# IEAGHG-IEA Technical study: Homogenized Cost review of $CO_2$ capture in the cement and iron and steel industries

Monica Garcia

Technology Analyst, IEAGHG

TCCS-10, June 18-19th 2019, Trondheim (Norway)

*Views, findings and publications of the IEAGHG do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.*

# Who are we?

Our internationally recognised name is the IEA Greenhouse Gas R&D Programme (IEAGHG). We are a Technology Collaboration Programme (TCP) and are a part of the International Energy Agency's (IEA's) Energy Technology Network.

# Disclaimer

The IEA Greenhouse Gas R&D Programme (IEAGHG) is organised under the auspices of the International Energy Agency (IEA) but is functionally and legally autonomous. Views, findings and publications of the IEA Greenhouse Gas R&D Programme do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.


Southern Company
Chevron
INSTITUT TEKNOLOGI BANDUNG 1920
TOTAL
J-POWER
CIAB
ExxonMobil
INSTITUTO DE INVESTIGACIONES ELECTRICAS
Evaluating technology options to mitigate greenhouse gas emissions
ieaghg
EPRI
JÜLICH FORSCHUNGSZENTRUM
DOOSAN Doosan Babcock
equinor
SOTACARBO SUSTAINABLE ENERGY RESEARCH CENTRE
BR PETROBRAS
جامعة خليفة Khalifa University
JGC
Powering. Reliable. Future. RWE

# The cost review method

*Garcia M., Berghout N. (2019),* ***Toward a common method of cost-review for carbon capture technologies in the industrial sector: cement and iron and steel plants.*** *International Journal of Greenhouse Gas Control 87, 142-158*

# The problem

- There are substantial differences between cost methods used by different organisations and initiatives to evaluate CCS technologies for the industrial sector.
- The communication of results varies from one organisation to another ($CO_2$ capture costs, $CO_2$ avoided costs and manufacturing costs)→ confusion, misunderstanding, unfair comparison.

| Cost Categories | CEMCAP (2017) | NETL (2014) | IEAGHG (2013) | Kuramochi (2012) |
|---|---|---|---|---|
| **BEC** | | | | |
| | Total equipment costs Installation costs | Process equipment | Civil, steelworks, erection others | Installation costs |
| | | Supporting facilities | | |
| | | Direct and indirect | | |
| | | Labour | | |
| **EPC** | | | | |
| | Indirect costs | EPC contractor services | EPCC | Engineering services |
| | Project contingency | Process contingency | Project contingency and fees | |
| | | Project contingency | | |
| | Owner Costs | Owner Costs | Owner Costs | Owner Costs |
| | Total Plant Cost (TPC) | Interest during construction | Working capital, start-ups, spare parts | Total Plant Cost (TPC) |
| | | | Interest during construction | Interest during construction |
| | | Total as spent cost (TASC) | Total Capital Requirement (TCR) | Total Capital Requirement (TCR) |

| Capital Cost Element | CEMCAP (2017) | NETL (2014) | IEAGHG (2013) | Kuramochi |
|---|---|---|---|---|
| **Process equipment cost (PEC)** | Process simulation with optimized design | Summing up individual equipment | Summing up individual equipment | From Original Study * |
| **Supporting facilities cost** | NA | NA | NA | 130% of PEC |
| **Others** | NA | Initial solvent and corrosion inhibitor : 0.035+0.02% TPC | Civil, steelworks, erection others: 108% PEC | |
| **BEC**** | | | | |
| **Engineering service cost** | Quantified as indirect costs (14%), with a breakdown | 8.50% of BEC | EPCC: 6.87% of BEC | |
| **EPC** | | NA | | |
| **Process contingency** | From 0 to 40% depending on the technology status | 21.70% of BEC | 10% of Installed costs (here EPC) as contingencies and fees | |
| **Project contingency** | Owner costs and contingencies vary from 19 % to 40% l of the total EPC cost, depending on maturity level | | | |
| **Others** | NA | NA | NA | |
| **Total Plant Costs (TPC)** | | | | |
| **Owner costs** | NA | 24.31% TPC | 7% of TPC | 10% of TPC |
| **Others** | NA | NA | 4.7% of TPC | |
| **Total Overnight Cost (TOC)** | NA | | | |
| **Interest during construction (IDC)** | NA | 9.9% of TOC | 3.8% of TPC | |
| **Total Capital Requirement (TCR)** | | | | |

