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CEMCAP techno-economic and retrofitability analysis

Mari Voldsund, Stefania Osk Gardarsdottir, Simon Roussanaly, Rahul Anantharaman, Chao Fu, David Berstad (SINTEF ER), Matteo Romano, Edoardo De Lena (Politecnico di Milano), Armin Jamali, Helmut Hoppe, Johannes Ruppert (VDZ), José-Francisco Pérez-Calvo, Daniel Sutter (ETH), Olaf Stallmann (GE*), Giovanni Cinti (Italcementi)

*Now Baker Hughes, a GE company

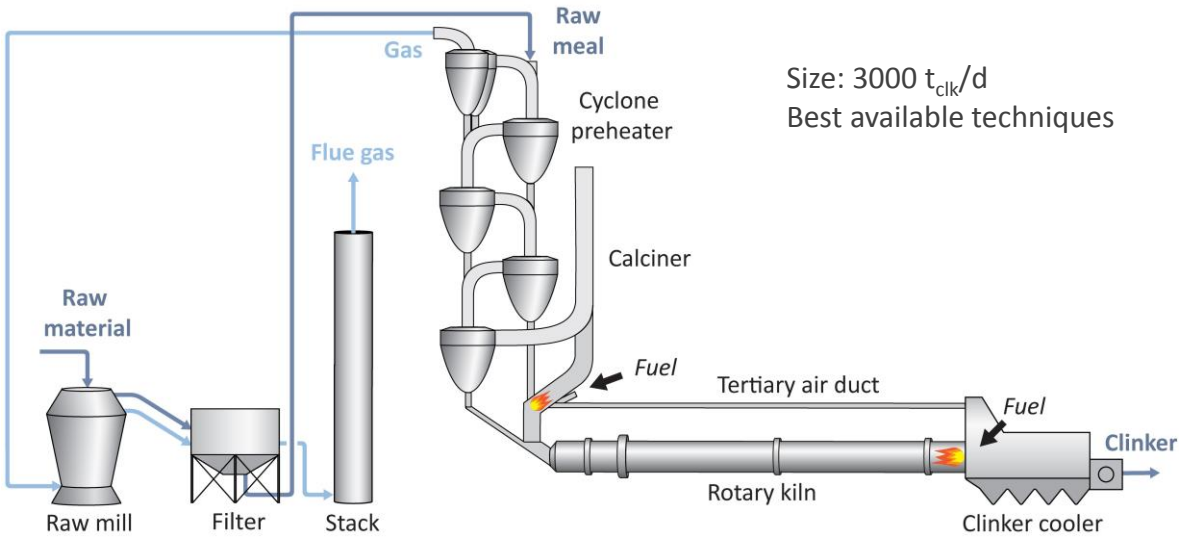
CEMCAP analytical work

Approach

- CEMCAP framework
- Reference cement kiln
- Reference technology: MEA absorption

Techno-economic evaluation

- KPIs
  - 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, ship transport, steam supply, etc.
  - Sensitivity analysis



Size: 3000 t_{clk}/d
Best available techniques

Retrofitability evaluation

- Impact on cement production
- Equipment and footprint
- Utilities and services
- New chemicals/systems
- Available experience

