California's Low-Carbon Fuel Standard and Opportunities for CCS as a Contributor to Compliance

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Initial statements

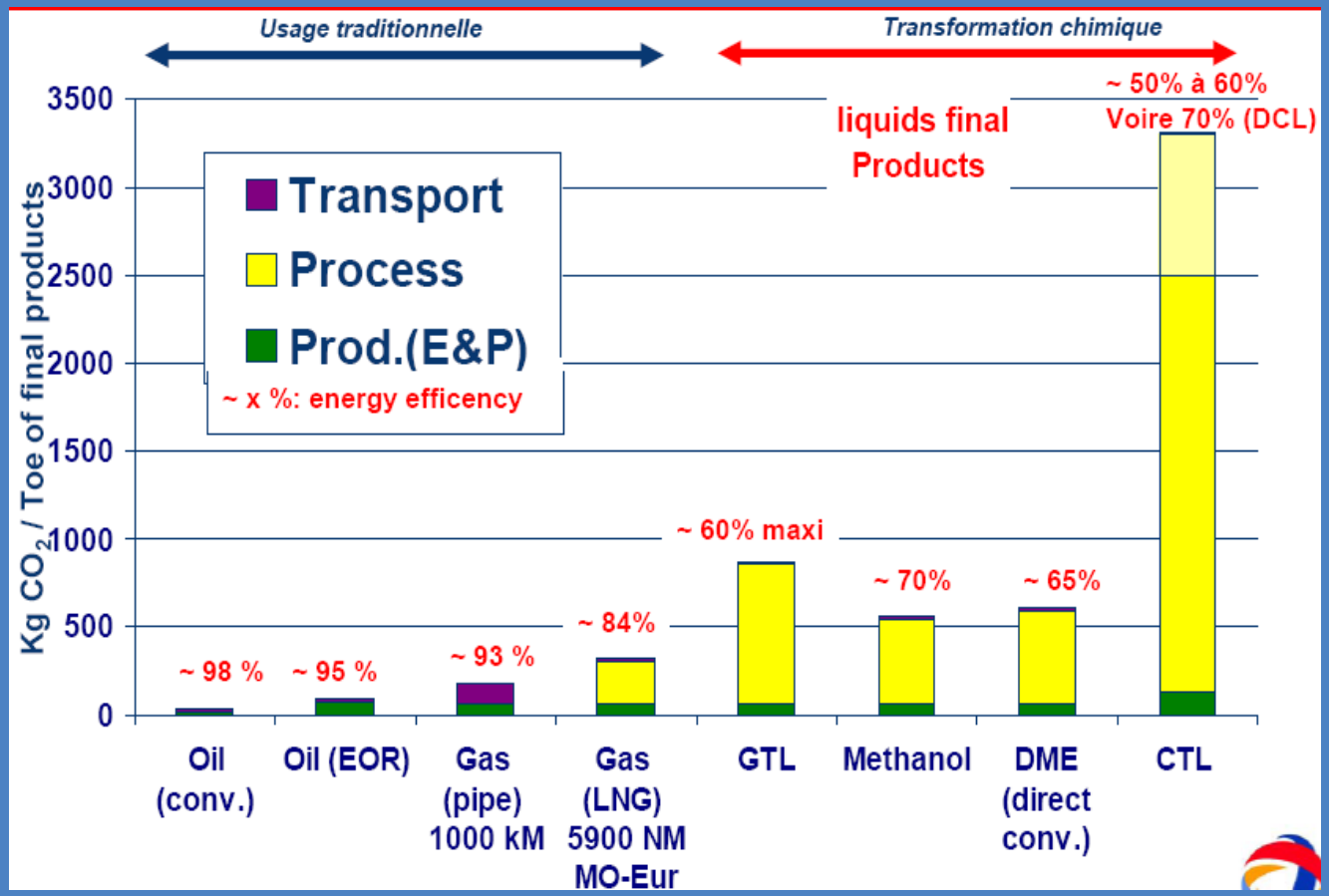
- Carbon capture is a proven technology in oil, gas, and chemicals industry with many decades of successful operations to supply CO_2 for the soft drinks industry, coolant and fire suppressant systems, enhanced oil recovery, etc.
- Carbon capture is in use today to provide markets with, natural gas, liquid natural gas, synthetic diesel, hydrogen, etc.
- CO_2 transport in ships and pipeline is a proven technology with decades of commercial operations worldwide
- Geologic permanent storage of CO_2 has been undertaken since 1996 with great results
- Although Carbon Capture and Storage (CCS) is deemed expensive, we need ask, expensive compared to what
- WESTCARB efforts to demonstrate CCS are crucial

The Low Carbon Fuel Standard

- Sets a limit for how much CO_2 a unit of energy delivered as fuel can contain
- CO_2 intensity is measured from well (production) to tank and its end use
- LCFS methodology enables addressing emissions reductions throughout the value chain of delivering cleaner fuels for our transportation needs
- Significant reductions of CO_2 can be enabled by CCS in the upstream, where oil and gas is produced, and in the refining of fuels here in California

