CO_2 Capture Project

Key Findings

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GCEP Workshop

www.co2captureproject.org

Introduction

- Background on the CO_2 Capture Project
  - Who is involved
  - Project objectives
  - Program structure
- Project progress and time line
- Overview of findings of the CCP
  - Capture
  - Storage, monitoring and verification
- Conclusions

Background on the CO_2 Capture Project

CO_2 Capture Project

bp ChevronTexaco EnCana Eni Hydro Statoil Suncor Energy

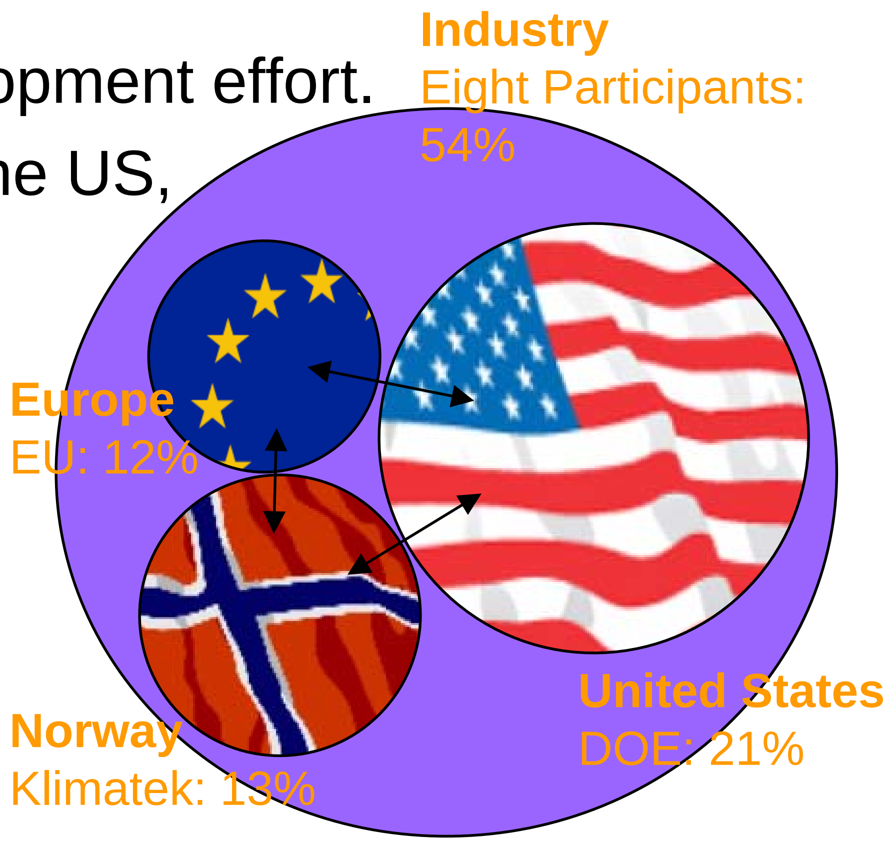
US Department of Energy

European Union

Klimatek NorCap

Program structure

- International technology development effort.
- Distinct *regional* programs in the US, Norway, and European Union.
- Sharing among programs to leverage results and reduce duplication.
- Project funding $25mm
- Project cost $50mm



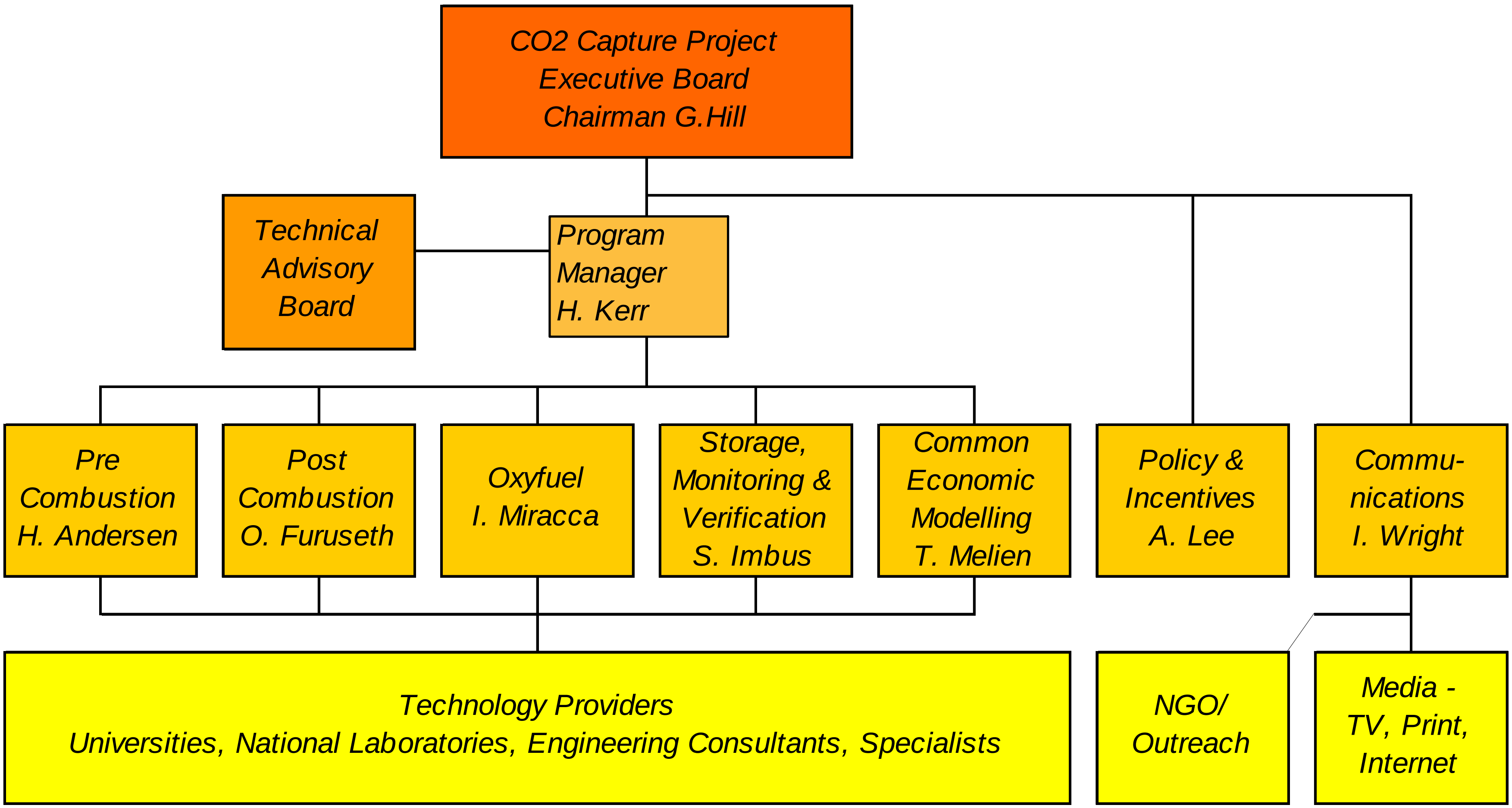
Why focus on capture and geologic storage?

