GHGT, Melbourne, 22.10.2018

Techno-economic evaluation of five technologies for CO_2 capture from cement production

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Introduction

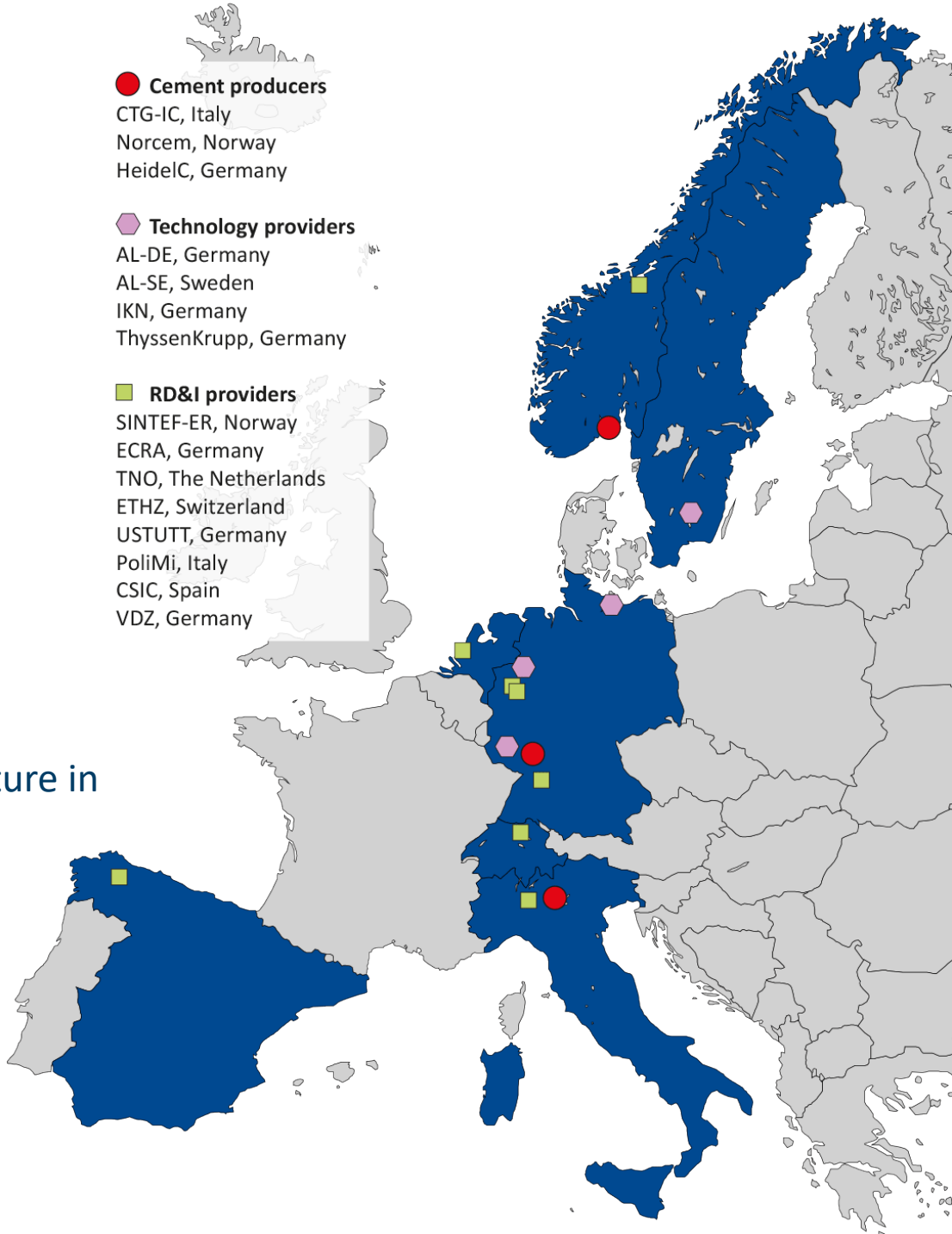
- Motivation

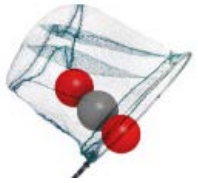
  7-9% of global anthropogenic CO_2 emissions from the cement industry – CCS only viable option

- H2020 project CEMCAP

  Prepare the ground for large-scale implementation of CO_2 capture in the European cement industry

  → Understanding costs and reducing uncertainties important!

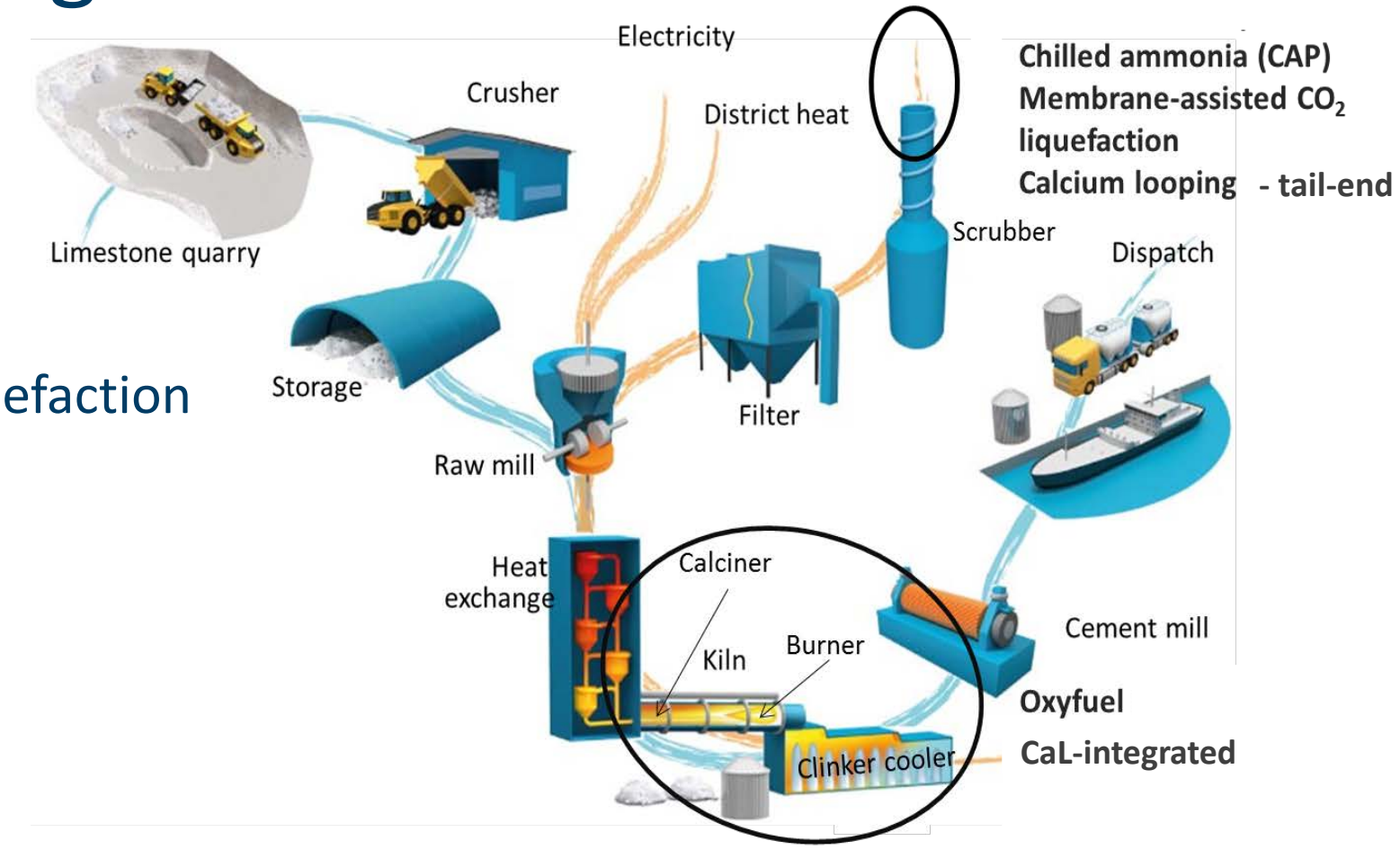


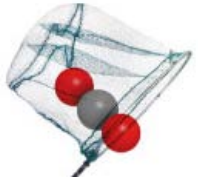


CEMCAP technologies

- Oxyfuel process
- Chilled ammonia process
- Membrane-assisted CO_2 liquefaction
- Calcium looping (CaL)
  - Tail-end
  - Integrated entrained flow

