

# Intergovernmental Panel on Climate Change

An update on Chapter 3 – Capture  
in the IPCC SAR on CCS

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INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)



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# Contents of Chapter 3 - Capture

Executive Summary

*A team of 18 authors*

Introduction CO<sub>2</sub> Capture

*Approximately 115 pages*

Industrial Processes

*First step in the CCS chain*

Post Combustion Capture

*The most costly step*

Oxyfuel

*Technology & risks known*

Precombustion Capture

*Needs new developments to reduce energy use and cost*

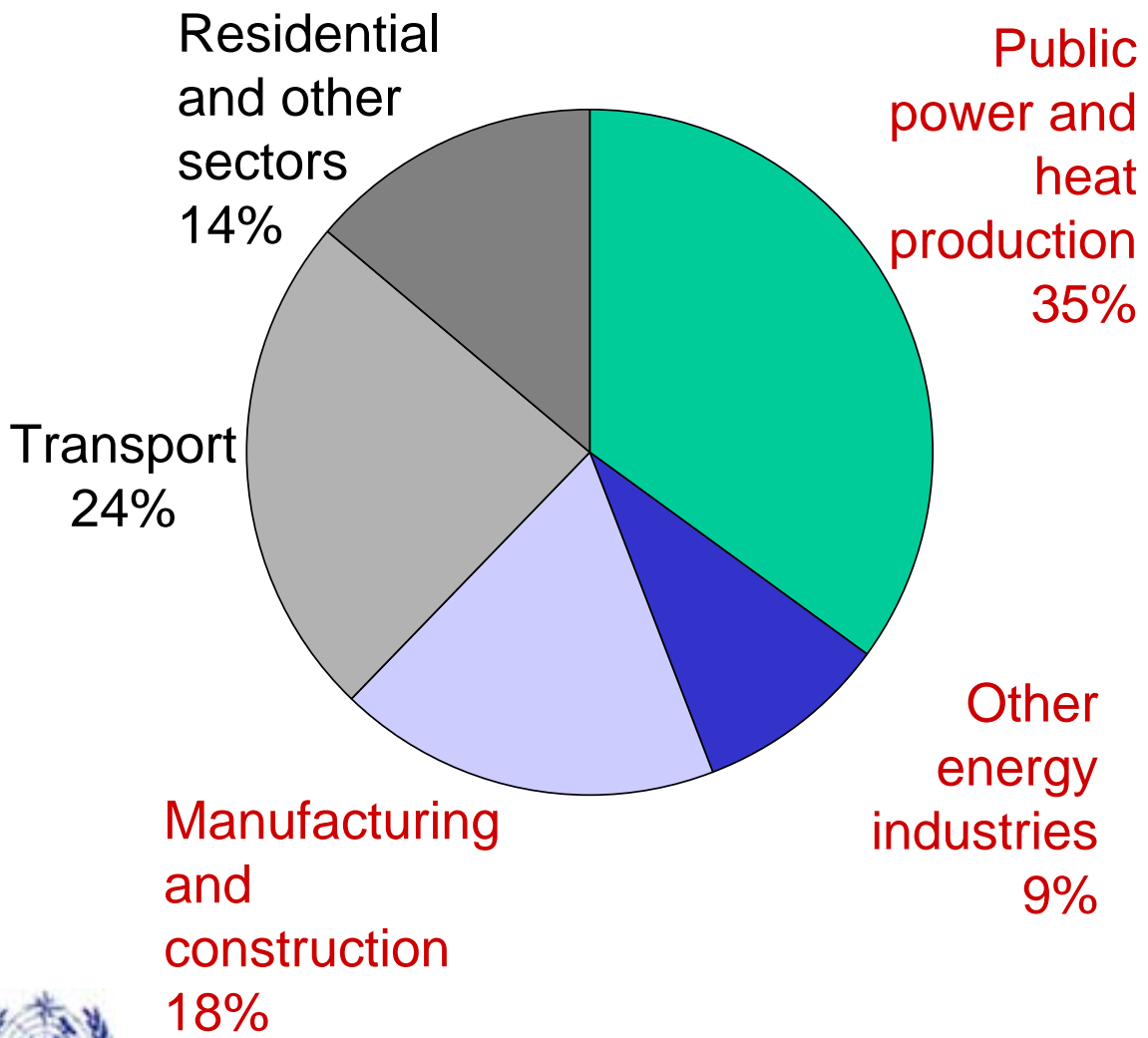
Env., Mon., Risk, Legal

*New sections on status and outlook and on gaps in knowledge*

Capture Cost

Gaps in Knowledge

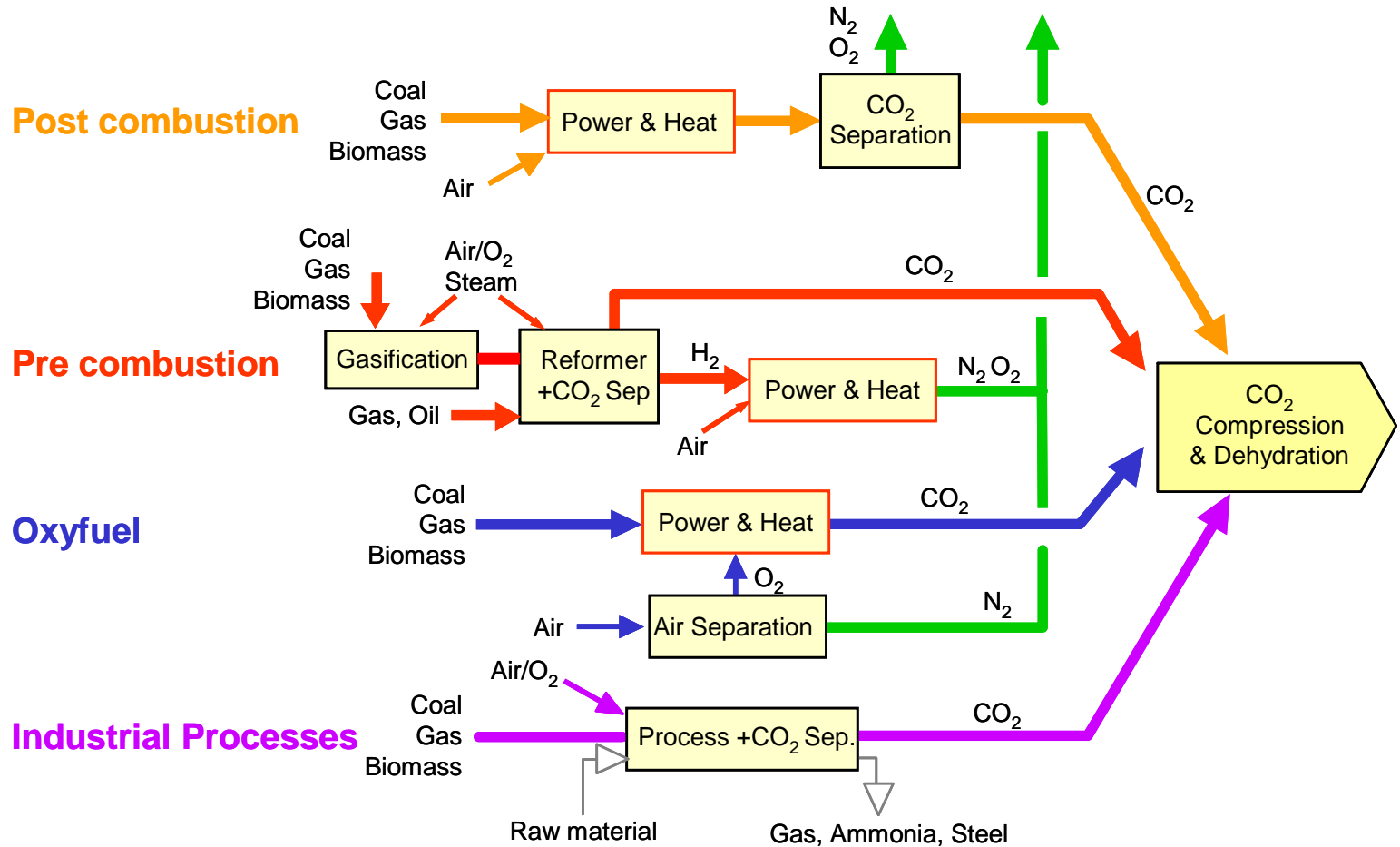
# Introduction to capture – where might it be applied



