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CEMCAP techno-economic and retrofitability analysis

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*Now Baker Hughes, a GE company



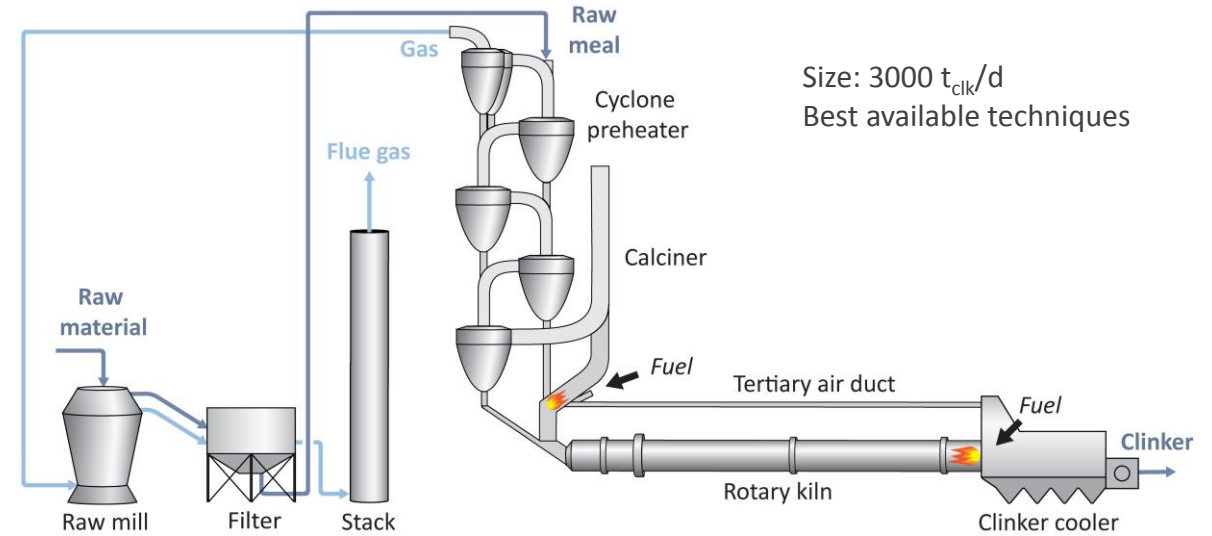
CEMCAP analytical work

Approach

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

Techno-economic evaluation

- KPIs
 - SPECCA
 - Cost of clinker
 - Cost of CO₂ 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