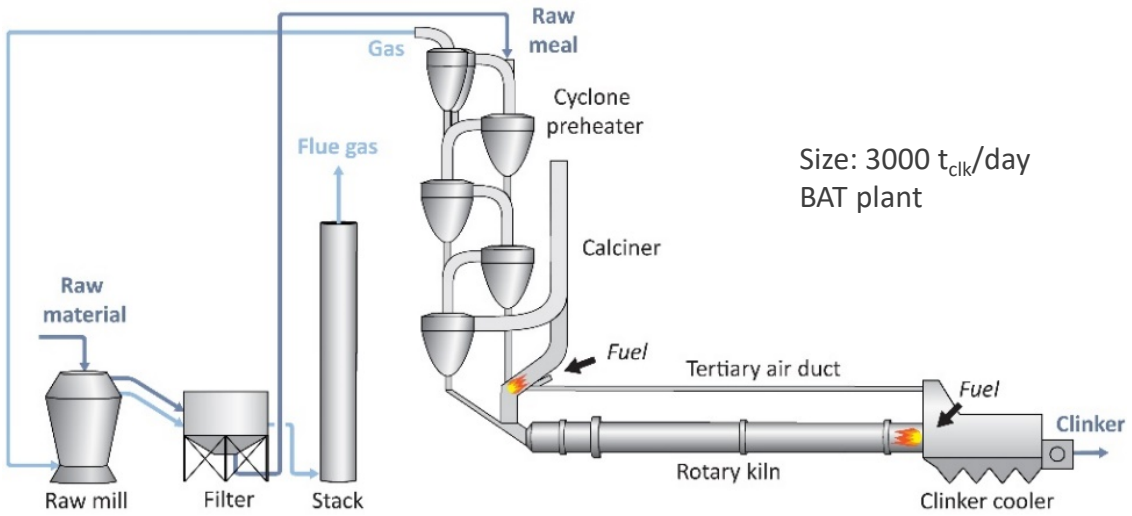
- Reference: MEA





Approach

- CEMCAP framework
- Reference cement kiln



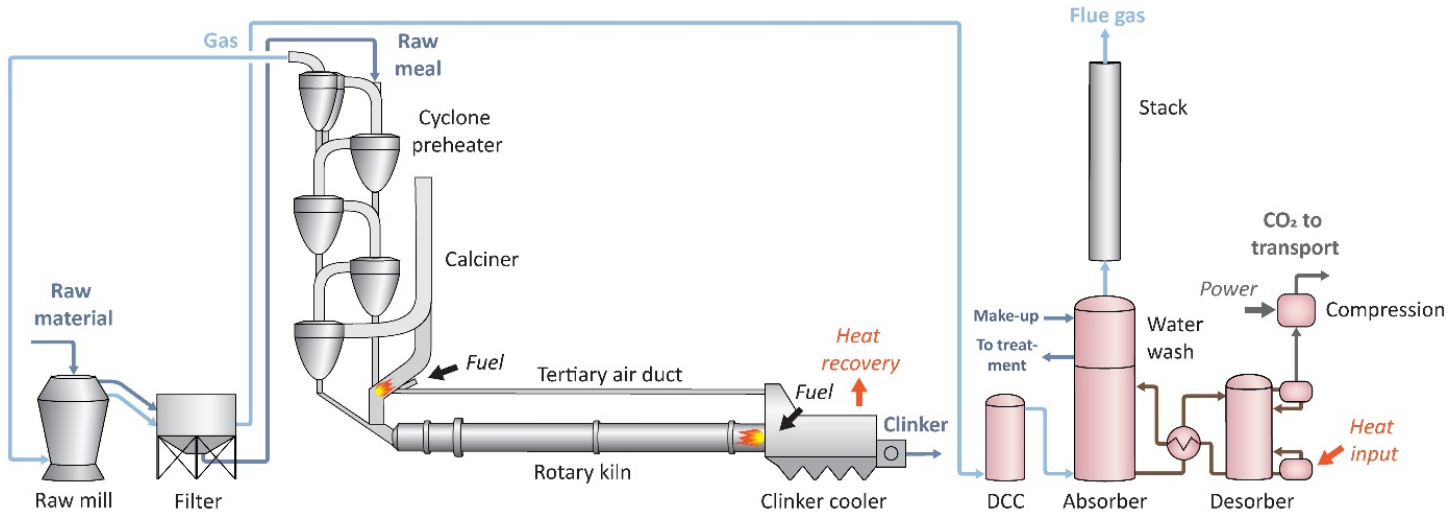
Size: 3000 t_{clk}/day
BAT plant

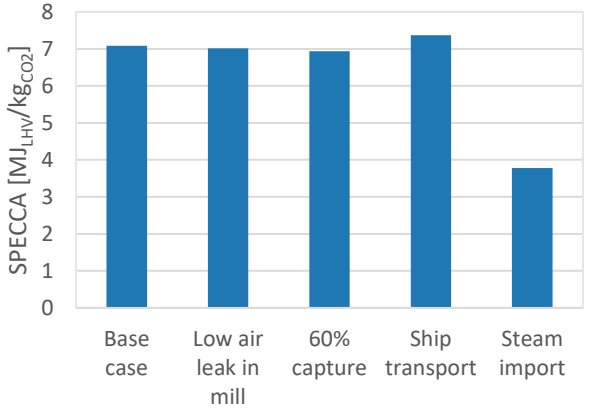
- Key performance indicators
  - Specific equivalent primary energy consumption per CO_2 avoided (SPECCA)
  - Cost of clinker
  - Cost of CO_2 avoided

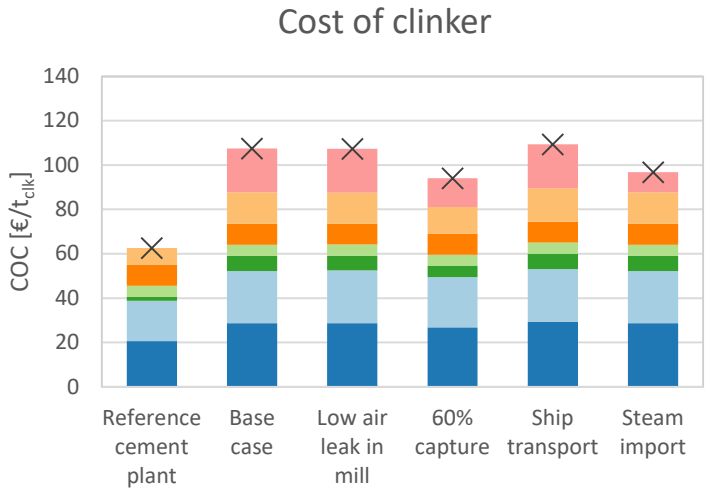
- Several conditions studied
  - Base case (90% capture, pipeline, steam from NG boiler)
  - Alternative cases: Low air leak, optional capture, ship transport, steam import, etc.
  - Sensitivity analysis