- Fossil fuels will be required to meet the worlds energy needs for the foreseeable future
- Possible to achieve material reductions in CO_2 emissions & provide a bridge to a lower carbon future
- Applicable to broad range of industry sectors
- Cost of decarbonising fossil fuels is currently too high
- Carbon sequestration is needed to make H_2 possible in near/medium term with no/low GHG emissions
- Can provide a win ~ win for both energy security and environment

CO_2 Capture Project objectives

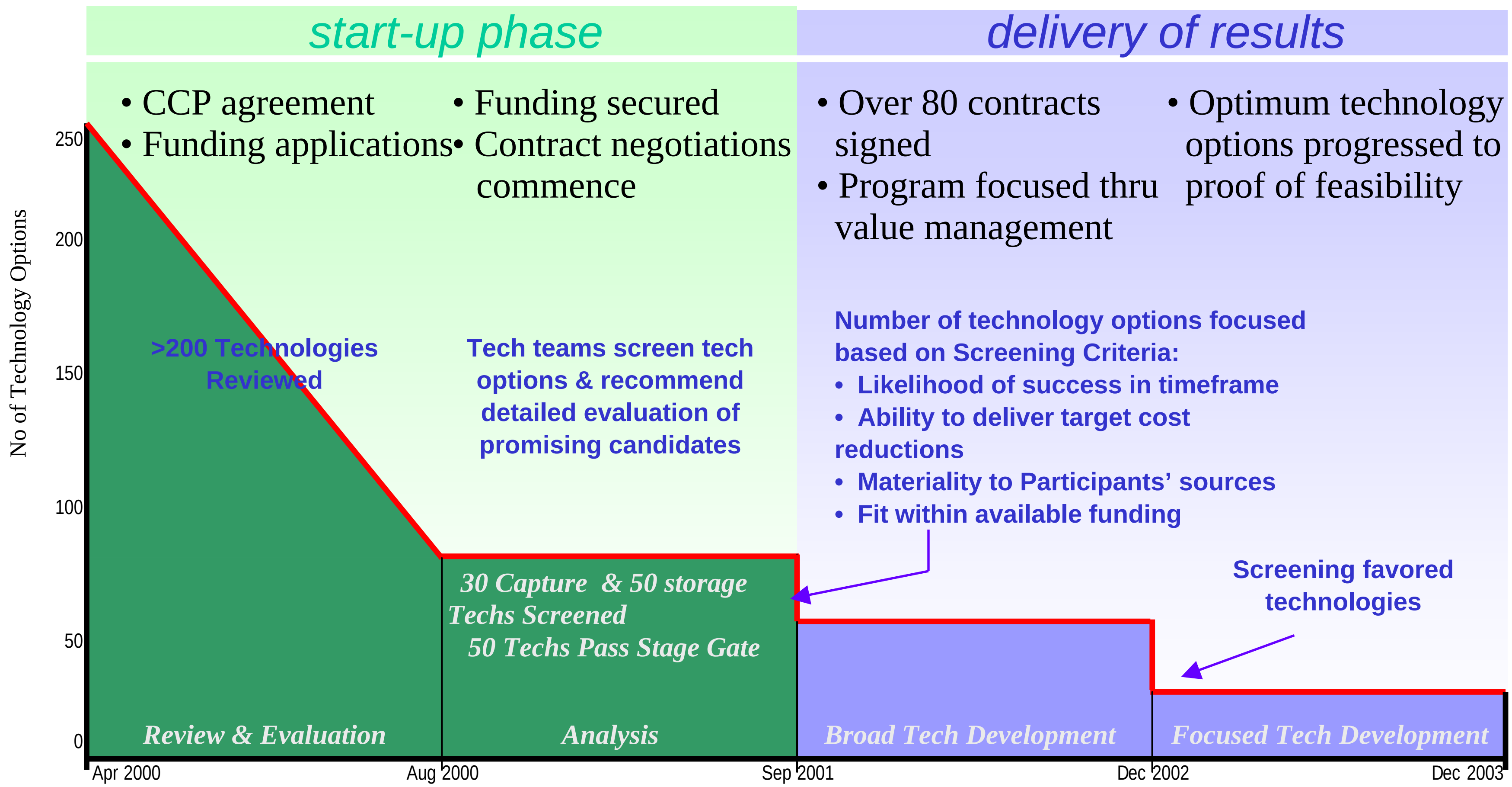
- Achieve major reductions in the cost of CO_2 capture and storage:
  - 50% reduction when applied to a retrofit application.
  - 75% reduction when applied to a new build application.
- Demonstrate to external stakeholders that CO_2 storage is safe, measurable, and verifiable.
- Progress technologies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