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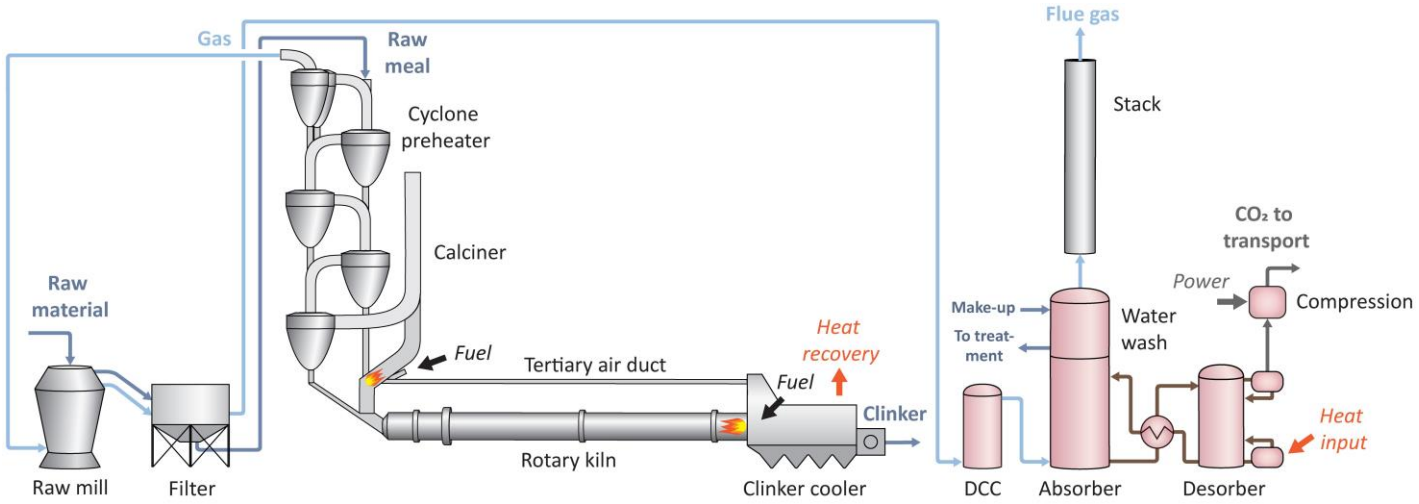
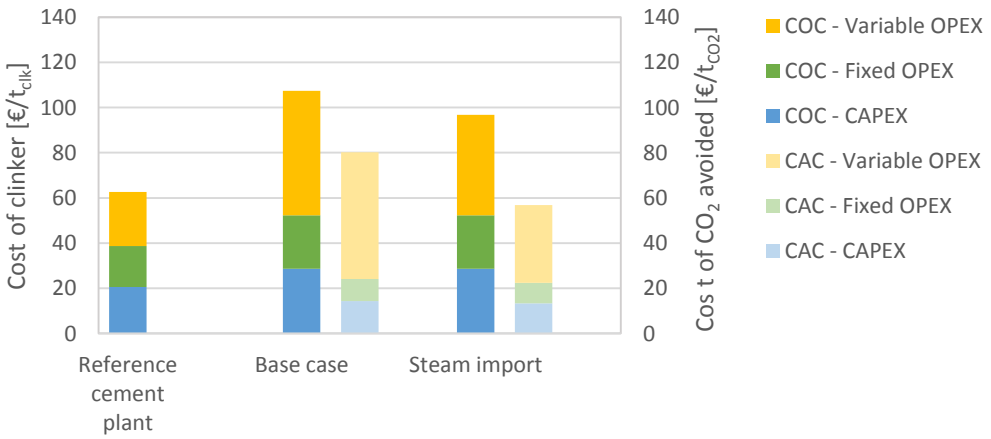
MEA absorption

Techno-economic evaluation

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





Retrofitability

- No impact on burning process/clinker quality
- Can be installed away from kiln
- Steam and power demand
- Amines introduced at plant
- Mature technology

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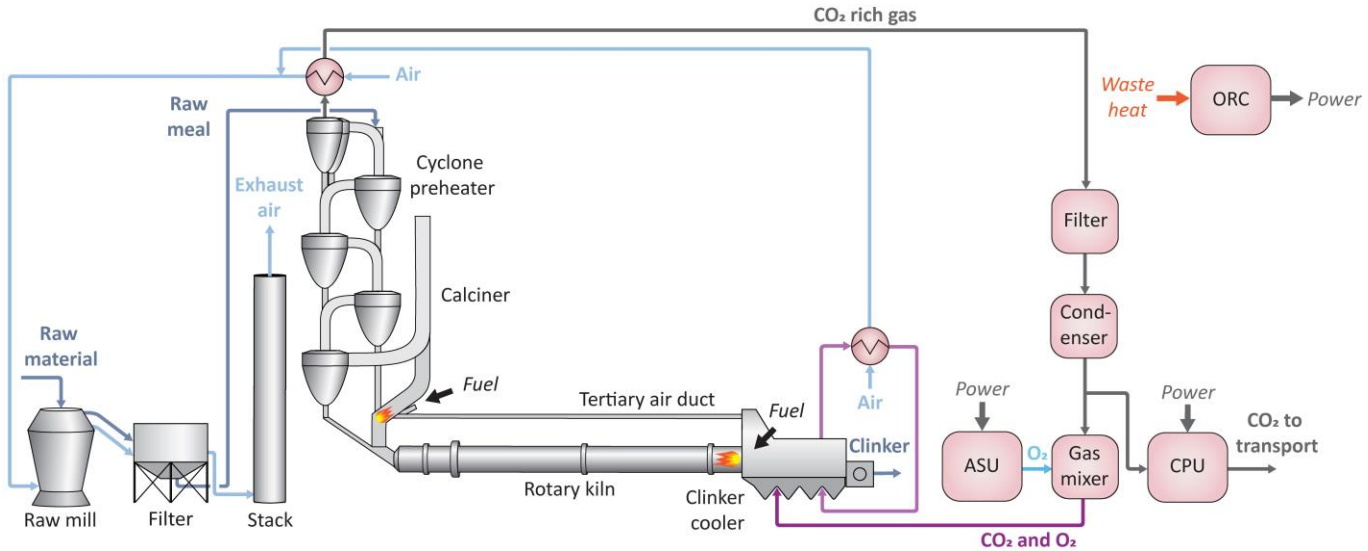
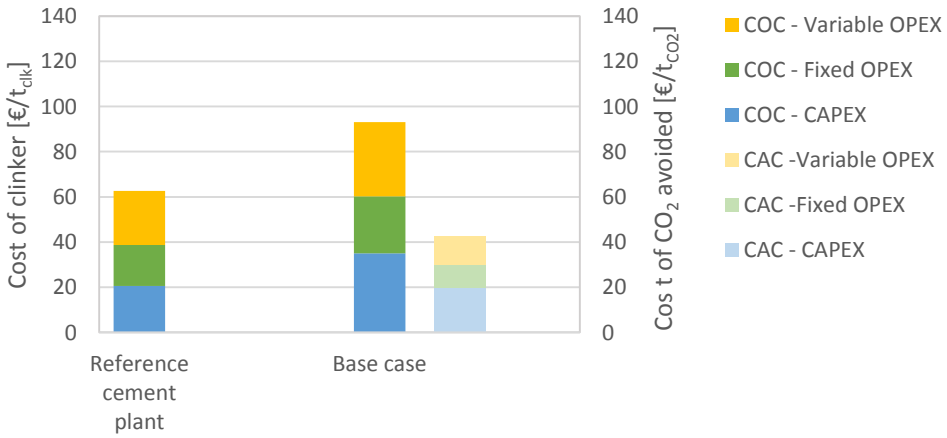
Oxyfuel process