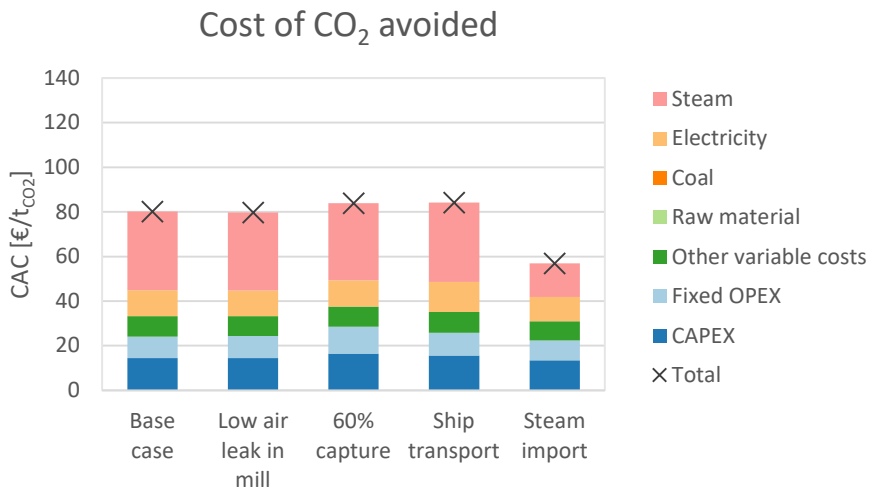
MEA absorption

- Base case
  - SPECCA: 7.1 MJ/kg_{CO2}
  - Cost of clinker: +72%
  - Cost of CO_2 avoided: 80 €/t_{CO2}
- Cost of steam critical



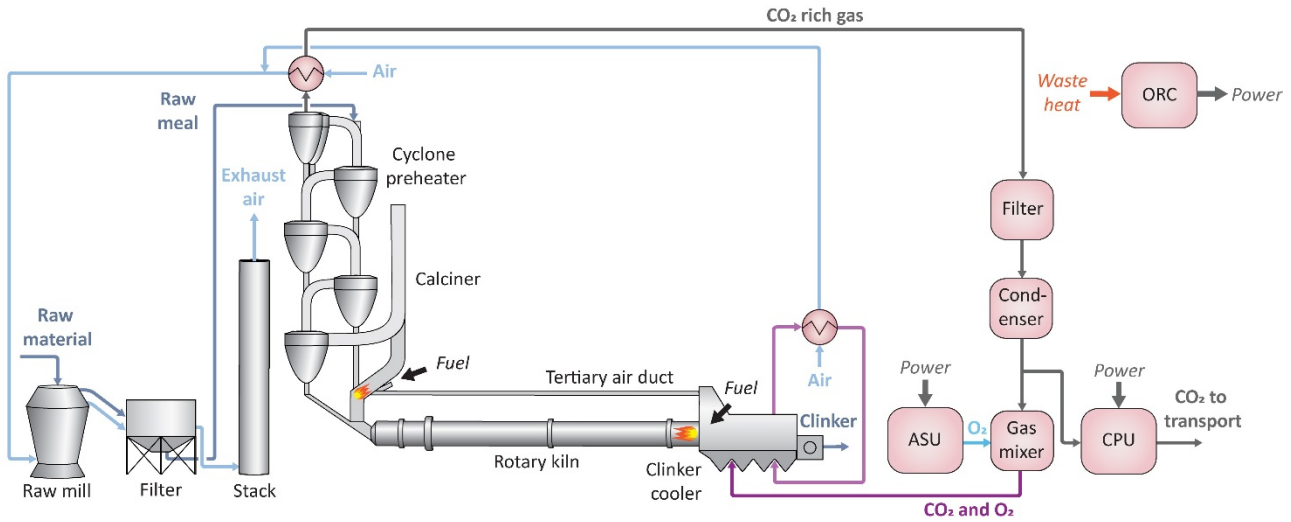


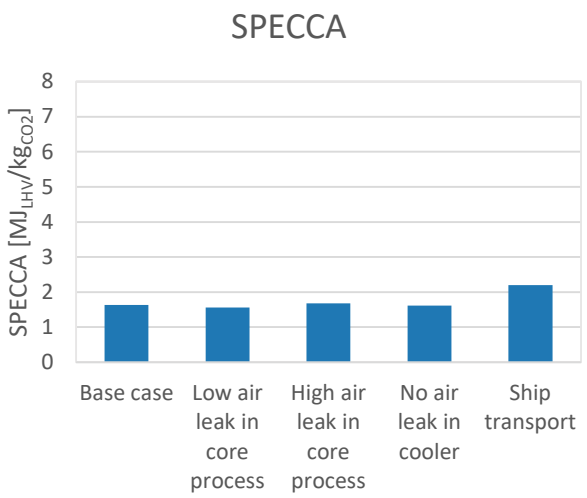


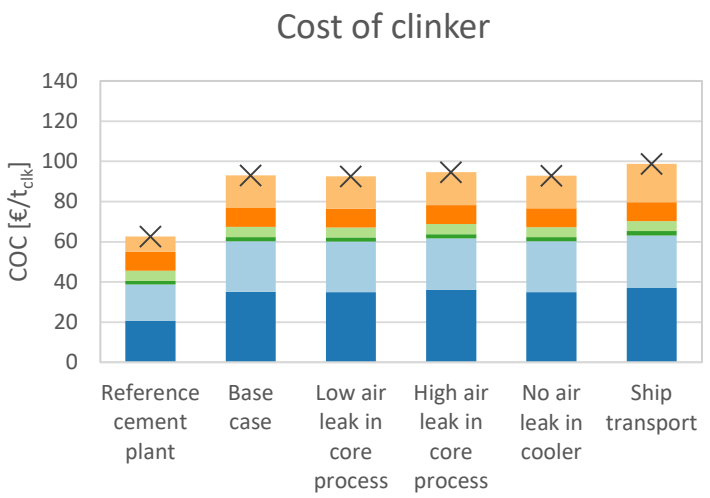


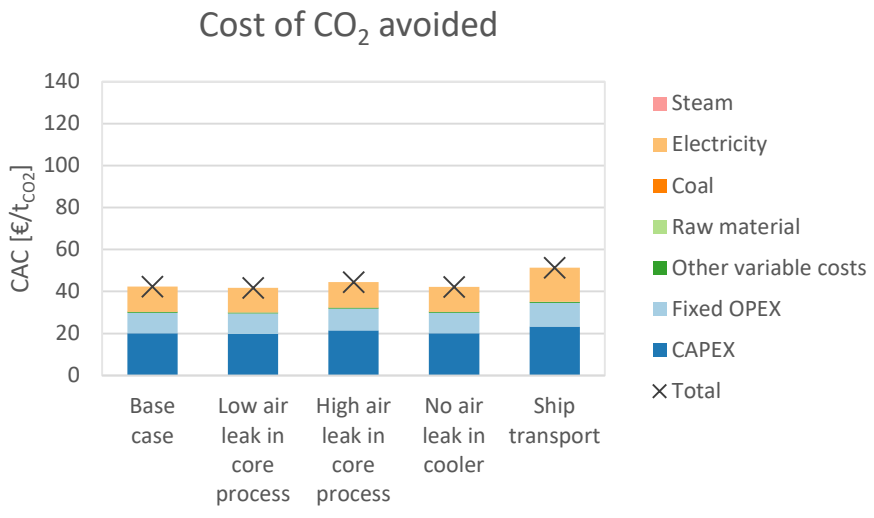
Oxyfuel process

- Base case
  - SPECCA: 1.6 MJ/kg_{CO2}
  - Cost of clinker: +49%
  - Cost of CO_2 avoided: 42 €/t_{CO2}
- Low CAPEX and OPEX



