Carbon Sequestration Leadership Forum
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CCS & industry

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CSLF Mid-Year Meeting / Technical Group Meeting

Abu Dhabi, United Arab Emirates

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Origin of the Task Force

The Task Force was established at the CSLF meeting in Tokyo, Japan, October, 2016, in order to make recommendations for the development of CCUS in the industrial sectors

Germany, the Netherlands, Norway, Saudi Arabia, and the United States, have proposed to join the task force leading by France

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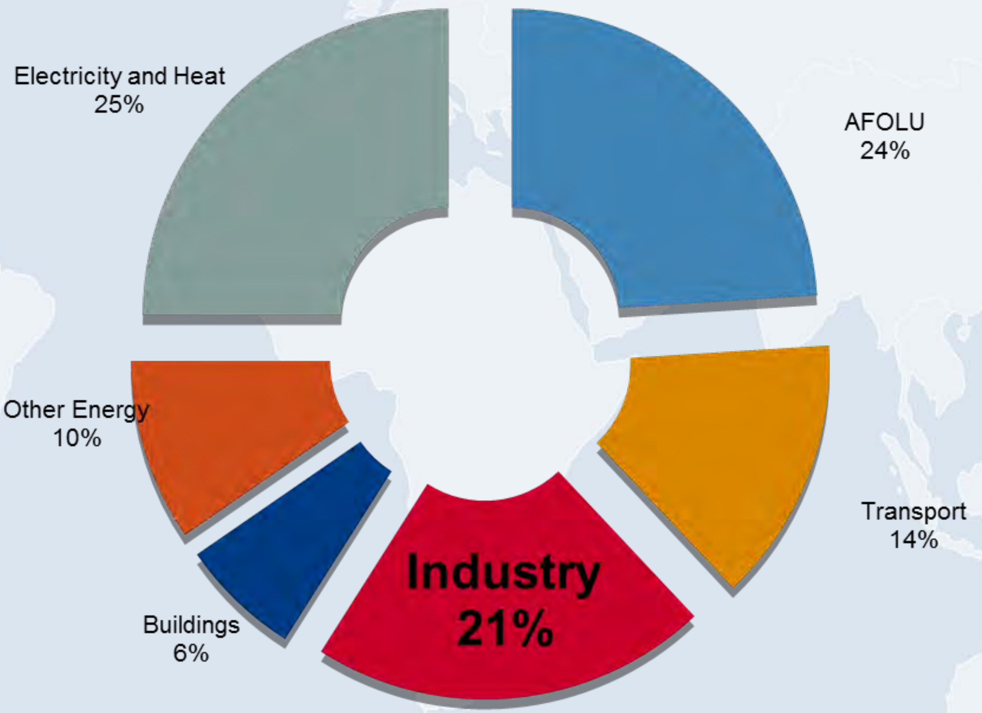
CO2 direct emission

