Fourth Annual Conference on Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

BP CO_2 capture and geological storage technology program: from science to field application

Gardiner Hill, BP

May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia

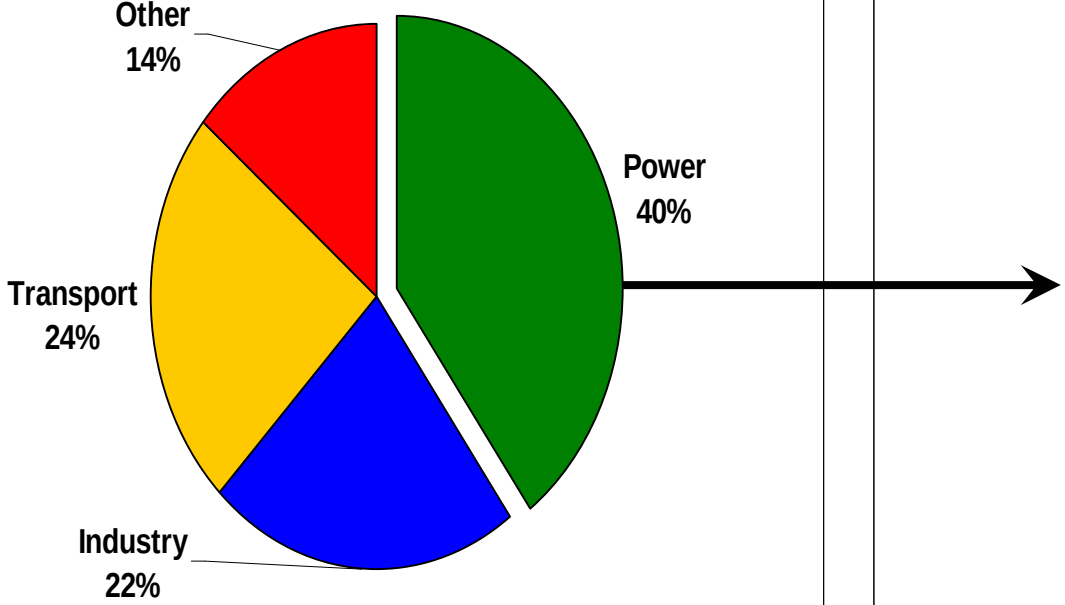
BP CO_2 capture and geological storage technology program: from science to field application

- Setting the context for Global CO_2 Emissions
- Meeting the Challenge with a portfolio approach
- Overview of the BP CO_2 Capture and Storage (CCS) program
- Market forces for CCS take-up

global CO_2 emissions

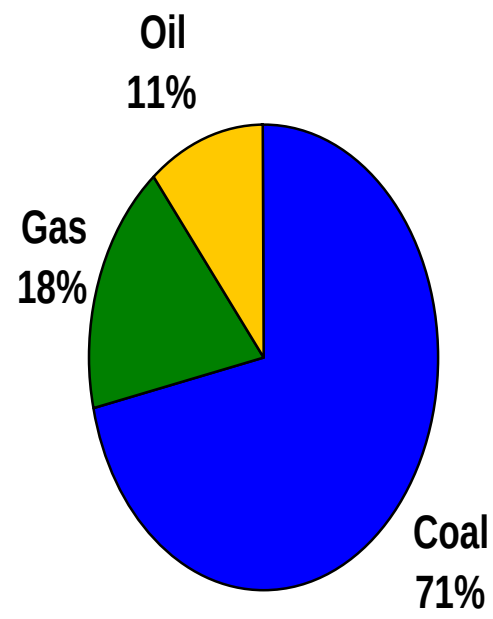
- Power sector is responsible for ~40% of global emissions
- Coal represents ~70% of emissions from power sector
- Many large stationary point sources (1GW coal plant emits 5-7MtCO_2 p.a.)
- Large opportunity for CO_2 capture and storage

2000 CO_2 Emissions by Major Sector



Global CO2 Emissions : 21GtCO_2 p.a.

Power Industry CO_2 Emissions by Fuel



Global Power Emissions : 8.3GtCO_2 p.a.

meeting the challenge: lower carbon products and the BP portfolio

Fuel Switching

Clean Fuels

Clean Lubricants

Hydrogen demonstration

Carbon Sequestration

Lower carbon products

» Gas growth

» Hydrogen

» Renewables

CO_2 capture & storage program overview

Science

R&D

CO_2 Capture Project

Studies and Reviews

- **Energy Technologies for stabilization**

Segment Supported

Sleipner CO_2 Store, Weyburn EOR Demo, Mt Simon Project, US Regional Centres

Demo

Business Application

Creating Options

Alaska EOR
Tangguh
North Sea Study
Trinidad Hubco
Iran LNG

CMI
Carbon Mitigation Initiative

Princeton University

PEI PRINCETON ENVIRONMENTAL INSTITUTE

bp

The **Carbon Mitigation Initiative** (CMI) at Princeton University is helping plot an alternative course for the future that will meet society's energy demands while limiting potential global warming. Founded in 2000, CMI is a 10-year, $20 million joint project of **Princeton University, BP, and Ford Motor Company**

CMI unites over 60 researchers from science, engineering, economics and policy into four teams: **Capture, Storage, Science, and Integration**. Together our researchers are developing strategies to reduce global carbon emissions that are safe, effective, and affordable.

Capture

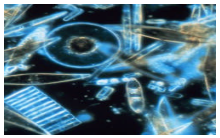
To meet global energy demands and at the same time reduce carbon emissions, the world must transition to energy technologies that produce little to no carbon dioxide. CMI's Capture Group is seeking ways to speed that change by making low-carbon energy technologies more cost-effective.

Working with partners in China and Italy, the group studies technologies for capturing CO_2 emissions from fossil fuels used in electricity, hydrogen, and synfuels production. Other research areas include combustion studies of alternative low-carbon fuels and hydrogen, and analysis of renewable energy production from biomass and wind sources.

Storage

Fossil fuels can be a part of a low-carbon energy economy if the carbon dioxide produced by burning coal, oil, and gas can be successfully captured and stored. The Storage Group is assessing the safety and effectiveness of one promising storage strategy—injecting CO_2 into saline aquifers deep underground.

A key factor in underground carbon storage is the risk of leakage from wells that penetrate storage aquifers, particularly old wells in areas that have produced oil and gas. Simulation of carbon dioxide plumes and laboratory studies of well cement degradation are helping the Storage Group evaluate that risk.



Science

To chart a course toward stabilizing atmospheric CO_2, scientists must predict the natural carbon cycle's response to climate change and carbon mitigation. CMI's science group is increasing understanding of the carbon cycle by combining observations of the earth system's present and past behavior with computer simulations of the future.

Researchers in the Science Group collect data from the oceans, atmosphere, ice cores, and the land biosphere to study how natural sources and sinks of carbon have varied in recent and ancient times, and are developing new modeling tools to improve carbon cycle simulation. The group also studies environmental effects of carbon mitigation strategies, and impacts of global change on the biosphere.

