Report from CCS for EII task force

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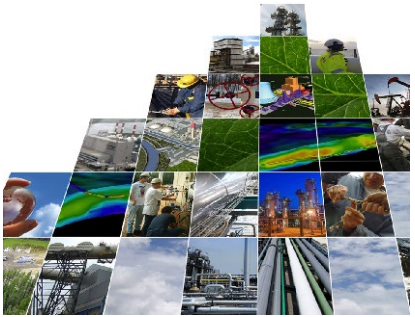
CSLF Technology Roadmap (TRM) 2017

- Objective
  - Provide recommendations to Ministers of the CSLF countries on technology developments that are needed to accelerate the deployment of CCS
- Contents
  - Emphasis on importance and urgency of CCS in light of COP21
  - Sections on industrial CCS, infrastructure, hubs and clusters, transport, storage and utilisation
  - Section on other applications:
    - BioCCS / H_2 production w/CCS

2017 Carbon Sequestration TECHNOLOGY ROADMAP



https://www.cslforum.org/cslf/sites/default/Files/2017CSLFTechnologyRoadmap.pdf

CSLF launched a task force on CCS on EII to

Show how CCS development in Energy Intensive Industries will contribute to the double target of economic growth and climate change mitigation

- The role of EII in economic growth and energy transition.
- Identify the most emitting EIIs and describe their emissions.
- Identify the candidates for CO_2 capture for each EII
  - And the associated challenges, technical as well business and policy related
  - Development status
    - From lab scale to…
    - …large scale facilities (the vast majority of the current CCUS projects are based on emissions from industries rather than from power generation)

Our team

- Commitment from :
  - Norway, Canada, France, UAE, Saudi Arabia, Germany, Netherlands, USA.
- All the industrial sectors are engaged either via a company of those sectors or via a professional organization
  - Total, SABIC, Saudi-Aramco, ADNOC, Solvay, ArcelorMittal, Saint-Gobain, LafargeHolcim, Engie, Concawe, Cefic, Cembureau, GCCSI
- Norway is an essential partner
  - Contributions from Fortum Oslo Varme, Norcem and Yara

Status and way forward for CSLF task force (*)

- Draft versions of most EII chapters prepared
- Still some missing bricks.
- The target is still to be ready to publish the report ahead of the next CSLF Technical Group meeting.

(*) as presented in the last CSLF technical group meeting in april 2018

The content of the report

- Conclusions and recommendations (C/R).
- Executive summary (ES).
- Introduction (I).
- 2-to-4 pagers for each of the 9 sectors within our perimeter (Steel, Cement, Waste to Energy, Fertilizers, Hydrogen, Natural Gas Production, Heavy Oil Production, Chemicals, Refining) (CONT)
- Annex with detailed papers for each of the sectors

The status of the report

- C/R: discussed at length, but still a draft.
- ES: discussed at length, but still a draft.
- Introduction: to be reviewed, but well advanced.
- 9 CONT: all drafts are written, but they are at different level of maturities.
- Annex: drafts are written for all of them except one, still work to mature these drafts.

(C/R1): Conclusions and recommendations

- Some process CO_2 emissions may be difficult, if not impossible, to reduce without CCUS
- The value of CCUS for the whole society can be much higher than the current evaluation of costs.
- CCUS is costly and may present operational challenges: it needs incentives and creative business models to stimulate widespread large-scale implementations.
- CO_2 utilisation options can provide many EIIs a revenue stream to offset the high costs of carbon capture. However, the climate mitigation potential for some utilisation approaches can be limited.
- RD&D must be accelerated to drive down CCUS costs.
  - Topics for joint RD&D include:
    - Reducing combustion related CO2 emissions by CCUS
    - Linking the level of purification required to how CO2 is utilized can minimize the cost of carbon capture and improve the economics of CCUS.
  - In addition, EIIs can develop customized R&D CCUS projects focusing on reducing CO_2 emissions from their specific processes.

(C/R2): the roles of the different stakeholders

- The roles of EIIs for the development of CCUS
  - EIIs should cooperate with the early adopters of CCUS both at the R&D and project levels
  - EIIs, possibly through trade organisations, should cooperate on the transport and storage infrastructures.
  - EIIs should inform governments of the necessity of CCUS in combating climate change and the associated challenges.
- The roles of government for the development of CCUS:
  - Providing a level playing field so that the EIIs can make sound profitable investment decisions on CCUS in a global market
  - Supporting appropriate infrastructure developments
  - Supporting development of business models for CCUS
  - Introducing effective measures to encourage procurement of low-carbon industrial products and infrastructure to avoid carbon leakage.
- The role of the oil and gas sector will be
  - to bring its expertise to develop CO_2 infrastructure and storage capacities to alleviate the risks undertaken by EIIs willing to invest in CCUS
  - to help develop collaborations between EIIs.
- End-use consumers must be made aware of the fact that low-carbon industrial products may incur only modest additional costs to them.
- The role of national and international CCUS organisations will be to advocate to the main relevant stakeholders.