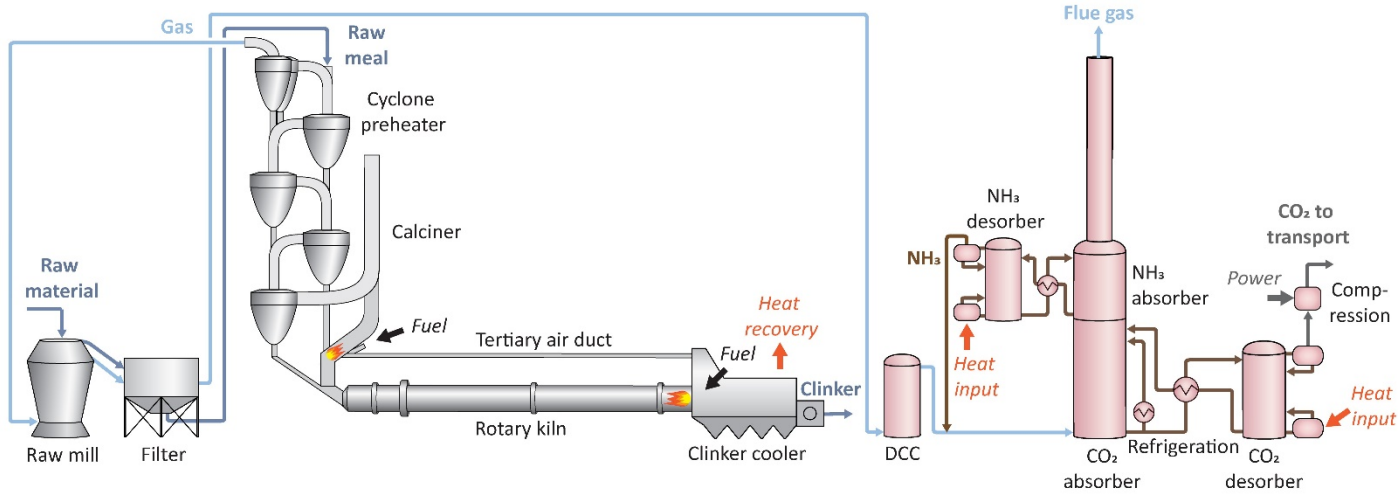




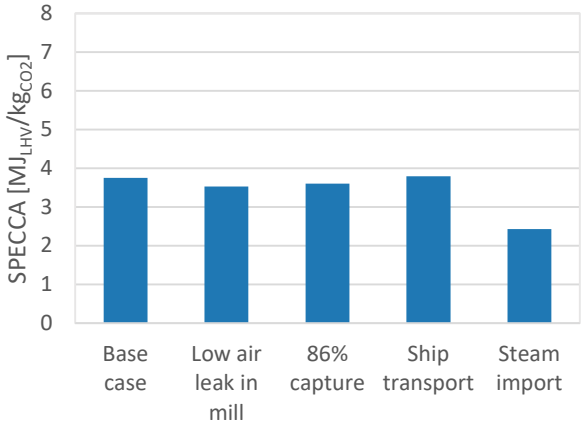


Chilled ammonia process

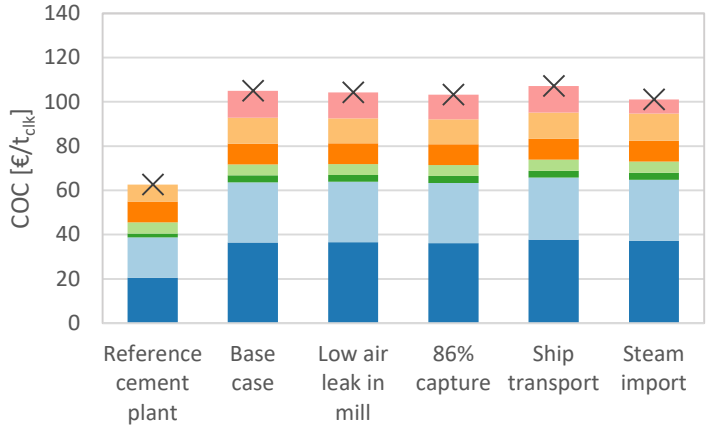
- Base case
  - SPECCA: 3.8 MJ/kg_{CO2}
  - Cost of clinker: +68%
  - Cost of CO_2 avoided: 66 €/t_{CO2}
- Lower steam and power demand than MEA
- IP protection for improved process ongoing