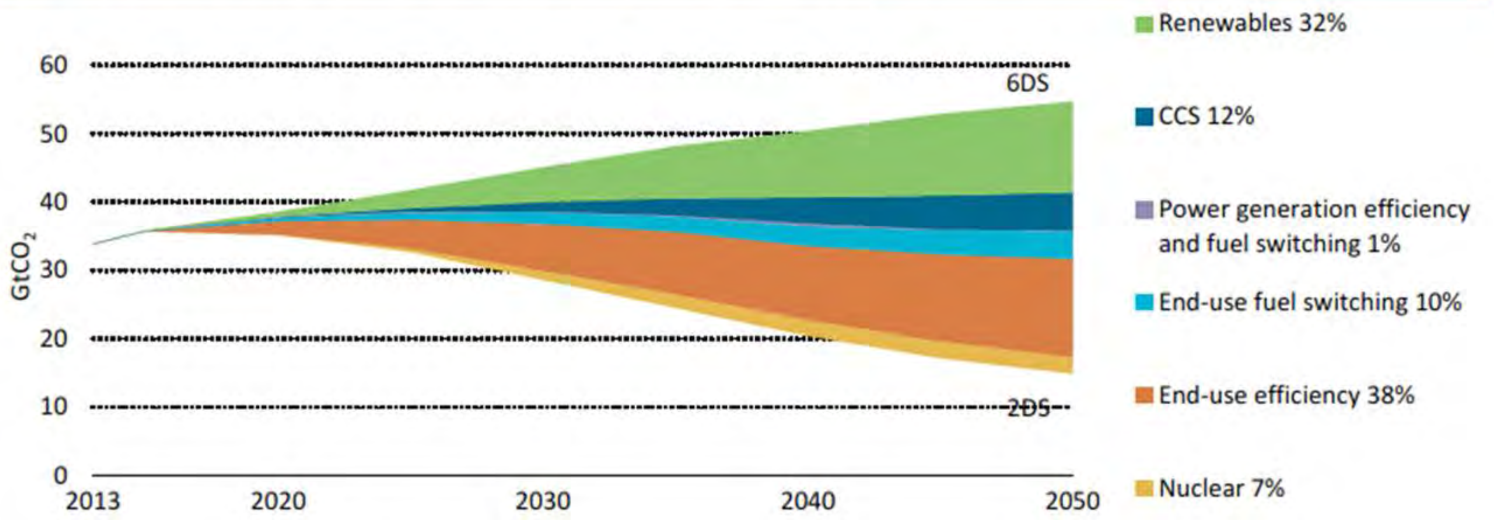


Source : IPCC AR 5

AFOLU : agriculture, forestry and other land use

CCS: a major contributor to climate change mitigation

Figure 2.1 • CCS is a key contributor to global emissions reductions[15]



Source: IEA (2016b), *Energy Technology Perspectives 2016.*

- Without CCS, the likelihood to achieve <2°C is much lower, and when this target is achieved, the cost to get it is much higher.

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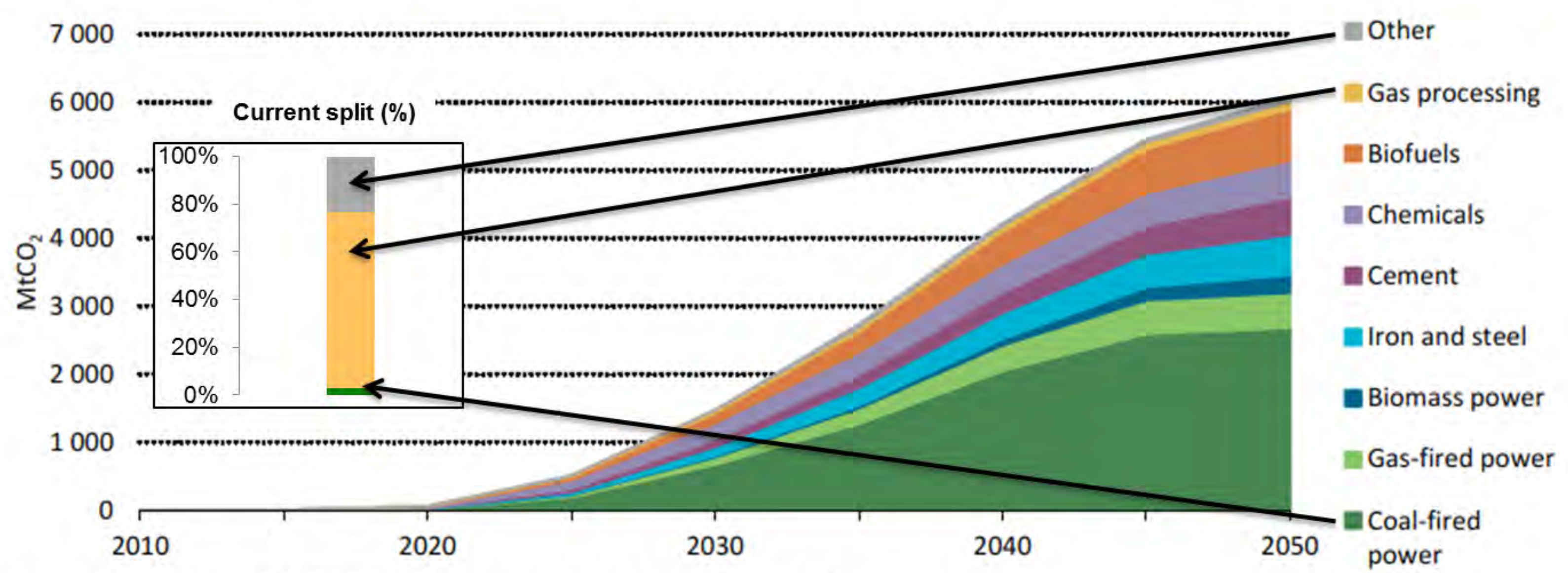
On the long run, industry share of CCS will be 50%. Today, it is 100% (~ 80% from oil&gas industries)

Figure 2.2 • Power and industry are the predominant sources of CO_2 captured in the 2DS



Source: Derived from IEA (2016b), *Energy Technology Perspectives 2016*.

