CCS in Industrial Processes

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IEA Greenhouse Gas R&D Programme

Cheltenham, UK

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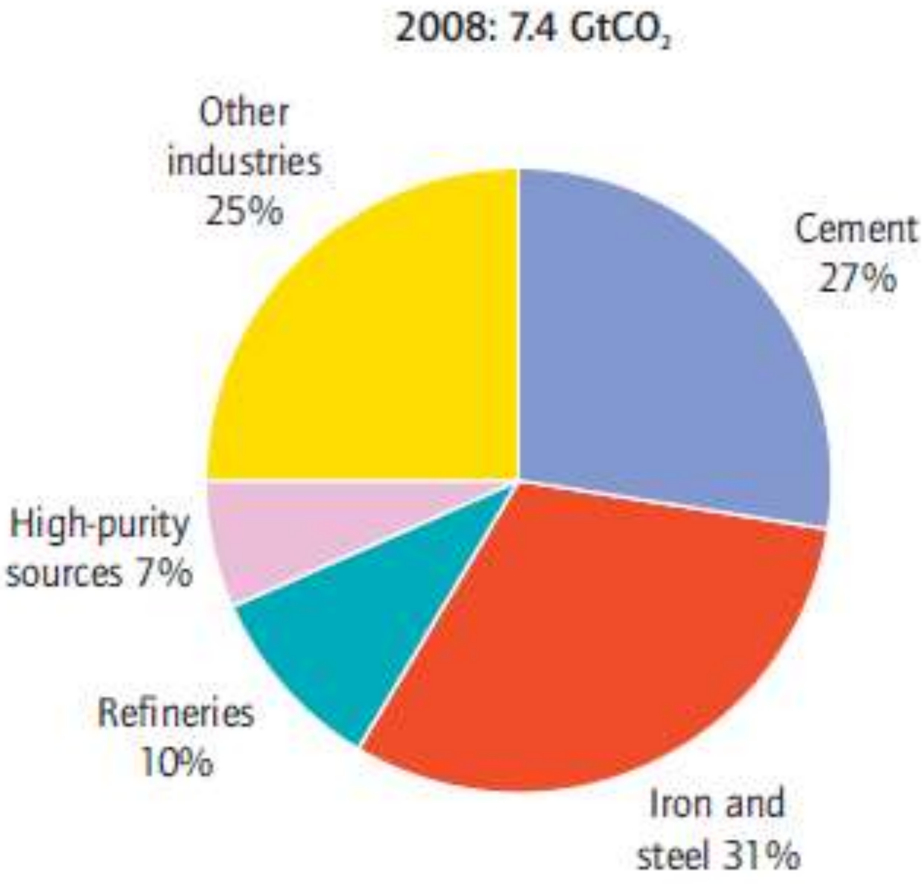
IEA Greenhouse Gas R&D Programme (IEAGHG)

- 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

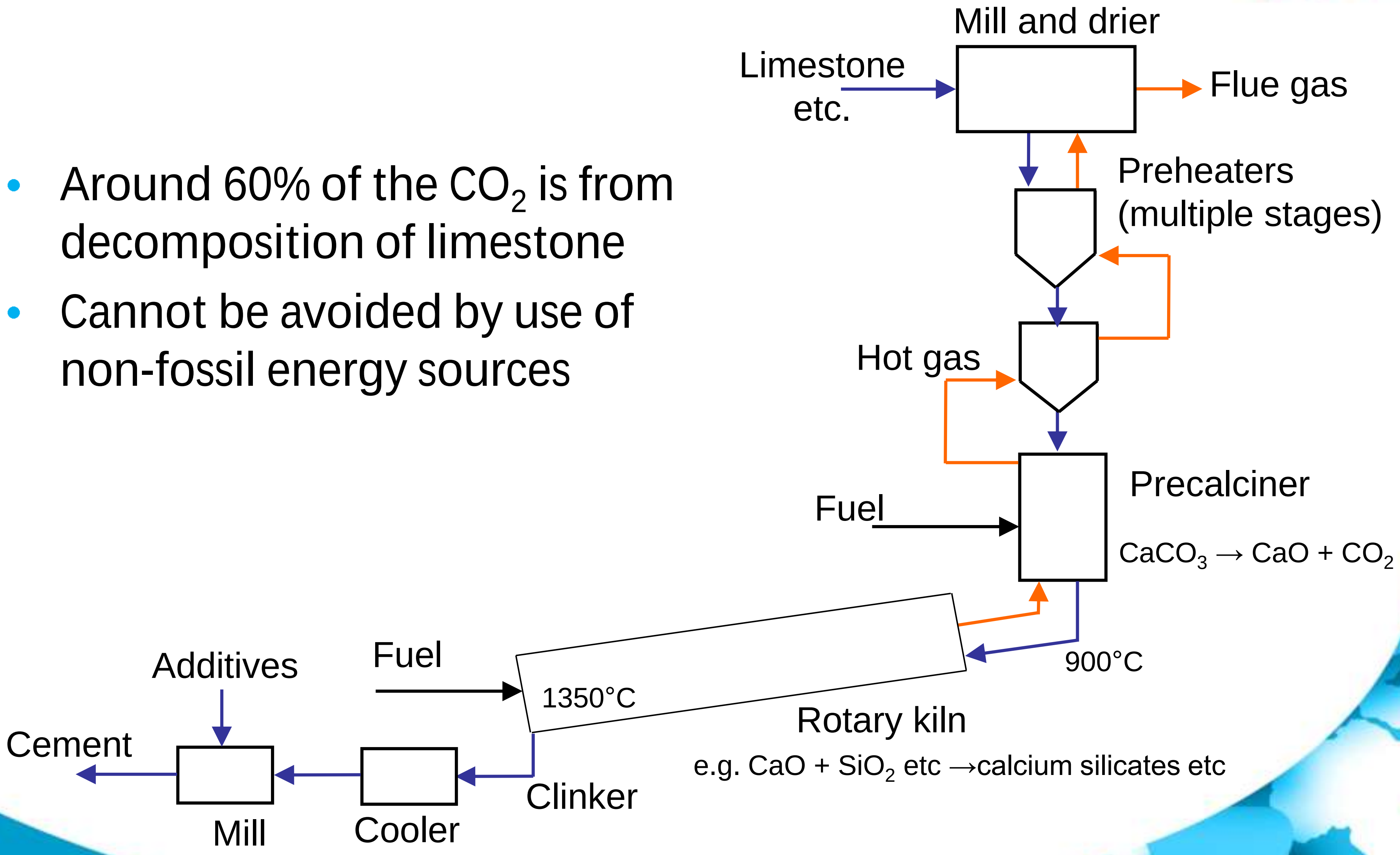


Source: IEA/UNIDO Technology Roadmap, Carbon capture and storage in industrial applications, 2011