CO_2 Capture Project



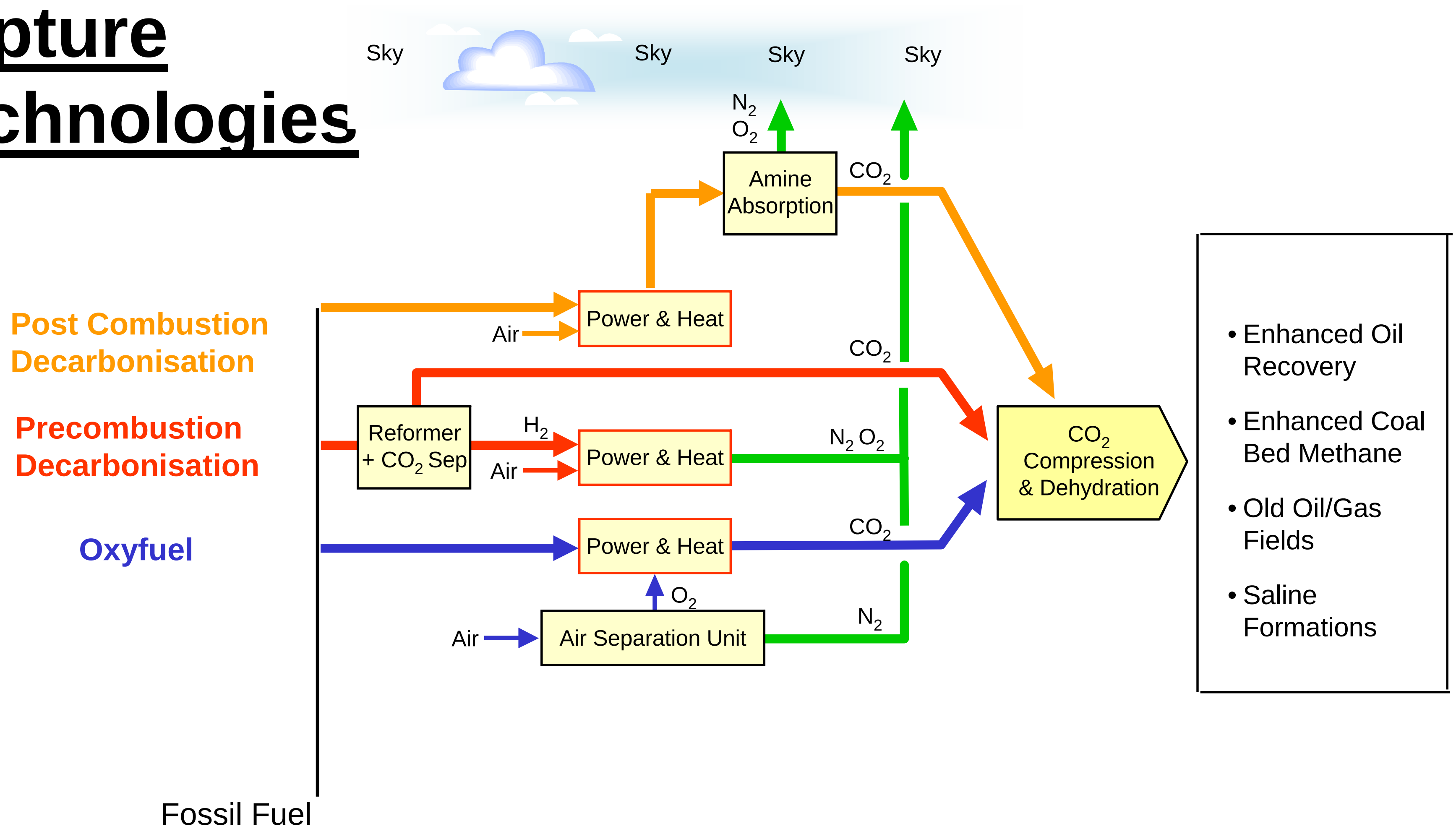
CCP project progress and time line

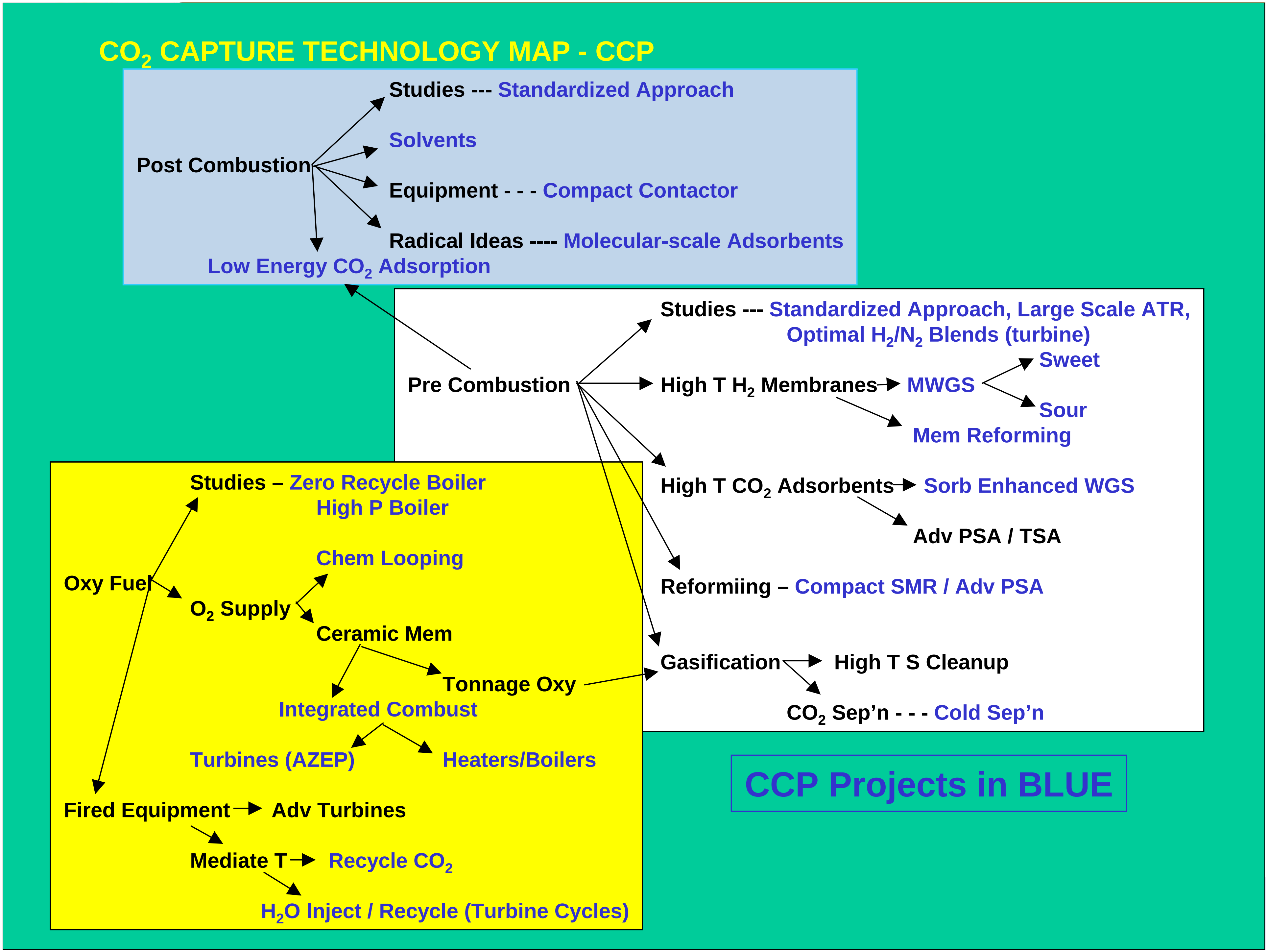
Project overview- we've come a long way!