Integration

Turning research results into practical solutions requires placing science and technology in a broader context. The Integration Group works to synthesize research discoveries and explore the real-world implications of carbon mitigation strategies.

Led by Co-Directors Pacala and Socolow, the Integration Group analyzes possible pathways for carbon mitigation. It also works to communicate issues of carbon and climate to industry, government, non-governmental organizations, the media, and the general public.

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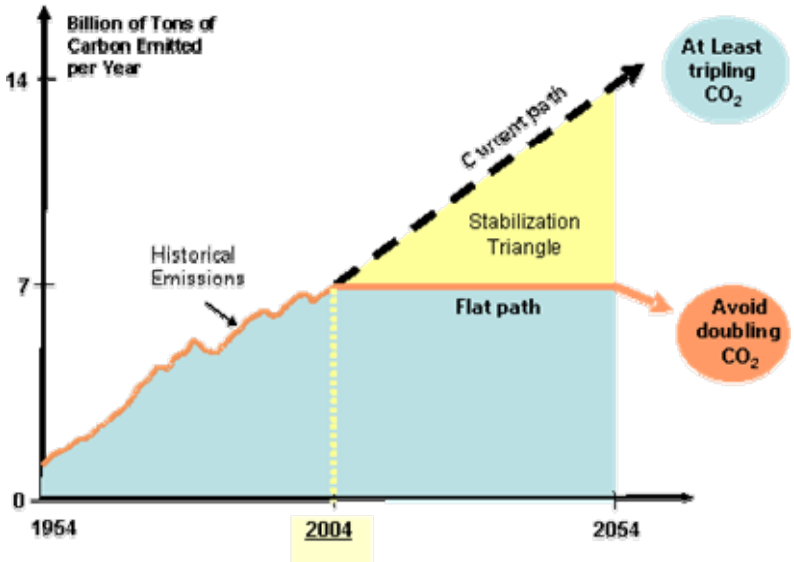
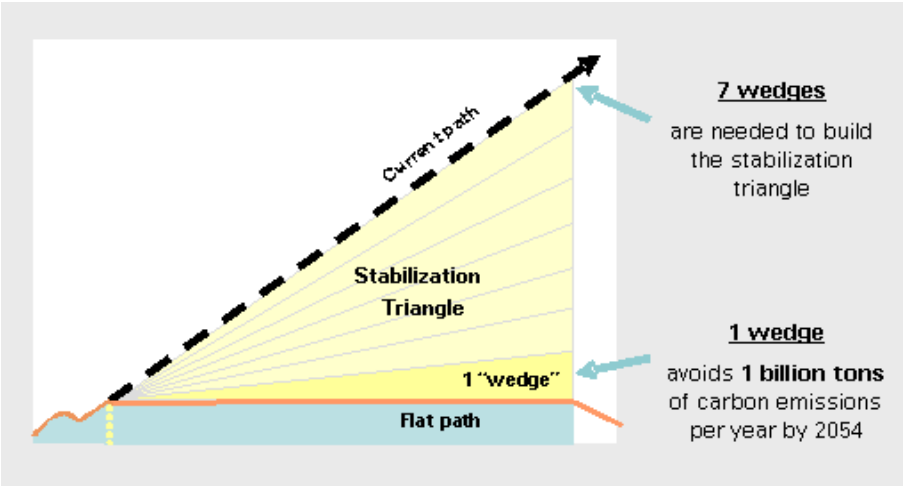
Ford

CO_2 'stabilisation triangle'





Potential wedges

- Efficiency
- Fuel switching
- Carbon capture and storage
- Nuclear
- Wind
- Solar
- Natural sinks
- Biomass Fuels

7 wedges of the stabilisation triangle

Wedges	Detail	Feasibility
Efficiency	Double fuel efficiency of 2 billion cars from 30 to 60 mpg	There are 600 million cars in the world today, Projection is 2 billion by 2054. **1 wedge ❁ Double the average fuel efficiency of the fleet.**
Fuel Switching	Replace 1400 coal electric plants with natural gas-powered facilities (Adding an amount in 2054 almost equal to today's world gas usage)	**1 wedge ❁ bringing one Alaska pipeline** on line every year for 50 years; or **1 wedge ❁ 50 large LNG tankers** docking and discharging every day
Carbon capture and storage	Capture AND store emissions from 800 coal electric plants	**1 wedge ❁ 3500 In Salah** developments (each need to last through to 2054)
Nuclear	Add double the current global nuclear capacity to replace coal-based electricity	400 nuclear plants today, **1 wedge ❁ adding 700** more in the next 50 years
Wind	Increase wind electricity capacity by 50 times relative to today, for a total of 2 million large windmills	**1 wedge ❁ windmills on an area approx 4 times that of UK**
Solar	Use 40,000 square kms of solar panels to produce hydrogen for fuel cell cars	**1 wedge ❁ solar panels covering area 230 times the area of London (1/12 size of UK)**
Natural sinks	Eliminate tropical deforestation AND create new plantations on non-forested land to quintuple current plantation area	**1 wedge ❁ new plantations with a total area 25 times that of the UK**

CO_2 capture & storage: summary

CO_2 Capture & Storage (CCS) is an emerging technology suited to large stationary point sources of CO_2 from power generation, industry and H_2 production.

CO_2 Capture

- √ Post-Combustion
- Pre-Combustion
- Oxyfuels
- $40-100+/Tonne CO2

High Purity Sources

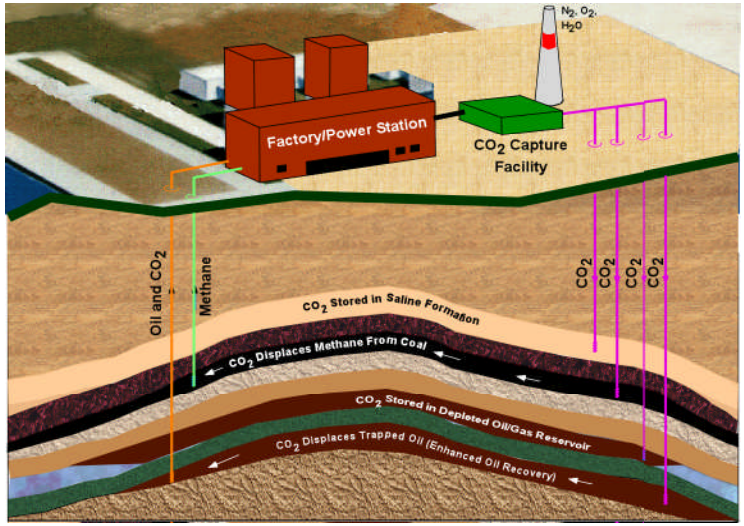
- Already separated
- Hi Concentration
- √ Amines, Membranes, H2
- $0-10/t CO2