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

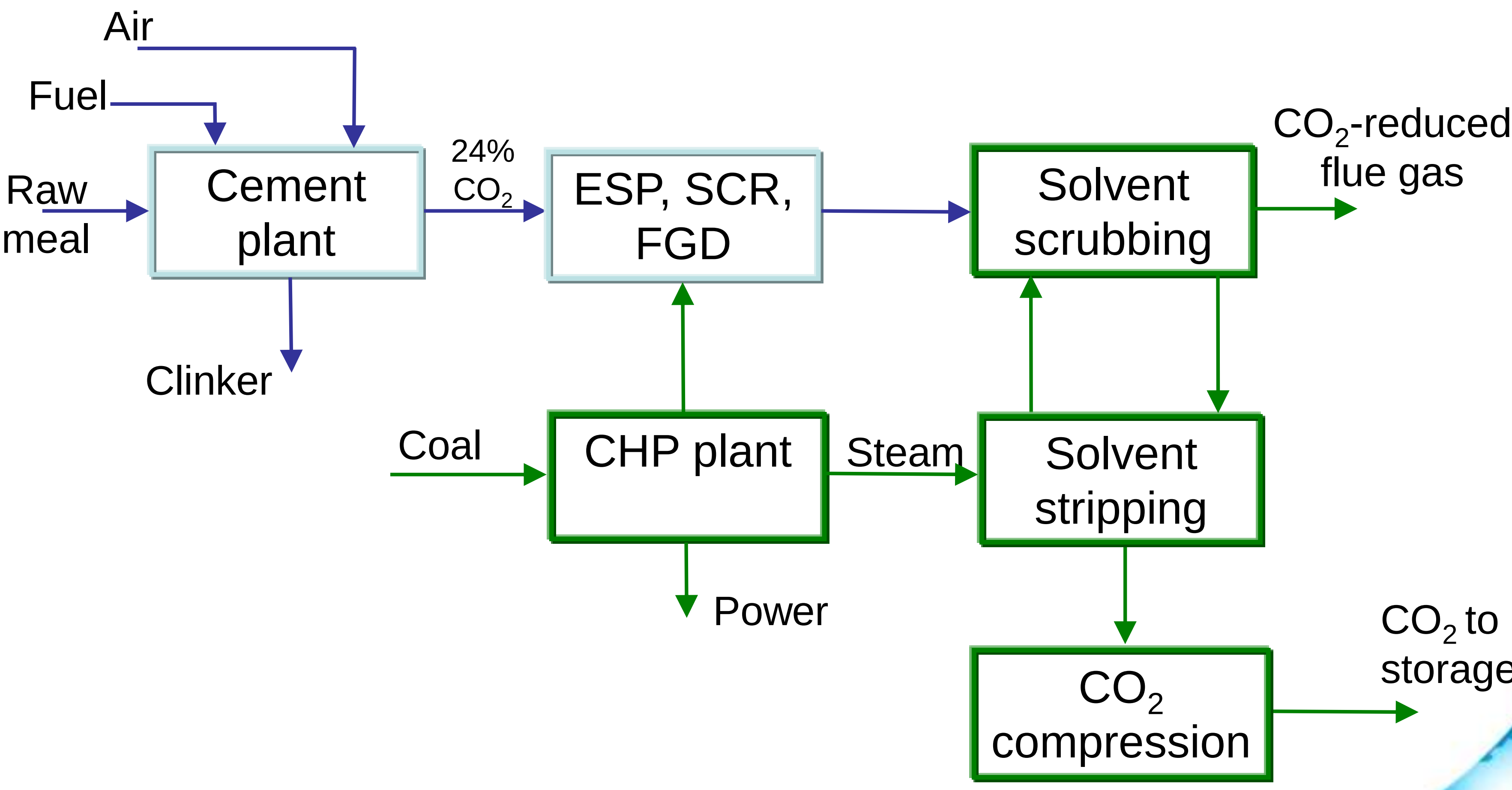
Cement Production

- 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

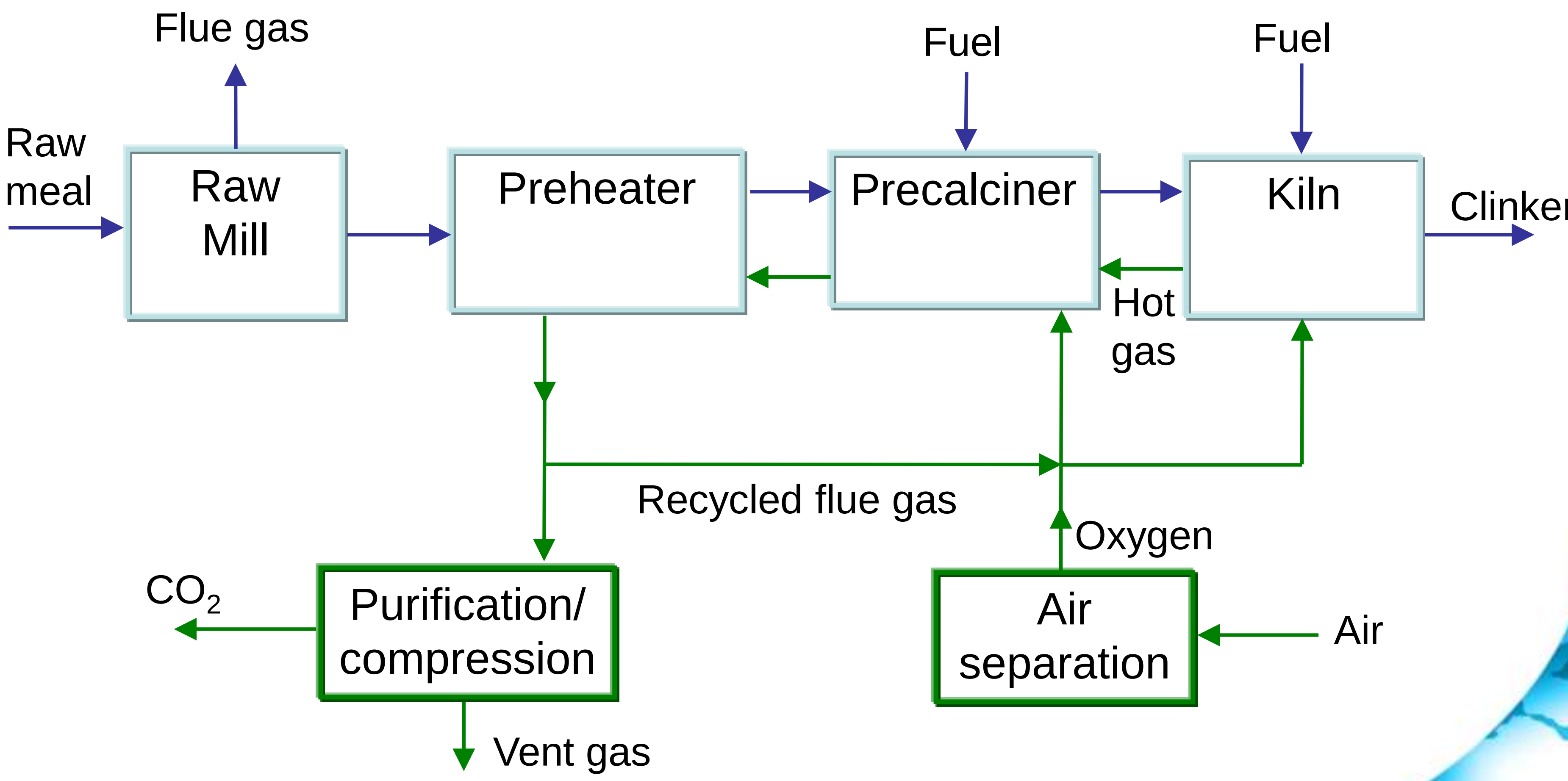