- 6 GtCO2/year ~150 Mbpd in geological storage conditions, which is close to the current production of oil and gas (in Mboepd).

ClubCO2

TOTAL COMMITTED TO BETTER ENERGY

For Power there are alternatives to CCS. This is not the case for a significant share of the industry CO2 emissions

Taken from IEA 20 years of Carbon and Storage (autumn 2016)

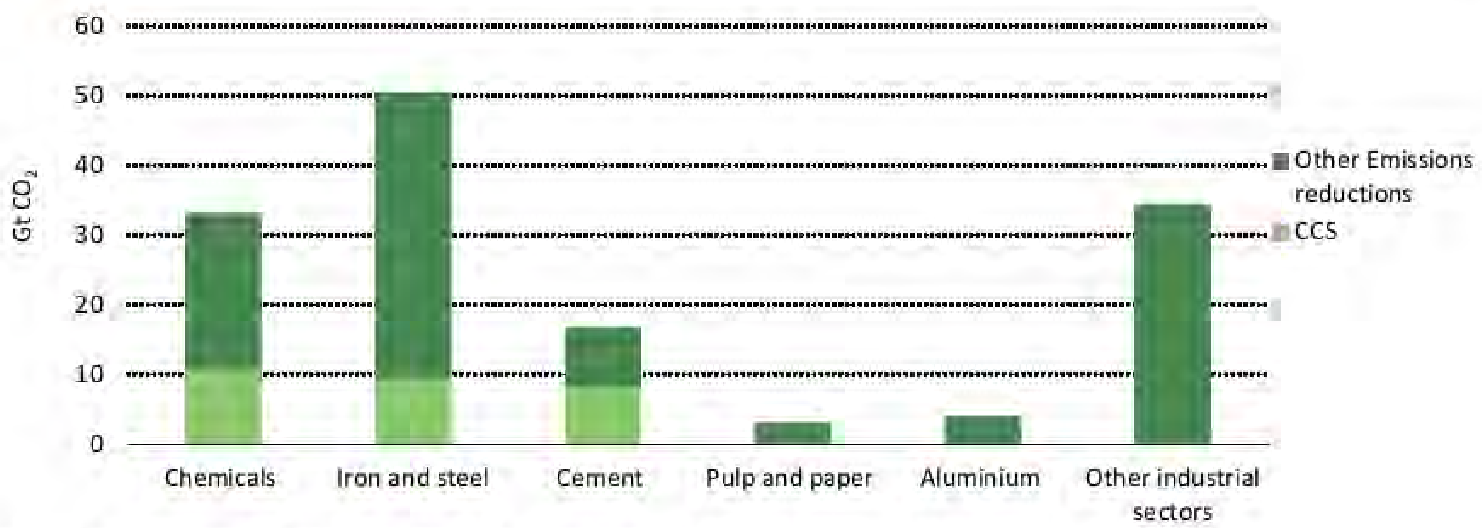
- **Without CCS, the transformation of the power sector will be at least USD 3.5 trillion more expensive**

but/and

- **CCS is essential in industry :**
  - **If CCS were not available, it is likely that much of the reductions achieved by CCS would need to be offset by efforts in other sectors**

Until 2050, industry cumulative CCS ~ 30 Gt
(without CO2 from natural gas)

Figure 2.3 • Cumulative emissions reductions from CCS in industry (2DS relative to 6DS)



Source: Derived from IEA (2016b), *Energy Technology Perspectives 2016*.

Note: There are 97 $MtCO_2$ captured from pulp and paper production

Source : IEA 20 years of Carbon Capture and Storage

- An important share of the CO2 emissions in building blocks of the economy probably cannot be avoided without CCS.