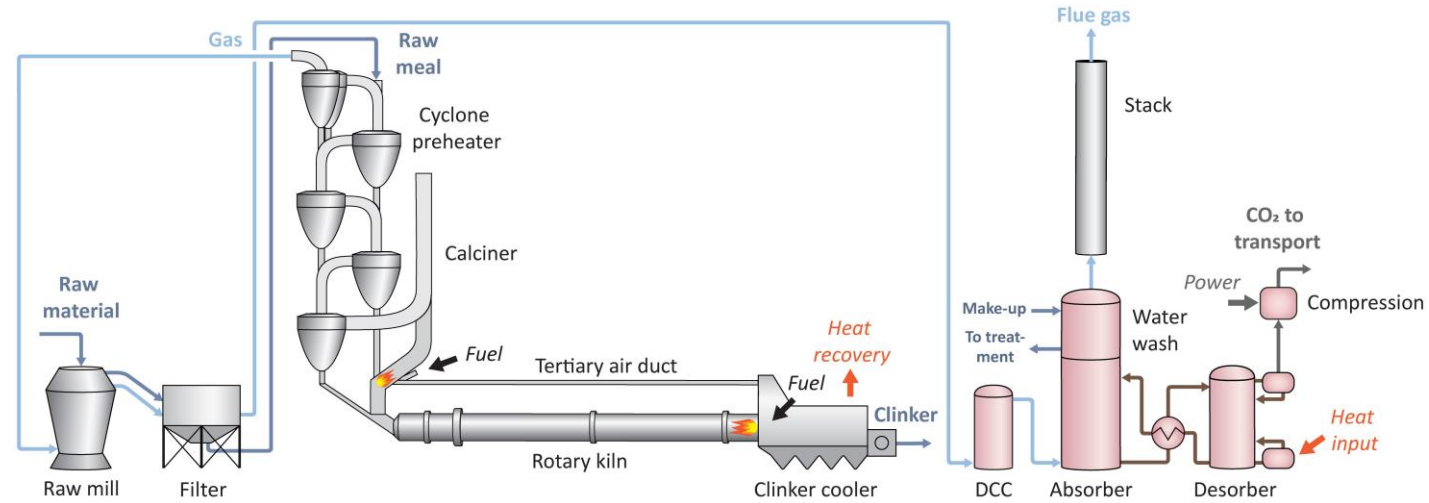
Retrofitability evaluation

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

MEA absorption

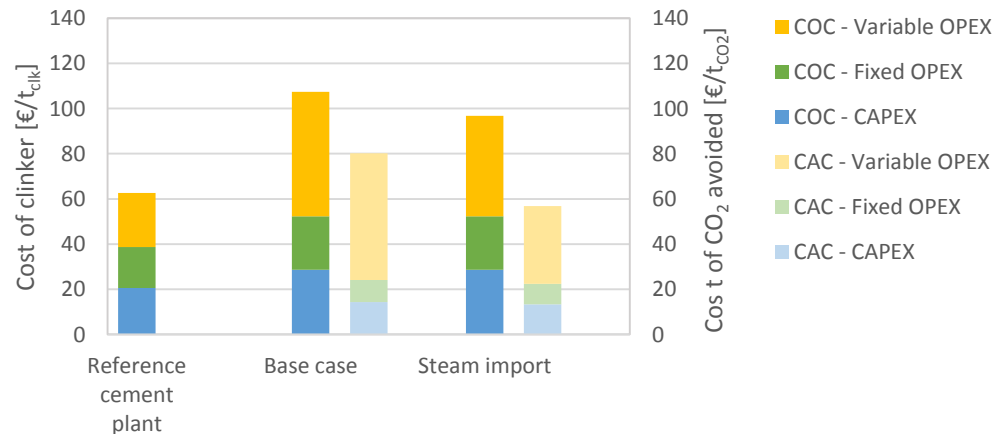
Techno-economic evaluation

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



Retrofitability

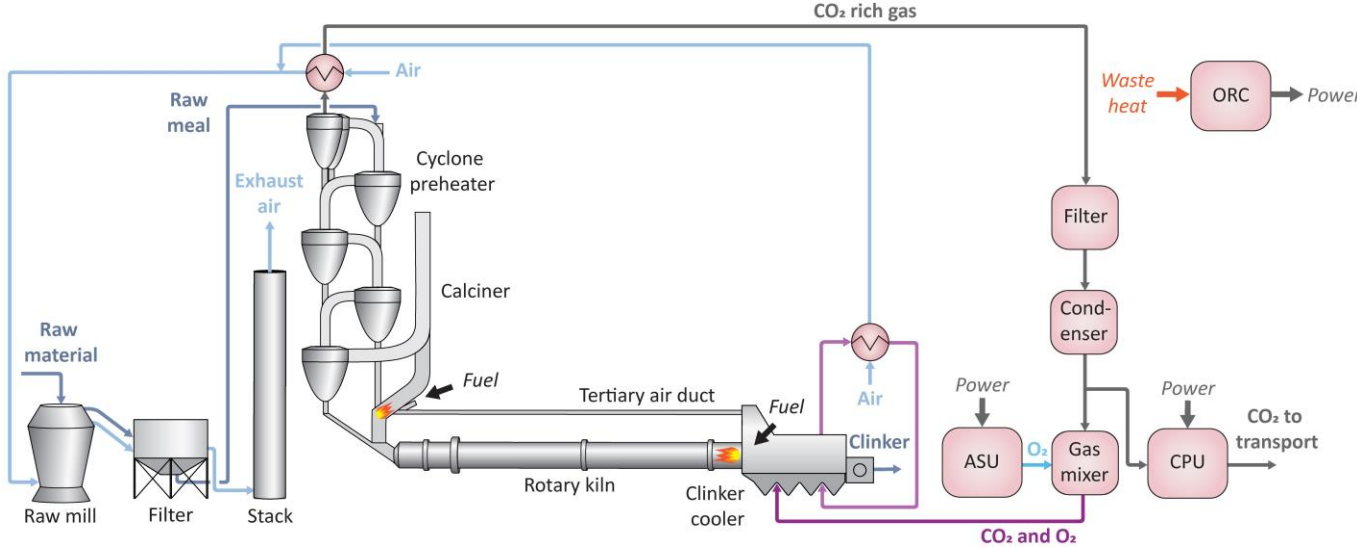
- No impact on burning process/clinker quality
- Can be installed away from kiln
- Steam and power demand
- Amines introduced at plant
- Mature technology