Post-combustion Capture

- 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

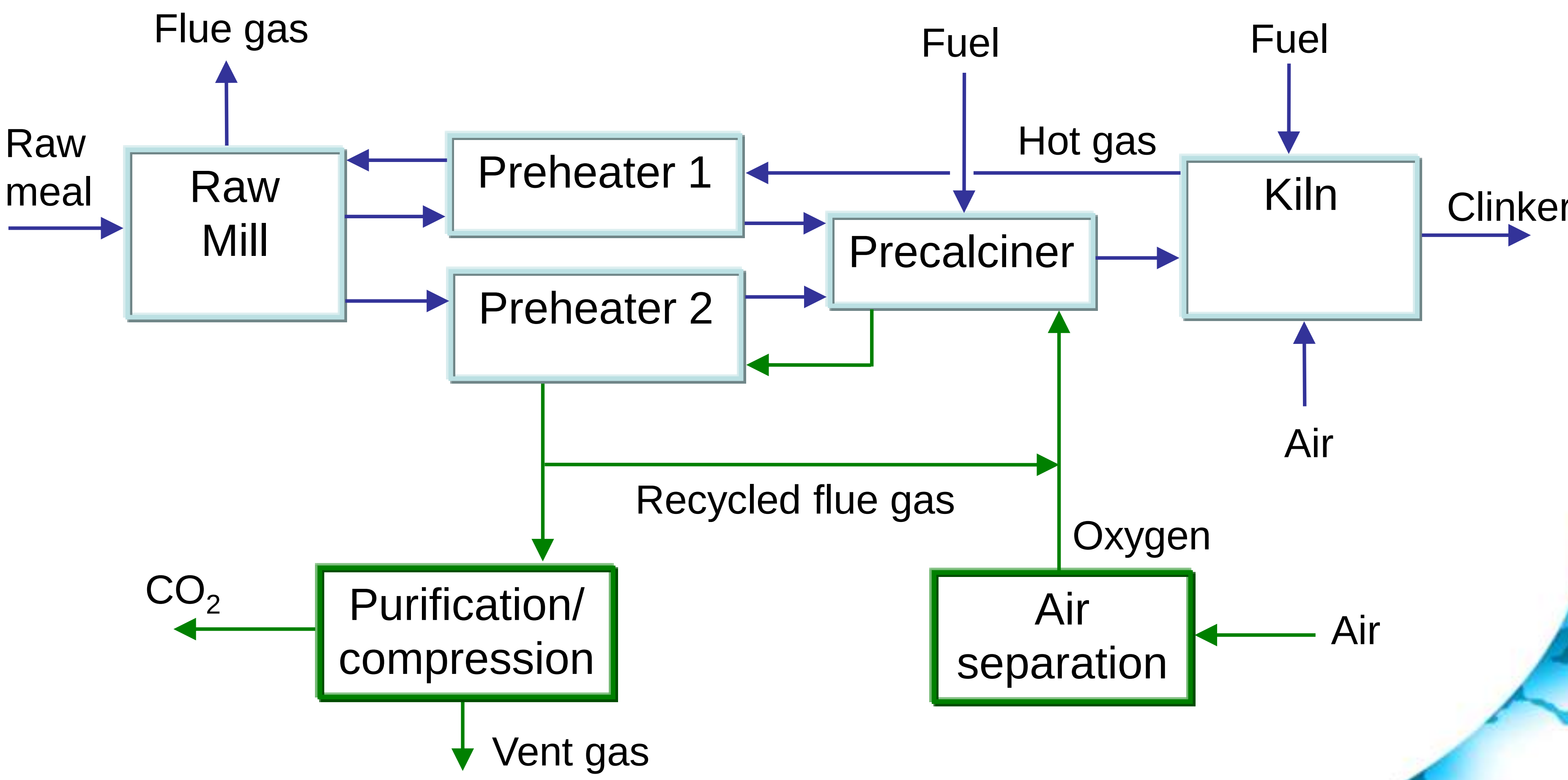
Oxy-Combustion Capture

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.