Techno-economic evaluation

- Base case
  - SPECCA: 1.6 MJ/kg_{CO2}
  - Cost of clinker (COC): +50%
  - Cost of CO_2 avoided (CAC): 44 €/t_{CO2}
- Low CAPEX and OPEX





Retrofitability

- Modified burning process
- Space required close to kiln
- Power demand
- ASU and possibly ORC introduced at plant
- No experience with full system

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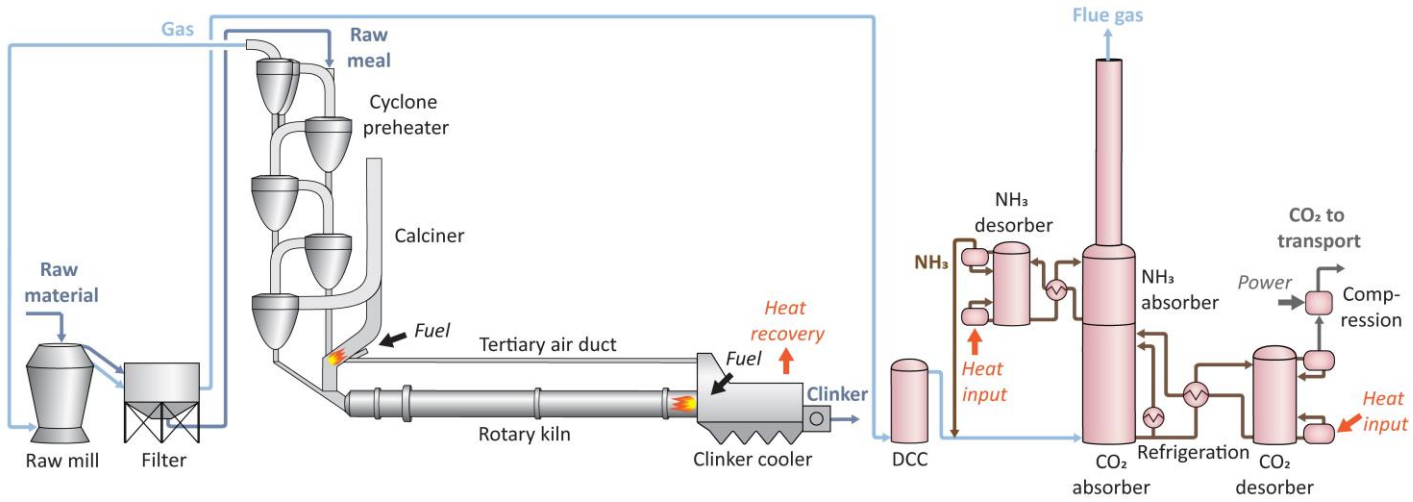
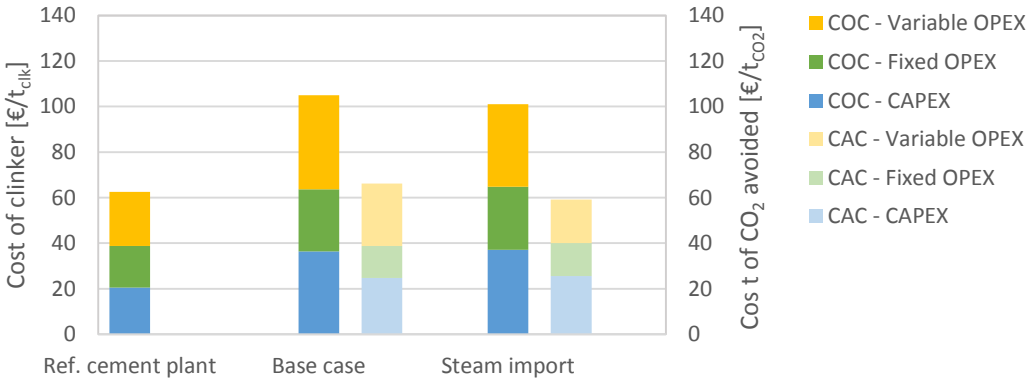
Chilled ammonia process