- Large point sources
- Need economy of scale
- Applied mainly in power, energy and other manufacturing industries
- Could produce decarbonised electricity and hydrogen energy carriers for small scale and distributed applications



# Introduction to capture – how to capture CO<sub>2</sub>



# Introduction to capture – options for application

- **Retrofit equipment for CO<sub>2</sub> capture** in existing plants – drawbacks include site limitations, poor system integration and reduced energy efficiency
- **Replace all equipment** at a given site to upgrade process efficiency and with process integrated capture plant – benefit of high efficiency base equipment with lower energy penalties and costs for capture. Also reduces other environmental emissions
- **New build “capture ready” or “capture” plants** – the former providing opportunities for conversion when fiscal incentives are in place

# Capture – industrial processes

## – status and outlook

- Category that covers the application of CO<sub>2</sub> capture in processes that manufacture industrial products – natural gas sweetening (50 Mt/y CO<sub>2</sub>), steel production (1,442 Mt/y CO<sub>2</sub>), cement production (932 Mt/y) and ammonia manufacture (127 Mt/y of CO<sub>2</sub>)
- Capture processes applied are common to post, oxyfuel and pre combustion capture
- Natural gas sweetening – 2 large applications removing 2 Mt/y of CO<sub>2</sub> for storage in a saline aquifer and gas field already underway at Sleipner, Norway and In Salah, Algeria
- Over 7 Mt/y of CO<sub>2</sub> additionally from natural gas sweetening and ammonia production being used in the USA for enhanced oil recovery
- Significant potential for CO<sub>2</sub> capture in steel manufacturing and cement production
- Although CO<sub>2</sub> capture from industrial processes are potentially the lowest cost options implemented, the total amount that can be captured is insignificant in terms of the scale of the climate change challenge – currently an estimated capacity of 360 Mt/y of low cost opportunities
- However, industrial process systems will be the early examples for the implementation of CCS globally

# Capture – post combustion –status and outlook

- An over whelming proportion of the global fossil fuel infrastructure is currently based on the combustion of fossil fuels in air and remain the most cost competitive infrastructure for the provision energy and power
- If this pattern continues post combustion capture will likely be the most significant option for the application of CCS
- Main systems of interest for applications in power generation are the current air blown power plant infrastructure – coal-fired (1135 GWe), oil fired (454 GWe) and gas fired (893 GWe) – total approximately 2482 GWe or 67% of global power plant infrastructure
- MEA or MEA based hybrid solvents that have lower energy penalties are the leading commercial or near commercial options – current systems operating at the scale of approximately 400 tonnes/day in a single train operation - facing a big challenge of plant scaling of 20-50 times of current capacity for a power plant in the 500 MWe capacity range and process integration to further minimise energy use with capture
- Emerging power system developments involving USC-PC and NGCC plants indicate that the application of post combustion amine capture will result in capture plants over the next decade of comparable efficiency to the best available power plant technologies today without CO<sub>2</sub> capture for coal and marginally lower for NGCC
- Potential for new capture developments incorporating membranes, hybrid sorption processes and solid absorbents