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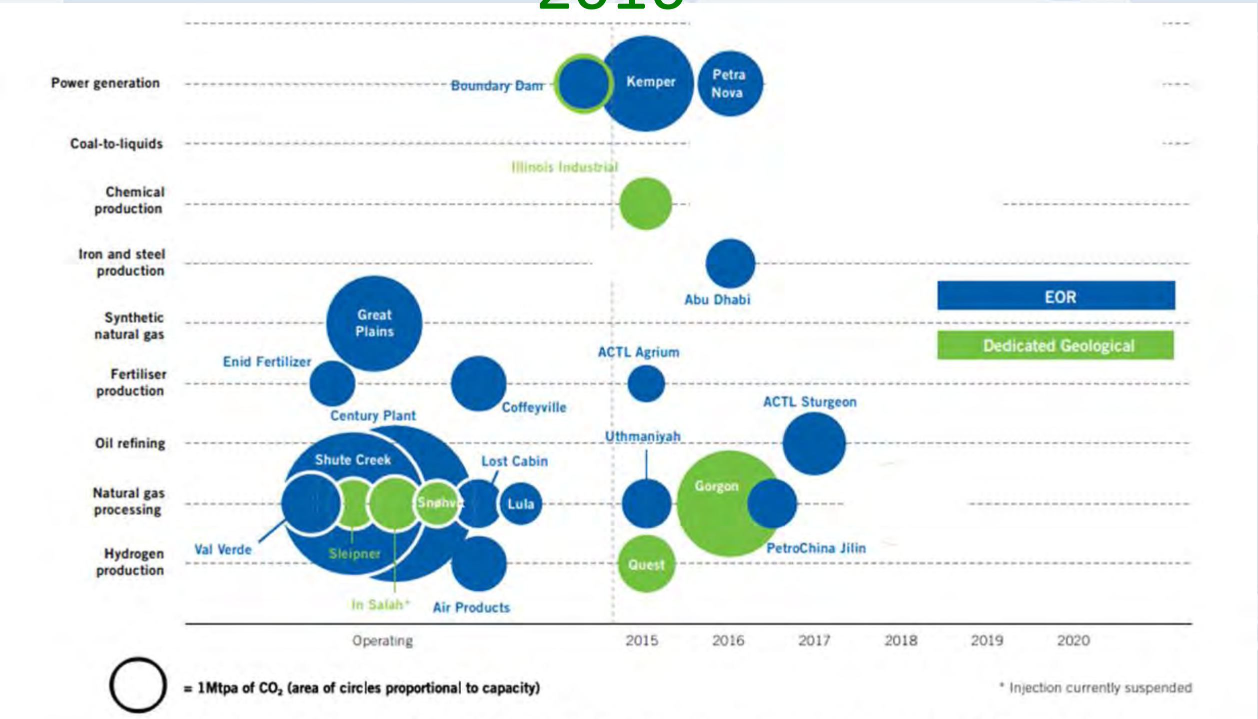
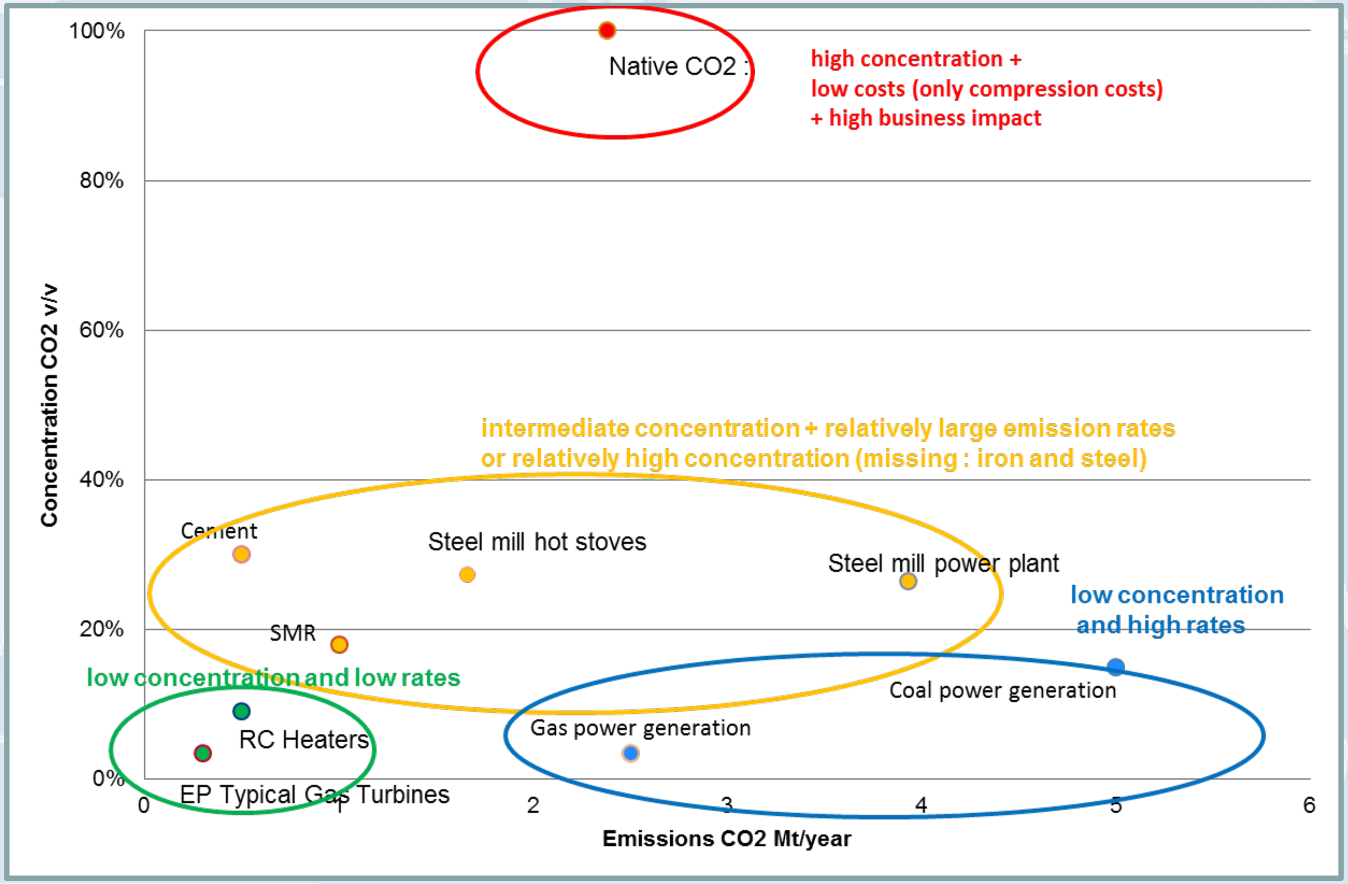
Projects under operation or execution at the end of 2016



