CCS in Industrial Processes

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Cheltenham, UK

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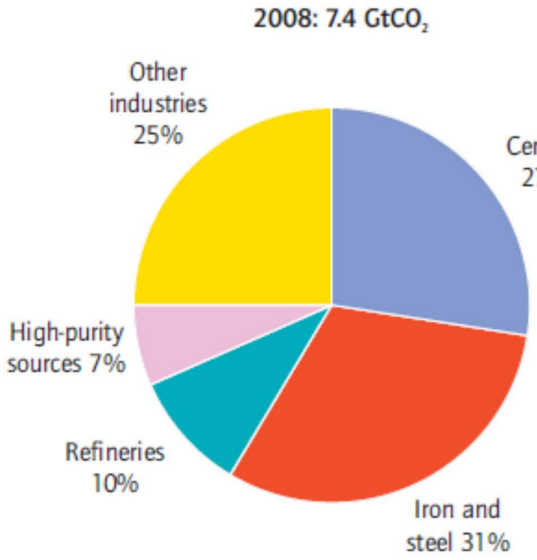
www.ieaghg.org

IEA Greenhouse Gas R&D Programme (IEAGHG)

- A 'Multilateral Technology Initiative' based in the UK, established in 1991 by the International Energy Agency
- Aim:
  To provide information on the role that technology can play in reducing greenhouse gas emissions from use of fossil fuels. Objective, independent, policy relevant but not policy prescriptive
- Focus on CCS
- Activities:
  - Technical studies - over 250, freely available to our member countries
  - Organise networks of researchers, conferences and summer schools
  - Provide information to policy makers and regulators

Industrial Sources of CO_2

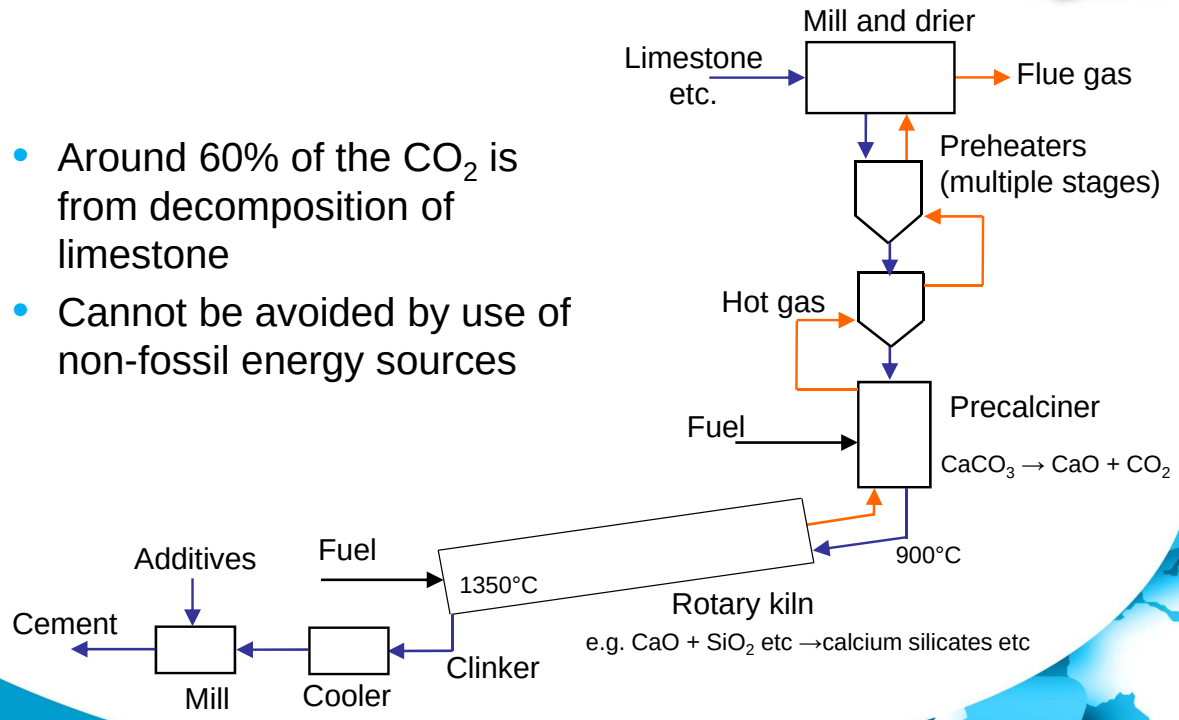


Source: IEA/UNIDO Technology Roadmap, Carbon capture and storage in industrial applications, 2011