# Capture – oxyfuel – status and outlook

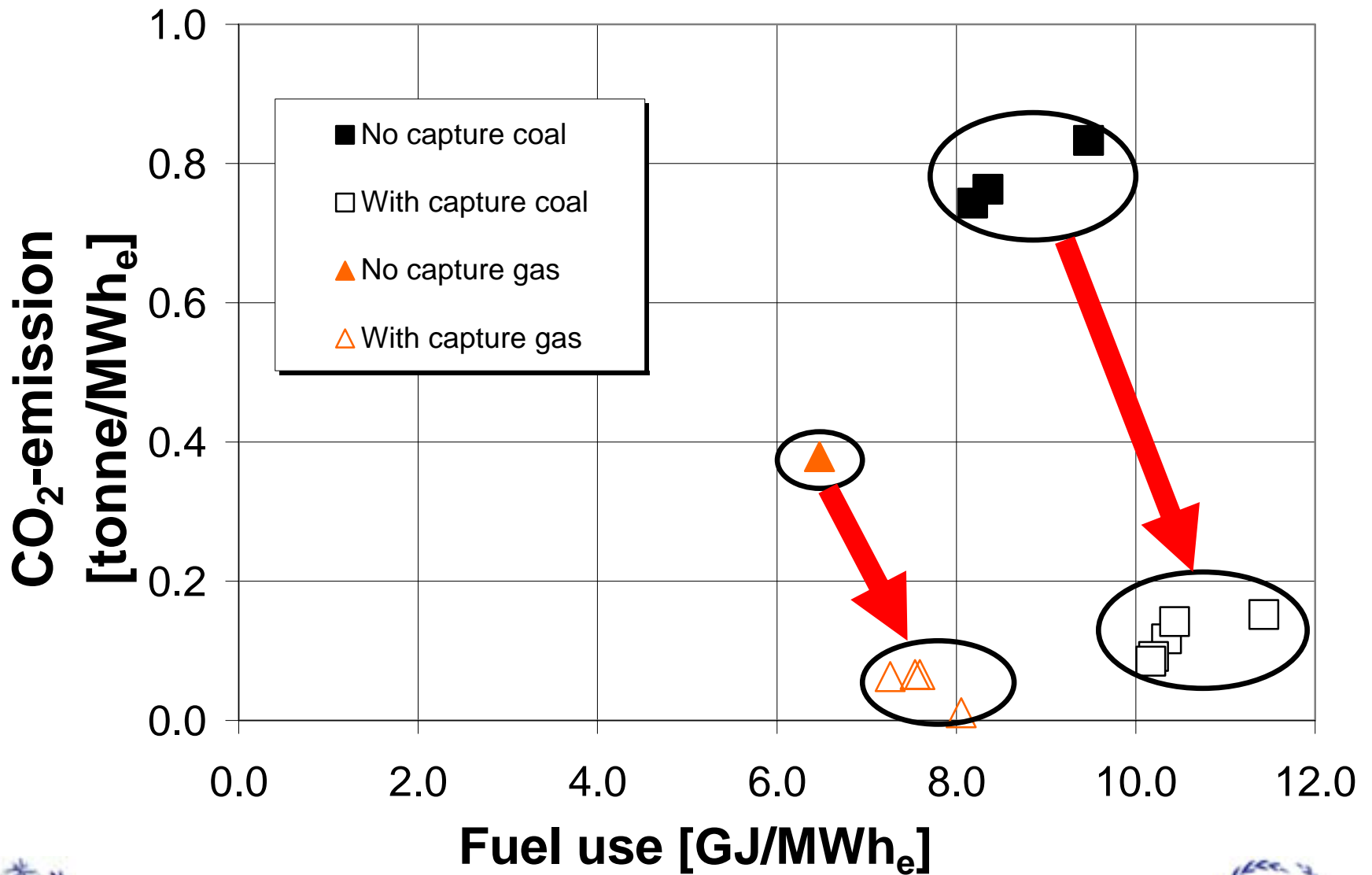
- **Combustors/boilers** for oxyfuel capture could be fairly conventional **with CO<sub>2</sub> recycle** to moderate flame temperatures – **can use existing air fired fossil fuel infrastructure** and is a leading contender in these applications to post combustion capture – **but applications are currently in the demonstration stage**
- **Several other novel applications** proposed for direct heating in steam turbine or gas turbine cycles for power generation **require the development of new and/or higher temperature tolerant components**
- Currently relatively **high cost and energy use for oxygen production** continuing developments in cryogenic plants and advanced oxygen membranes (ITM's) are expected to lower cost and energy consumption
- **Main systems of interest for applications in power generation** are the current air blown, steam based **coal and gas fired plants representing 1468 GWe of capacity** or 40% of the total global power plant infrastructure
- **Emerging power system developments** involving USC-PC and NGCC plants indicate that the application of oxyfuel capture **will result in capture plants over the next decade of comparable efficiency to the best available power plant technologies today without CO<sub>2</sub> capture for coal and marginally lower for NGCC**