(C/R3): the roles of the different stakeholders

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- End-use consumers must be made aware of the fact that low-carbon industrial products may incur only modest additional costs to them.
- The role of national and international CCUS organisations will be to advocate to the main relevant stakeholders.

CCUS complements, rather than competes, with other low-carbon solutions to help the transformation to a decarbonized society.

(ES): Headlines of the Executive Summary

- Energy Intensive Industries are key building blocks of all economies
- EIIs are needed for climate change mitigation and adaptation
- EII industries are intensive in CO_2 emissions.
- EIIs are actively working on decreasing CO_2 emissions but there are obstacles
- CCUS will play an essential role in decreasing the emissions from EIIs
- CCUS in EIIs: On-going Efforts and Challenges

(I) Introduction

- Introduction to Carbon Sequestration Leadership Forum (CSLF)
- Task force mandate and objectives of report
- Motivation, industry's role in global CO2 emissions
- The role of CCUS in the industry sector
- The industries considered in more detail in this report

(CONT): The individual 2-to4 pages contributions

- Role in today's economies
- Contribution to the economic growth
- Geographical split
- Production and CO2 emission trends
- CO2 emission pattern of a typical plant, which technology to reduce CO2 emissions
- Development status of the CCUS technologies
- The challenges to overcome
- The alternatives to CCUS

Annex

- Each sector will provide a more detailed set of information to feed the shorter contributions of the main report (previous slide).

The way forward

- We are late compared to the plans 6 month ago ☹.
- Generally good support from the representatives of the industries ☺.
- We moved forward quite a bit ☺.
- Showing the roles of the different stakeholders might be a promisive way of making progress on CCUS for industries ☺?

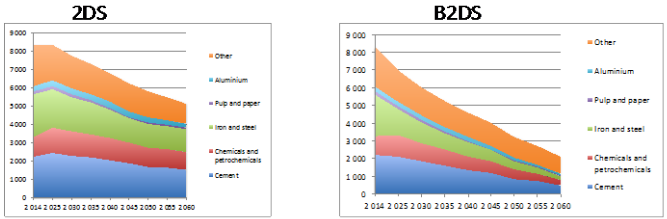
Thank you for your attention

Back-up slides

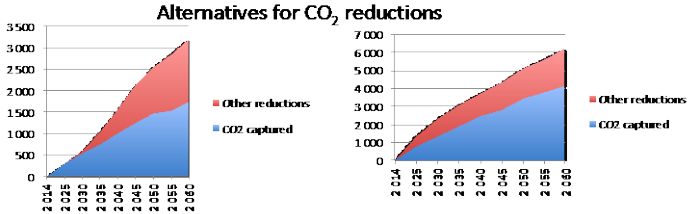
The role of CCUS in EII for CO2 emissions reduction

- World needs EII
- EII needs CCS
  - 40% reduction in 2DS
  - 75% reduction in B2DS

CO_2 emissions from EII, in Mt/year
(IEA Energy technology Perspectives 2017)



World needs CCS for EII



- Industries which are considered
  - Steel, cement, fertilizers, refining, natural gas, heavy oil, waste-to-energy, hydrogen, other chemical industries

IN WHAT IS CCS on EII = or ≠ Power ?

- Power emissions are significantly larger than individual EIIs' emissions, but cumulative EII's emissions are comparable to Power emissions.

- Significant CO2 emissions from EII are not linked to energy consumption.

  cement : $CaCO_3$=>$CaO + CO_2$ (60% of CO_2 emissions)

  steel : $2Fe_2O_3+3C$=>$4Fe+3CO_2$ (0.6t CO_2/tFe)

  hydrogen from SMR : CH_4+2H_2O=>$4H_2+CO_2$ (5,5tCO_2/tH_2)

  CO_2 from natural gas : separation from natural gas

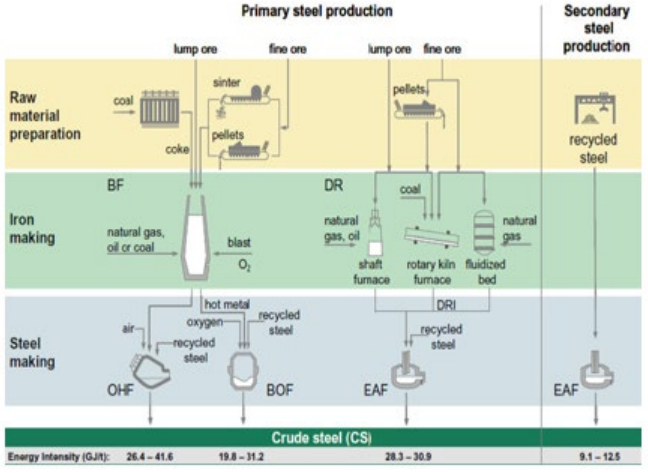
- CO_2 emissions characteristics depend very much on which EII and on which process of a given EII.