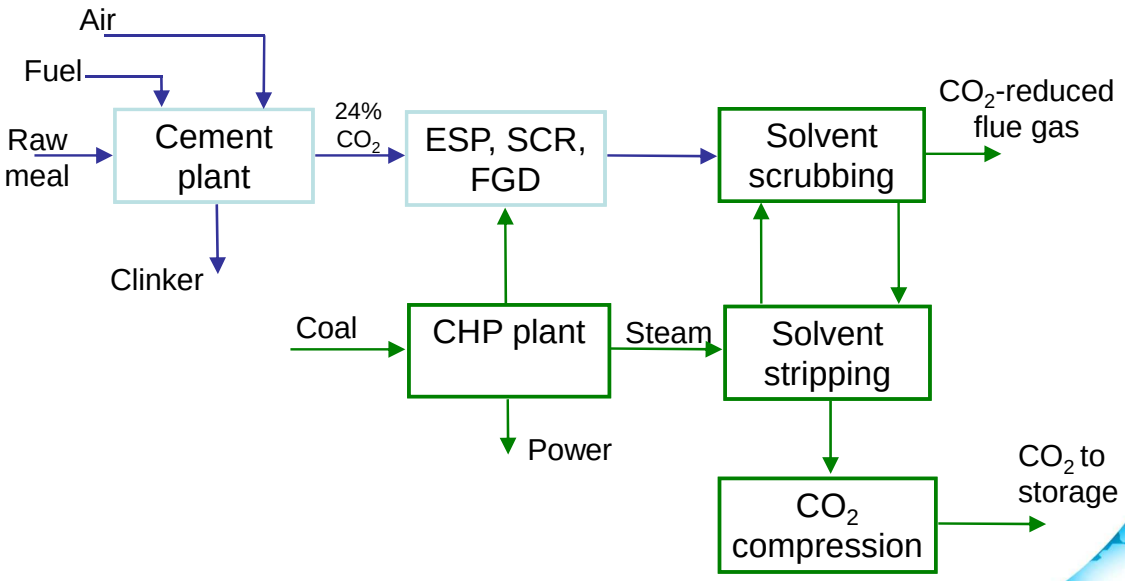
- About a quarter of global emissions
- A large proportion of emissions are in developing countries

Cement Production

- Around 60% of the CO_2 is from decomposition of limestone
- Cannot be avoided by use of non-fossil energy sources