Transport

- √ Pipelines
- Ships
- $ Depends distance

Geological Storage

- √ Enhanced Oil Recovery
- √ Saline Aquifer Formations
- √ Depleted Oil/Gas Reservoirs
- Enhanced Coal Bed Methane
- $1-10/t CO2



the big issues

- Costs
  - Cost of technology – Capture, Storage & Monitoring
- Acceptance by Stakeholders that it's Safe and Effective:
  - Public/NGO acceptance that it is safe and can be managed safely
  - Storage Integrity and Duration
    - Leakage rates, retention times, environmental and safety impacts
    - Monitoring, site selection, mitigation and standards
    - Long time horizon and field abandonment requirements
  - Market Eligibility (CDM,ET)
  - Governments: Legal & regulatory: OSPAR, Ownership and Liabilities
- Developing the Business Framework, Value Chain

CO_2 capture project

cooperating for a better environment

US Dept. of Energy

National Energy Technology Laboratory
David Hyman, Program Manager

EU DG Research

Directorate -General Research
Program Manager: Dennis O'Brien

Norges forskningsråd

The Research Council of Norway
Program Manager: Hans -Roar Søarheim

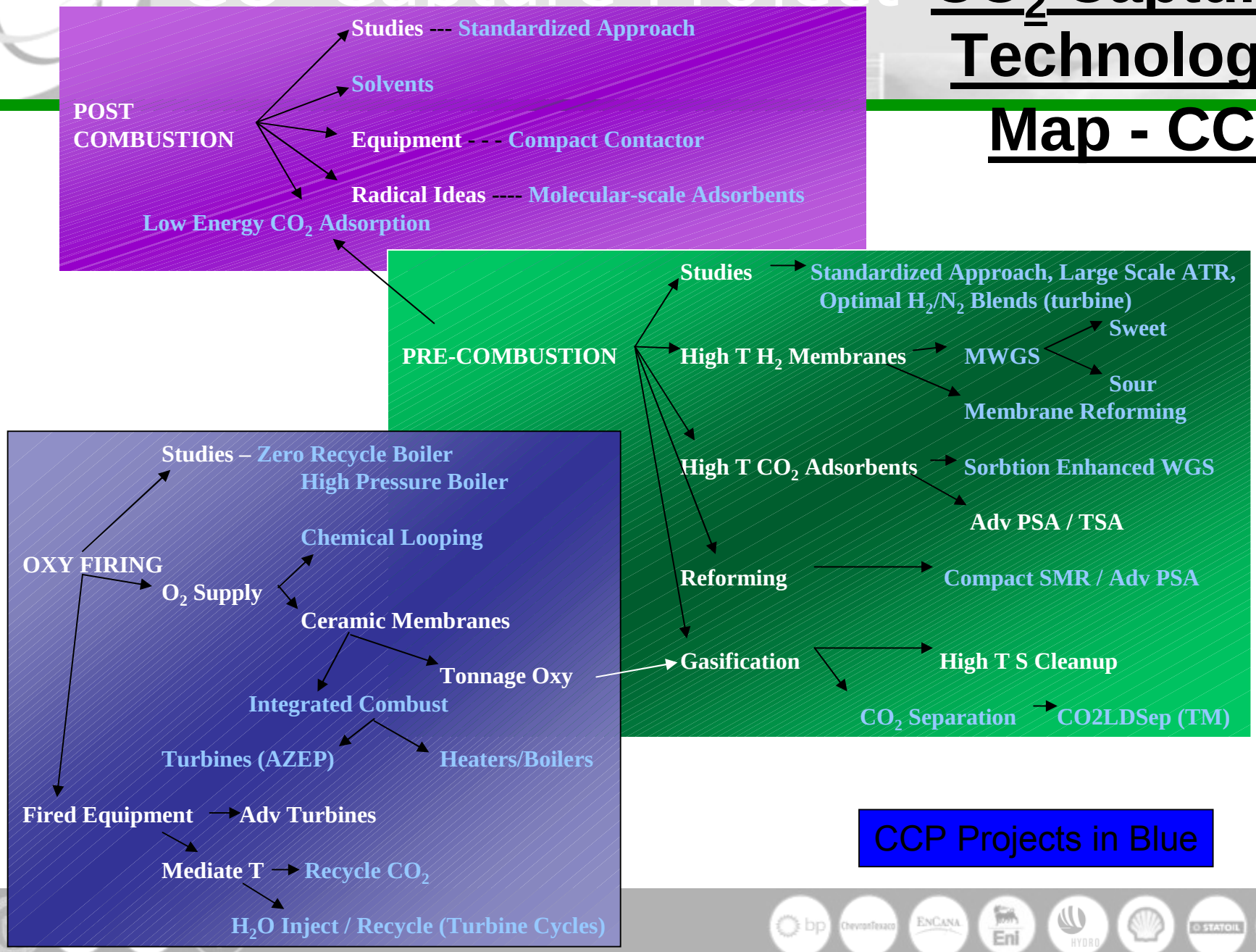
EU DG Energy and Transport

Directorate -General Energy and Transport
Program Manager: Vassilios Kougionas

CO_2 capture project; objectives

- Achieve major reductions in cost of CO_2 capture & storage:
  - 50% reduction when applied to a retrofit application.
  - 75% reduction when applied to a new build application.
- Demonstrate to external stakeholders that CO_2 storage is safe, measurable, and verifiable.
- Progress technologies to:
  - 'Proof of concept' stage by 2003/4 (Commercialization post 2010).