Techno-economic evaluation

- Base case
  - SPECCA: 3.7 MJ/kg_{CO2}
  - Cost of clinker (COC): +68%
  - Cost of CO_2 avoided (CAC): 66 €/t_{CO2}
- Less steam and power demand than MEA
- IP protection for improved process ongoing





Retrofitability

- No impact on burning process / clinker quality
- Can be installed away from kiln
- Steam and power demand
- Ammonia, sulfuric acid and refrigeration system
- Certain experience from power plants

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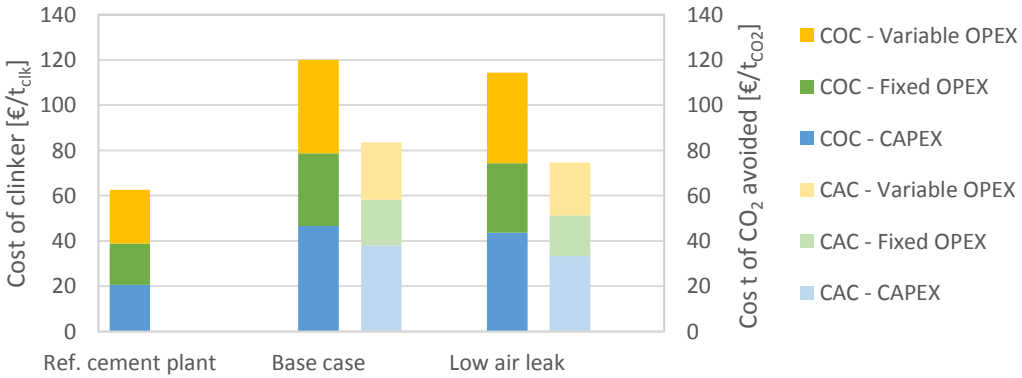
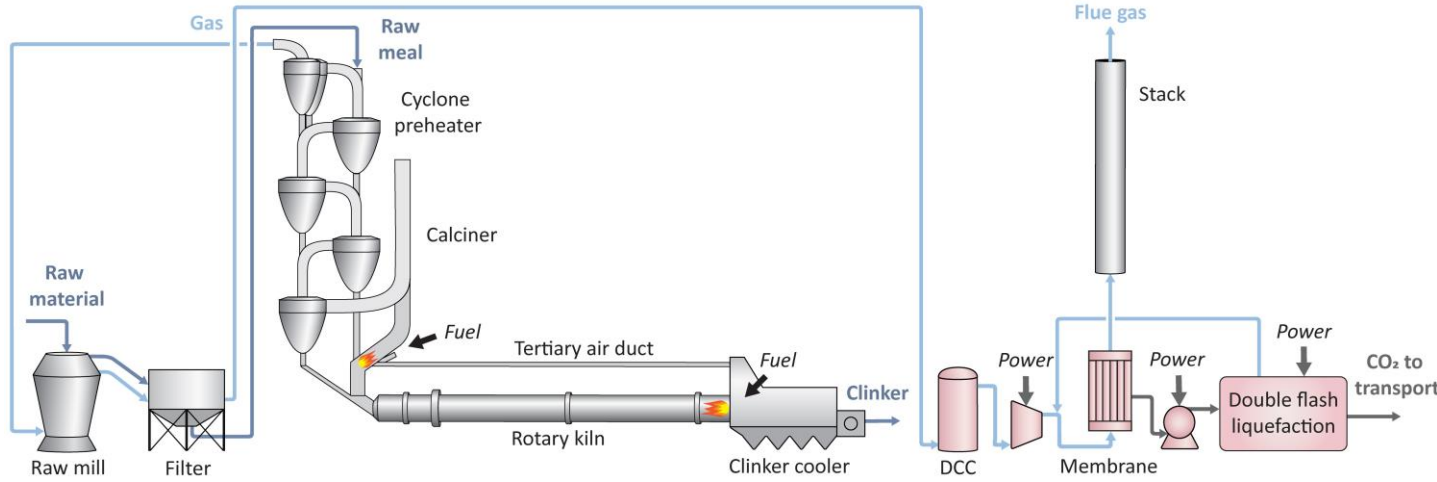
Membrane-assisted CO_2 liquefaction

Techno-economic evaluation

- Base case
  - SPECCA: 3.2 MJ/kg_{CO2}
  - Cost of clinker (COC): +91%
  - Cost of CO_2 avoided (CAC): 84 €/t_{CO2}
- Power consumption and CAPEX
- Membrane performance critical
- Low membrane maturity -> High contingency





Retrofitability

- No impact on burning process/clinker quality
- Can be installed away from kiln
- Power demand
- Refrigeration system introduced at plant
- Experience with membranes from Norcem