Post Combustion Capture
Solvent scrubbing

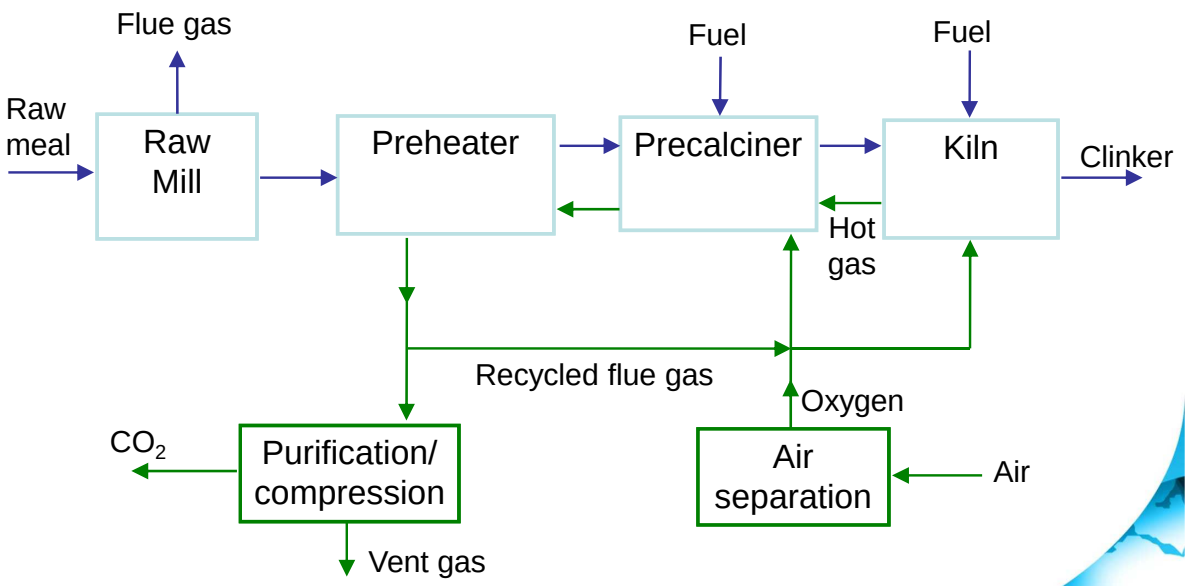


Post-combustion Capture

- Advantages for cement plants
  - Flue gas CO_2 concentration is high (around 24%vol.)
    - Advantageous, particularly for alternative capture technologies
  - The cement plant itself is unaffected
    - But more stringent flue gas cleaning may be needed
  - Retrofit to existing plants is possible
    - Provided space is available and CO_2 can be transported off site
- Disadvantages
  - A large quantity of low pressure steam is needed for solvent stripping, requiring an on-site CHP plant
    - Coal is usually available at cement plants but coal CHP plants have relatively high investment costs and high emissions
    - Natural gas CHP plants have lower investment costs

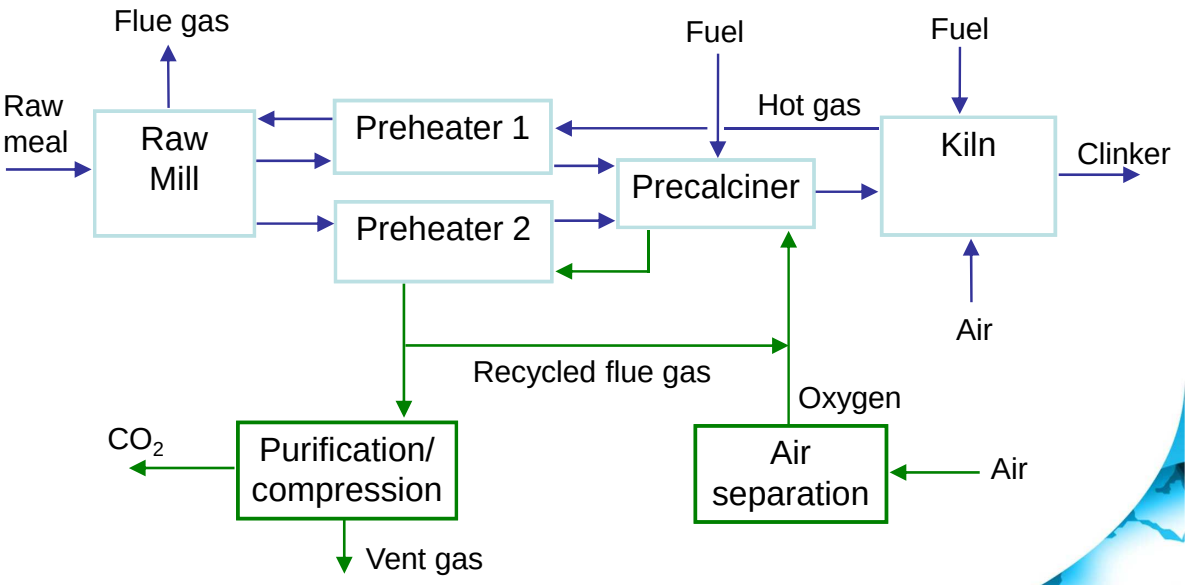
Oxy-Combustion Capture

Precalciner and kiln



Oxy-combustion Capture

Pre-calciner only



Oxy-combustion Capture

- Advantages for cement plants
  - Low oxygen consumption
    - 1/3 of the amount of O_2 is needed per tonne of CO_2 captured, compared to a coal fired boiler
  - Potentially low cost process
- Disadvantages
  - Retrofit may be more difficult
  - Involves changes to the core cement process
    - Impacts on plant design and chemistry etc.