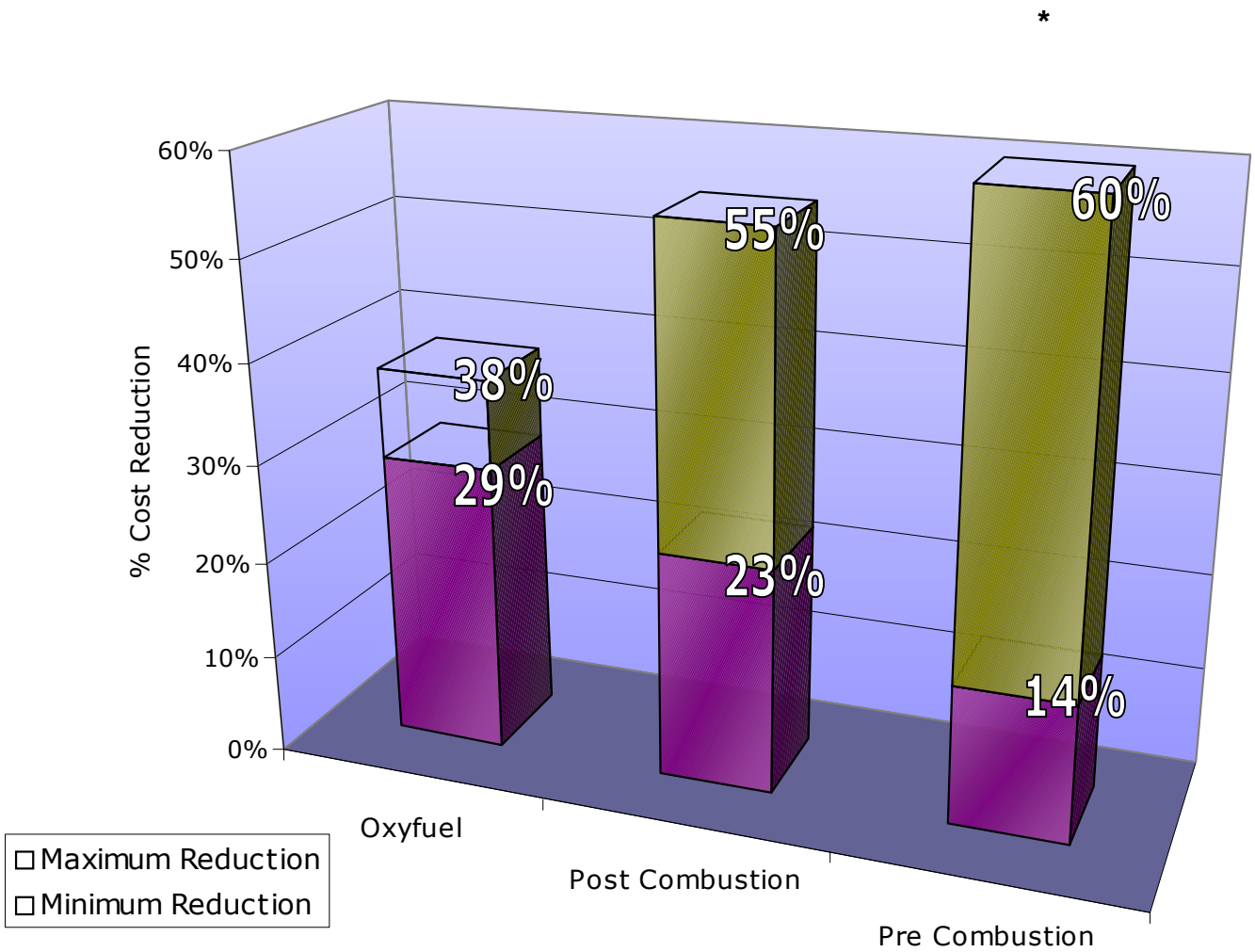
CO_2 Capture Technology Map - CCP



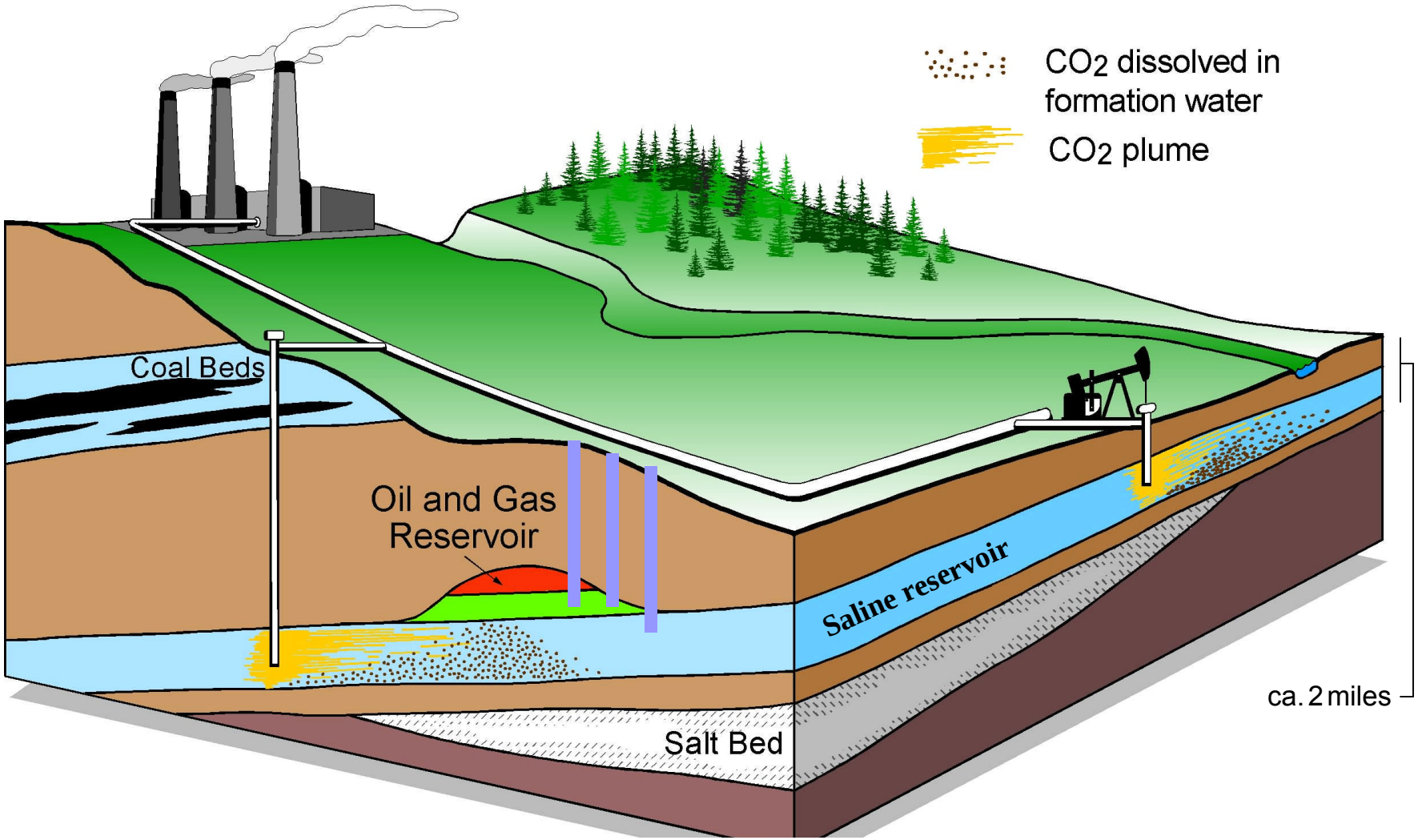
CCP Projects in Blue

CO_2 capture project

* Preliminary data, +/- 30% cost estimates, min reduction & maximum reduction data points shown.