CO_2 Capture

Capture Technologies





CO2 CAPTURE TECHNOLOGY MAP - CCP
Post Combustion
Studies --- Standardized Approach
Solvents
Equipment - - - Compact Contactor
Radical Ideas ---- Molecular-scale Adsorbents
Low Energy CO2 Adsorption
Pre Combustion
Studies --- Standardized Approach, Large Scale ATR, Optimal H2/N2 Blends (turbine)
High T H2 Membranes
MWGS
Sweet
Sour
Mem Reforming
High T CO2 Adsorbents
Sorb Enhanced WGS
Adv PSA / TSA
Reformiing – Compact SMR / Adv PSA
Gasification
High T S Cleanup
CO2 Sep'n - - - Cold Sep'n
Oxy Fuel
Studies – Zero Recycle Boiler
High P Boiler
O2 Supply
Chem Looping
Ceramic Mem
Tonnage Oxy
Integrated Combust
Turbines (AZEP)
Heaters/Boilers
Fired Equipment
Adv Turbines
Mediate T
Recycle CO2
H2O Inject / Recycle (Turbine Cycles)
CCP Projects in BLUE

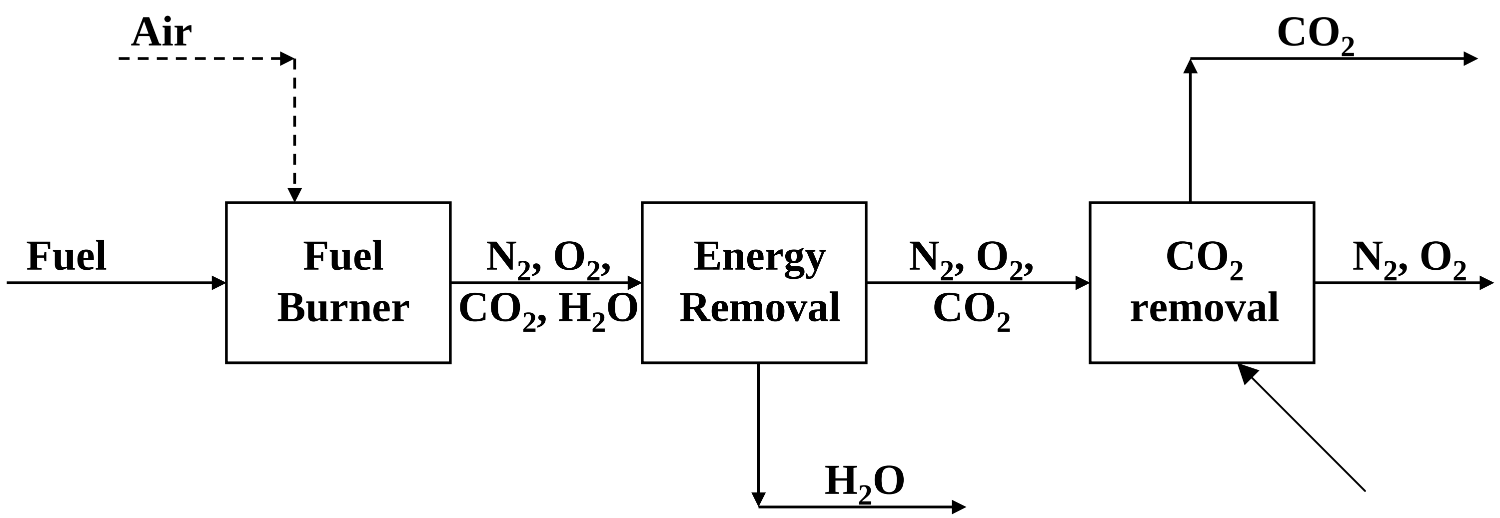
CCP Baseline Scenarios

Scenario	Fuel	CO_2 Source	CO_2 Sink	Capture Target (MM tonne/yr)
Grangemouth Refinery in Scotland	Gas and Fuel Oil	Flue gas from heaters and boilers	Offshore EOR	2.0
Norway 385-MW power plant in Karsto, Norway	Gas	Flue gas from turbine outlet	Offshore EOR	1.1
Alaska Eleven 30-MW gas turbines.	Gas	Flue gas from distributed turbines	Onshore EOR	1.8
Canada Gasification plant	Pet Coke	Syngas from gasifier	Onshore EOR	6.8

Example of avoided CO_2 calculation

- Uncontrolled case
  - Production and emission of 10 million tonnes per year of CO_2
- Controlled case
  - ~20% reduction in efficiency
  - Production of 12 million tonnes/yr of CO_2
  - Capture of 6 million tonnes/yr of CO_2 (50% capture efficiency)
  - Avoided CO_2 = 4 million tonnes/yr (10 – 6)

Basic Post-Combustion Process Scheme



Conventional absorption processes

Post-Combustion CO_2 Capture

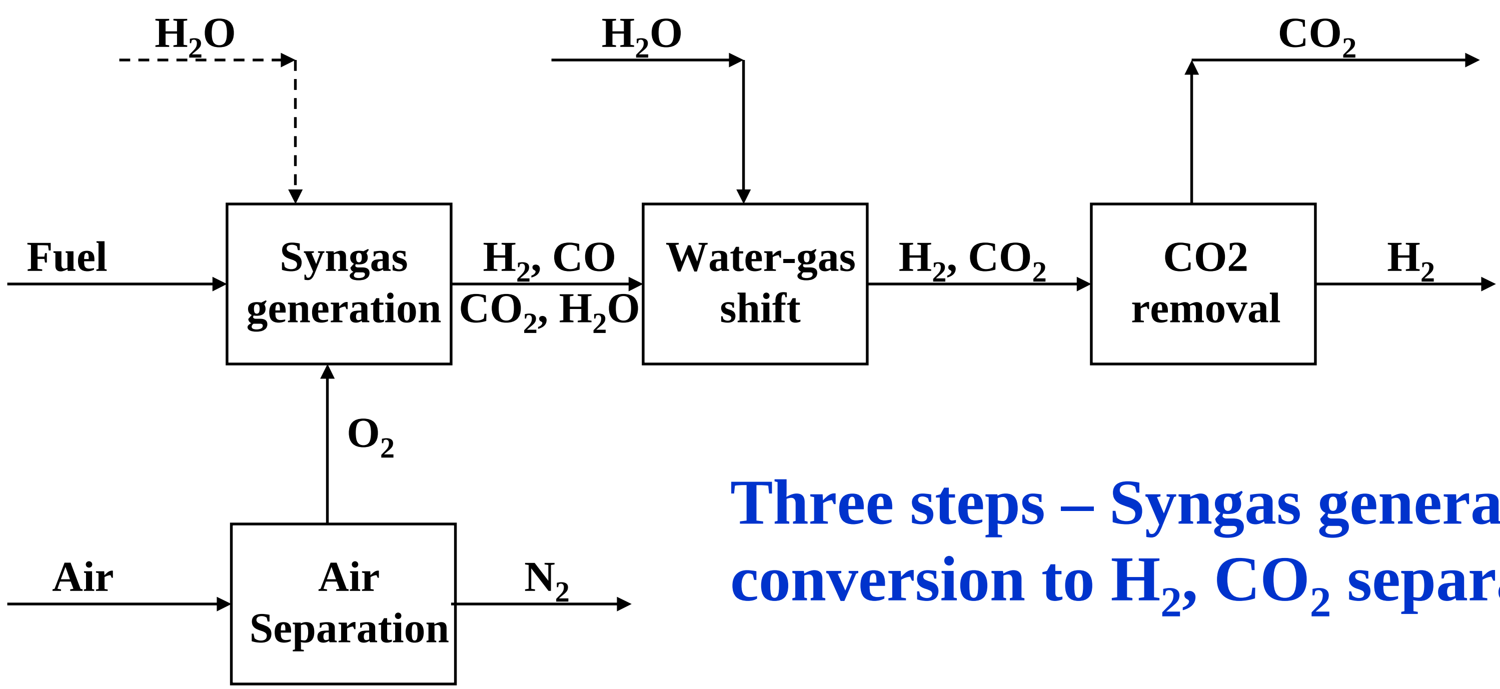
- Key CO_2 sources are boilers, heaters, and turbines
- Flue gas is hot, low pressure, and dilute in CO_2 (4-10 vol.%)
- Current technology is proven and is based on amine scrubbing using very large equipment
- Large energy requirements for CO_2 recovery
- Other flue gas components (e.g., O_2, NO_X, SO_X degrade amines)
- Post-combustion capture used for baseline studies of Norway, Grangemouth and Alaska scenarios
    - Baseline analysis for Canadian scenario used precombustion capture