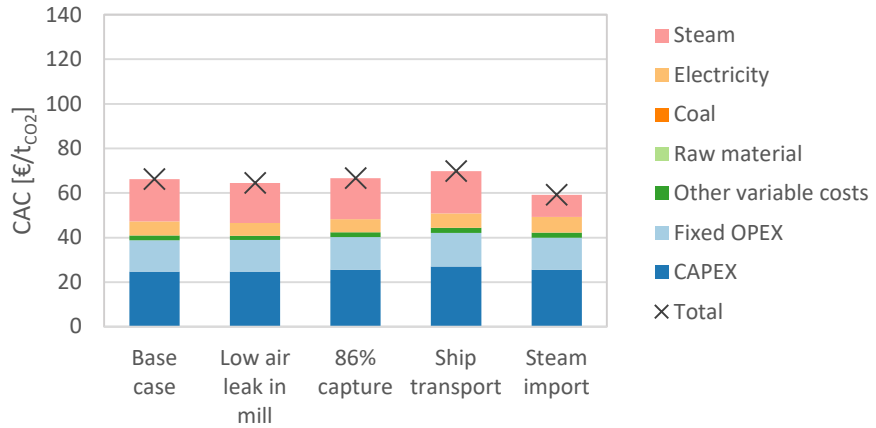
SPECCA



Cost of clinker

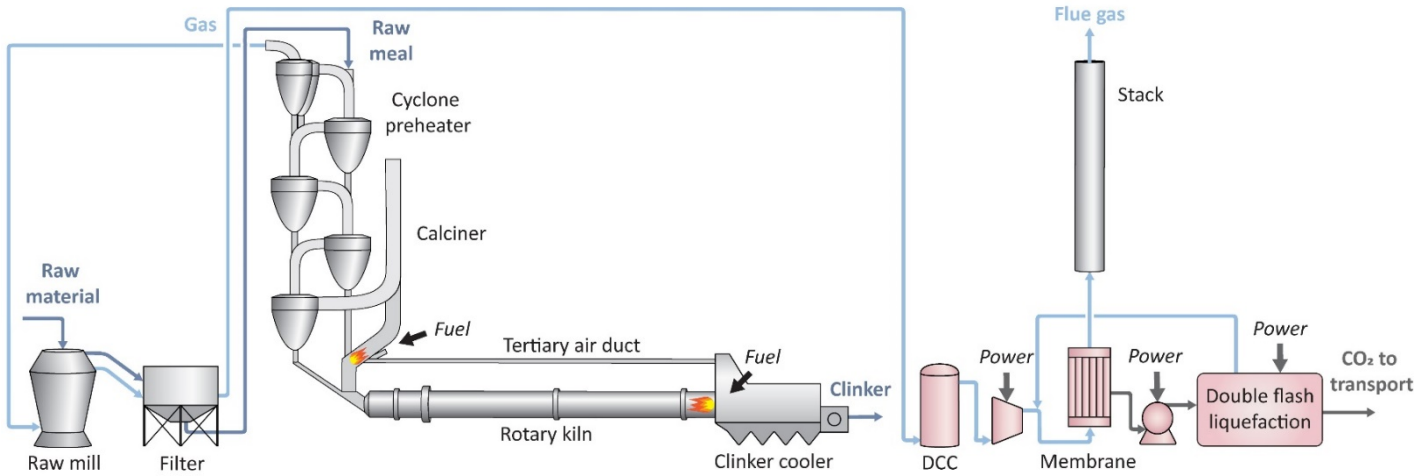


Cost of CO_2 avoided

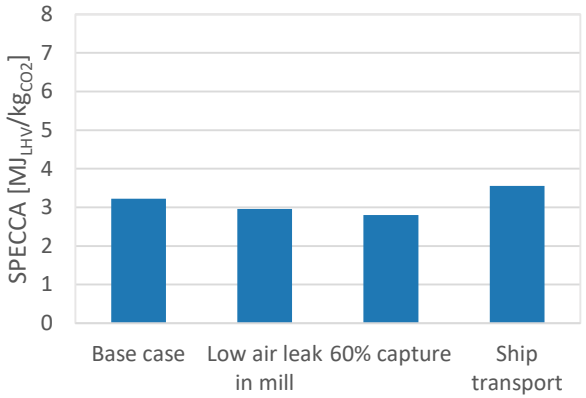


Membrane-assisted CO_2 liquefaction

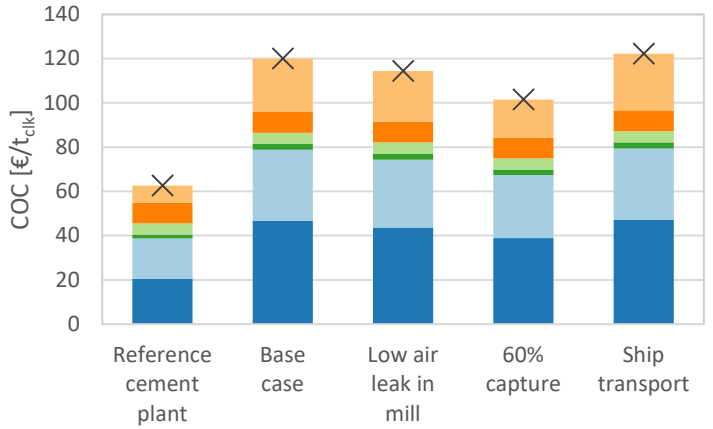
- Base case
  - SPECCA: 3.2 MJ/kg_{CO2}
  - Cost of clinker: +92%
  - Cost of CO_2 avoided: 84 $€/t_{CO2}$
- Power consumption and CAPEX
- Membrane performance critical
- Low maturity → high contingency



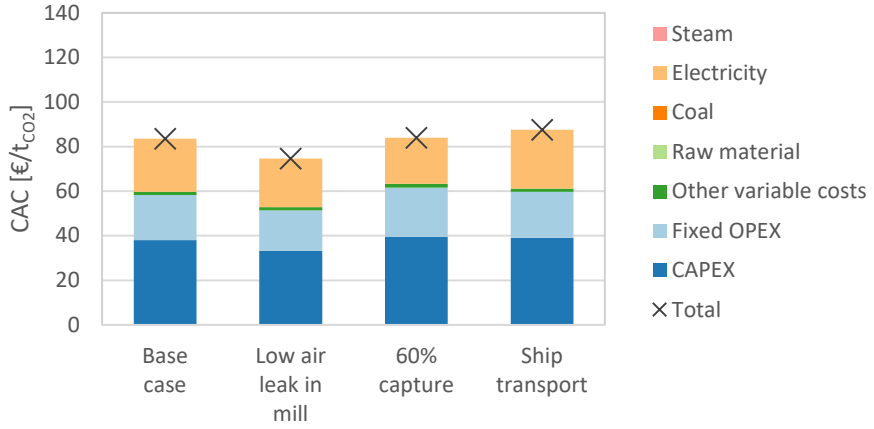
SPECCA



Cost of clinker



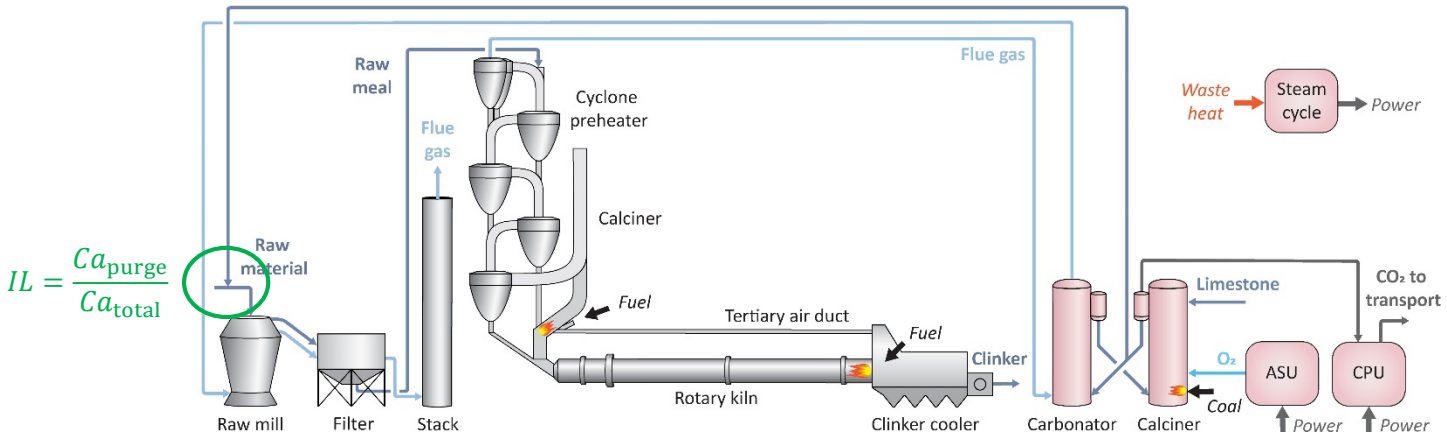
Cost of CO_2 avoided



Calcium looping – tail-end

- Base case
  - SPECCA: 4.1 MJ/kg_{CO2}
  - Cost of clinker: +66%
  - Cost of CO_2 avoided: 52 €/t_{CO2}
- Coal consumption
- Power import/export
- Dependent on integration level (IL)

$$IL = \frac{Ca_{\text{purge}}}{Ca_{\text{total}}}$$



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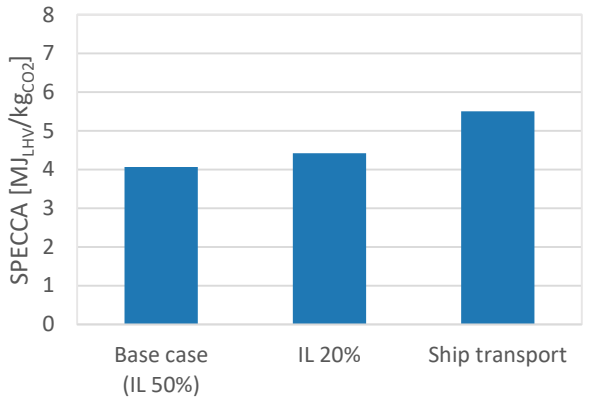
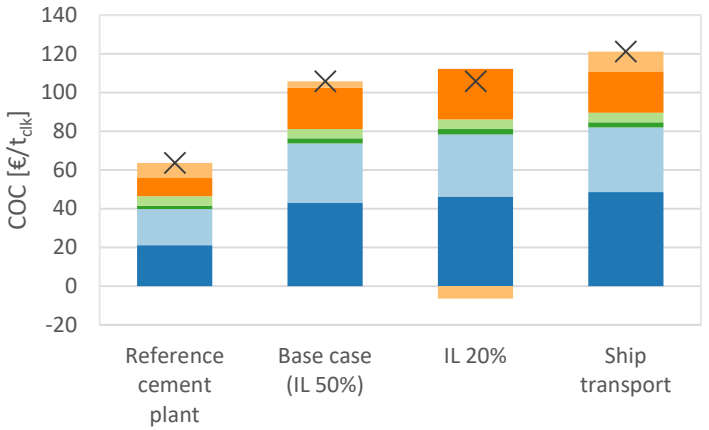
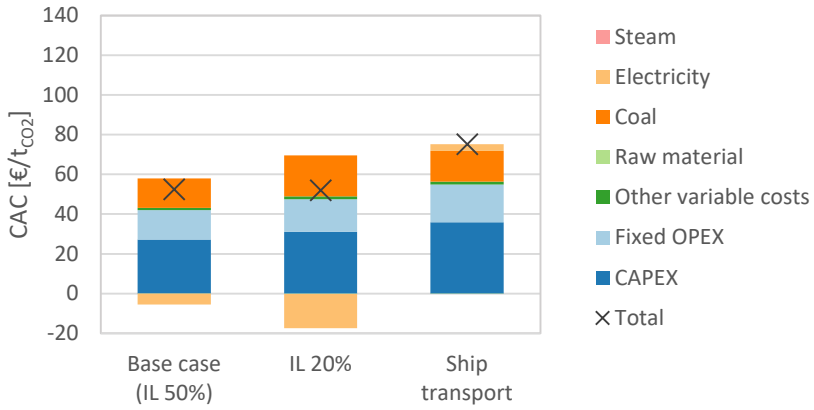