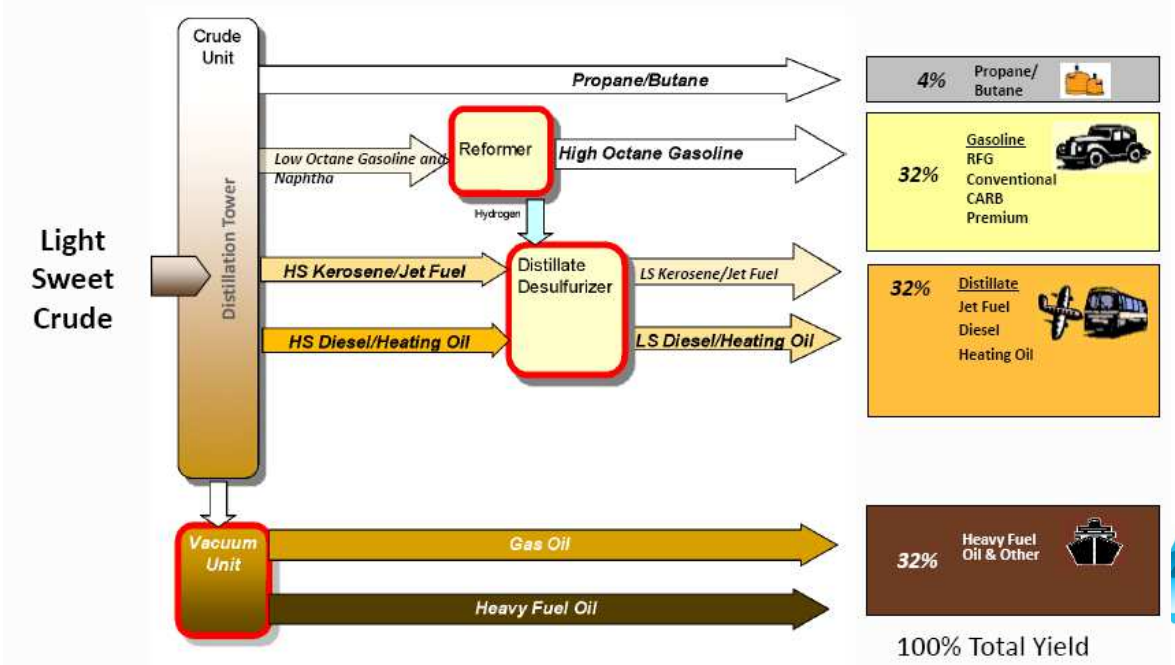
Status of Cement Plant CCS

- Post combustion capture
  - Test centre for small scale and pilot trials at a cement plant, Norcem, Brevik, Norway
    - Amine scrubbing, Dry adsorption, Membranes, Ca looping
  - ITRI/Taiwan Cement Corp.
    - 1t/h CO_2 calcium looping unit
  - Skyonic Corp, Texas
    - 83 kt/y CO_2 plant at a cement plant, $NaOH + CO_2 \rightarrow NaHCO_3$
- Oxy-combustion
  - Laboratory studies – ECRA, Germany
  - Pre-calciner pilot plant, Denmark,
    - Lafarge, FL Smidth, Air Products, c1t/h CO_2

Oil Refineries

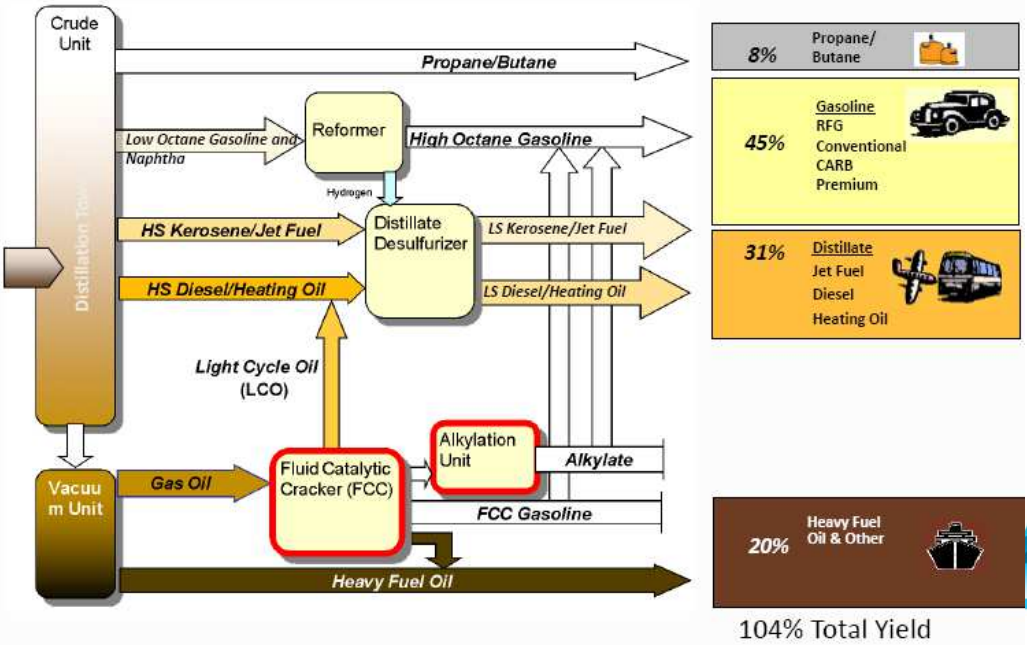
- Many CO_2 emission sources
- Complex plants - all are different
- Space can be a constraint for retrofits
- Design standards for capture plants at refineries may be different to power plants
  - Potentially higher costs