ECONAMINE[TM] Unit at Bellingham, MA CO_2 Plant
Courtesy of Val Francuz (Fluor) and Cliff Lowe (CVX)

Post Combustion Key Findings

- Post combustion technology is the most mature capture technology, with some technologies ready for deployment today at scale and others close to commercialization;
  - Cost reductions of 43% over BAT at the start of the CCP are reported
  - $35/t CO_2 avoided is now considered possible
  - There is the potential for further cost reductions through process integration and advanced solvents

Basic Pre-Combustion Process Scheme



Three steps – Syngas generation, conversion to H_2, CO_2 separation

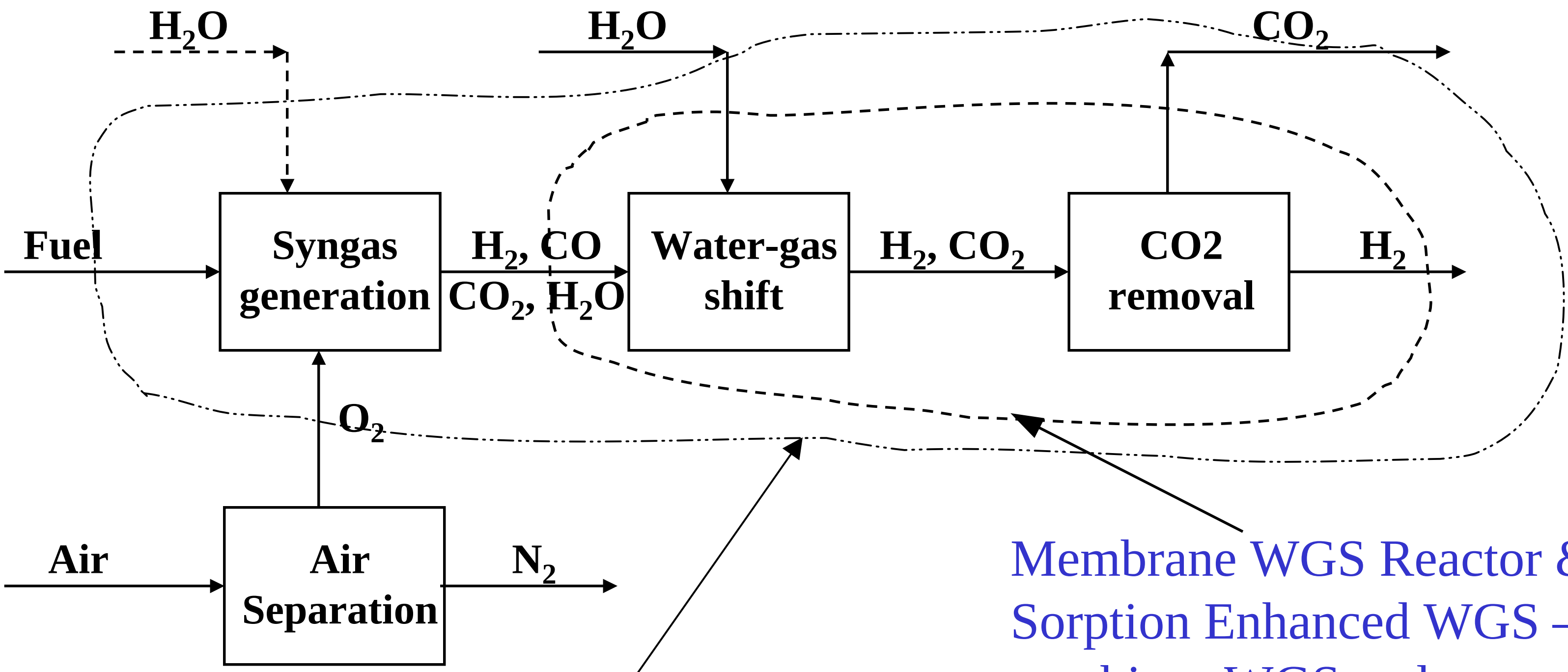
PCDC advantages

- CO_2 removal via solvent absorption is proven
  - Elevated pressures and high CO_2 concentrations aid removal
- Applicable to new-build or retrofit
  - Can be designed as stand-alone – minimum integration
- Possible production of CO_2 at moderate pressures (lower compression costs)
- Produces hydrogen
- Low SOx, NOx
- Flexible fuel sources (gas, oil, coke, coal, etc.)

PCDC disadvantages

- Must convert fuel to syngas first
- Requires major modifications to existing plants
- Gas turbines, heaters, boilers, must be modified for hydrogen firing