Cost of clinker

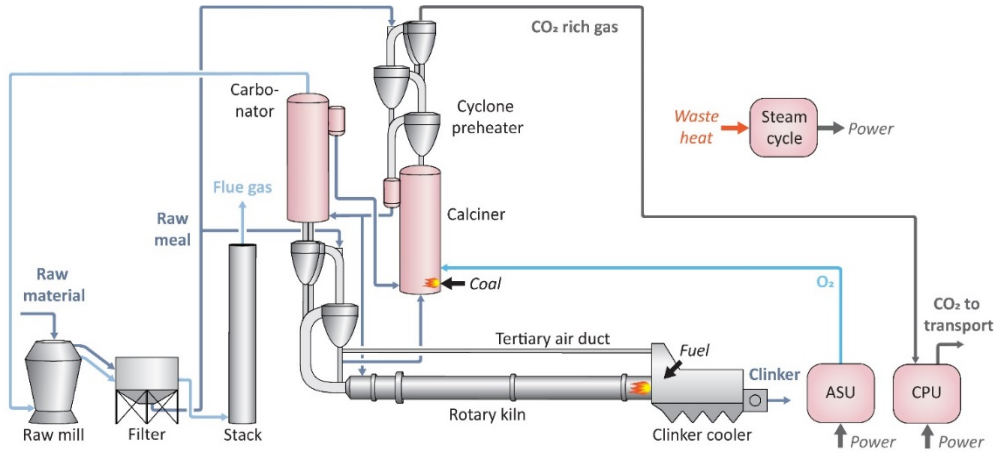


Cost of CO_2 avoided

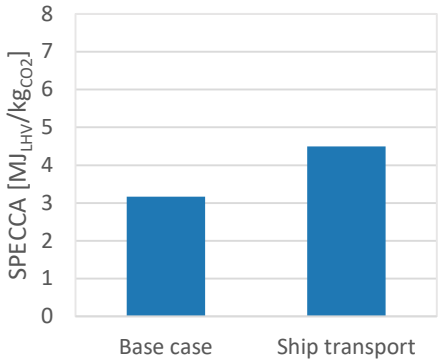


Calcium looping – integrated EF

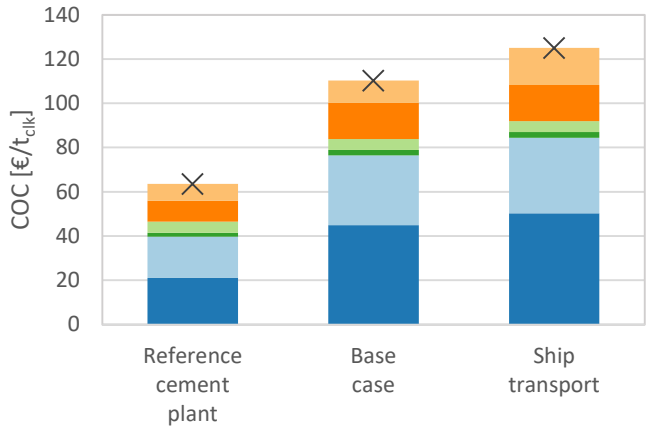
- Base case
  - SPECCA: 3.2 MJ/kg_{CO2}
  - Cost of clinker: +73%
  - Cost of CO_2 avoided: 59 €/t_{CO2}
- Lower coal demand than CaL tail-end
- Less heat recovery/power generation
- Low maturity → high contingency