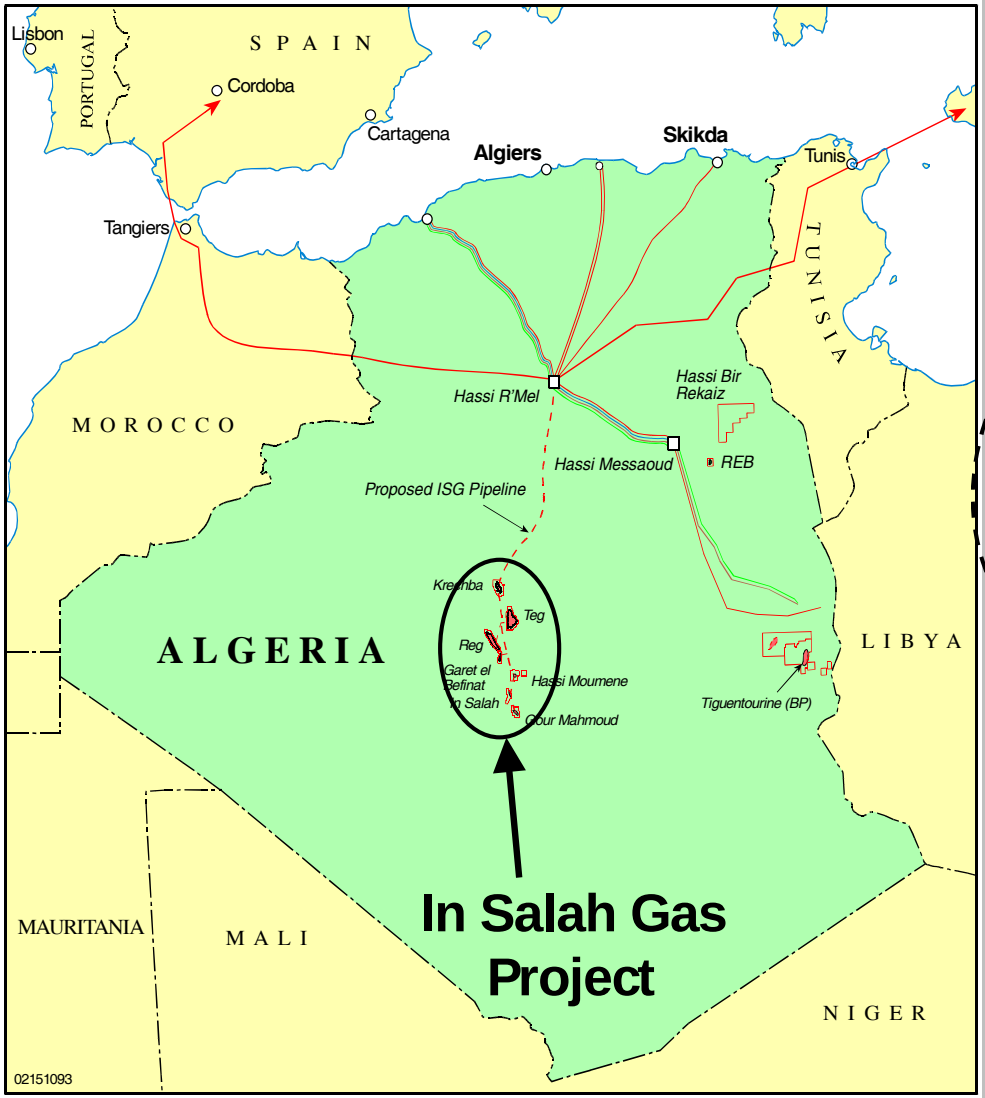
CO_2 storage options

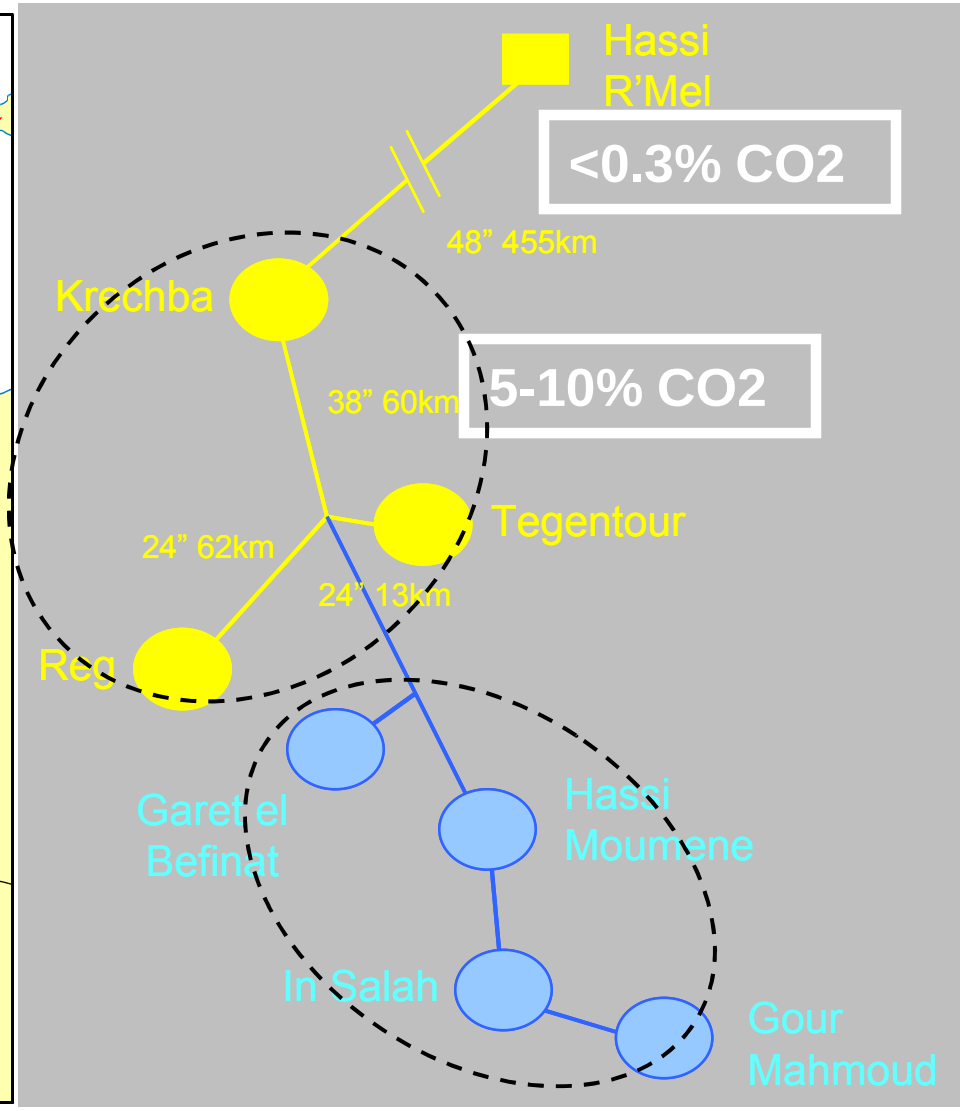


next steps: CCP phase 2 (2004 – 07)