Hydroskimming/Topping Refinery



Simple, low upgrading capability refineries run sweet crude

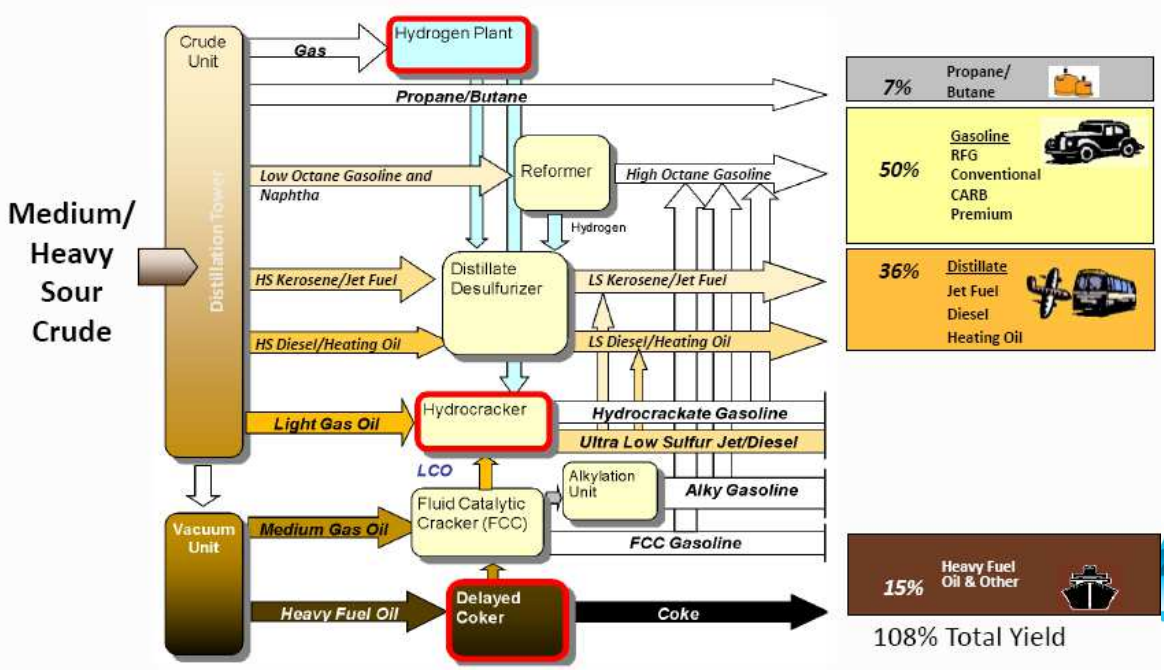
Medium Conversion: Catalytic Cracking



104% Total Yield

Moderate upgrading capability refineries tend to run more sour crudes while achieving increased higher value product yields and volume gain

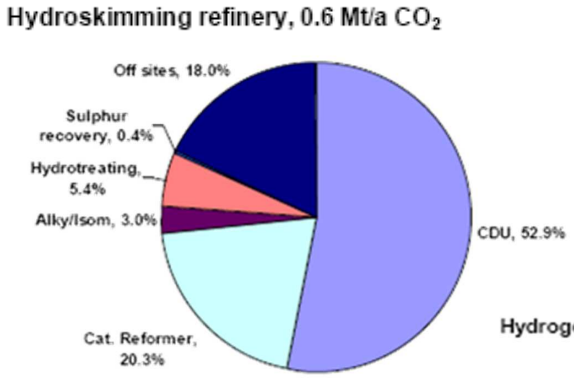
High Conversion: Coking/Resid Destruction