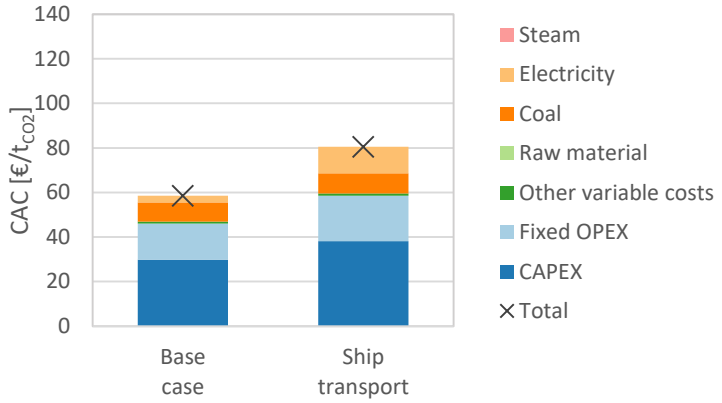
SPECCA



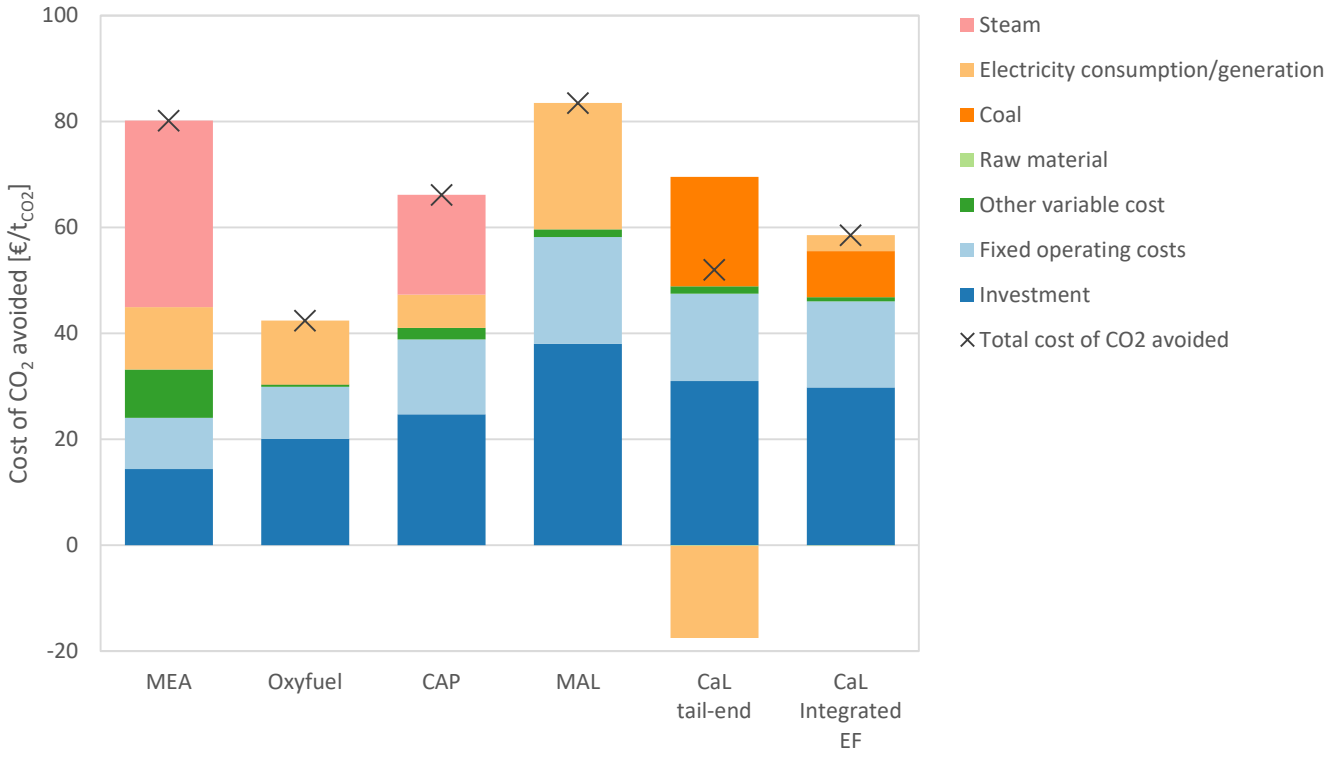
Cost of clinker

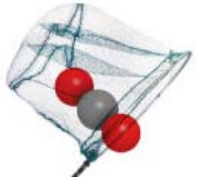


Cost of CO_2 avoided



Base case overview





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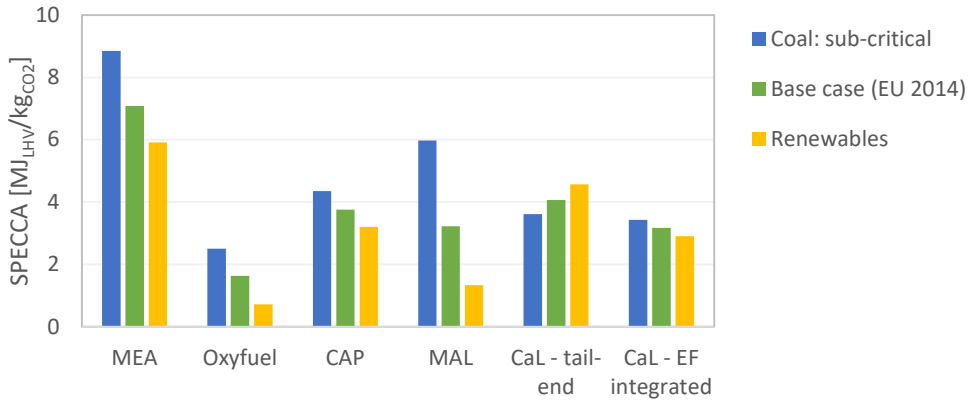
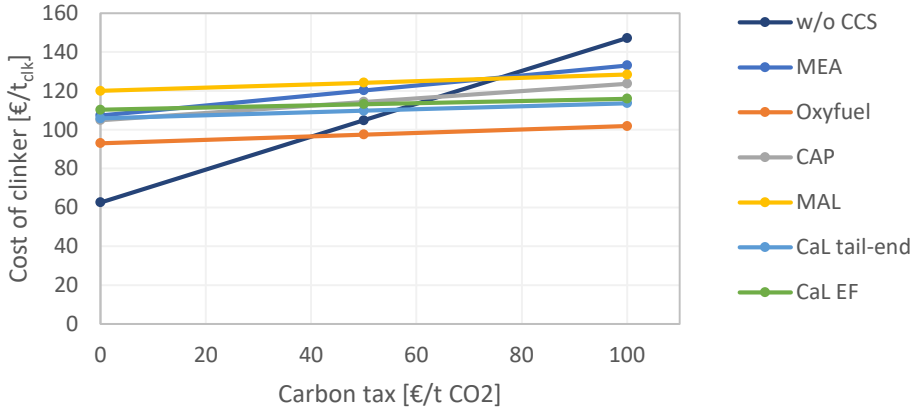
Sensitivity analysis

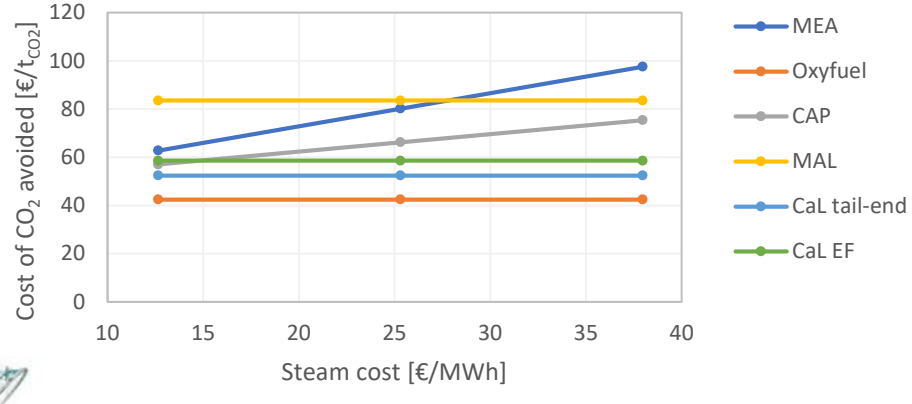
SPECCA – electricity mix



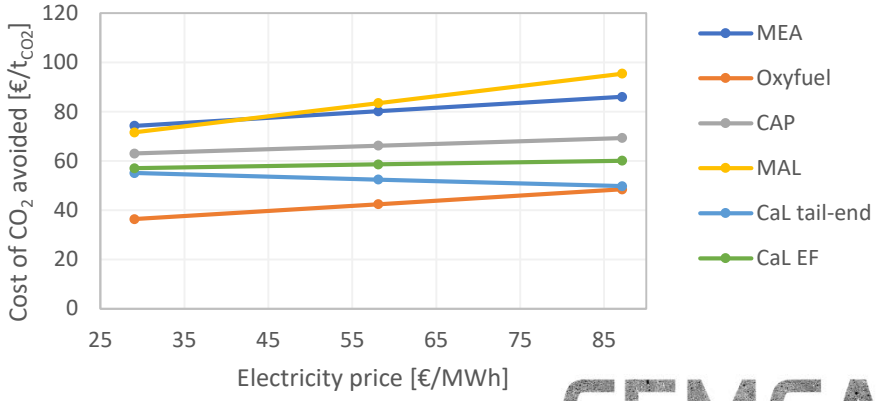
Cost of clinker – carbon tax



CO_2 avoided – steam cost



CO_2 avoided – electricity price



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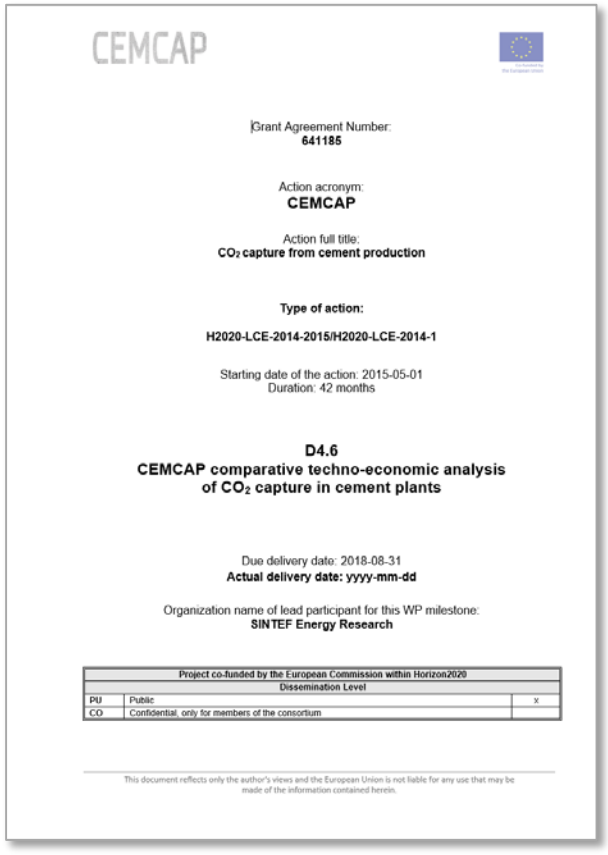
Conclusions

- Methodology for cost evaluation developed
- Results sensitive to assumptions
- More integrated technologies more promising from cost perspective
- Other important aspects should be considered together with costs
- Final evaluation must be taken for the specific plant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Grant Agreement Number:
641185

Action acronym:
CEMCAP

Action full title:
CO_2 capture from cement production

Type of action:

H2020-LCE-2014-2015/H2020-LCE-2014-1

Starting date of the action: 2015-05-01
Duration: 42 months

D4.6
CEMCAP comparative techno-economic analysis of CO_2 capture in cement plants

Due delivery date: 2018-08-31
Actual delivery date: yyyy-mm-dd

Organization name of lead participant for this WP milestone:
SINTEF Energy Research

Project co-funded by the European Commission within Horizon2020		
Dissemination Level		
PU	Public	x
CO	Confidential, only for members of the consortium	

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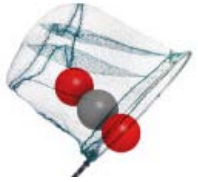
Final report:
D4.6 CEMCAP comparative techno-economic analysis of CO_2 capture in cement plants

To be shared in:
https://zenodo.org/communities/cemcap/



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CEMCAP Partners

Cement Producers

Italcementi HEIDELBERGCEMENT Group

NORCEM HEIDELBERGCEMENT Group

HEIDELBERGCEMENT

Technology providers

IKN ENGINEERING THE FUTURE

thyssenkrupp

R&D providers

SINTEF

ecra european cement research academy

TNO innovation for life

ETH zürich

University of Stuttgart

POLITECNICO MILANO 1863

CSIC Consejo Superior de Investigaciones Científicas

vdz.