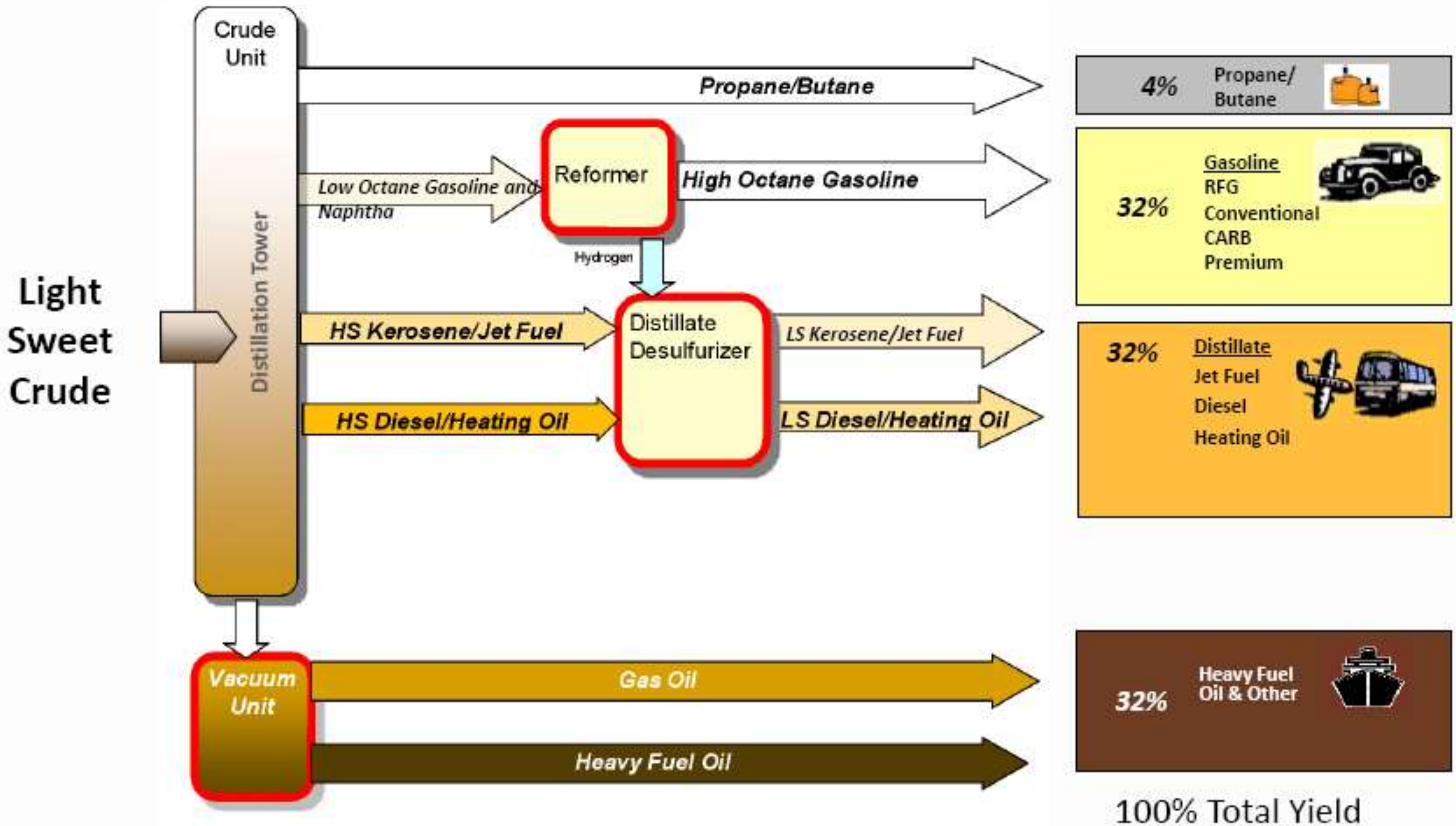
Status of Cement Plant CCS

- 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

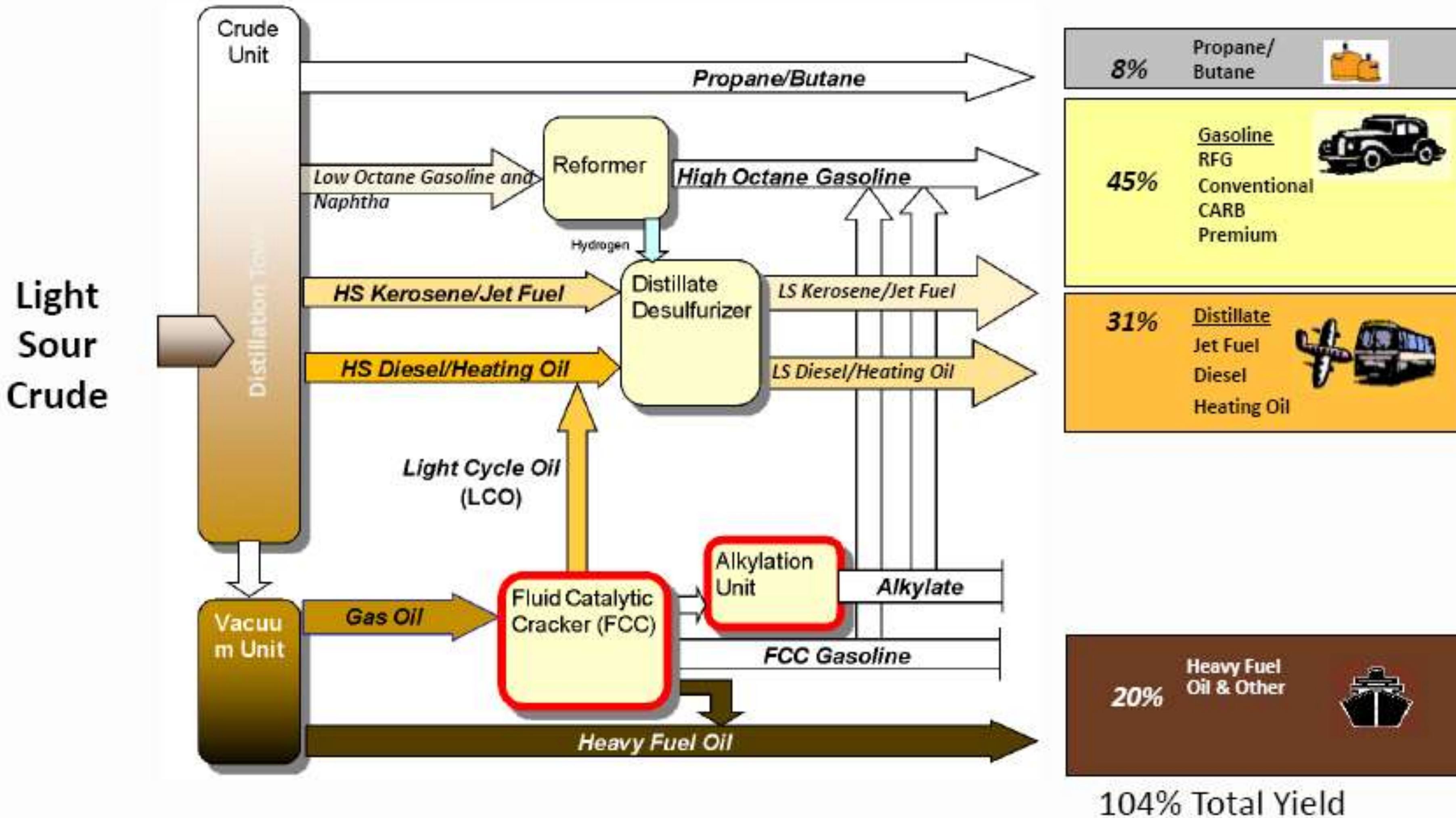
- Many CO_2 emission sources
- Complex plants - all are different
- Space can be a constraint for retrofits