# The objectives

- To develop a method based on a bottom-up analysis which allows for a comparative assessment of $CO_2$ capture technologies in the industrial sector
- Conduct a consistent assessment of the techno-economic performance of $CO_2$ capture technologies applied to the cement and iron and steel industries

# The objectives

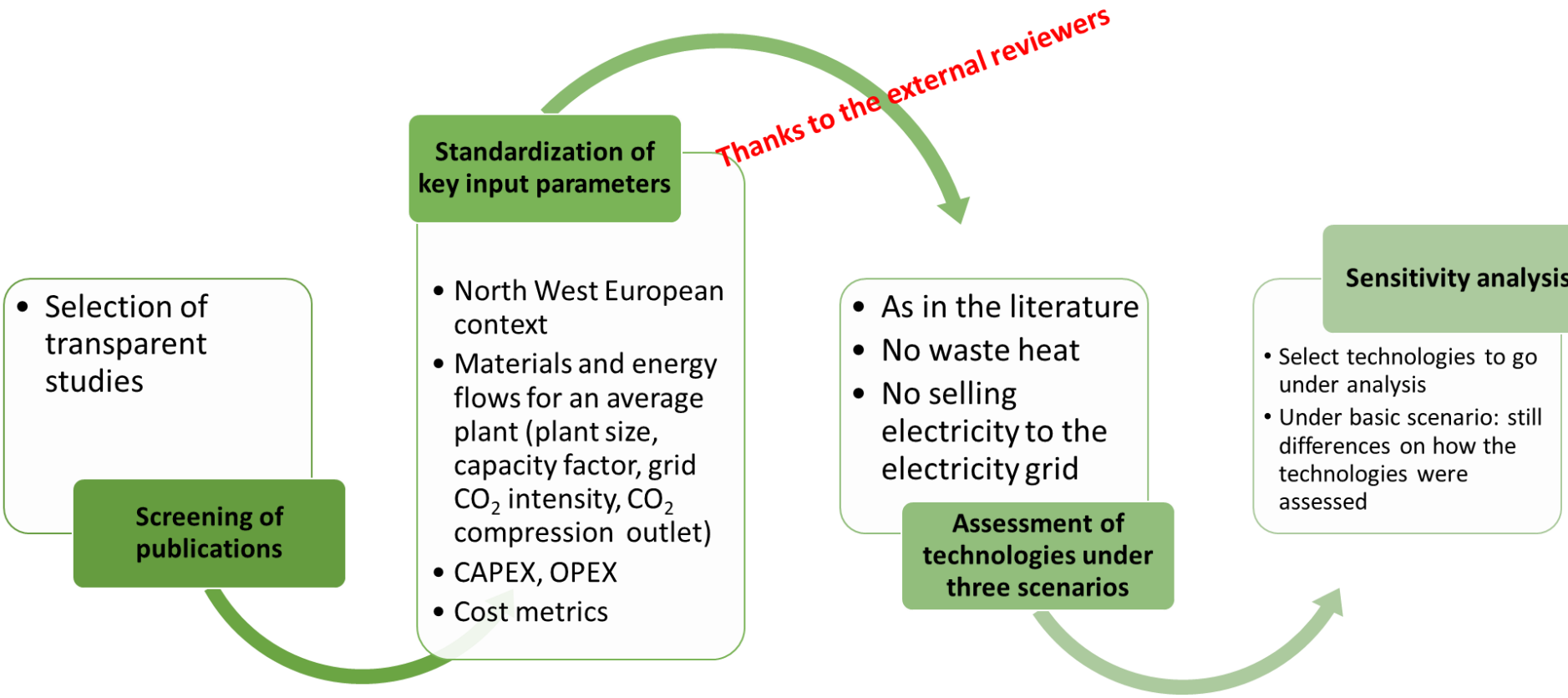
- IEAGHG & IEA joint efforts to:
  - Provide a **tentative set of parameters and assumptions** to take into account on the evaluation of the cost of CCS in the cement and iron and steel sectors.