Increased upstream CO_2 intensity

- CO_2 emission per bbl oil-eq. produced on the rise
- "Low hanging fruit" light oil in decline
- Mature and heavy oil on the rise
- CO_2 intensive unconventional oil under development



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Addressing CO_2 reductions through CCS

- Use a carbon abatement curve for the carbon value chain where efficiency will rank high
- CCS in the upstream such as from heavy oil upgrades, steam-intensive hydrogen (H_2) production, and sour gas fields
- Midstream, supply greener power to compressors and shipping such as LNG driven tankers
- Refineries have several sources amenable to capture of CO_2
  - Catalytic crackers
  - Steam methane reformers (Hydrogen producers)
  - Power and heat producers
- Capture of CO_2 also requires that other pollutants in the flue gas, such as SO_X, NO_X, and particulates, are removed prior to capture of CO_2 so there is a net gain in both local air quality and global CO_2 emissions

CO_2 sources at oil refineries

Source Type	Source	Percent Contribution to Total CO_2 Equivalent Emissions		
		CO_2	CH_4	N_2O
Combustion Sources	External combustion	42.3	3.9 E-3	7.1 E-2
	Internal combustion	7.4	1.7 E-1	5.6 E-1
	Flares[a]	2.8	1.2 E-4	0
	Incinerators	0.3	3.0 E-5	5.5 E-4
	Combustion Total	**52.9**	**1.8 E-1**	**6.3 E-1**
Vented sources	Hydrogen plant vents	10.7	0	0
	Catalytic cracking regeneration vent	35.2	0	0
	Storage tanks	0	Negligible	0
	Loading / transit	0	0	0
	Vented Total	**45.9**	**0**	**0**
Fugitive Sources	Fugitive components	Negligible	?[b]	0
	Fugitive Total	Negligible	Negligible	0
Indirect Sources	Electricity purchased	5.8 E-1	2.6 E-4	2.7 E-2
	Indirect Total	5.8 E-1	2.6 E-4	2.7 E-2

Source: API Compendium, Table 7-24, 2004

Average estimates from American Petroleum Institute indicates over 10 % CO_2 vented from refineries is from hydrogen production