- More alternatives exist for Power than for most of EII.

A relevant level of description of EII emissions (quantity is not the full story)?

Example of a steel plant

	Primary energy[2] (GJ/t)	Direct energy[3] (GJ/t)	Total CO_2 emission[4] (tCO_2/t)	Direct CO_2 emission[5] (tCO_2/t)
Coke plant	6.827	6.539	0.824	0.794
Sinter plant	1.730	1.549	0.211	0.200
Pellet plant	1.204	0.901	0.075	0.057
Blast furnace	12.989	12.309	1.279	1.219
BOS plant	-0.253	-0.853	0.202	0.181
Electric arc furnace	6.181	2.505	0.240	0.240
Bloom, slab and billet mill	2.501	1.783	0.125	0.088
Hot strip mill	2.411	1.700	0.120	0.082
Plate Mill	2.642	1.905	0.133	0.098
Section Mill	2.544	1.828	0.127	0.084
Pickling line	0.338	0.222	0.016	0.004
Cold mill	1.727	0.743	0.075	0.008
Annealing	1.356	1.086	0.070	0.049
Hot dip metal coating	2.108	1.491	0.104	0.059
Electrolytic metal coating	4.469	2.619	0.208	0.046
Organic coating	1.594	0.758	0.074	0.003
Power Plant	12.173	12.173	1.989	1.989



	Blast Furnace	Basic Oxygen Furnace
CO2 concentration	25%	20%
Pressure	50mbar	20mbar
Temperature	30°C	30°C
Humidity	100%	100%
Impurities	Dust, H2S,…	Dust
Others	CO (25%)	CO (60%)

Is there a unique point of emission or are there multiple points?
CO2 stream characteristics : concentration, pressure, impurities

Steel – preliminary findings

- CO2 emission reductions are being performed without CCS:
  - Continuing with a fossil fuel based metallurgy
    - Increased recycling
    - Coal-to-gas
    - Change of steel making route
  - Shifting to a non-fossil based metallurgy
    - Use of carbon from sustainable biomass
    - Switch to H_2 as reducing agent, produced from electrolysis with carbon-free electricity

- **But it is only with CCS that CO2 emissions will be achieved in line with**
  - 2DS (55 to 60 % reduction) or B2DS (>80%),
  - or a net zero emissions target for this sector,
  - or even a net negative emissions target via BECCS

Some findings (1/2)

- EII are essential for the future economic growth
  - How to build 1 Shanghai every 4 months without cement and steel?
  - How to increase food production without fertilizers?

- And for energy transition
  - How to increase hydrogen production without fossil energy?
  - How to increase natural gas production without separating CO2 from natural gas?
  - How to build new energy generators and infrastructure without steel and cement?

- In most EII, CO2 emissions are not due to fossil fuel combustion only
  - For these types of emissions, low-carbon energies are not an alternative and alternatives will be either a change of process, or a substitution of one product to another one with the same characteristics without CO2 emissions.
  - Process CO2 streams may offer better characteristics than combustion CO2 (higher concentrations)

=> **Energy Intensive Industries could be requalified as Emission Intensive Industries**

Some findings (2/2)

- Almost all the industrial sectors will grow significantly in the next decades particularly in emerging countries.

- A particular case to be noted : Hydrogen production is anticipated to multiply by a factor higher than 5 until 2050.

- The most advanced industries are :
  - Natural gas treatment (by far the largest area for CCS industrial projects),
  - Hydrogen, steel, fertilizer, ethanol production industries have developped CCS projects.
  - Cement industry and waste to energy have no project yet, but… Norway!

- Beyond technology-linked challenges to be met, business models will have to be invented by the industries itself with the support of the public authorities.

Some reminders and findings (*)

- EII are essential for the future economic growth
- And for energy transition
- In most EII, CO2 emissions are not due to fossil fuel combustion only :

  => Energy Intensive Industries could be requalified as Emission Intensive Industries

- Almost all the industrial sectors will grow significantly in the next decades particularly in emerging countries.
- A particular case to be noted : Hydrogen production is anticipated to multiply by a factor higher than 5 until 2050.
- The most advanced industries are :
  - Natural gas treatment (by far the largest area for CCS industrial projects),
  - Hydrogen, steel, fertilizer, ethanol production industries have developped CCS projects.
  - Cement industry and waste to energy have no project yet, but… Norway!
- The impediments to CCUS developments in industries are more of a business model type than of a technology type. The impact of capture costs on the total production costs of these industries are generally important.