PCDC Technology Development



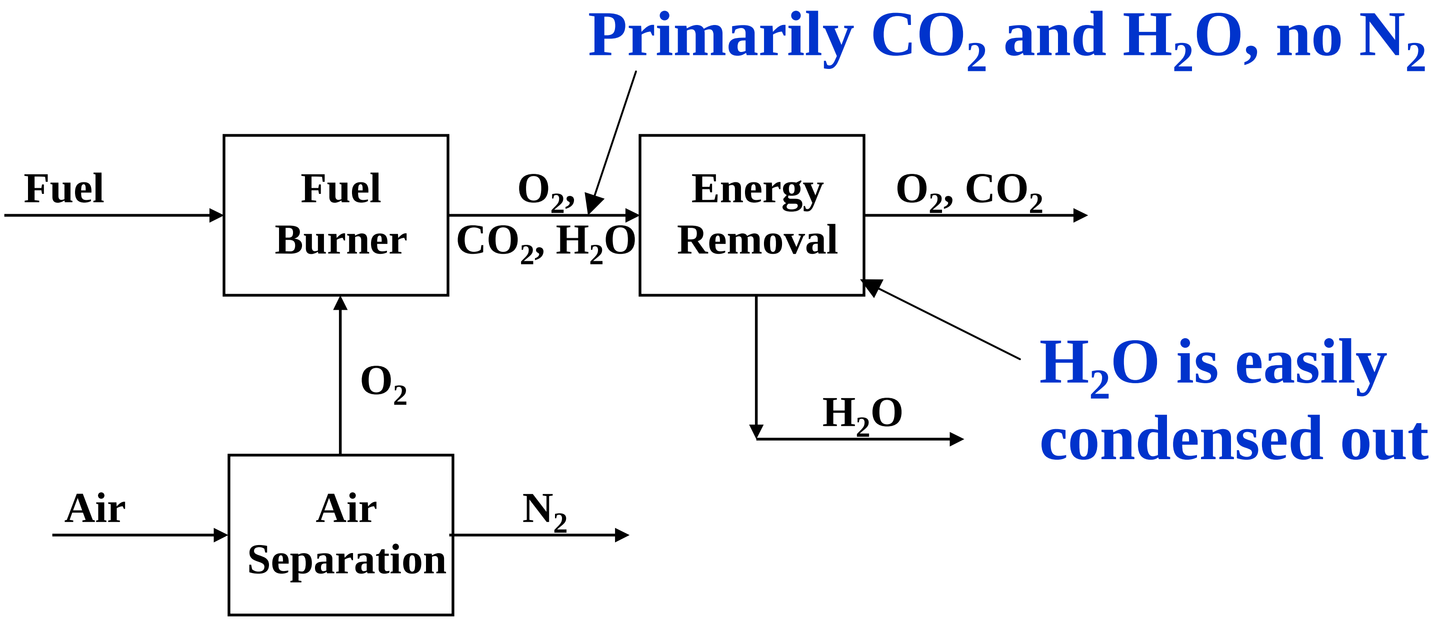
Membrane WGS Reactor & Sorption Enhanced WGS – combines WGS and separation steps

Membrane reformer combines all three separation steps

Pre-combustion Key Findings

- Advanced Pre-combustion technology offers significant long-term cost reduction opportunities and the possibility of hydrogen production with minimal associated CO_2 emissions;
  - Cost reductions of 55% over BAT at the start of the CCP
  - For situations where syngas must be produced for reasons other than carbon sequestration (for example to make H_2 or to produce power by IGCC), the incremental cost to capture CO_2 can be as low as $15/t."
  - Process step reduction and H_2 membranes offer significant capital cost reductions and further potential for reducing CO_2 avoided cost

Basic OxyFiring Process Scheme



Oxyfiring CO_2 removal

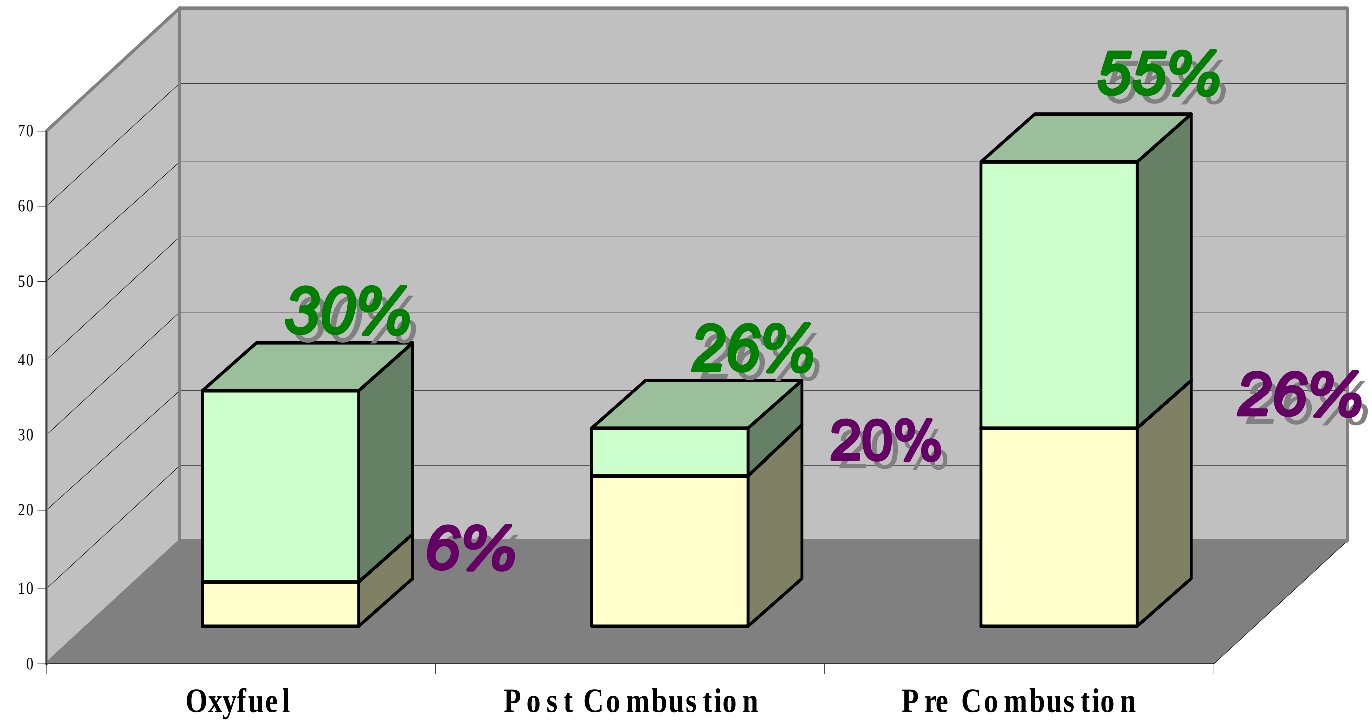
- Uses oxygen instead of air for fuel combustion
- Advantages
  - No CO_2 removal process required
  - CO_2 could be produced at moderate pressures
- Disadvantages
  - Requires an expensive air separation plant
  - Gas turbines, heaters, boilers, must be modified (higher combustion temperatures)
    - CO_2 recycle or H_2O may be required for temperature moderation

Oxyfiring Key Findings

- Oxyfiring can be practiced today using conventional air separation technology, along with flue gas recycle, in boilers and heaters – even in retrofit applications – at a cost less than the Baseline.
  - Cost reductions of 40% over BAT at the start of the CCP are reported
  - \$30/t CO_2 avoided is now considered possible through application of state of the art technology with heaters and boilers
  - Additional benefit of eliminating over 90% emissions of NOx
  - Oxy firing technology using advanced ceramic membranes for oxygen separation is a longer term capture technology that has great potential
  - Application with (gas) turbines requires further significant technology development to deal with the high thermodynamic energy from this process. The CCP has made important advances in this area and identified promising technologies for further development.