Over 35 % from cracking processes

Over 52 % from combustion sources

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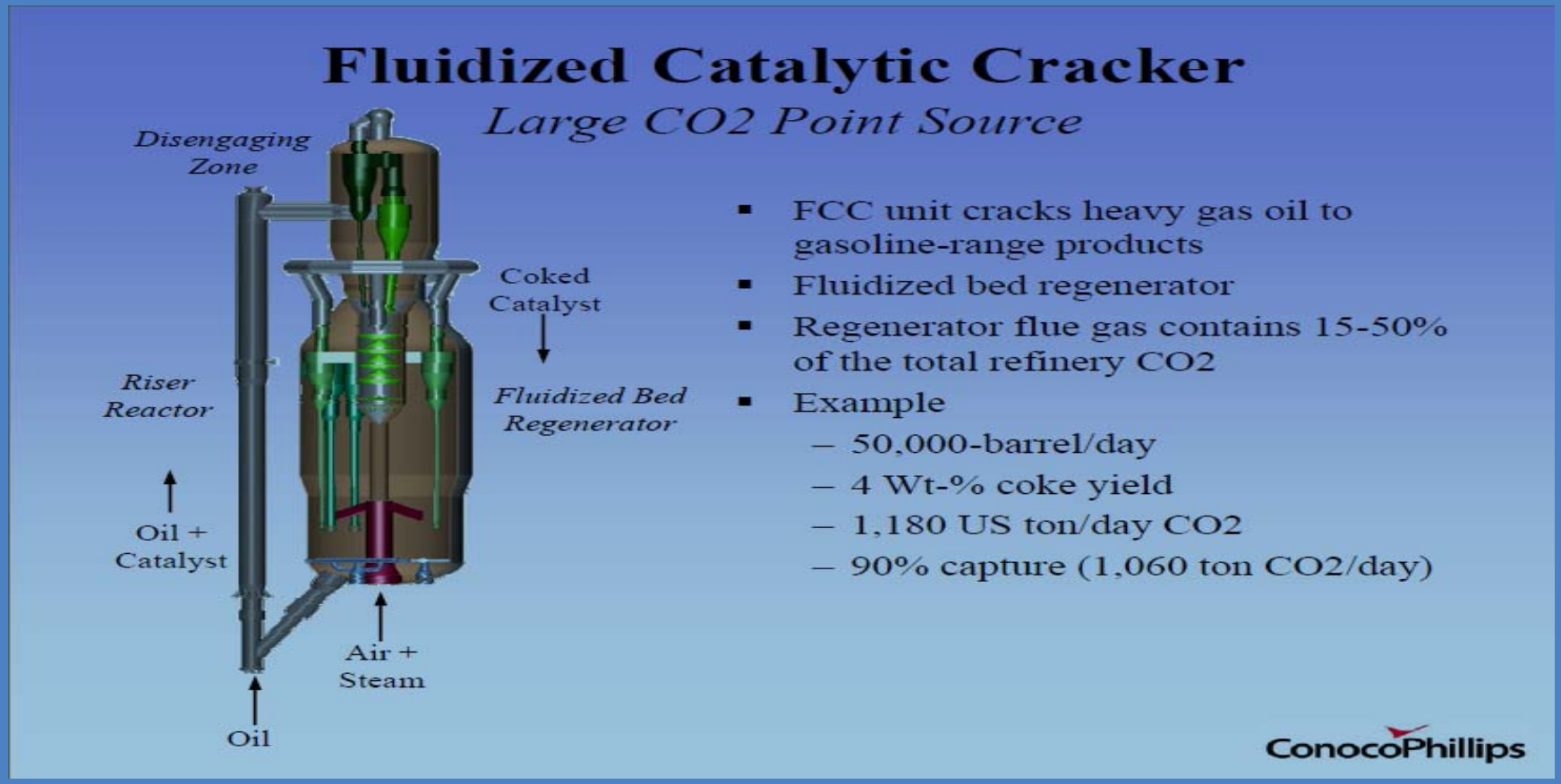
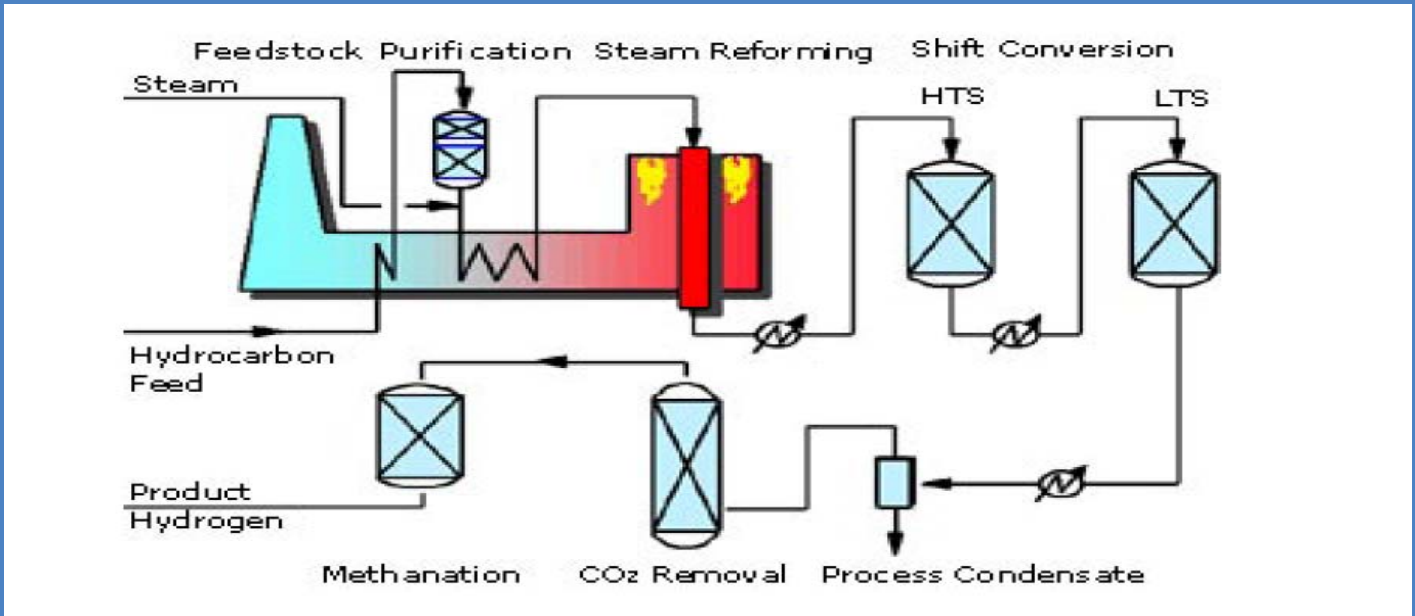
Fluidized Cat Cracker



15-50% of CO_2 emissions from a refinery can come from a FCC unit

Hydrogen production in a refinery: Steam Methane Reforming (SMR)



Hydrogen demand is increasing rapidly as the need to process heavy oil increases because light oil is in decline globally. Hydrogen demand will increase significantly more if mass deployment of hydrogen fueled vehicles becomes a reality.

