC and ultrasupercritical pf firing
- At this point in time IGCC looks favourite to produce deep CO_2 emissions reductions at the most acceptable cost
- BUT given the technology choices being pursued in developing countries right now and given the large potential for cost reductions arising from R & D it makes sense to develop a twin pronged approach – very similar in concept to COORETEC.
- OECD governments have a central role to play in creating a balanced approach which will encourage and foster CO_2 capture and storage with least possible effect on power production costs.
- The time to deployment of ZETs technologies in developing countries is longer, but opportunities to truncate this by technology transfer will be available.
- Investment requirements will be huge on a global scale. Even with appropriate policies it will take 20 years or more to see significant market penetration of capture and storage

Thank you!