CO_2 Avoided Cost Reductions*

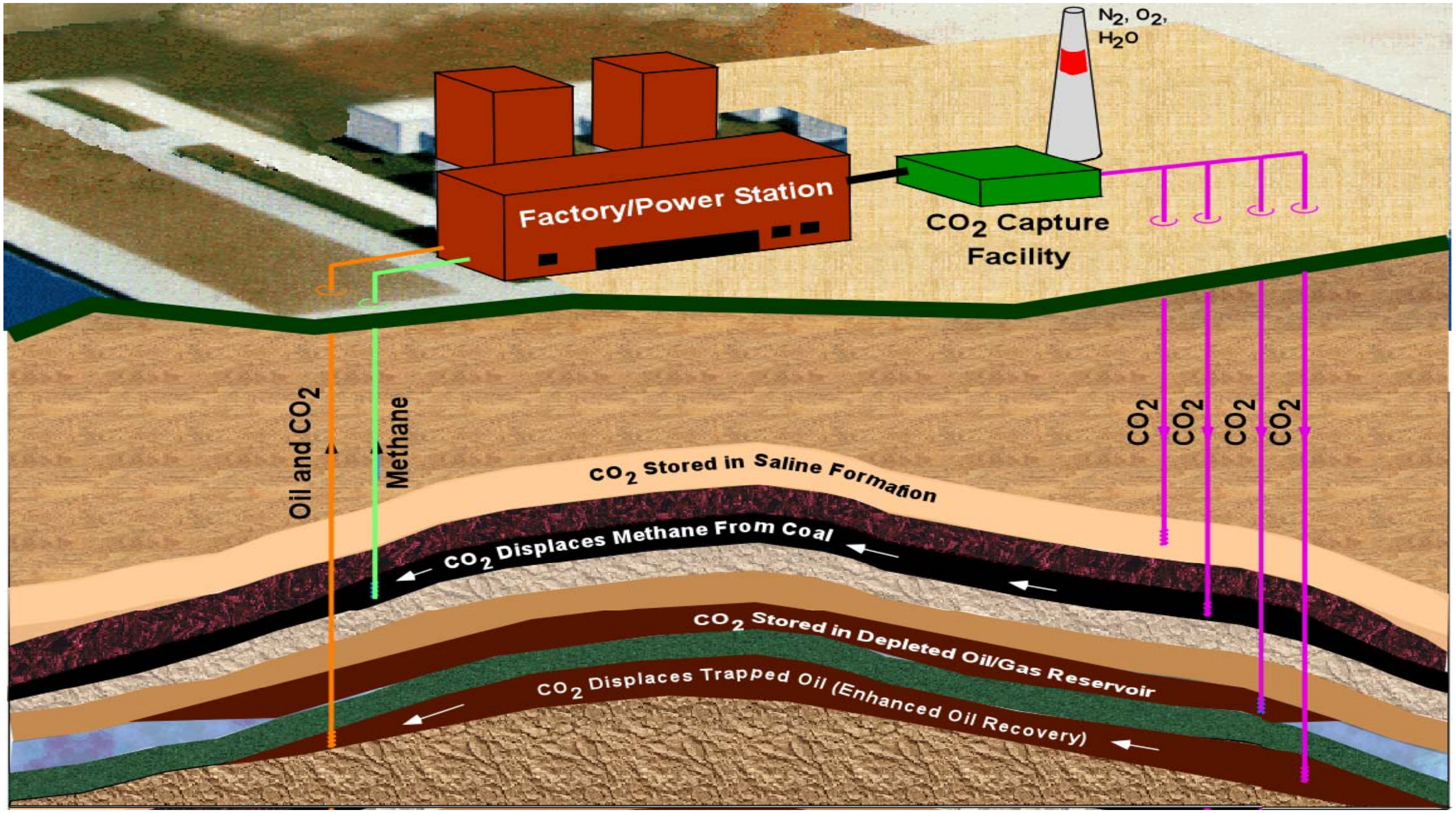
[redacted]



* Preliminary data , +/- 30% cost estimates, minimum and maximum data points shown

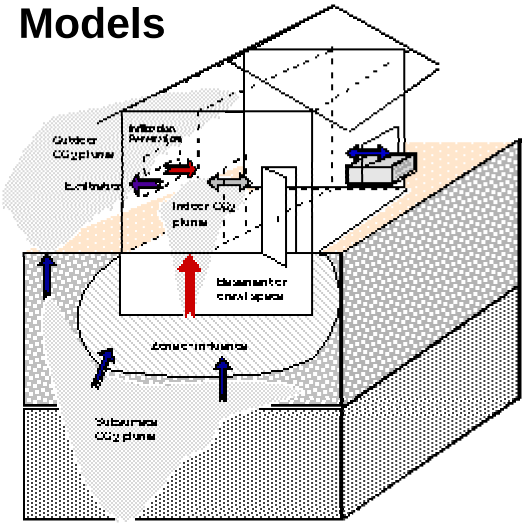
Storage, Monitoring and Verification (SMV)