Hydrogen in refineries and CCS

- H2 is produced largely from fossil fuels without CCS (48% from natural gas, 30% from refinery/chemical off-gases, 18% from coal, the rest from electrolysis).
- CO_2 available for capture and storage in this process can be as much 10-20% of total refinery emissions.
- Steam methane reformers in refineries with CCS can provide low intensity H_2 compared to H_2 produced from electrolysis with high carbon intensive electricity.
- California refines ca 2.1 million bbls per day, emits around 17.3 mt CO_2 per year, where ca 7.5 mt CO_2 is from hydrogen production (WESTCARB data)

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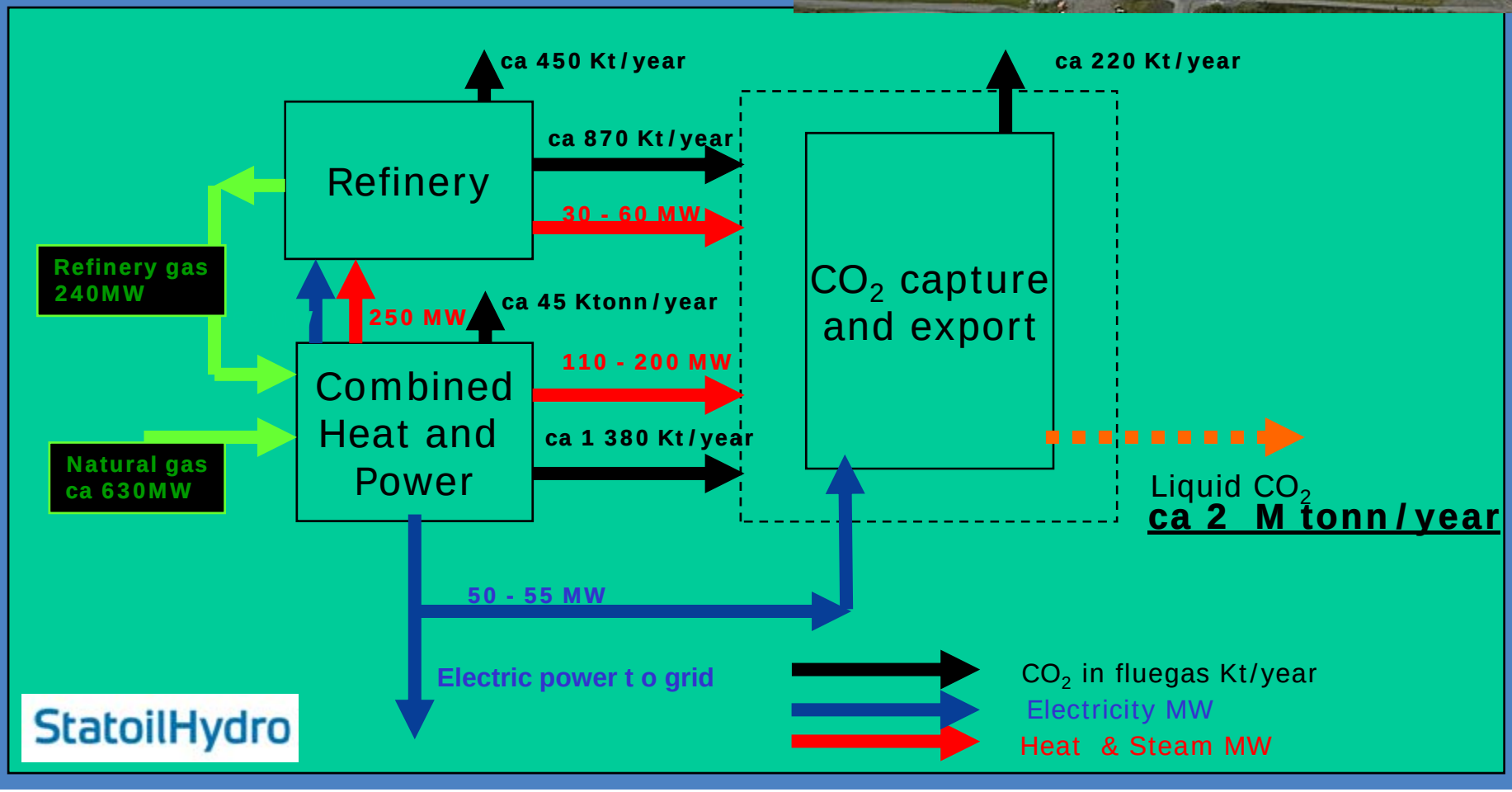
Statoil's Mongstad Refinery
CCS project
Simplified energy and mass balance