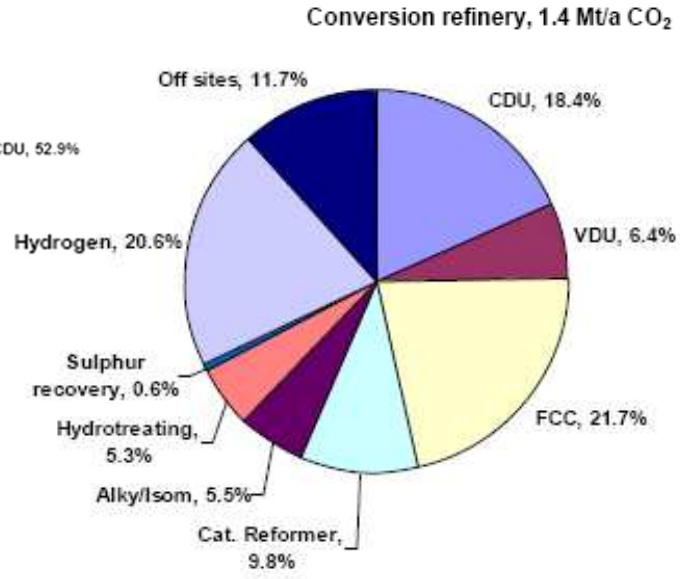


108% Total Yield

Complex refineries can run heavier and more sour crudes while achieving the highest light product yields and volume gain

Emissions from Simple and Complex Refineries





CDU: Crude distillation unit
VDU: Vacuum distillation unit
FCC: Fluid catalytic cracker

Data from CONCAWE 2011

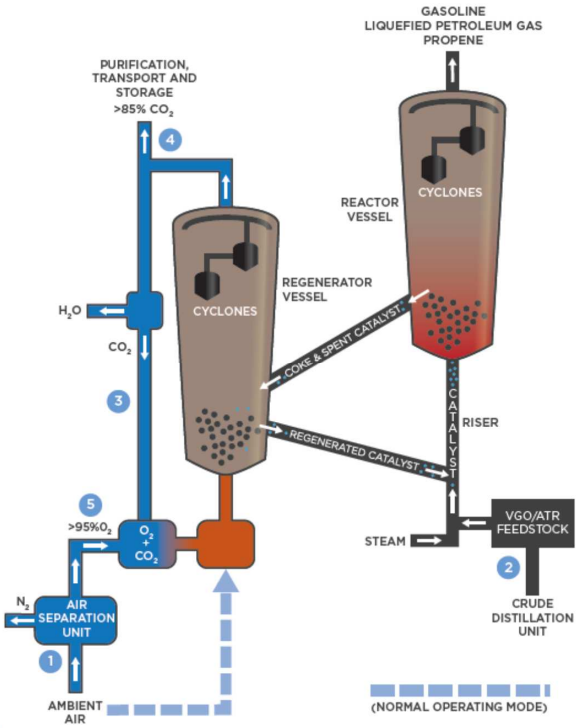
CO_2 Capture at Refineries

- Post combustion capture
  - Fired heaters, fluid catalytic cracker and utility steam and power generation
  - Centralised solvent stripping may be feasible
- Pre-combustion capture
  - Hydrogen plants (steam reforming, residue gasif.)
  - Hydrogen could also be used in fired heaters and utility steam and power generation
- Oxy-combustion
  - Fired heaters and steam/power generation
  - Fluid catalytic crackers

Capture from Refinery Flue gas
Test Centre Mongstad, Norway

- 2 capture plants: Amine and Chilled Ammonia processes
- 100,000t/y CO_2 capture
- Flue gases from the refinery:
  - Combined cycle power plant
  - Fluid catalytic cracker

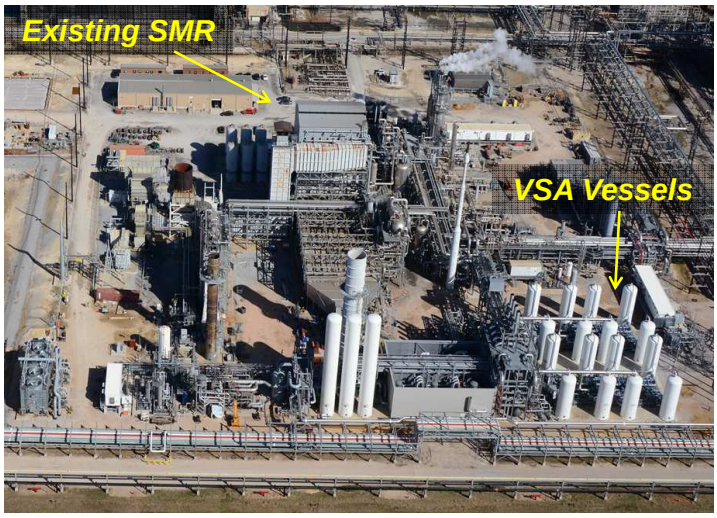
Oxy-Combustion FCC



Courtesy: CCP / Petrobras

- Retrofit at Petrobras research facility, Brazil
- 1t/d CO_2
- Operated 2011-12
- CCP consider oxy-combustion to be viable and competitive with post combustion capture for FCCs