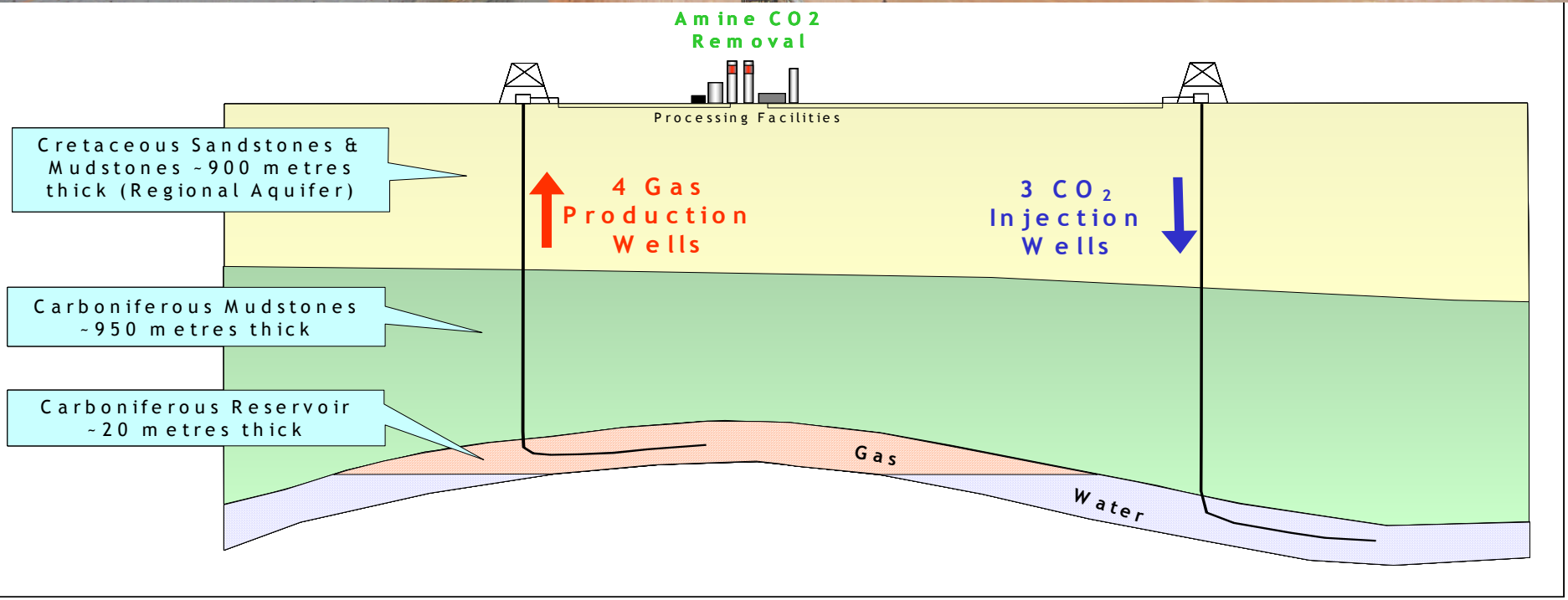
- Undertake additional research, development and pilot testing to reduce the cost of CO_2 capture from large, fixed sources.
- Reduce technology and cost uncertainty associated with those technologies and deliver low-cost CO_2 capture technologies to demonstration stage by 2007.
- Demonstrate that the geological storage of CO_2 is secure and can represent a viable Greenhouse Gas mitigation technique. Further develop technology, best practice and industry standards for storage site evaluation, risk assessment, well integrity, monitoring & verification.
- Establish an extended network for CO_2 storage demonstrations to share learning and best practice.

demonstrating CO_2 storage: In Salah gas development





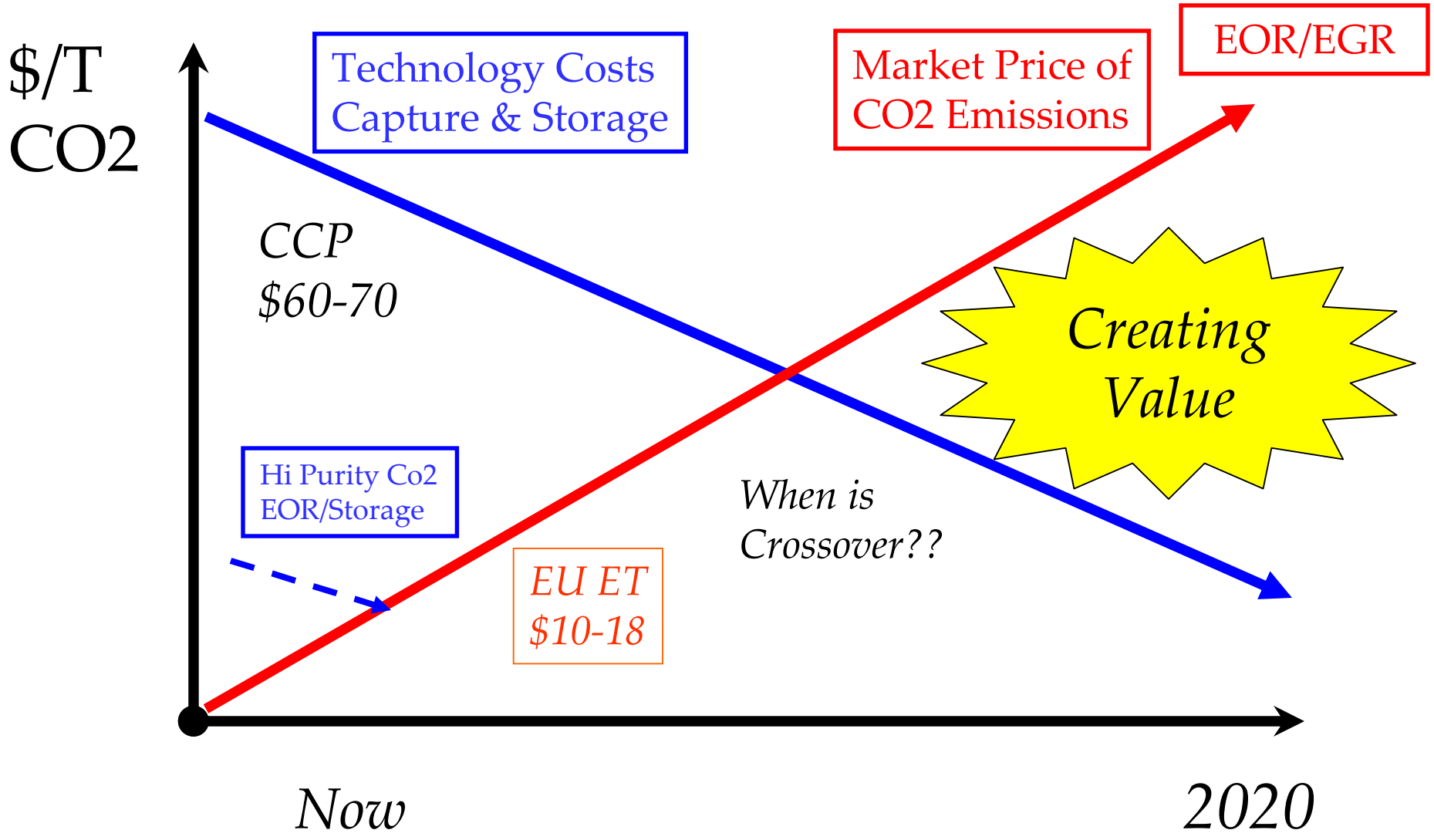
ISG CO_2 storage at Krechba



why In Salah ?