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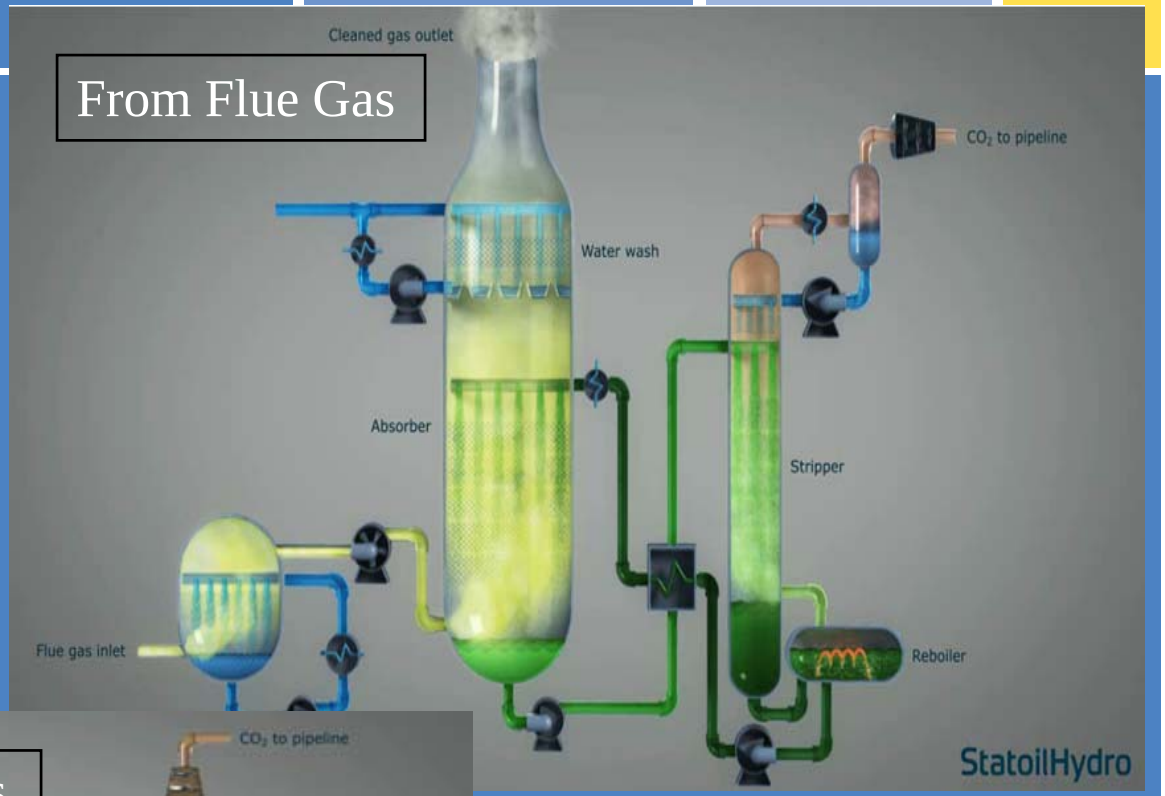
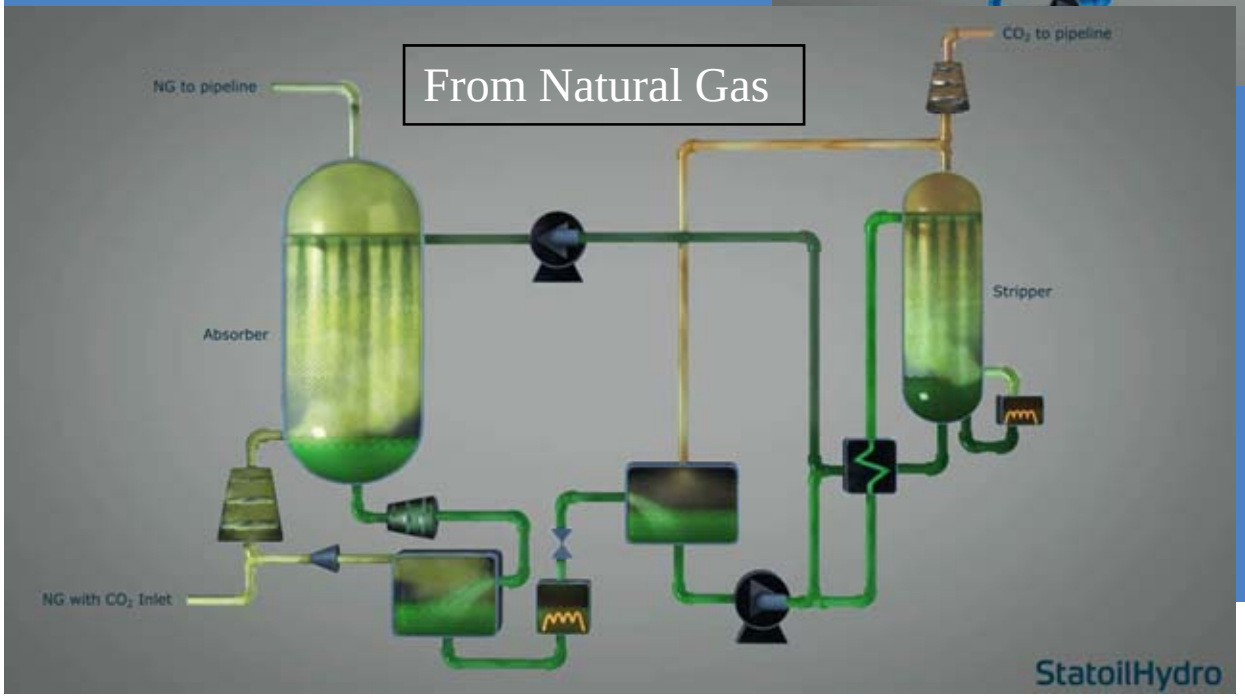
CO_2 scrubber (CO_2 capture)