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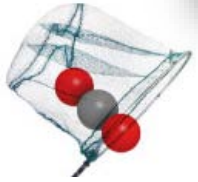

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Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 641185

This work was supported by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 15.0160

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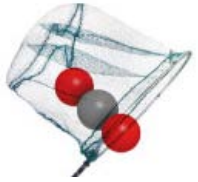

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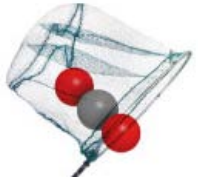
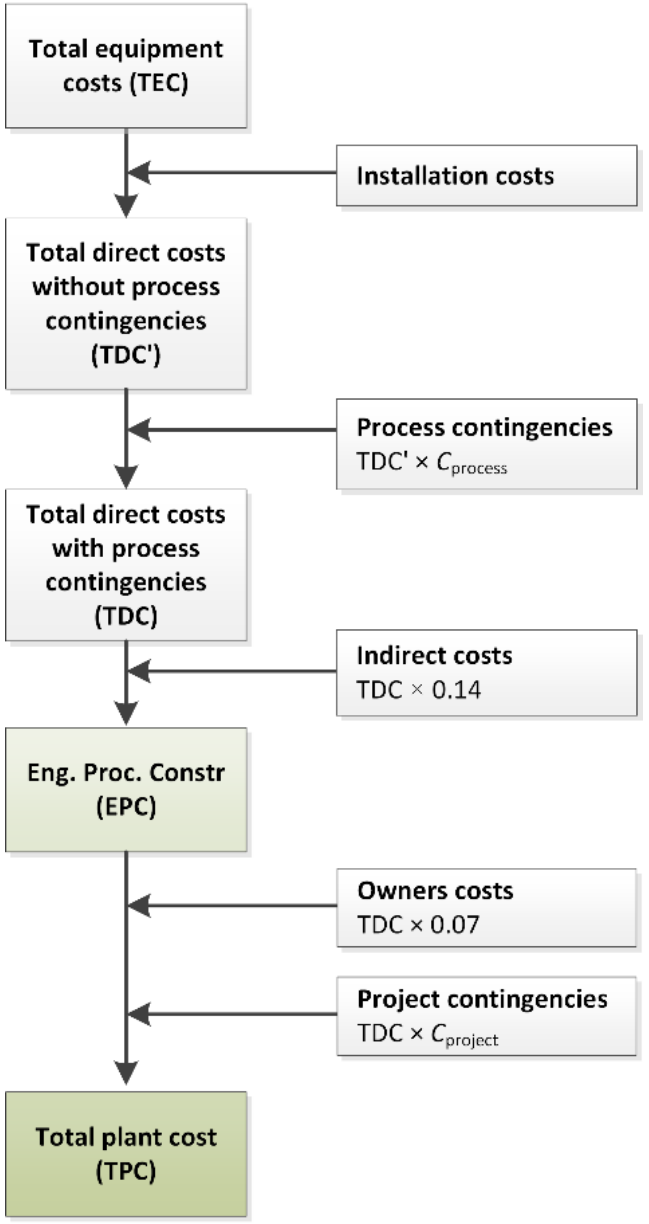
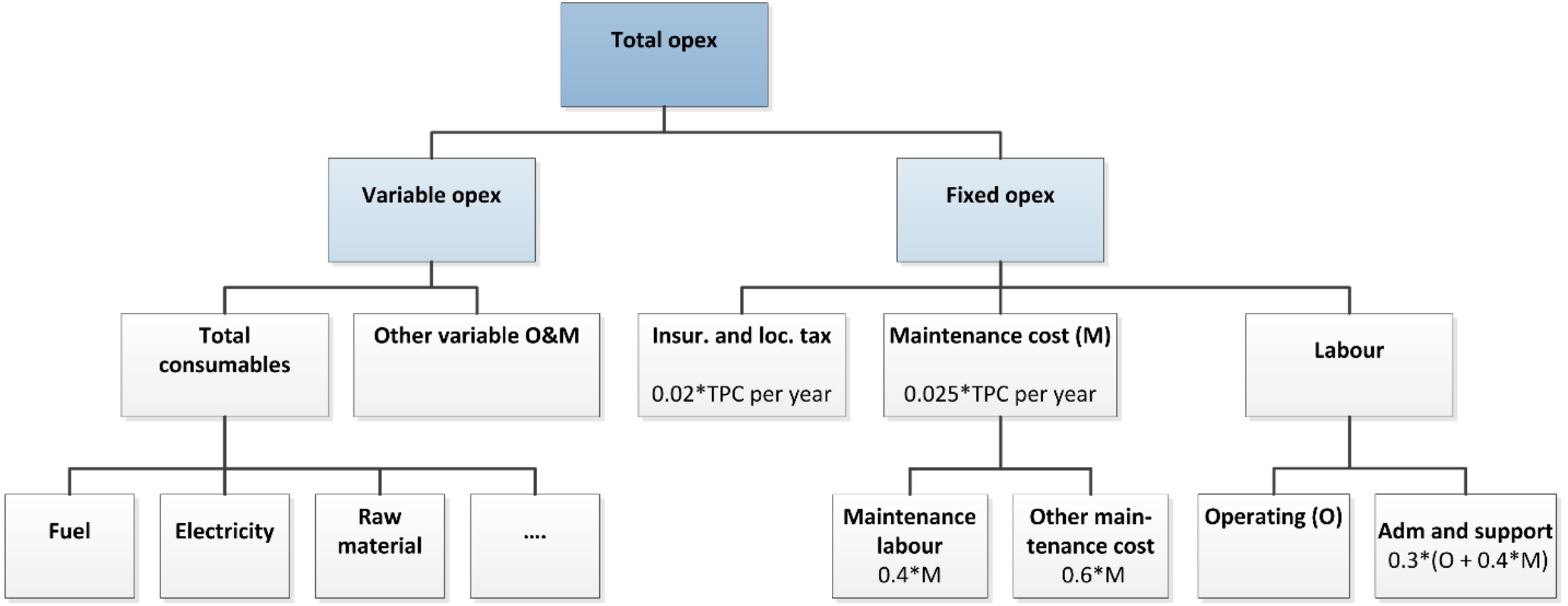
CAPEX

- Bottom-up approach
- Standard process equipment
  - Aspen Process Economic Analyser®
  - Thermoflex
- Non-standard equipment
  - Estimates from industry partners
  - Literature
- Annualized CAPEX





OPEX


Total opex
Variable opex
Fixed opex
Total consumables
Other variable O&M
Insur. and loc. tax
0.02*TPC per year
Maintenance cost (M)
0.025*TPC per year
Labour
Fuel
Electricity
Raw material
....
Maintenance labour
0.4*M
Other main-tenance cost
0.6*M
Operating (O)
Adm and support
0.3*(O + 0.4*M)