Oxyfuel process

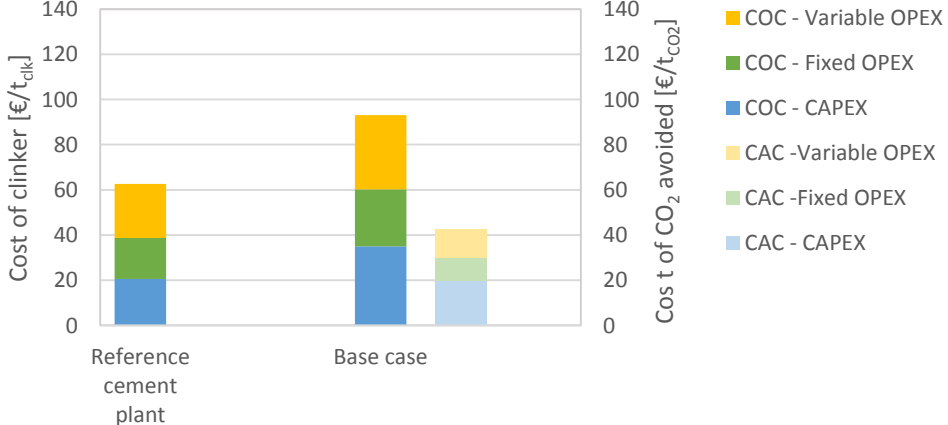
Techno-economic evaluation

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



Retrofitability

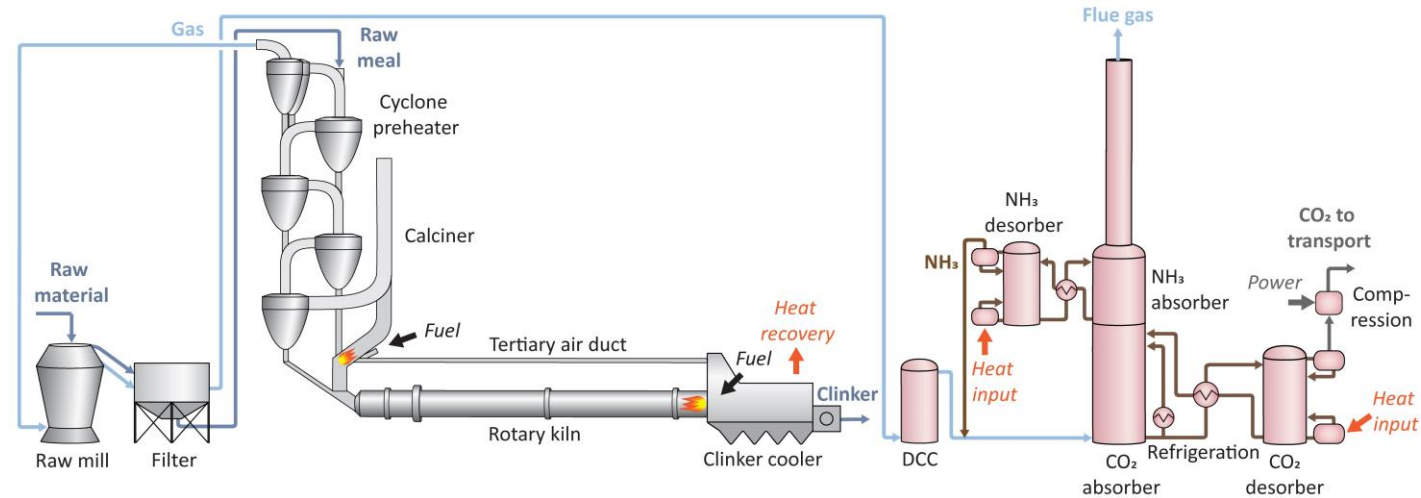
- Modified burning process
- Space required close to kiln
- Power demand
- ASU and possibly ORC introduced at plant
- No experience with full system