  - To **homogenise** CCS costs reported in the literature for the cement and iron and steel sectors
  - **Perhaps:** A number of assumptions are onsite specific and cannot be extrapolated → how to communicate transparent evaluations by describing technical and economic parameters to include in future studies. Limitations are given

# The objectives

- IEAGHG & IEA joint efforts to:
  - Compare the set of cost assumptions given in transparent studies and this work → Partly explain the cost differences reported in the literature.
    - ✓Identify cost-methods
    - ✓Identify assumptions: process configurations, energy supply/demand,

# Phases of this study



# The proposed solution

- To standardize cost measures and metrics
- To define and homogenise boundaries
- To define and quantify elements of CCS cost: CAPEX, OPEX
- To define and homogenise technical and financial parameters

# Limitations

- The **underlying data** and process designs of the manufacturing and carbon capture systems differ between the reviewed studies. Different process designs selected by the authors of the studies
- Several studies provided **insufficient information** required for the standardisation process
  - Additional assumptions were made
  - Detailed cost estimations tend to present higher costs
- **Technological improvements** in capture technologies that have taken place **over recent years** are not necessarily reflected in the quantitative results
- The **energy or steam production technologies** differ among studies, affecting the CAPEX and fixed OPEX
- In the cases of steelmaking, the **blast furnace and basic oxygen furnace route (w/o $CO_2$ capture) was used as the reference** case against the costs of all other cases, including configurations with advanced steelmaking processes
- The results should be corrected using **location** cost factors, as presented in IEAGHG (2018), to determine the techno-economic performance for specific locations.

# Assumptions for alternative scenarios

- NO waste heat
  - If required, a new natural gas-fired boiler was assumed to be built to supply the steam, with a CAPEX of 85€/KW and an additional 2% of such CAPEX as operational cost.
  - From the results, it helped to homogenise the "most optimistic" studies on waste heat recovery
- If there is electricity surplus, that cannot be sold to the electricity grid, neither obtaining "environmental" revenue