Storage technology

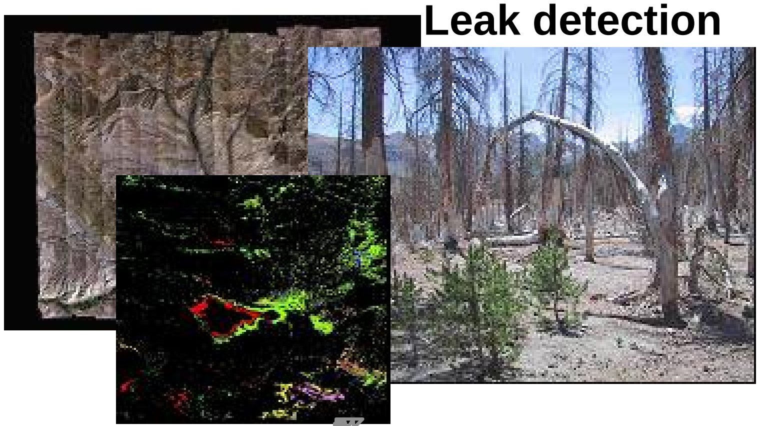


CO_2 Capture Project

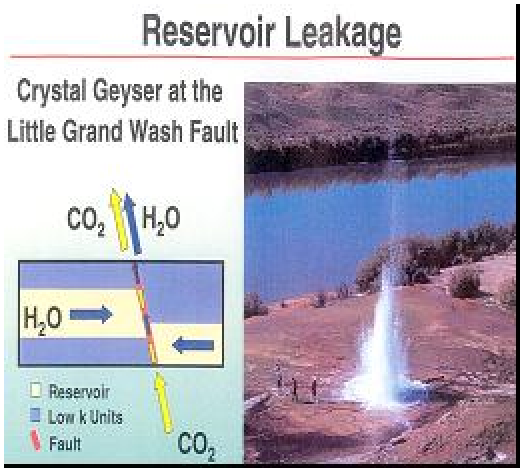
Models



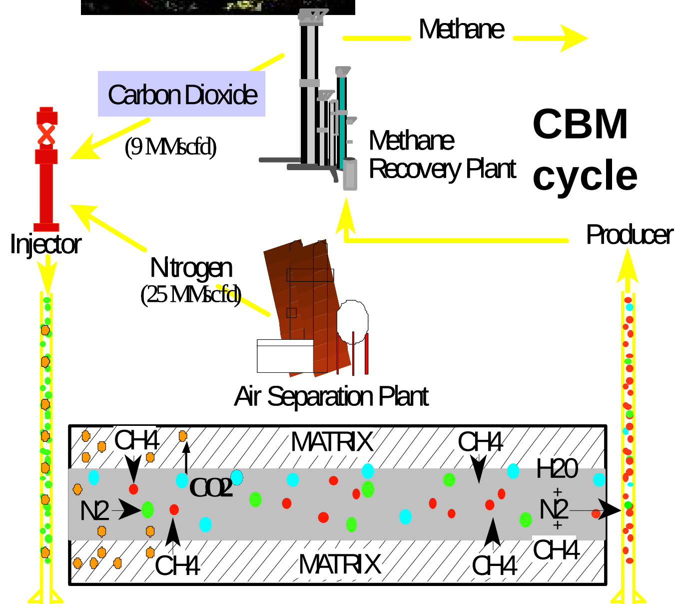
Leak detection



Natural analogs

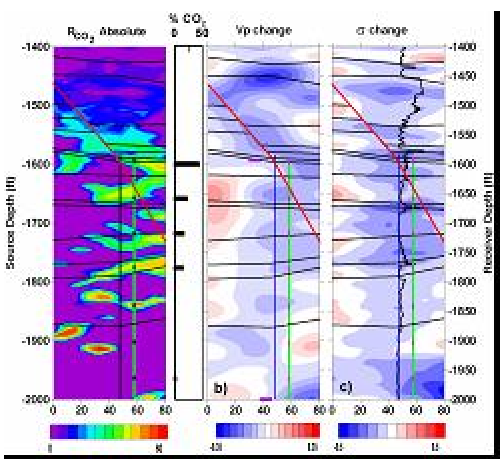


CBM cycle



Caprock mechanics

Reservoir movement



SMV Program

Four Technical Areas

- **<u>Integrity</u> – Competence of Natural / Engineered Systems**
- **<u>Optimization</u> – Economic Offsets, Efficiency, Transportation**
- **<u>Monitoring</u> – Performance and Leak Detection**
- **<u>Risk Assessment</u> – Probability x Consequences, FEPs, Methodologies, Modeling, Mitigation / Remediation**

SMV Key Messages

- Much has been learned from natural CO_2 analogues,
- Well integrity is likely to be more critical than most geologic factors in the longer term.
- CO_2 used in EOR, EGR and ECBM applications has the potential to offset the cost of anthropogenic CO_2 capture.
- The feasibility of diverse, low cost monitoring techniques has been assessed and leading technologies identified for further development.
- Two comprehensive RA methodologies were independently developed and tested.
- Leakage intervention / remediation opportunities identified

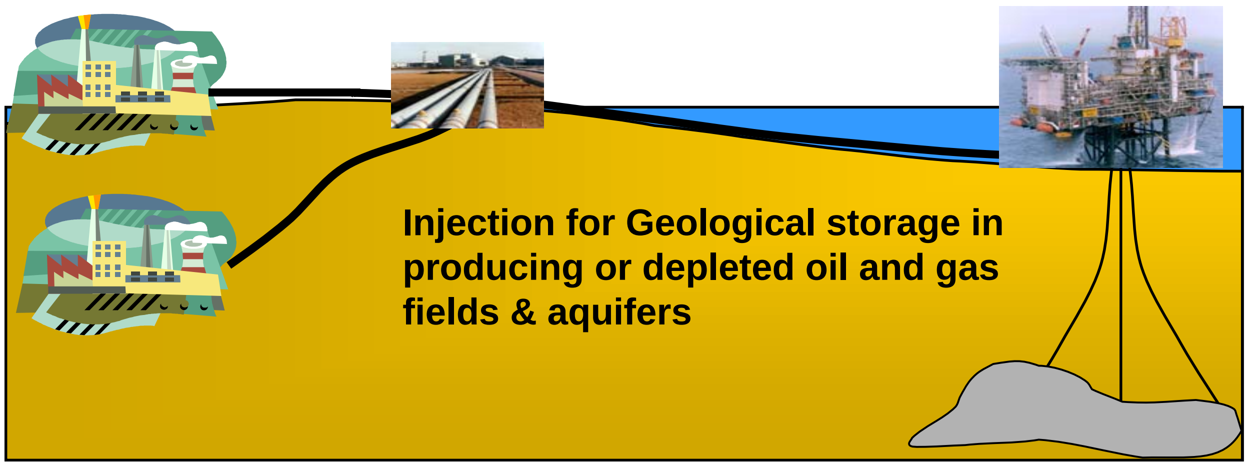
Progress in other program areas

- **Common Economic Model** - methodology developed and used for cost comparison and technology selection
- **Policy and Incentives** - conducted review of current policy matters and identified opportunities and barriers for technology development and application
- **Technology Advisory Board** – provided an unbiased review of project technology and progress
- **Communications** – communications strategy and engagement of NGO's from an early stage

CO_2 cost chain

Power & Industrial processes with CO_2 capture and conditioning

CO_2 export terminal and pipeline infrastructure



Cost $3 – 160 /t → $1 - 25/t* → $2 - 5/t* = **$ 6 – 190/t****

* Cost is distance dependant

*long term monitoring costs to be determined

** These numbers are indicative only

Overall Conclusions

- ✓ Industry and governments have come together, on an international scale to provide strong leadership on technology development
- ✓ A portfolio of technologies with broad application have been developed and represent state-of-the-art
- ✓ Technology R&D is producing step reductions in cost
- ✓ CO_2 sequestration must be proactively managed to reduce risks and ensure broad acceptance
- ✓ Communication and publication of results is in hand
- ✓ Visit www.co2captureproject.org for more information
- ✓ Planning in hand to build on this success with CCP2