Capture at a Hydrogen Plant
Air Products, Port Arthur, Texas



- Capture retrofit to 2 steam methane reformer units
- Vacuum swing adsorption process
- 1Mt/y CO_2 for EOR
- >90% CO_2 capture
- Started operation Dec. 2012 / March 2013

Capture at a Hydrogen Plant
Shell Quest Project, Canada

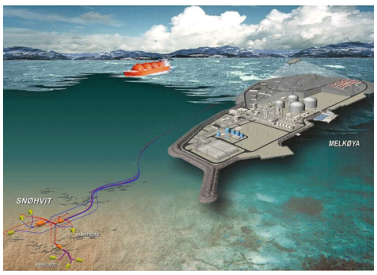
- Capture of CO_2 from 3 steam methane reformer units
- H_2 provided to the Athabasca Oil Sand Upgrader
- Shell amine technology (ADIP-X system based on MDEA/Pz)
- ~1.2 million tonne of CO_2/y
- Saline Aquifer with potential EOR application
- Operation starts 2015/16

Natural Gas Processing

- CO_2 sometimes has to be separated from natural gas to satisfy purity standards
- Separation is usually by amine scrubbing, e.g. MDEA
- Physical solvents and low temperature separation are also used for high CO_2 gas
- CCS is a low cost “Low hanging fruit”
  - CO_2 just has to be compressed and dried
- Several million tonnes/year of CO_2 separated from natural gas is used for EOR
- CO_2 is also used for storage demonstration projects

CO_2 Capture in Gas Production

Sleipner, Norway; 9% CO_2,
Around 1 Mt/y CO_2 captured



Snøhvit, Norway; 5-8% CO_2
Around 0.7 Mt/y CO_2 captured

LaBarge, USA; 65% CO_2,
Around 6 Mt/y CO_2 captured
and used for EOR

In Salah, Algeria; up to 10% CO_2
Around 1.2 Mt/y CO_2 captured

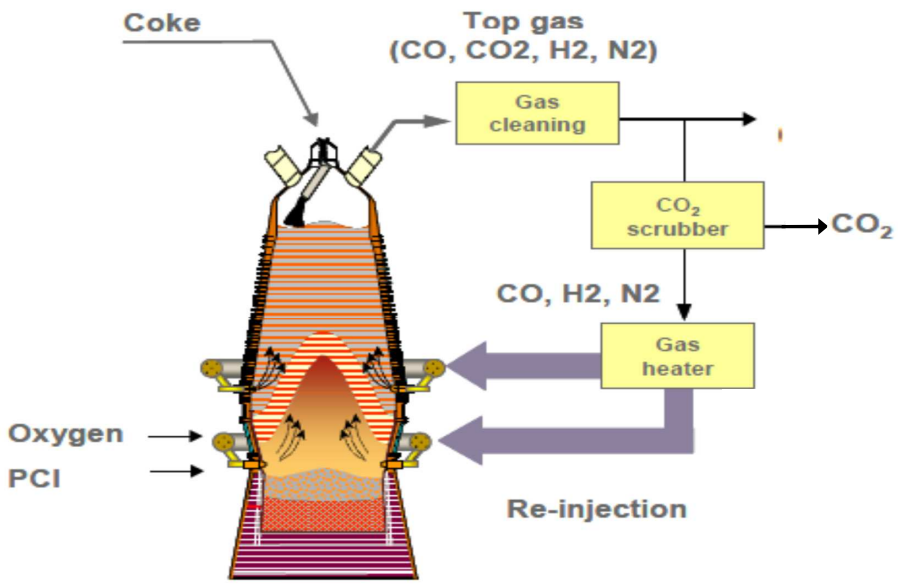
Other High Purity CO_2 Sources

- Bio-ethanol production
  - Dacatur project, USA, 1Mt/y CO_2
- Synthetic natural gas from coal
  - Dakota Gasification plant, USA, ~2.5Mt/y CO_2
- Coal-based chemicals plant
  - Coffeyville ammonia plant, USA, ~0.7Mt/y CO_2
  - Many Chinese coal to