Chilled ammonia process

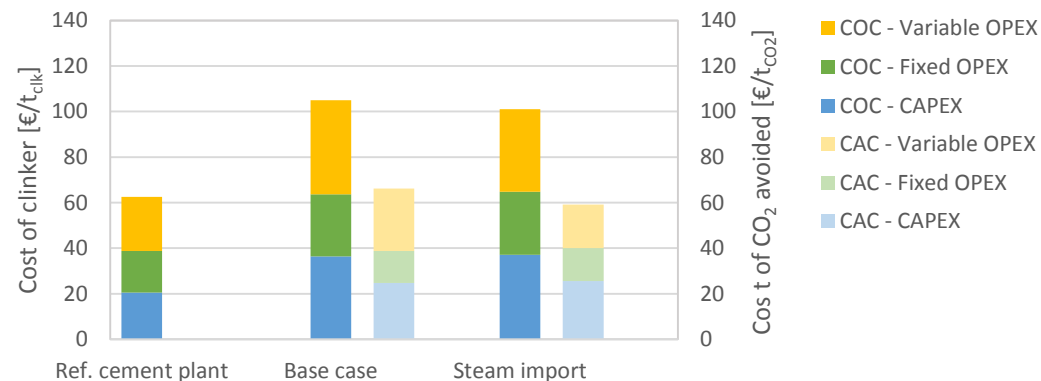
Techno-economic evaluation

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



Retrofitability

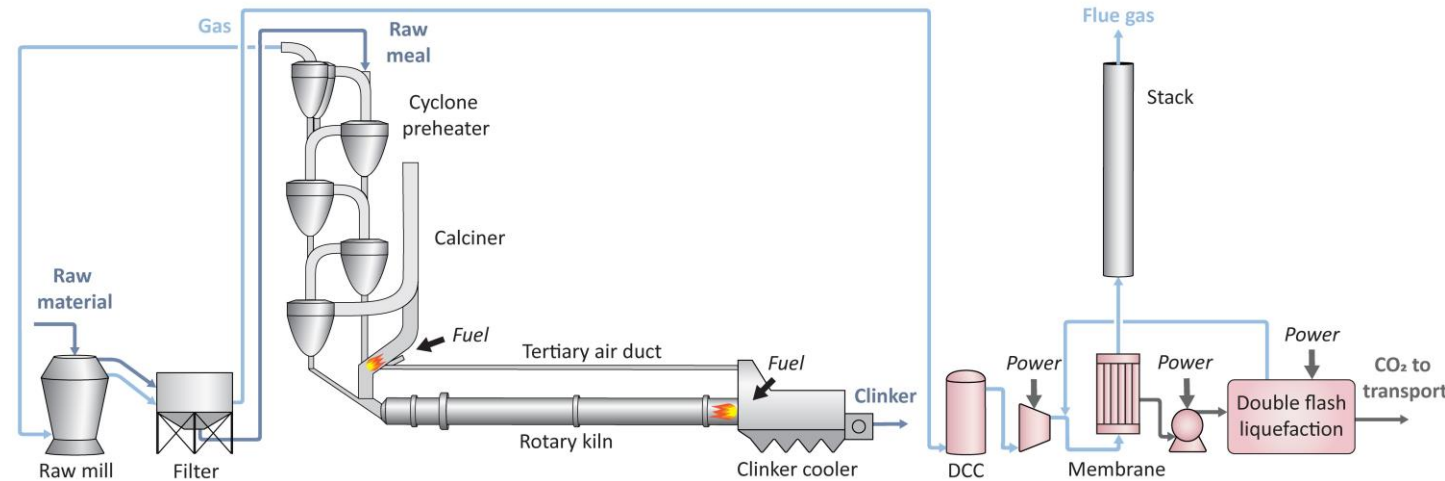
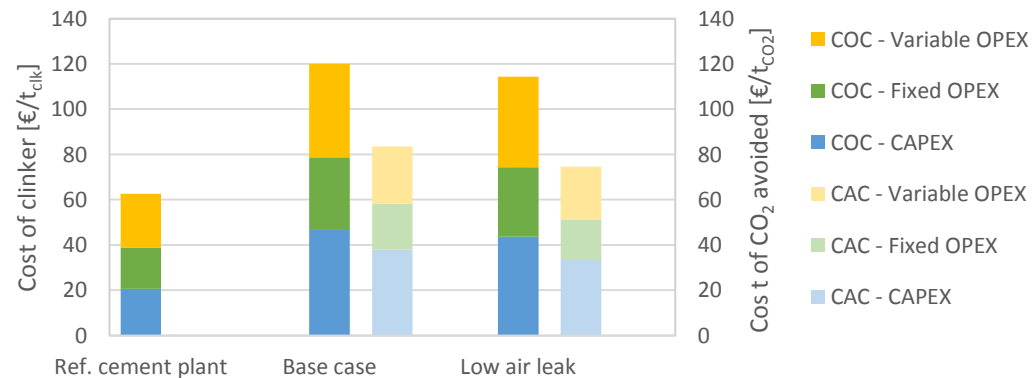
- No impact on burning process / clinker quality
- Can be installed away from kiln
- Steam and power demand
- Ammonia, sulfuric acid and refrigeration system
- Certain experience from power plants