- Design standards for capture plants at refineries may be different to power plants
  - Potentially higher costs

Hydroskimming/Topping Refinery



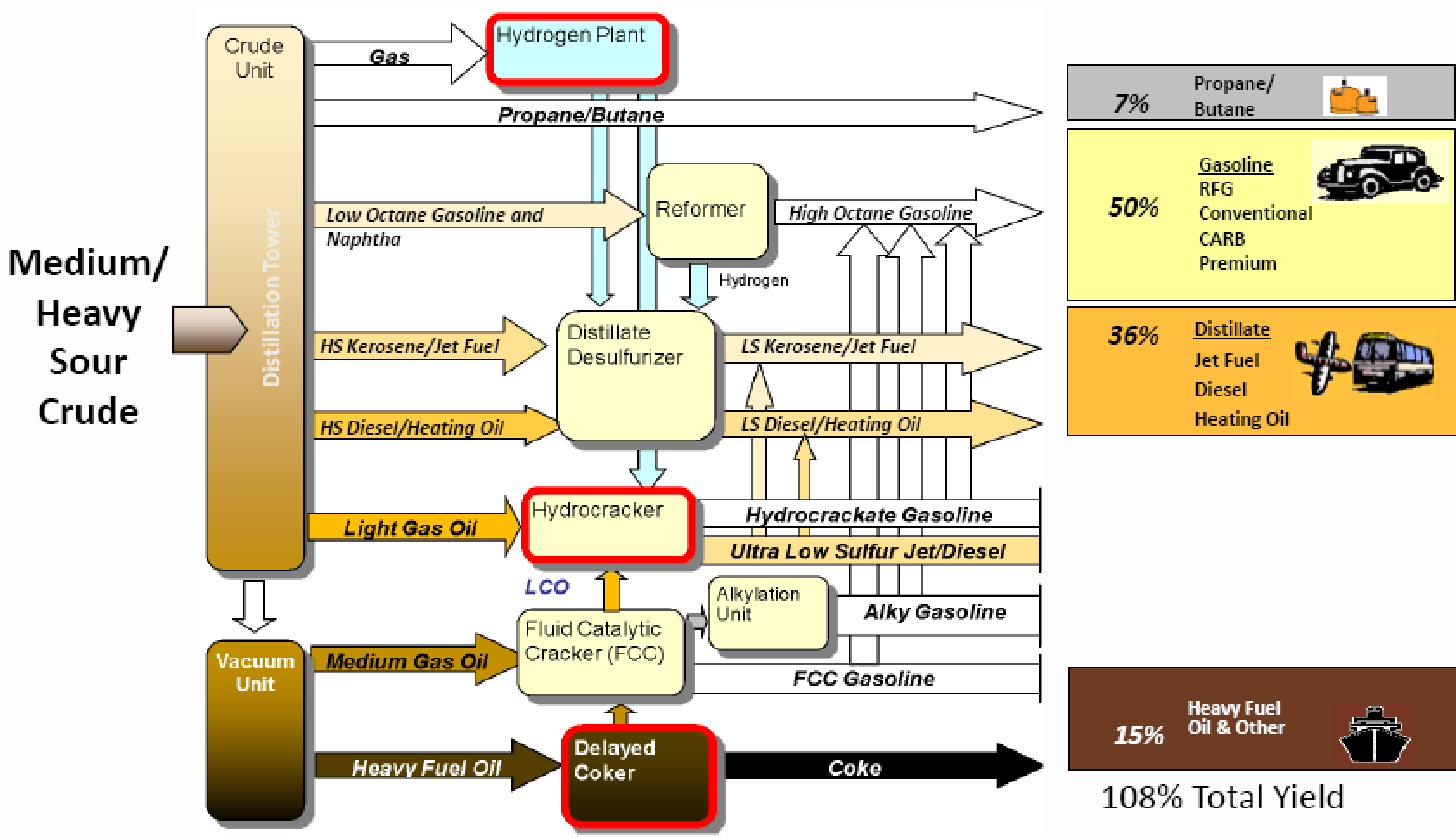
Simple, low upgrading capability refineries run sweet crude