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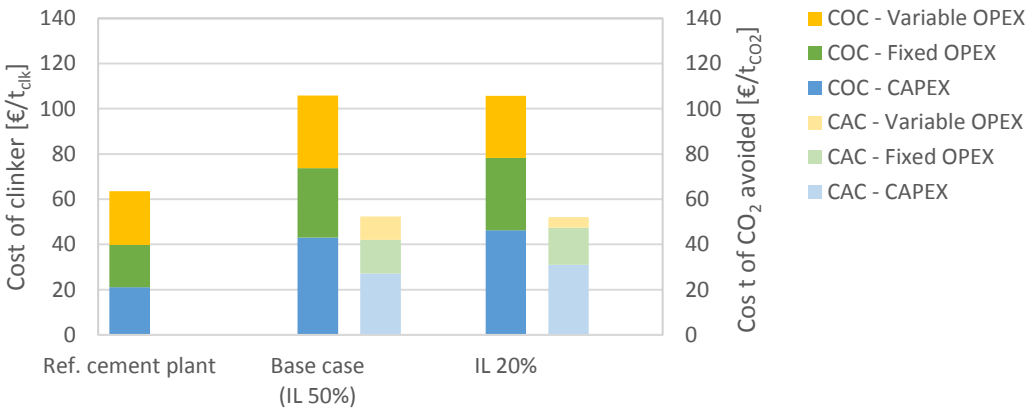
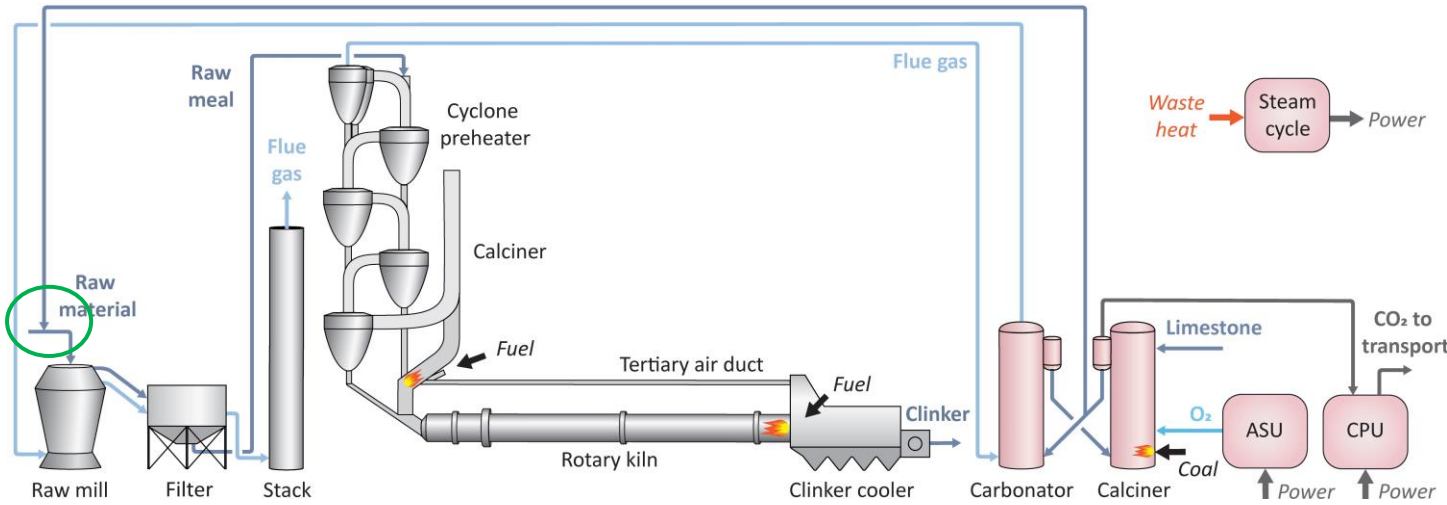
Calcium looping – tail-end

Techno-economic evaluation

- Base case
  - SPECCA: 4.1 MJ/kg_{CO2}
  - Cost of clinker (COC): +68%
  - Cost of CO_2 avoided (CAC): 52 €/t_{CO2}
- Coal consumption
- Power import/export
- Dependent on integration level (IL)