Results after applying the cost-review method

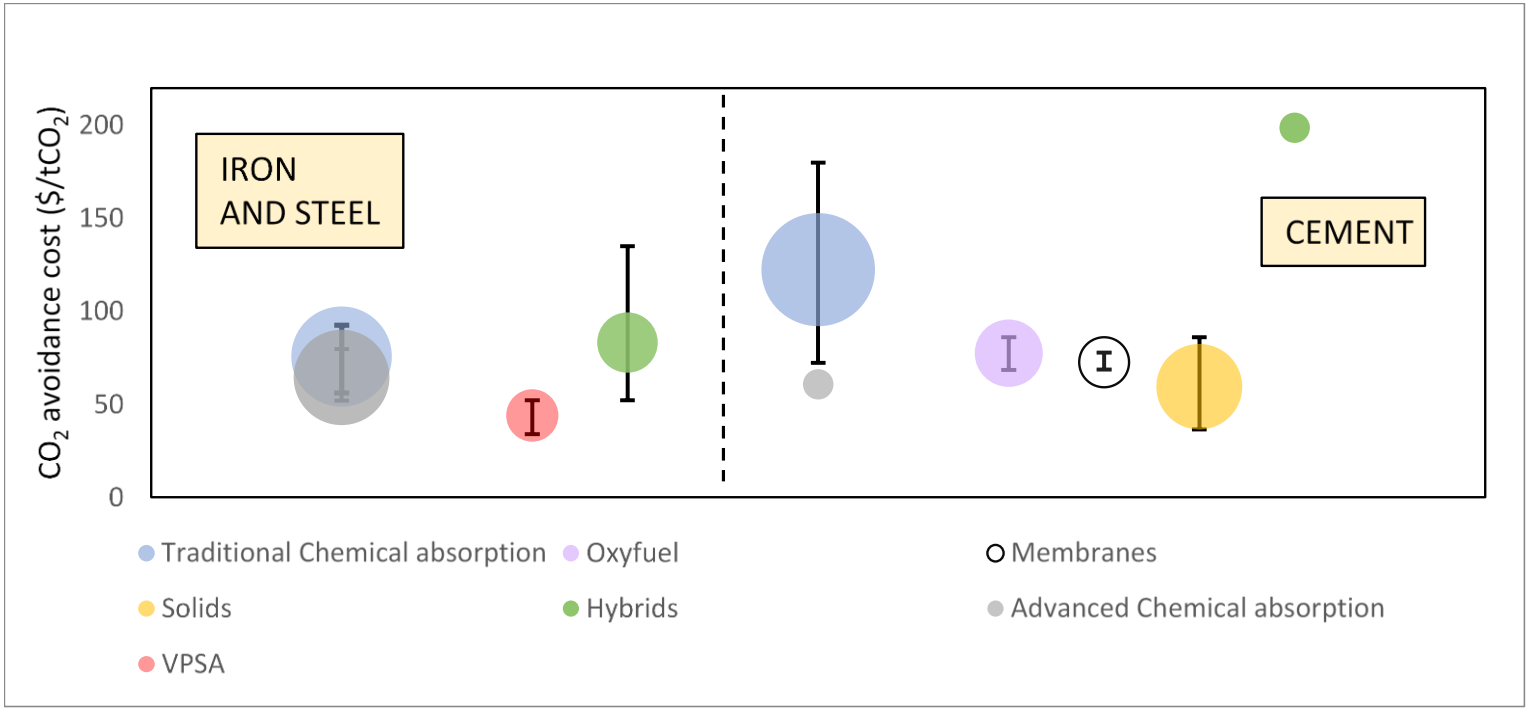
***IEAGHG 2018-TR03, Cost of $CO_2$ capture in the industrial sector: Cement and Iron and Steel industries*** , Sept 2018

| COST PARAMETER | SCENARIO | Cement | | | | | | Iron and Steel[g] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Traditional chemical absorption | Advanced chemical absorption | Membrane | Oxy- | Solids-based | Hybrid[d] | Traditional chemical abs. | Advanced chemical abs. | VPSA | Hybrid[e] |
| **$CO_2$ avoidance cost ($\$_{2016}$/ t $CO_2$ avoided)** | BASIS | 72-180 | 61 | 69-78 | 69-86 | 38-86 | 199 | 56-82 | 52-80 | 34-52 | 65-135 |
| | No-heat-recovery | 77-215 | 91 | 69-78[a] | 69-86[a] | 64-348 | 261 | 56-119 | 28-70 | 34-52[a] | 81-135 |
| | No electricity export | 72-215 | 61 | 69-78[b] | 69-86[b] | 38-91 | 199[b] | 69-93 | 12-37[f] | 34-52[b] | 52-90 |
| **$CO_2$ captured cost ($\$_{2016}$/ t $CO_2$ captured)** | BASIS | 34-79 | 45 | 51-57 | 50-63 | 11-63 | 146 | 16-21 | 7-16 | 11-14 | 23-66 |
| | No-heat-recovery | 34-93 | 59 | 51-57[a] | 50-63[a] | 21-68 | 171 | 17-30 | 7-18 | 11-14[a] | 33-66 |
| | No electricity export | 36-101 | 45 | 51-57[b] | 50-63[b] | 20-67 | 146[b] | 7-23[f] | 3-9[f] | 11-14[b] | 33-44 |
| **Increase of manufacturing cost [c] ($\$_{2016}$/ t cement or steel)** | BASIS | 46-116 | 20 | 39 | 38-39 | 26-40 | 94 | 54-93 | 74-76 | 30-45 | 69-86 |
| | No-heat-recovery | 46-116 | 26 | 39[a] | 38-39[a] | 37-65 | 110 | 54-117 | 77-78 | 30-45[a] | 69-86[a] |
| | No electricity export | 49-116 | 20 | 39[b] | 38-39[b] | 40-74 | 94[b] | 39-117[f] | 36-37[f] | 30-45[b] | 69-86[b] |