Medium Conversion: Catalytic Cracking



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

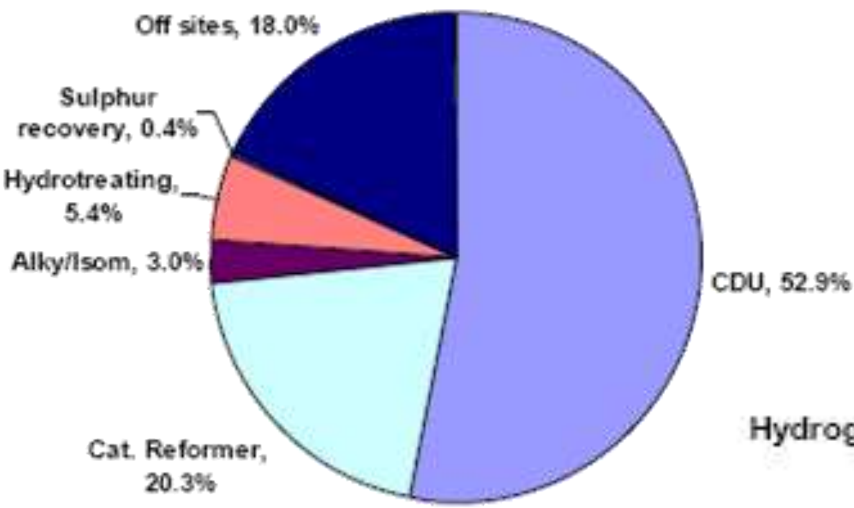
High Conversion: Coking/Resid Destruction



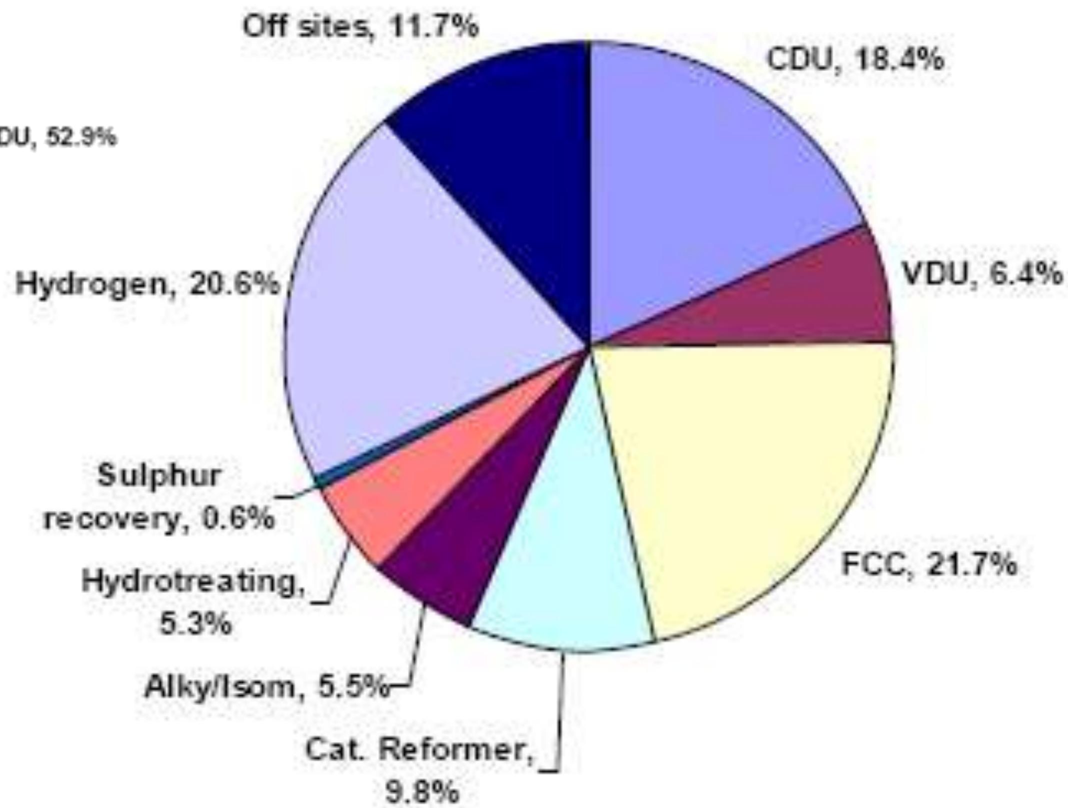
Complex refineries can run heavier and more sour crudes while achieving the highest light product yields and volume gain