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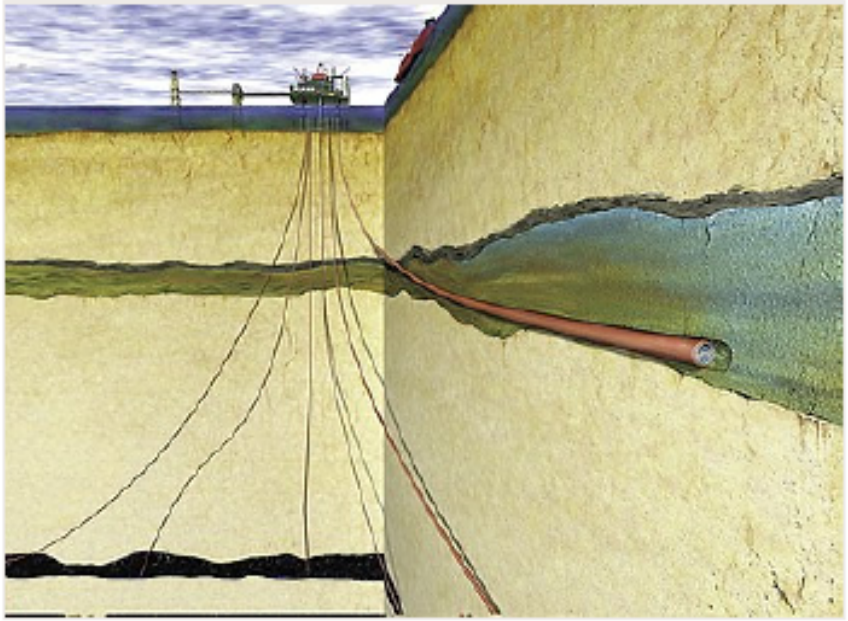
CO_2 injection - examples

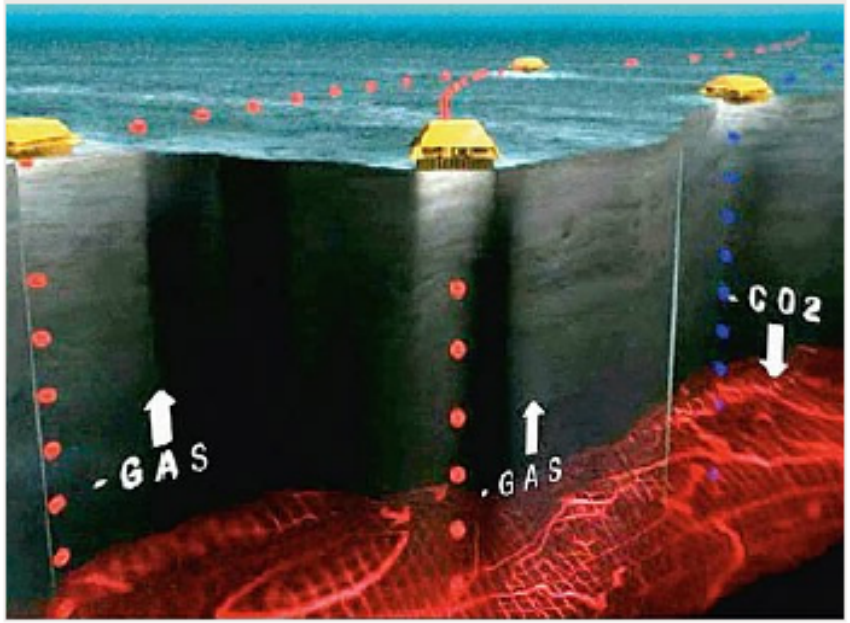
Source: Slide from Statoil ASA - Olav Kårstad