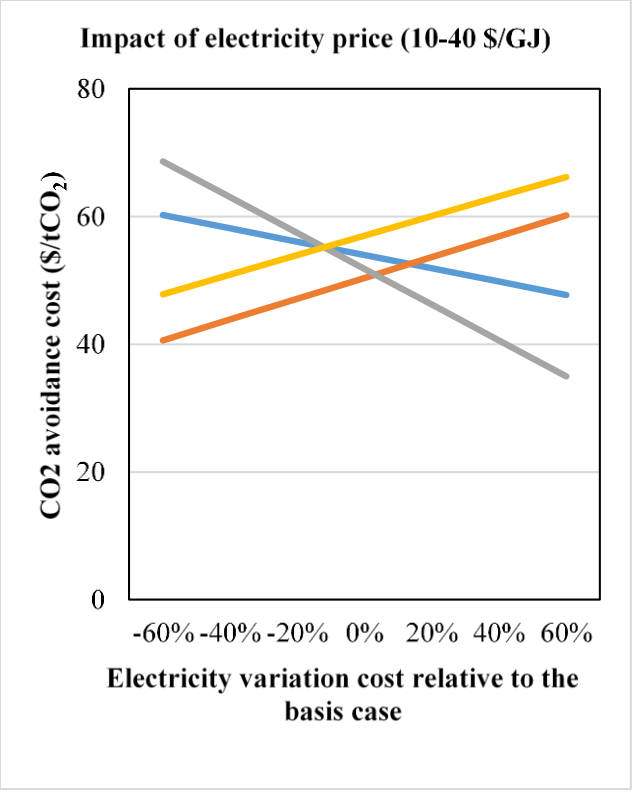
## More information: Sensitivity analysis

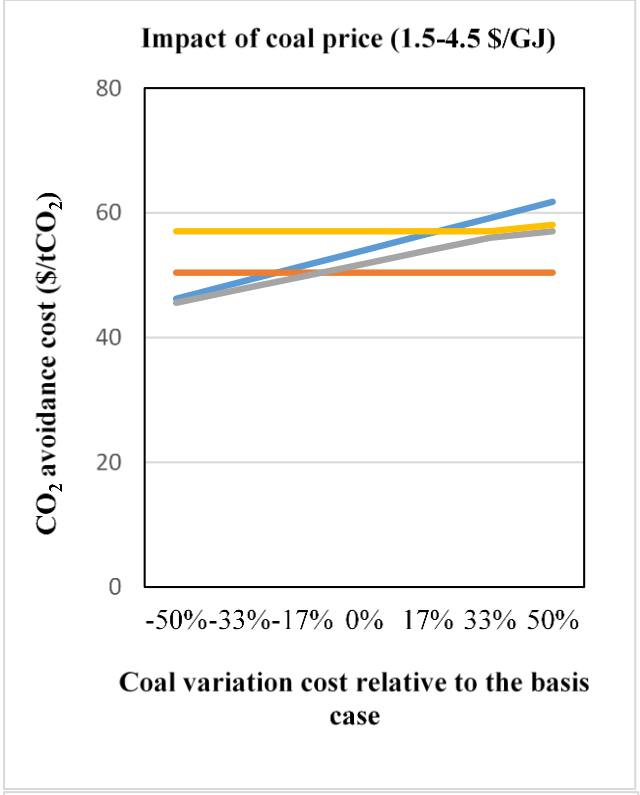
Garcia M., Berghout N., Herraiz L. (2018) **$CO_2$ Capture in the Cement and Iron and Steel Sectors: A Homogenised Techno-Economic Review,** GHGT-14 Proceedings