# Capture – precombustion - status and outlook

- CO<sub>2</sub> capture occurs at high pressure which generally lowers the energy penalty for capture, although overall system losses involving energy penalty for shift and a loss of bulk gas in power generation increases the energy penalty for capture
- Chemical, physical solvent scrubbing for CO<sub>2</sub> separation or adsorption for selective H<sub>2</sub> removal well proven & commercial and CO<sub>2</sub> separation processes also available on a scale large enough for power plant applications
- Precombustion capture involves greater plant complexity and/or pressurised operation but provides advantage of decarbonised hydrogen, electricity and/or chemical production
- Plant reliability is excellent in industrial applications but relatively poor so far for IGCC – only 1 GWe of coal IGCC and 3GWe of oil IGCC without capture
- Improvements in combined cycle efficiencies are expected to improve the efficiency of IGCC power plants with capture within the next decade to levels comparable to current plants without capture. Pre-combustion capture yet to be demonstrated for NGCC power plants.
- Several new options involving high temperature membrane separation of H<sub>2</sub> or CO<sub>2</sub> or sorption enhanced reaction with combined gas separation are being evaluated

# Capture – env., monitoring, risk & legal

- CO<sub>2</sub> capture **incurs an energy penalty** relative to the same base plant without capture – **consumes more energy resources** for the same plant output
- However **continuing improvements in energy efficiency**, particularly in power generation, **show that over the next decade, the efficiency of new plants with capture can match or exceed that of older plants it replaces** – situation also needs to be modelled in the context of existing infrastructure
- **Further work is needed to improve power, industrial plant and capture process efficiency** to significantly reduce both the energy consumption and environmental footprints and to reduce costs
- **Environmental, monitoring, risk and legal aspects** of CO<sub>2</sub> in the process industry **are well established** and covered under standards, codes of practice and regulations both national and international



# Capture cost

- Extensive survey of the published literature undertaken and data on capture cost evaluated, to the extent possible, on a common basis
- Systems evaluated generally include the cost of capture to at least 90% removal and compression of CO<sub>2</sub> to pipeline specifications
- Nevertheless there is a great deal of variation in cost data due to location of the plant and the price of fuel
- Lowest cost options are for CO<sub>2</sub> capture from existing and new gas fired hydrogen plants and confidence levels in the cost of capture in these plants are higher than for power generation with capture
- In power generation the capture cost vis a vis coal and gas fired units is dependent on the gas price although coal prices have also risen recently
- Very little difference in the cost of electricity with capture from a pulverised coal or IGCC plant.
- Capture costs are expected to reduce by at least 20-30% over approximately the next decade
- Need for caution in the use of \$/tonne of CO<sub>2</sub> avoided as a metric in the selection of CCS options

# CO<sub>2</sub> Emissions Avoided

- **Quantity of emissions avoided depends on:**
  - The fraction of CO<sub>2</sub> that is captured (normally 85-95%)
  - The baseline, i.e. the type of plant that would be displaced by a plant with CO<sub>2</sub> capture
- **Effect of baseline plant on quantity of CO<sub>2</sub> avoided**