Adapated from GCCSI (to be updated with recent changes in post-2015 starts)

- A majority of projects are based on natural gas processing.
- Power is relatively recent.

CO2 emissions from big emitters (oil and gas, cement, steel, power)



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Emission (IPCC Special Report on CCS - 2005)

Table SPM.1. Profile by process or industrial activity of worldwide large stationary CO_2 sources with emissions of more than 0.1 million tonnes of CO_2 ($MtCO_2$) per year. Source : IPCC SRCCS 2005

Process	Number of sources	Emissions ($MtCO_2\ yr^{-1}$)
Fossil fuels		
Power	4,942	10,539
Cement production	1,175	932
Refineries	638	798
Iron and steel industry	269	646
Petrochemical industry	470	379
Oil and gas processing	Not available	50
Other sources	90	33
Biomass		
Bioethanol and bioenergy	303	91
Total	**7,887**	**13,466**

- This study was published in 2005 in the SRCCS
- It would create value to update and complete this exercise in order to understand both sides of the coins:
  - Emissions which is the topic of this presentation and
  - Storage and Utilisation.

Characteristics of the emissions

Table 2.1 Properties of candidate gas streams that can be inputted to a capture process (Sources: Campbell et al., 2000; Gielen and Moriguchi, 2003; Foster Wheeler, 1998; IEA GHG, 1999; IEA GHG, 2002a).

Source	CO_2 concentration % vol (dry)	Pressure of gas stream MPa[a]	CO_2 partial pressure MPa
CO_2 from fuel combustion			
• Power station flue gas:			
Natural gas fired boilers	7 - 10	0.1	0.007 - 0.010
Gas turbines	3 - 4	0.1	0.003 - 0.004
Oil fired boilers	11 - 13	0.1	0.011 - 0.013
Coal fired boilers	12 - 14	0.1	0.012 - 0.014
IGCC[b]: after combustion	12 - 14	0.1	0.012 - 0.014
• Oil refinery and petrochemical plant fired heaters	8	0.1	0.008
CO_2 from chemical transformations + fuel combustion			
• Blast furnace gas:			
Before combustion[c]	20	0.2 - 0.3	0.040 - 0.060
After combustion	27	0.1	0.027
• Cement kiln off-gas	14 - 33	0.1	0.014 - 0.033
CO_2 from chemical transformations before combustion			
• IGCC: synthesis gas after gasification	8 - 20	2 - 7	0.16 - 1.4

[a] 0.1 MPa = 1 bar.
[b] IGCC: Integrated gasification combined cycle.
[c] Blast furnace gas also contains significant amounts of carbon monoxide that could be converted to CO_2 using the so-called shift reaction.