- demonstrate the concept - first major CO_2 storage in gas field in world
- different characteristics to other storage demonstrations
  - gas reservoirs
  - paleozoic sandstone reservoirs
  - seismic Imaging more complex
- opportunity for baseline and monitoring without hydrocarbon production history (EOR)
- onshore, low cost operating environment
- stakeholder interest in demonstrating storage
- first operational CO_2 storage project for BP
- Established a JI science project to learn from experience

market forces for CCS take-up



market forces for CCS take-up

CCS technology;

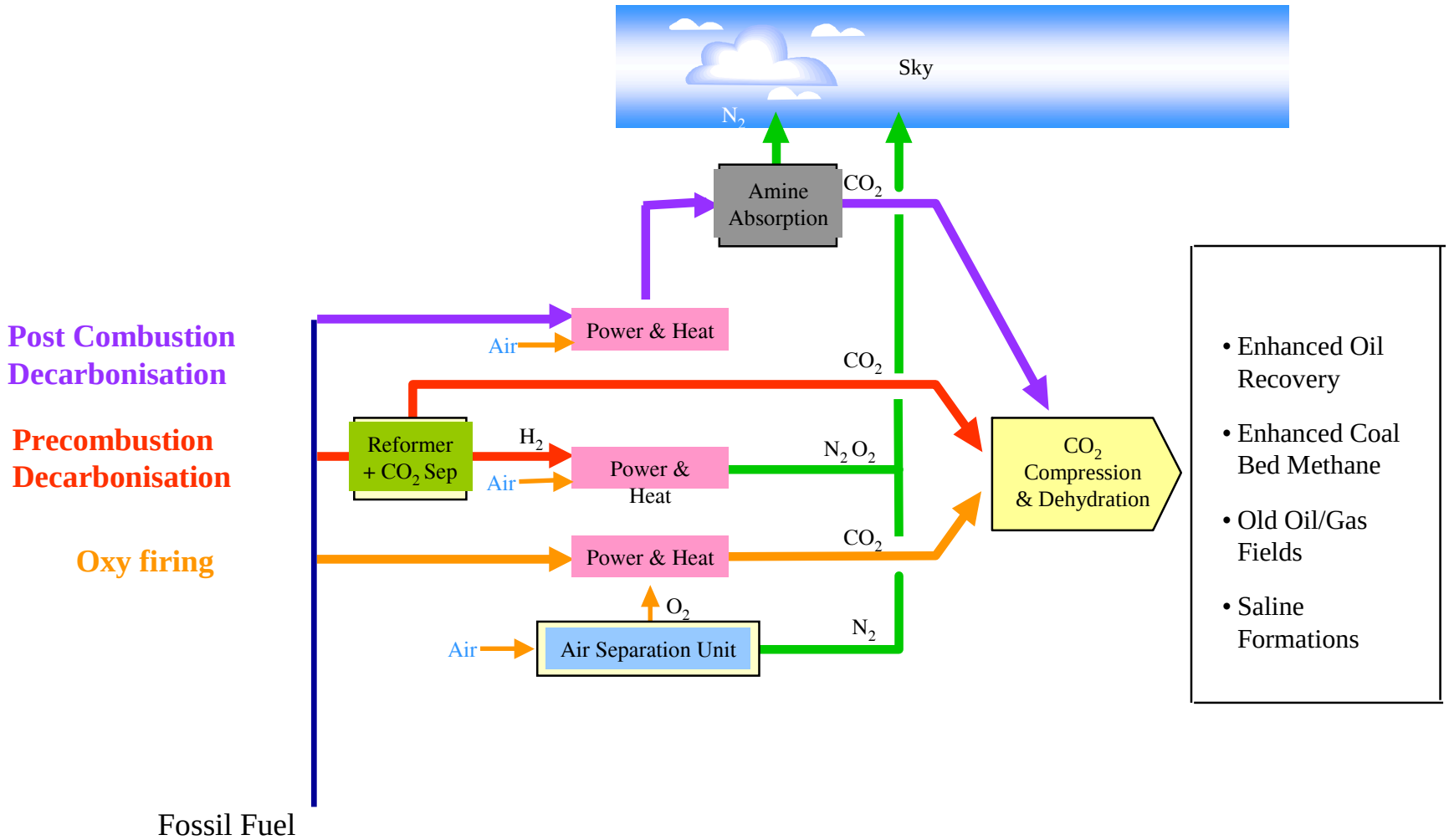
- can break the link between use of fossil fuels and emissions of GHG's
- potential for enabling material reductions in emissions of CO_2 and other GHG's
- could be applied in the short – medium term
- provides a bridge to a hydrogen economy
- must be competitive with other low or no carbon energy alternatives
- can be used to deliver benefits to the nation, such as energy security (EOR & EGR), cleaner air, diversity of supply through enabling all fossil fuels (coal, oil, gas), can use existing infrastructure, jobs, a reliable base load carbon free power supply, etc.
- should be delivered through market based forces

END

Questions?