Sleipner and Snøhvit

Sleipner, North Sea



Snøhvit LNG, Barents Sea



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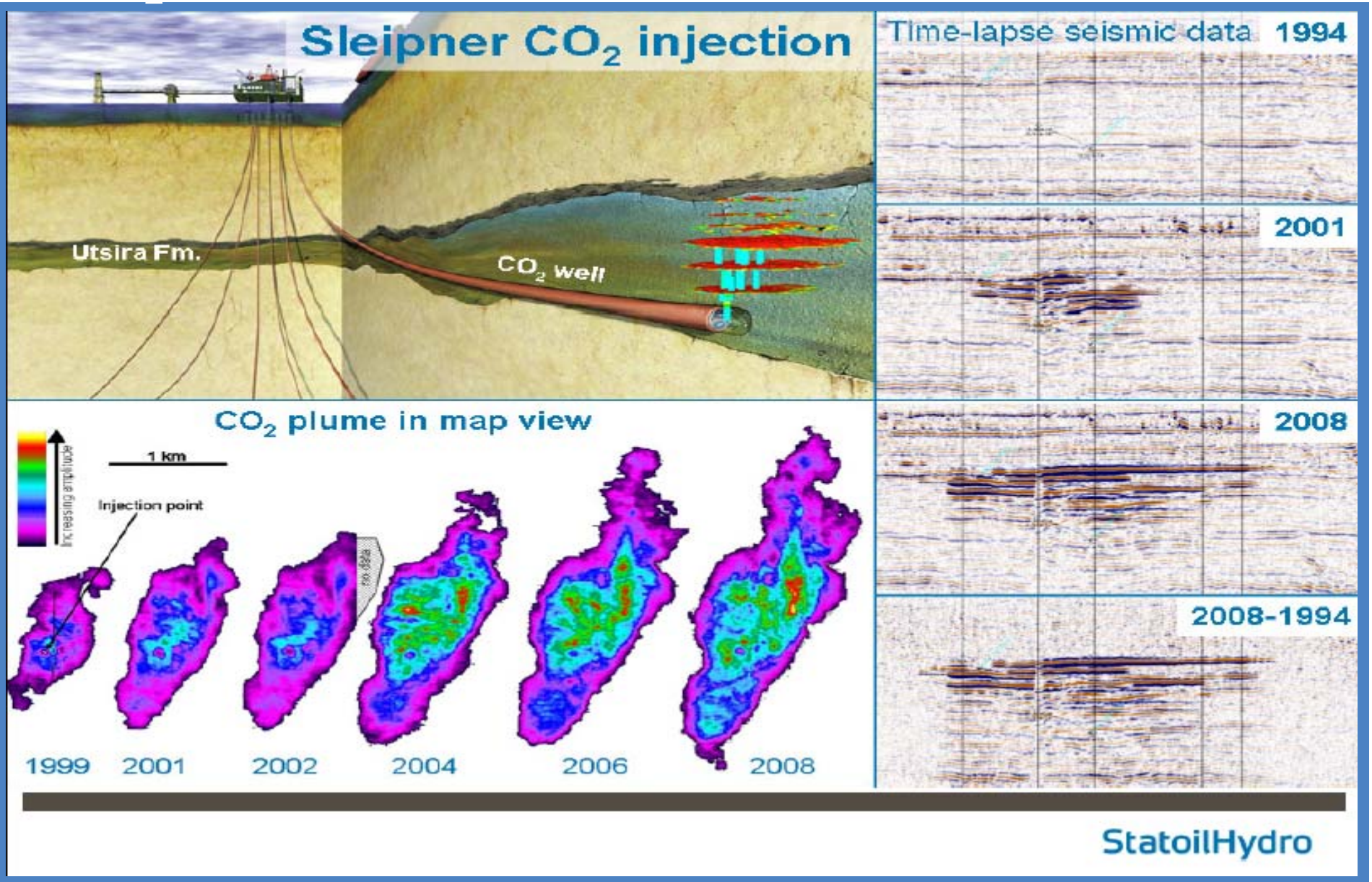

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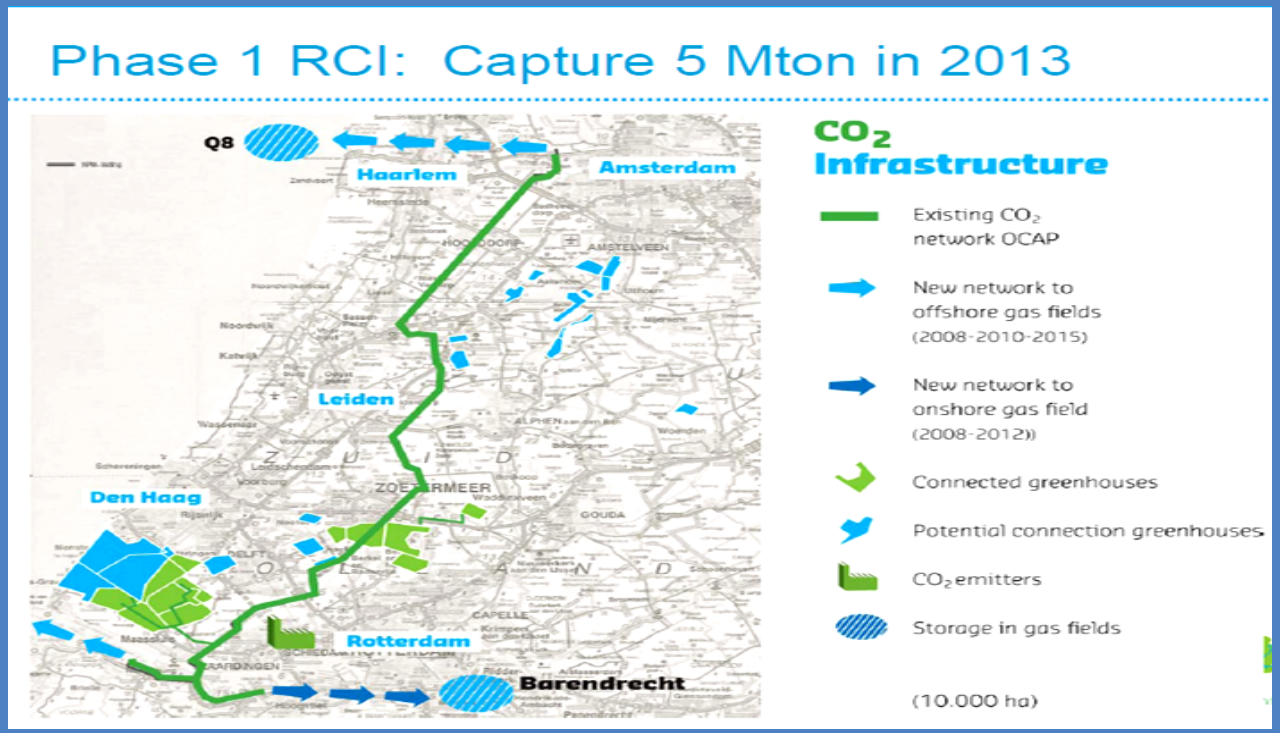
The Netherlands – CO_2 from Shell's Pernis Refinery