- Interesting point of view but this could be improved in order to better encapsulate the emissions from the facilities within the plants

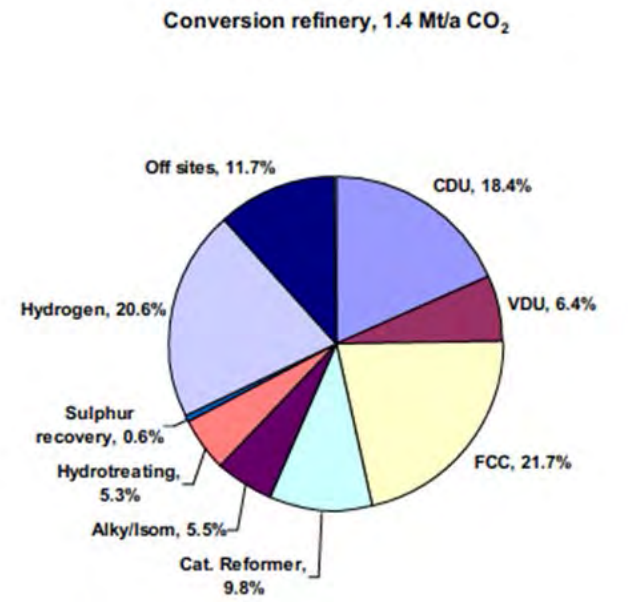
Factories are complex: the example of a refinery

Table 1 Typical properties of refinery CO_2 emission sources

Emission sources	CO_2 % v/v	Oxygen % v/v	SO_2 ppmv	Other contaminants
Gas Fired Process/Utility Furnaces[(1)]	3-6	2-6	10-20	SO_3
Oil Fired Process/Utility Furnaces[(2)]	7-12	2-6	50-600	SO_3
FCC Regenerator Stack	8-12	1-2	1000-15,000	Catalyst Dust, CO, SO_3
Hydrogen via steam reforming:				
Solvent absorption	95-99[(3)]	0	0	Clean
PSA	40-50	0	0	CO, H_2
Hydrogen via residue gasification (POX)	95-99[(3)]	ppm levels	ppm levels	H_2S, COS
SRU Incinerator	2-7	1-8	200-6000[(4)]	COS, CS_2, Sulphur, SO_3

Notes

[(1)] Assuming refinery gas at < 200 ppmv H_2S
[(2)] Assuming heavy fuel oil at up to 1% m/m sulphur
[(3)] From solvent regenerator
[(4)] High variation depending on type of tail gas unit



- More complexity is an issue. But it can be an opportunity for capture. For example by using energy to regenerate amines.

Differenciation between combustion CO2 and process CO2

- Many industries emit CO2 from their specific process.
  - Cement.
  - Iron and steel.
  - Hydrogen production
  - …
- Are there alternatives to CCS for process CO2? Up to which point?
- If there are no alternatives for some emissions, would it have an impact on a prioritisation to access to storage?
- The role of the industry for CO2 utilisation?

Preliminary conclusions

- Industrial sources of CO_2 take a major role in the past development of CCS.
- By 2050, if CCS develops as much as needed for climate mitigation, the share of industry will be 50%.
- Large emitting industries for which there will be little or no alternative to CCS are also major contributors to economic development, particularly in emerging countries.
- Each industry has its own characteristics for its CO_2 emissions. This impacts the performance of capture: CAPEX, energy…

Proposals to go further

- Properly describe the emissions of the large CO2 emitting industries
  - Typical current plants, typical future plants (possibly taking into account the capture opportunities)
  - Current and future implantations in the different regions of the world.
- Which technologies to capture CO2 from industries? At which costs? With which economic/environmental impacts?
- Focus on the most critical industries?
- What are the principal obstacles to the development of CCS for the industry?
- Which alternatives to CCS in order to reduce emissions, including CO2 utilisation? Are they workable at the relevant scale?