Emissions from Simple and Complex Refineries

Hydroskimming refinery, 0.6 Mt/a CO_2



Conversion refinery, 1.4 Mt/a CO_2



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

Data from CONCAWE 2011

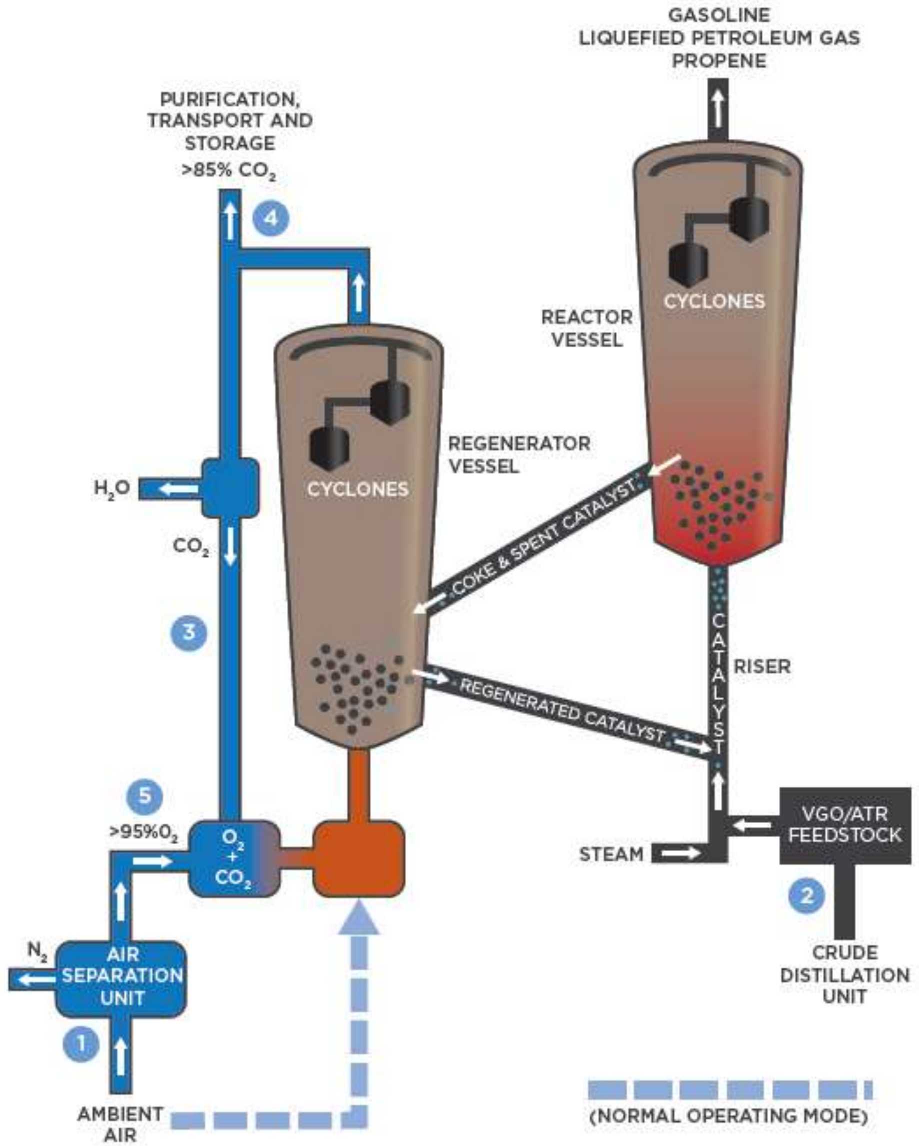
CO_2 Capture at Refineries

- 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

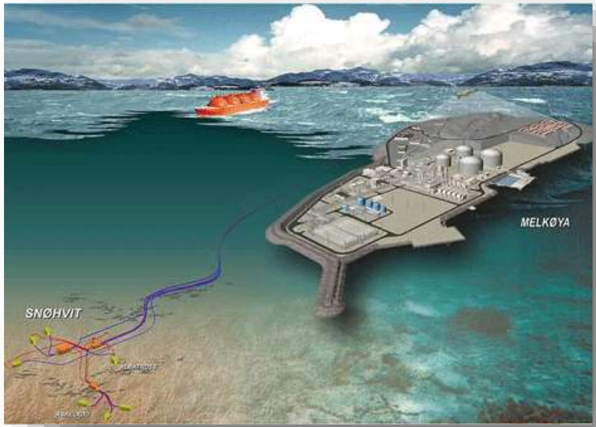
- Capture of CO_2 from 3 steam methane reformer units
- H_2 provided to the Athabasca Oil Sand Upgrader
- Shell amine technology (ADIP-X system based on MDEA/Pz)
- ~1.2 million tonne of CO_2/y
- Saline Aquifer with potential EOR application
- Operation starts 2015/16

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

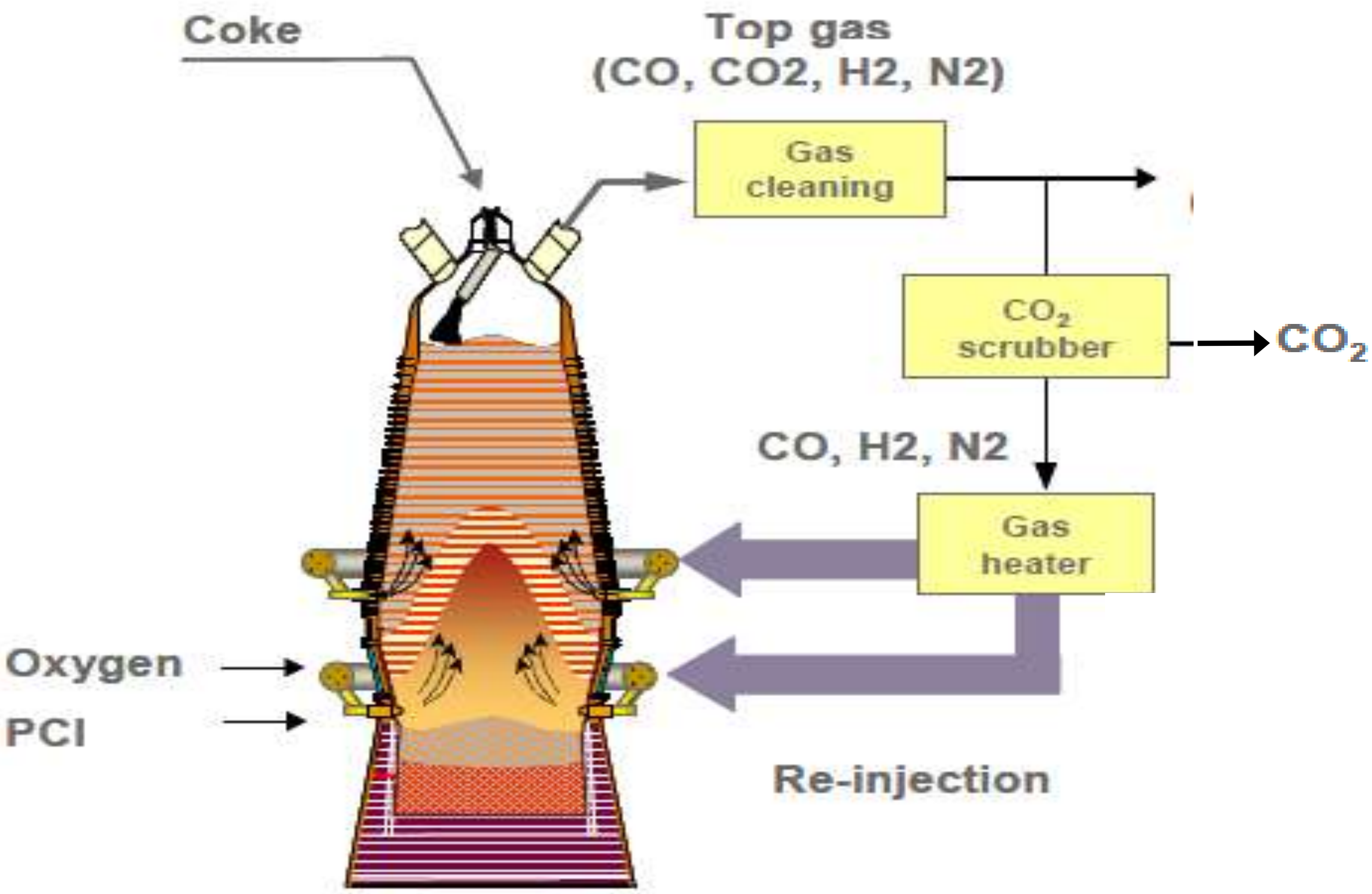
- Synthetic natural gas from coal
  - Dakota Gasification plant, USA, ~2.5Mt/y CO_2