Presentation by Gardiner Hill

capture routes



storage: technologies delivered

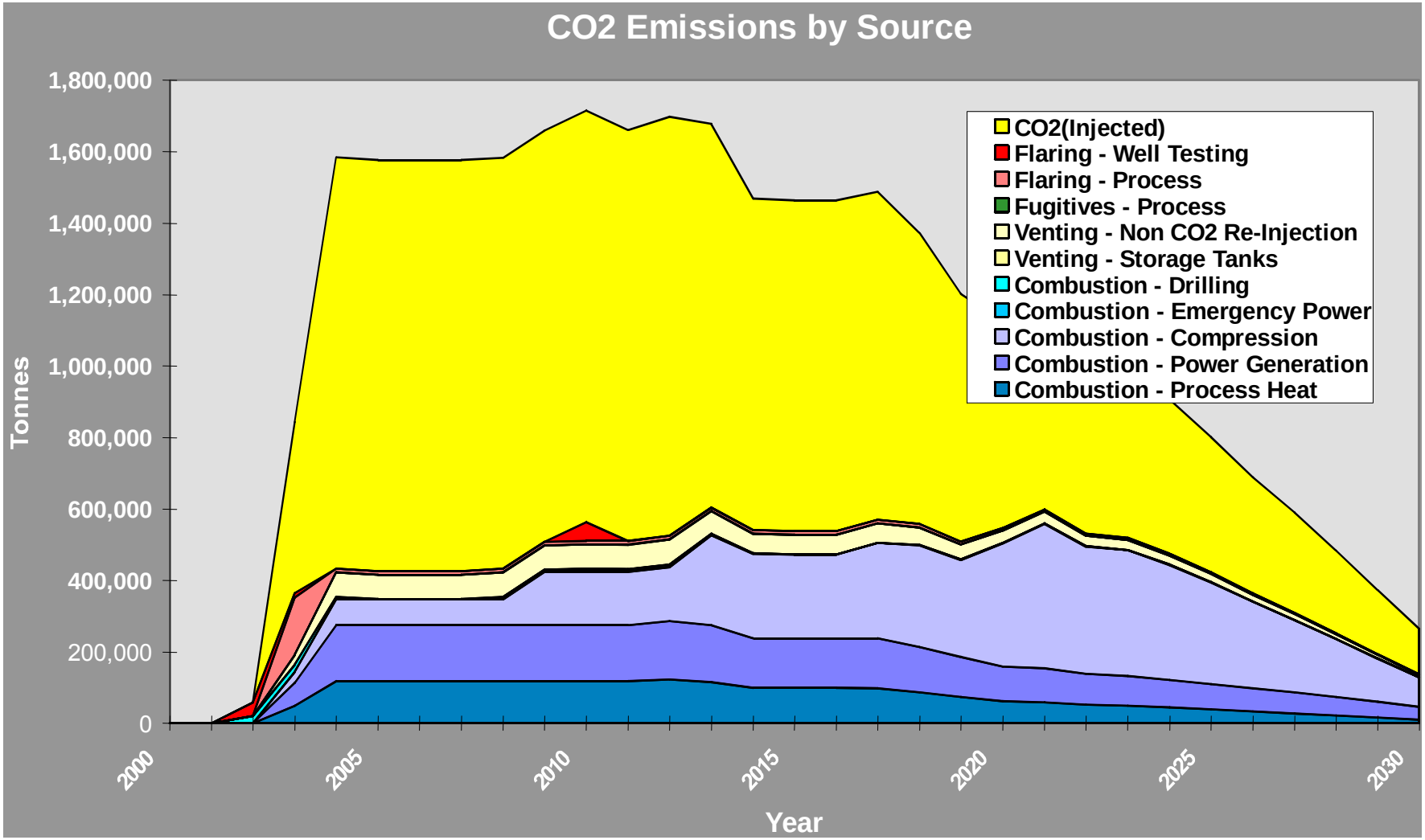
- Developed a **comprehensive understanding of the HSE risks** of, and the requirements for, secure geological storage
  - Geological formations more likely to be secure than man-made wells
  - Depleted oil & gas fields generally be more secure than saline formations

- Assembled a **large database of knowledge**, which will allow the risks associated with geological storage to be quantified and compared to other activities

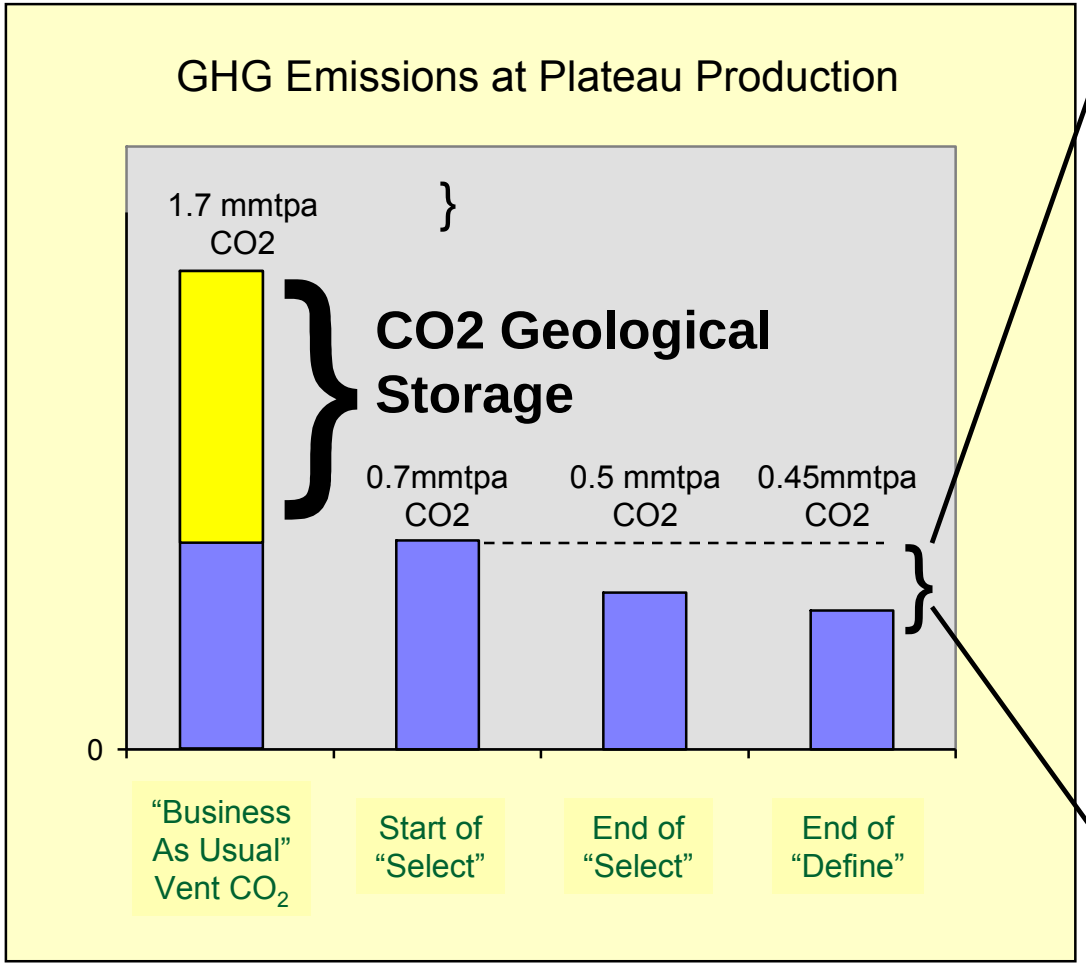
- Developed an extensive repertoire of **monitoring options**, applicable to a broad range of settings

- Potential **leakage scenarios** have been mapped and matched to remediation actions

evaluation of emissions by source



In Salah: GHG emissions reduction



Flaring
- Negligible Continuous Flaring
- Design to Minimise Start-up / Upset Flaring
- Design to Minimise Emergency Flaring
- All Hydrocarbon Relief Ignited

Venting
- Negligible Continuous Hydrocarbon Venting
- Re-Injection of Produced CO_2

Fugitives
- Reduction in Valves
- Valve Specification
- Reduced Flanging (CO_2 Re-injection System)

Fuel Combustion
- Power Generation Waste Heat Recovery
- CO_2 Removal Process Optimisation
- Aero-Derivative Pipeline Compressors
- Deferring Krechba Pipeline Compression
- Reduced CO_2 Re-injection Pressure
- Turbo-Expansion Gas Conditioning
- DLE Gas Turbines for Compression
- Hydraulic Power Turbines (Consideration)

joint industry R&D project

Objectives (2004-08)

1. Provide assurance that secure geological storage of CO_2 can be cost-effectively verified and that long-term assurance can be provided by short-term monitoring.
2. Demonstrate to stakeholders that industrial-scale geological storage of CO_2 is a viable GHG mitigation option.
3. Set precedents for the regulation and verification of the geological storage of CO_2, allowing eligibility for GHG credits