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



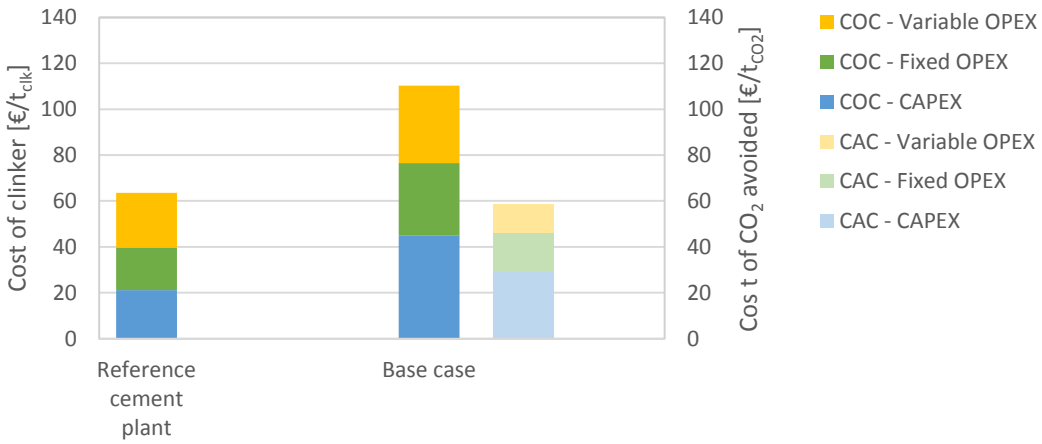
Retrofitability

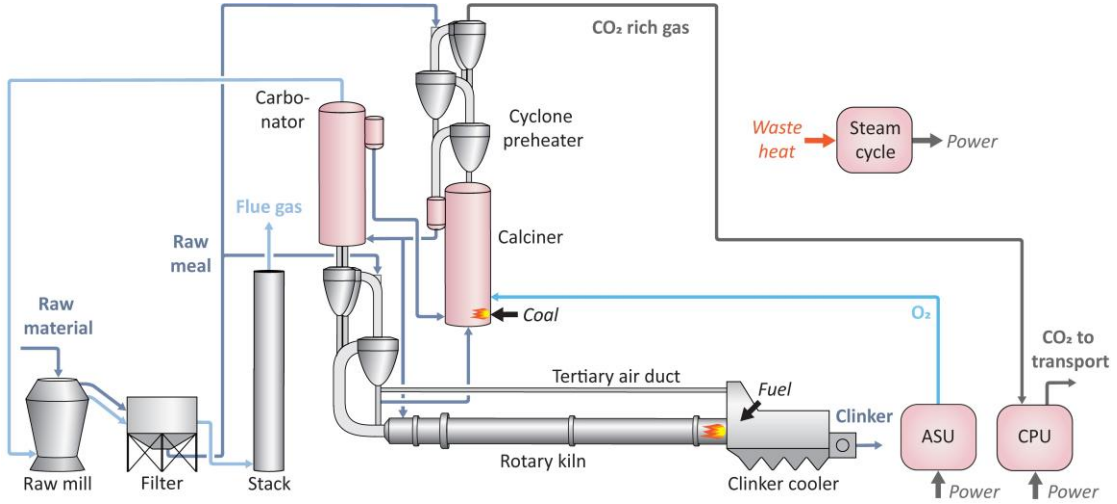
- Slight integration with burning process
- Can be installed away from the kiln line
- Additional coal demand
- Integrated power generation (import/export)
- ASU and steam cycle introduced at plant
- Small-scale demo at power plants

Calcium looping – integrated entrained flow (EF)

Techno-economic evaluation

- Base case
  - SPECCA: 3.2 MJ/kg_{CO2}
  - Cost of clinker (COC): +72%
  - Cost of CO_2 avoided (CAC): 55 €/t_{CO2}
- Less coal consumption than tail-end
- Less heat recovery/power generation
- Low technology maturity -> High contingency





Retrofitability

- Modified calciner and preheater
- Space required close to kiln
- Additional coal demand
- Low power demand
- ASU and steam cycle introduced at plant
- Early stage of development

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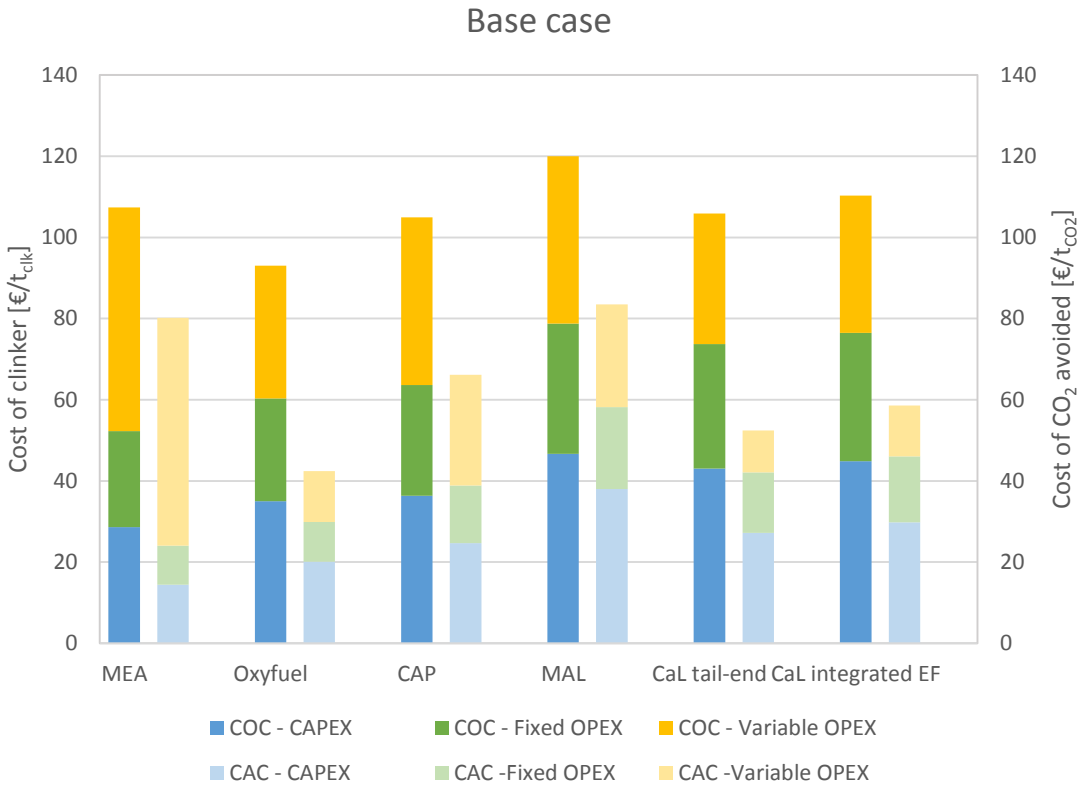
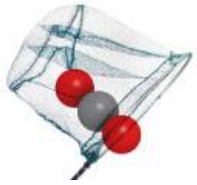
Retrofitability vs cost