- Coal-based chemicals plants
  - Coffeyville ammonia plant, USA, ~0.7Mt/y CO_2
  - Many Chinese coal to chemicals plants

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

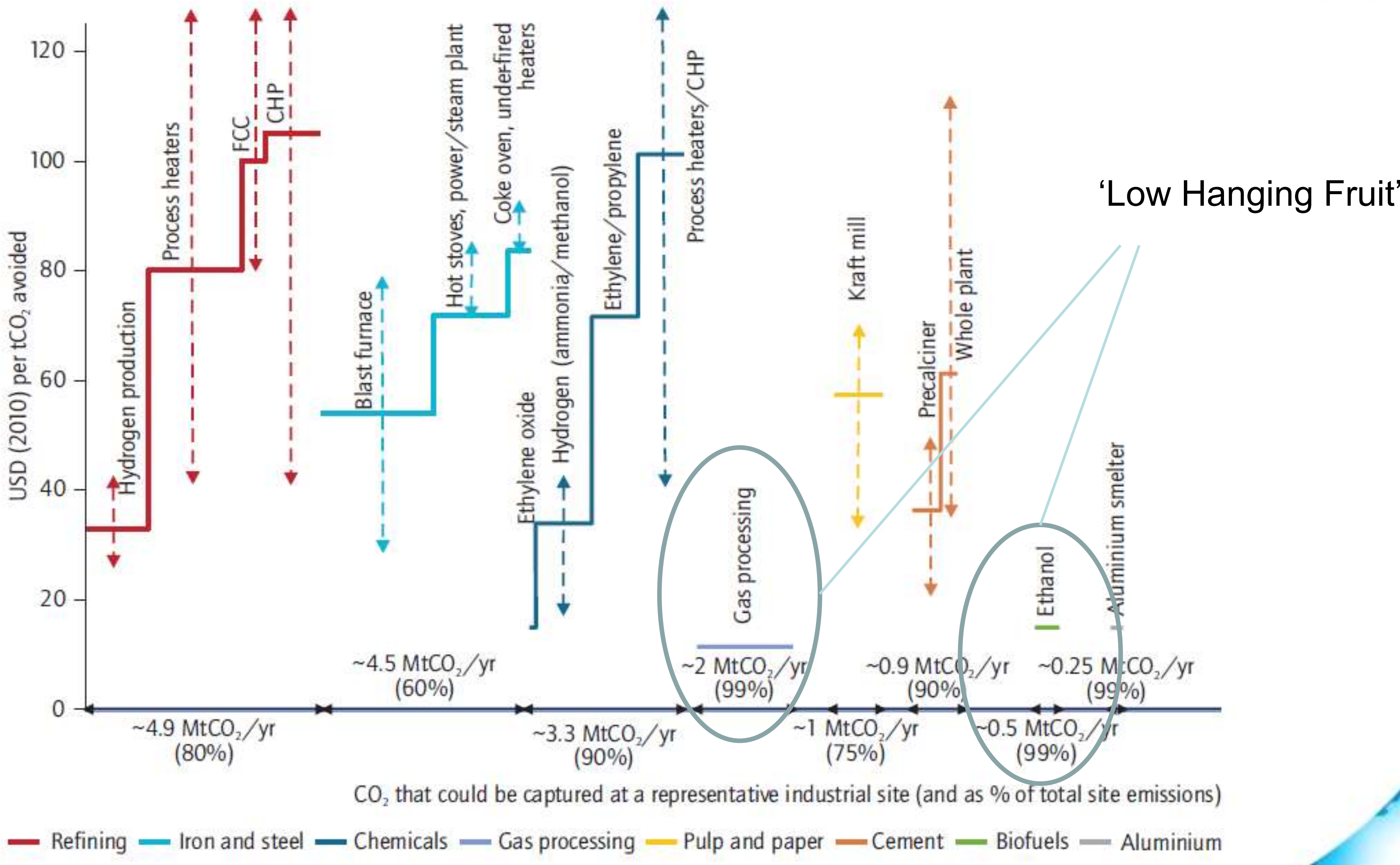
Technical Issues for CCS in Industries

- 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



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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