More CO<sub>2</sub>  
avoided



New natural gas combined cycle plant

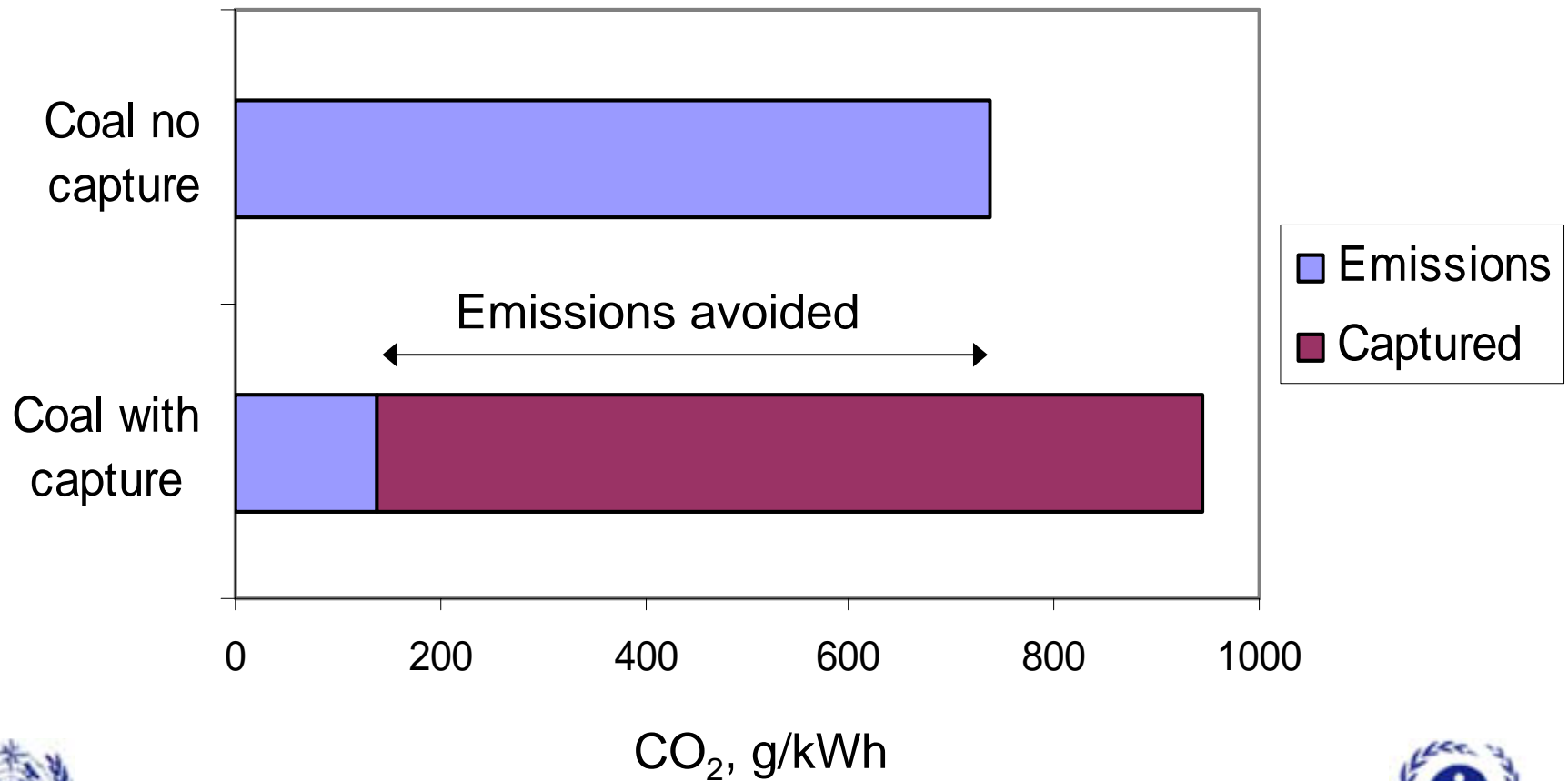
Old natural gas fired plant

Efficient new coal fired plant

Inefficient old coal fired plant

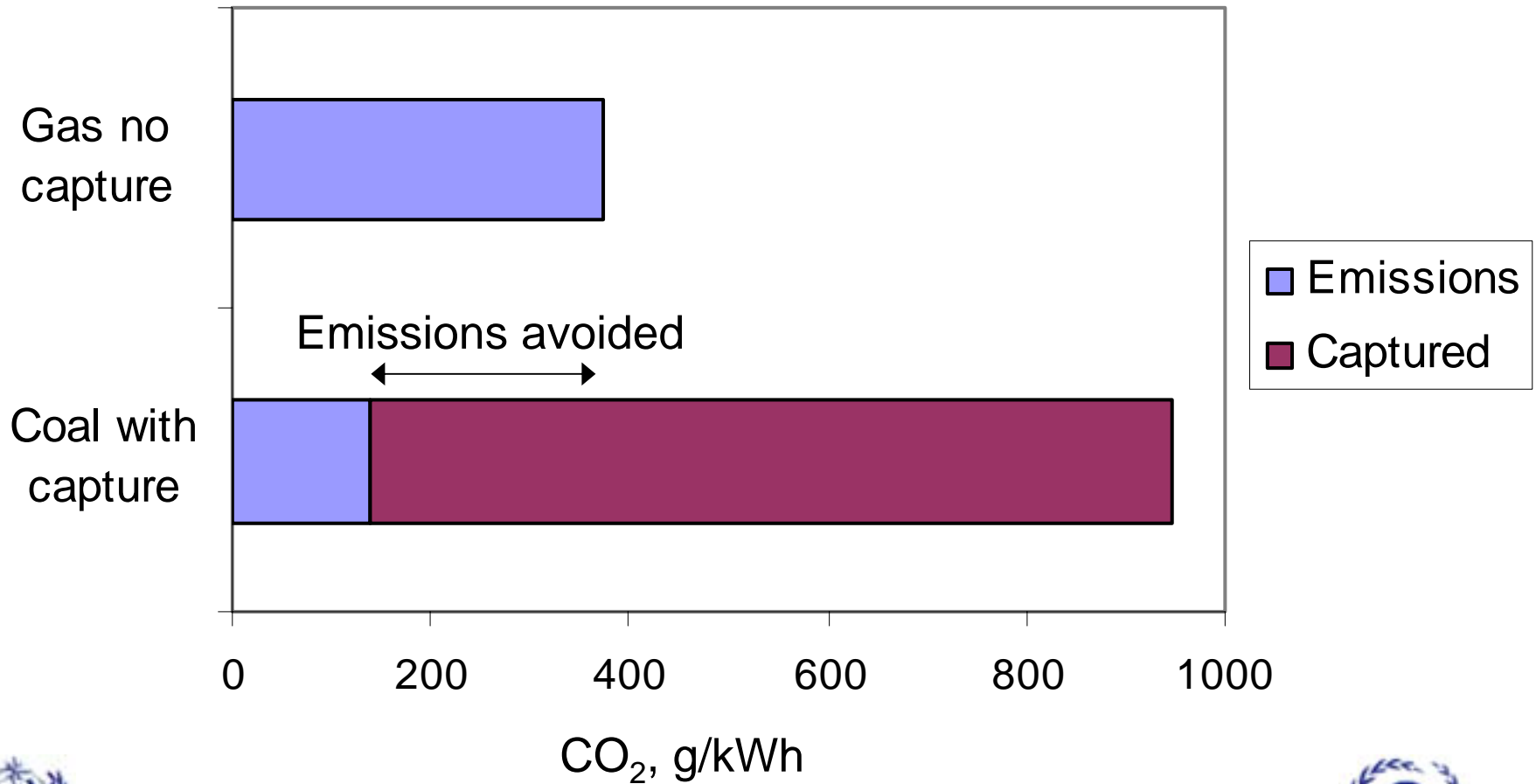
# CO<sub>2</sub> Emissions Avoided

## *Coal fired power plant baseline*



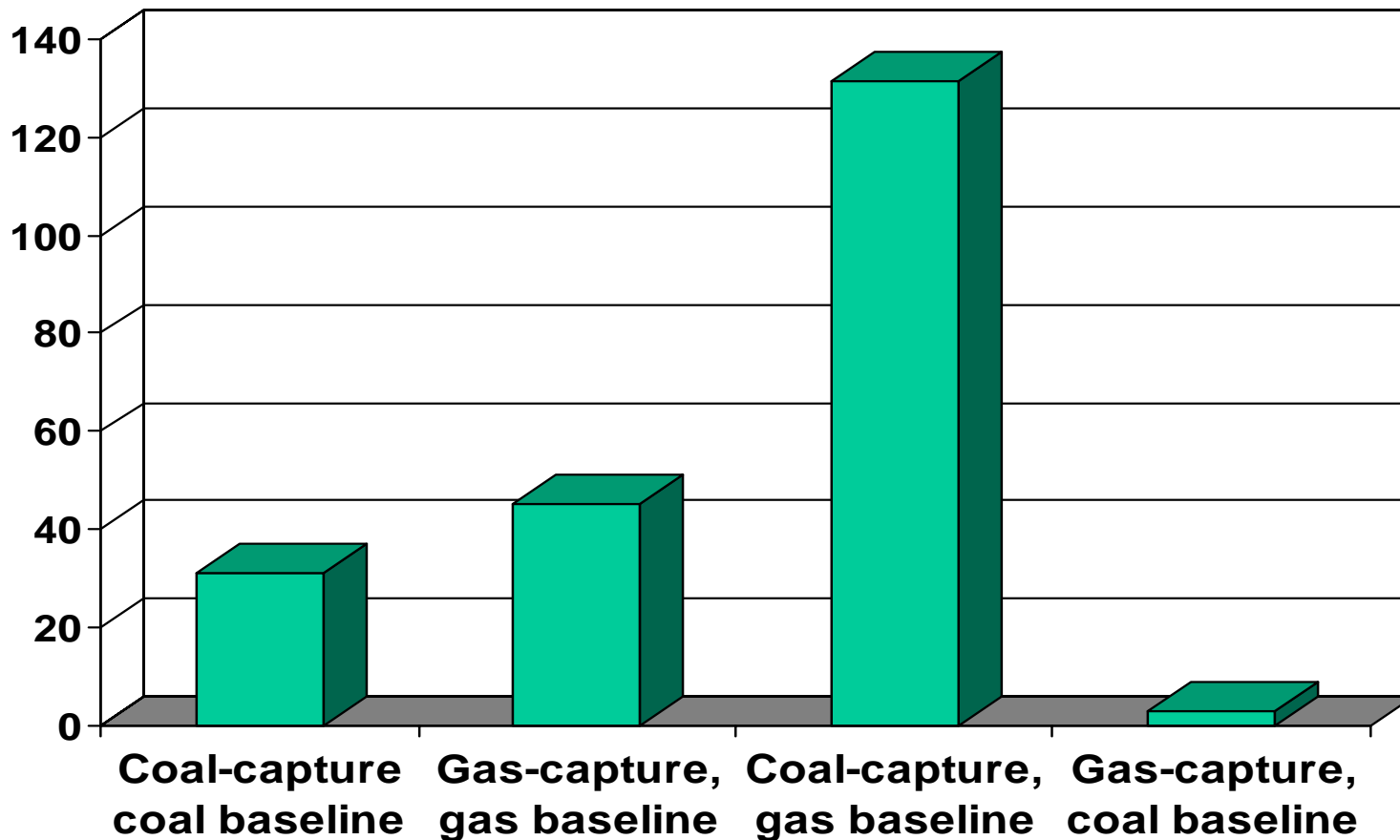
# CO<sub>2</sub> Emissions Avoided

*Natural gas combined cycle baseline*



# Cost per tonne of CO<sub>2</sub> avoided

\$ per tonne of CO<sub>2</sub> emissions avoided



***Best to compare only the absolute cost of product or power with capture***

# Gaps in knowledge (1)

- Gaps in knowledge are related to differences in the stages of development of capture technologies for industrial systems, oxyfuel, pre and post combustion capture
- For industrial systems involving natural gas sweetening and hydrogen/ammonia production capture systems are already available on a commercial scale
- Capture technologies developed above for industrial systems can be applied with the same degree of confidence and scale to pre-combustion capture in power generation
- More work is needed in the development of capture in steel and cement production
- For post combustion or oxyfuel capture in power generation work is needed to scale up applications for the larger flows handled or to demonstrate less well developed systems
- Significant gaps in knowledge exist in demonstrating capture in large scale, integrated applications, particularly those involving power plants – need to also test system reliability, improved process integration, reduce energy penalties and costs, improved process control strategies and use of optimised functional materials.

# Gaps in knowledge (2)

- In order to implement existing or improved capture systems work is also needed to improve critical gaps in the development of a range of enabling technologies – such as processes for the effective removal of sulphur, nitrogen compounds, chlorine, mercury and other pollutants, improved gasification reactors, availability of hydrogen burning turbines, fuel cells and combustors and turbines for oxyfuel systems
- Work is needed in a new range of capture technologies that would provide breakthrough concepts to reduce both energy penalties and costs
- Continuing improvements in the efficiency of both industrial and power plant systems are also an important requirement
- Many of these power system improvements and also improved capture and enabling technologies are linked to the development of better functional materials that can operate at higher temperatures with greater tolerance to fuel impurities