	Criteria	MEA	Oxyfuel	CAP	MAL	CaL (tail-end)	CaL (integrated)
1	Impact on cement production	✔	!!	✔	✔	✔	!
2	Equipment and footprint	!	!!	!	!	!	!!
3	Utilities and services	!	!	!	!	!	!
4	Introduction of new chemicals/subsystems	!	!	!	✔	!	!
5	Available experiences	✔	?	!	?	!	?

✔	retrofitability o.k.; suitable in most cases/plants
!	*some* attention needed for plant retrofit
!!	special attention needed for plant retrofit
?	needs further assessment for plant retrofit
X	retrofit not possible





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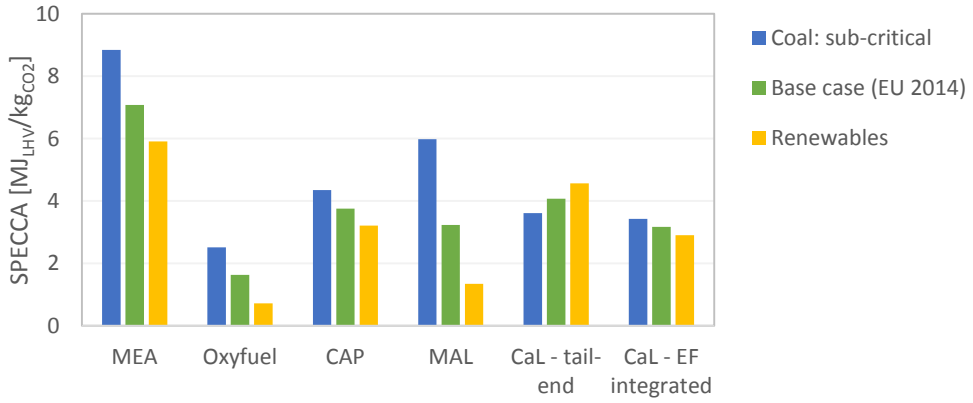
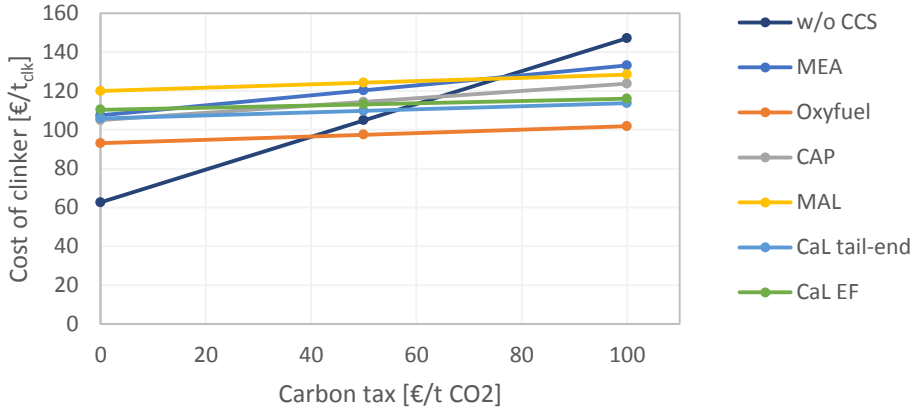
Sensitivity analysis