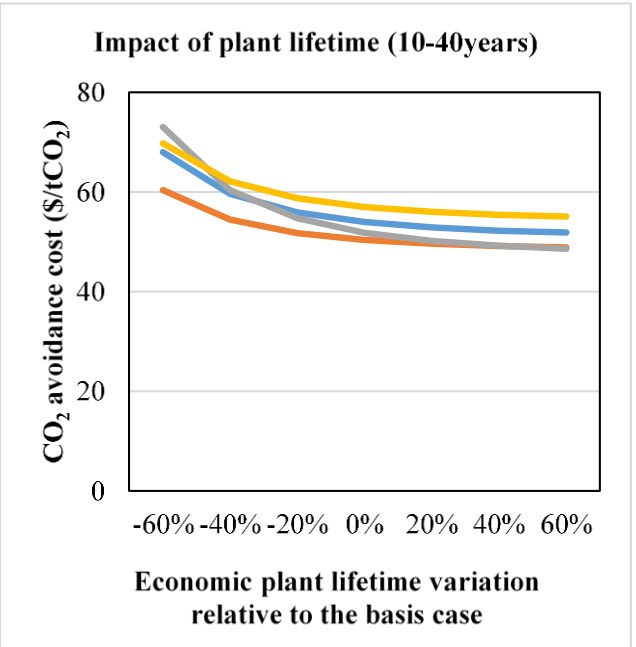
# Overview

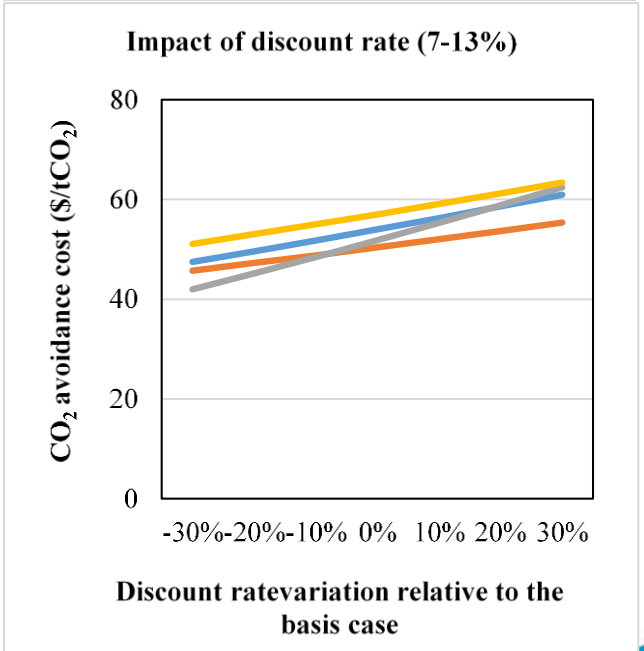



We cannot select the BEST technology for each sector. The review covered a wide range and the cost is very site-specific




- Expected impact of key parameters on the costs
- Site and region-specific

# Let's summarize

- Main differences found on the literature review
  - Waste heat available for the Capture process / Heat integration
  - Energy production/ Energy cost
  - Steam production/ Steam cost
  - Revenue from selling electricity to the electricity grid
- We provided a cost-review method to homogenise the $CO_2$ capture/avoidance costs and increase on the manufacturing cost
- Still, our **method has limitations.** This work is part of a bigger initiative
- Best technology? **Difficult to choose one**. Based on specific conditions

**Questions?**

**monica.garcia@ieaghg.org**