Plans exist to include other industrial CO_2 sources to the pipeline network

Source : Rotterdam Climate Initiative

- Ca 300,000 tons of CO_2 per year is captured and piped from Pernis Refinery to greenhouses
- The net environmental savings for greenhouses are 170,000 tons of CO_2 through displacement of natural gas
- Plans to inject CO_2 into the Barendrecht depleted gas field are under way

Source: OCAP – The Netherlands

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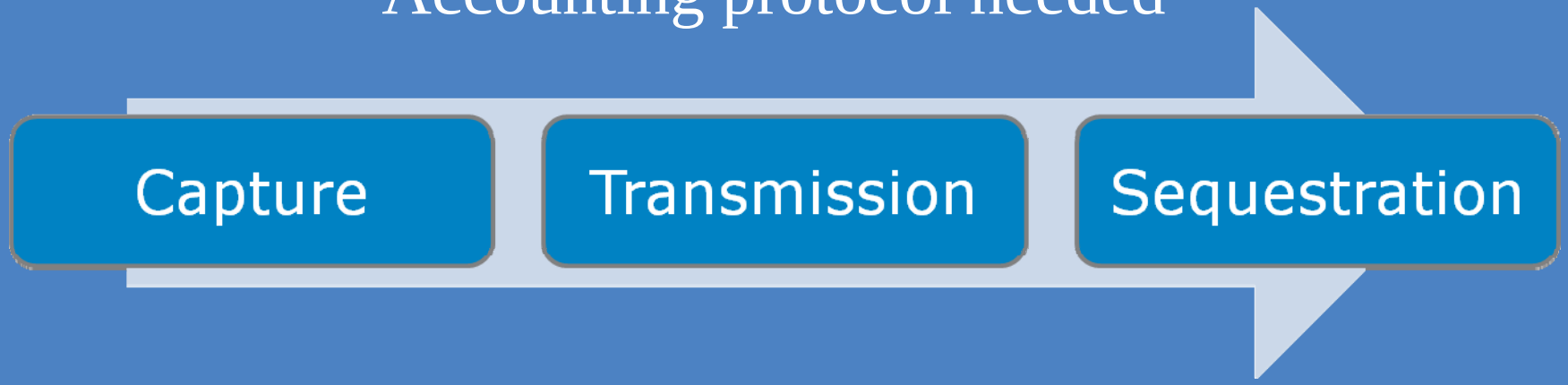
CO2 – from capture to storage
Accounting protocol needed



- Accurate measurements of CO_2 reductions from capture to final storage is needed. The IPCC concludes that retention time in a reservoir is very likely to be 99 % over 100 years and likely to be 99 % over 1000 years.
- The net stored CO_2 must be measured from the well or mine to its final storage, including energy use and CO_2 vented from source to sink.
- Various parties (e.g., Blue Source and the North American Carbon Capture and Storage Association) have initiated work to develop protocols to ensure accurate emissions reductions can be verified for CCS.

Final remarks

- It is not CO_2 capture and transport technology that is the challenge to lower emissions globally or for the Low Carbon Fuel Standard
- California , the U.S., and the world have sufficient geologic storage capacity
- Cost is a major challenge, but many facilities have “low hanging fruit” and cost and incentives need to be compared to not undertaking CCS
- Structural commodity costs such as oil, gas, coal, steel, and labor significantly impact total deployments costs
- Commercial and regulatory frameworks are the only showstoppers to enable CCS technology to radically reduce emissions globally
- The Low Carbon Fuel Standard is a good regulatory instrument and carbon capture and storage is crucial to ensure effective compliance and significant CO_2 reductions
- Finally, it is an issue now, not in 2020 nor 2050.

Thanks

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