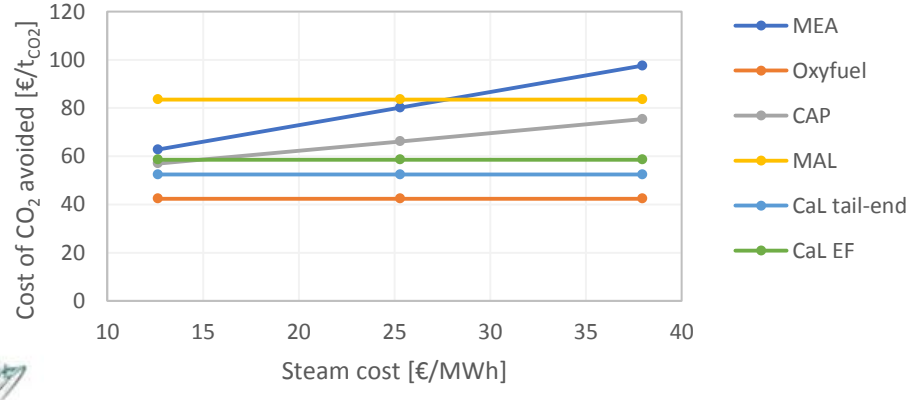
SPECCA and electricity mix



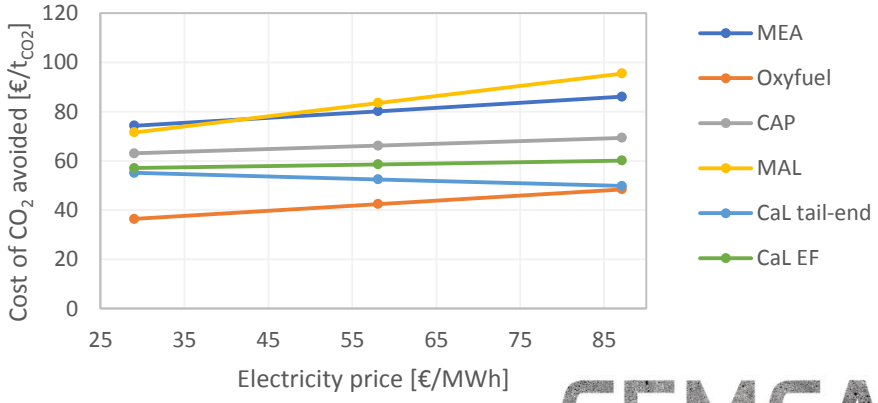
Cost of clinker and carbon tax



CO_2 avoided and steam cost



CO_2 avoided and electricity price



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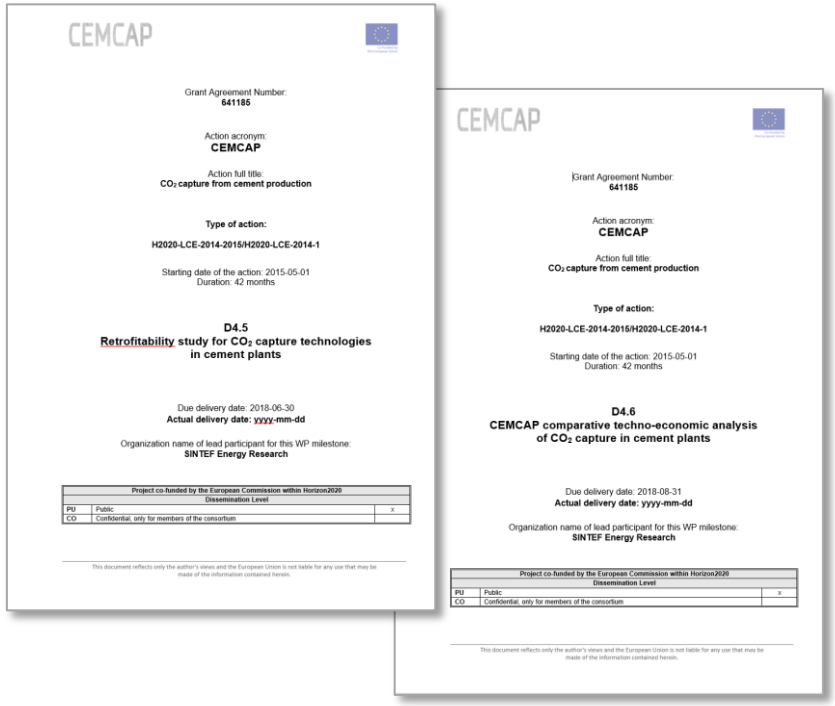
Conclusions

- Methodology for cost evaluation developed
- Results sensitive to assumptions
- More integrated technologies more promising from cost perspective
- End-of-pipe technologies easier from retrofitability perspective
- Final evaluation must be taken for the specific cement plant



Final reports:
D4.5 Retrofitability study for CO2 capture technologies in cement plants
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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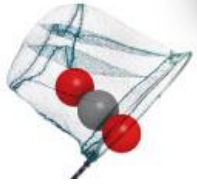

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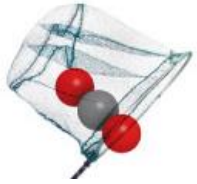

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