(*) as presented in the last CSLF technical group meeting in april 2018

Agreement of Paris

Reach global peaking of GHG emissions as soon as possible

Achieve a balance between anthropogenic emissions and removals by sinks of GHG in the second half of this century

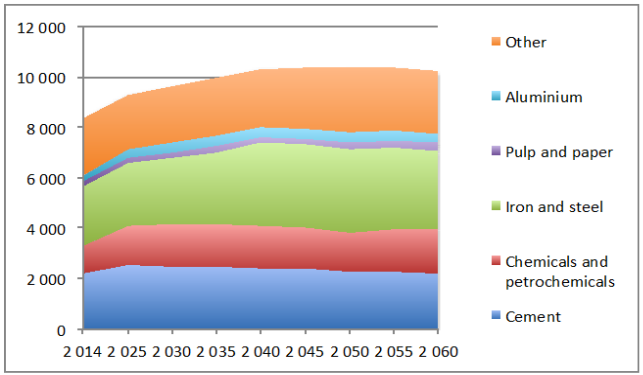
World needs CCS…

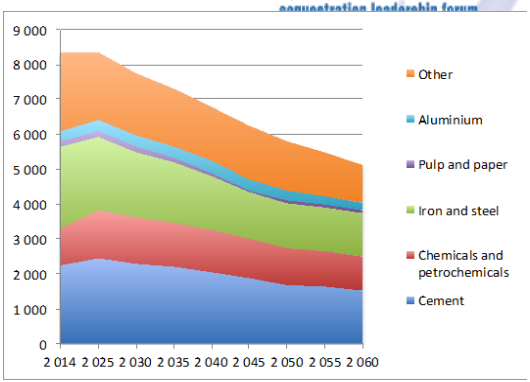
Balance between emissions and sinks means that owing to CCS : some sectors might not be zero emissions,

- But certainly not the Energy Intensive Industries,
- Need to develop negative emissions projects (an opportunity for EII?)

=> EII needs CCS

Which industries to consider?





- Cement
- Steel
- Chemicals
- Refining
- Natural gas
- Heavy oil
- Hydrogen
- Fertilizers
- Waste to energy

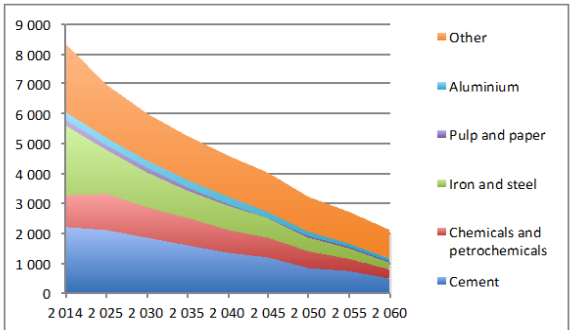
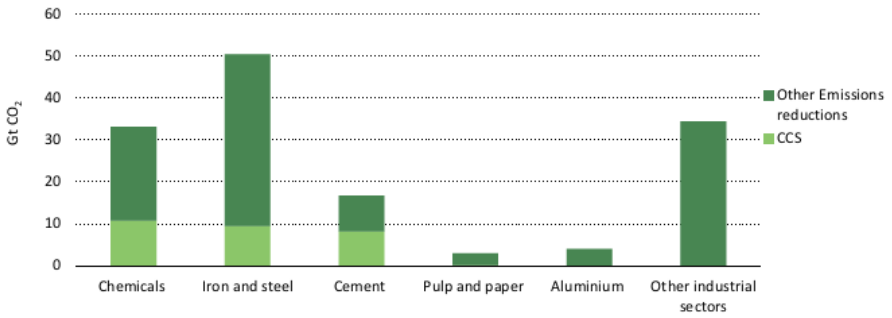


Figure 1.2. CO_2 emissions in Mt CO_2/year from industry in RTS (upper left), 2DS (upper right) and B2DS (lower) scenarios (from IEA, 2017).

Why CCUS for industry is an important issue

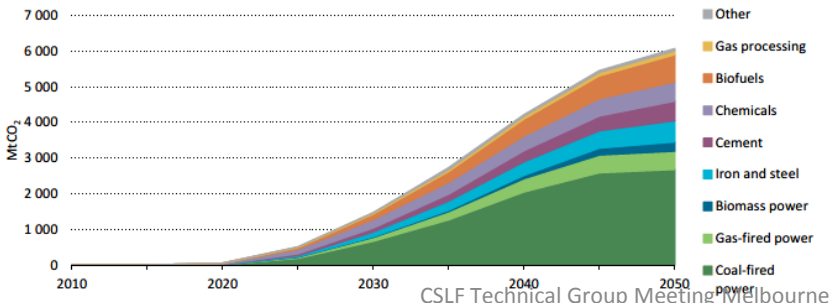
Example :
CaCO3 => CaO+CO2

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

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*.

CCS industry = CCS power

Source : IEA