Capture at Iron and Steel Plants

- Some of the world's largest sources of CO_2
- Steel plants are complex integrated plants with many sources of emissions
- Blast furnaces are the core of most large plants
  - Chemical reduction of iron oxide to iron
  - The focus of capture R&D, e.g Europe (ULCOS project), Japan (COURSE 50 project), and Korea
- New iron and steel processes with integrated capture are being developed

Oxy-Blast Furnace
Top Gas Recycling



Courtesy: Tata Steel

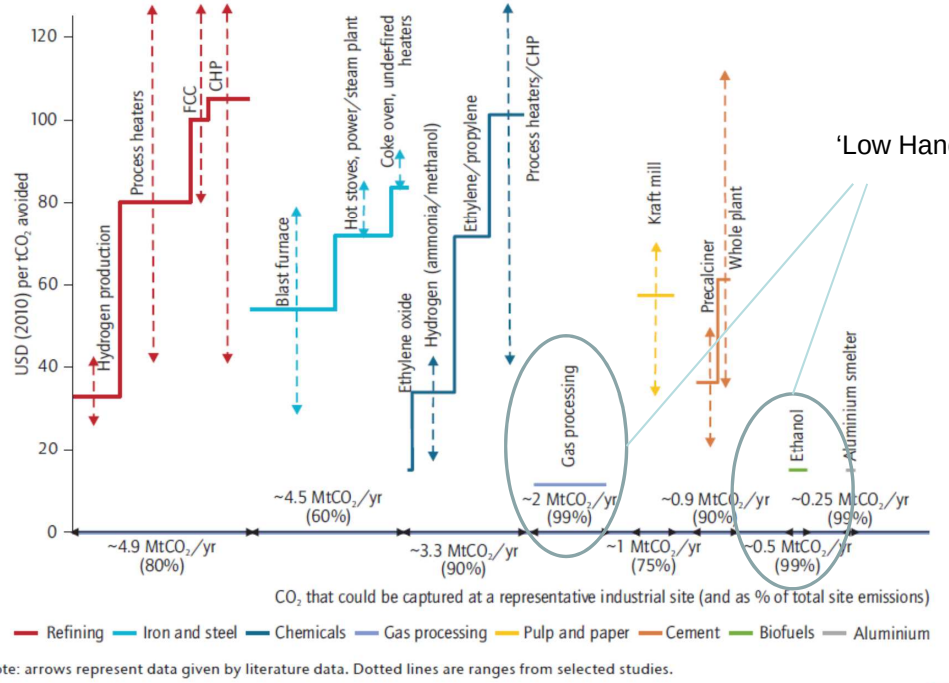
Technical Issues for CCS in Industries

- CO_2 capture technologies are well proven for some industries but not others
- Need to demonstrate CCS, particularly in cement, iron and steel and refineries
  - Different CO_2 concentrations and pressures
  - Impacts of different impurities
  - Operational profiles etc.
  - Develop and demonstrate new processes with integrated CO_2 capture
- Learn from technology demonstrations in the power sector

Costs of CCS in Industries

- Shortage of information on industrial CCS costs
  - Especially for developing countries, where most industrial emissions occur
- Estimating costs is difficult
  - Different costs for each CO_2 source at each site
  - Partial capture of CO_2 at a site may be preferred

Industrial CCS Costs



'Low Hanging Fruit'

Note: arrows represent data given by literature data. Dotted lines are ranges from selected studies.

IEA CCS Technology Roadmap 2013

Economics of Industrial CCS

- Some industrial capture is already economic
  - CO_2 is sold, particularly for EOR
- Economic incentives for industrial CCS without CO_2 utilisation in most countries are low or zero
- High potential for “leakage”
  - Industrial products are traded globally, unlike electricity
  - Transfer of production to countries with low GHG abatement requirements may be the most attractive choice for industries
  - A significant challenge for policy makers

Conclusions

- Technology status
  - CO_2 is already captured in some industries but is at a relatively early stage of development in other industries
  - Further R&D and demonstration is needed, particularly for iron and steel, cement and oil refineries
  - Industries can learn from deployment of CO_2 capture technologies in the power industry
- Economics
  - Industrial CCS cost estimates have high uncertainties
  - EOR can make some industrial CCS economic but further incentives are needed in most cases
  - Agreements are needed to minimise the risk of industries re-locating to countries where CCS is not required

Thank you

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