Membrane-assisted CO₂ liquefaction

Techno-economic evaluation

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



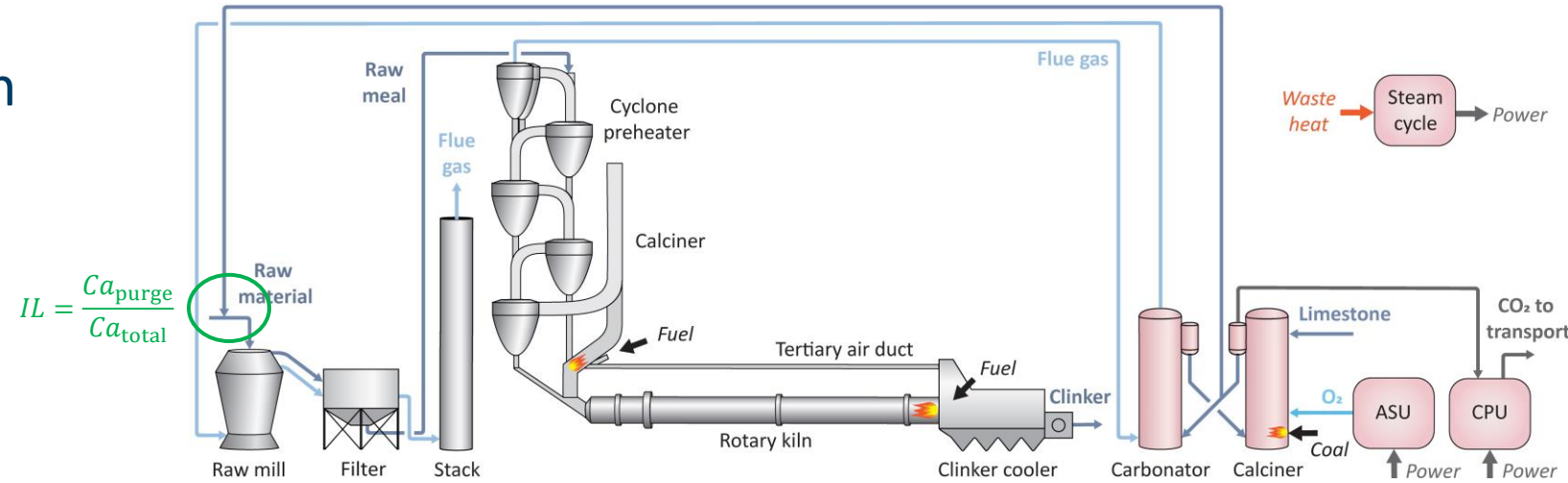
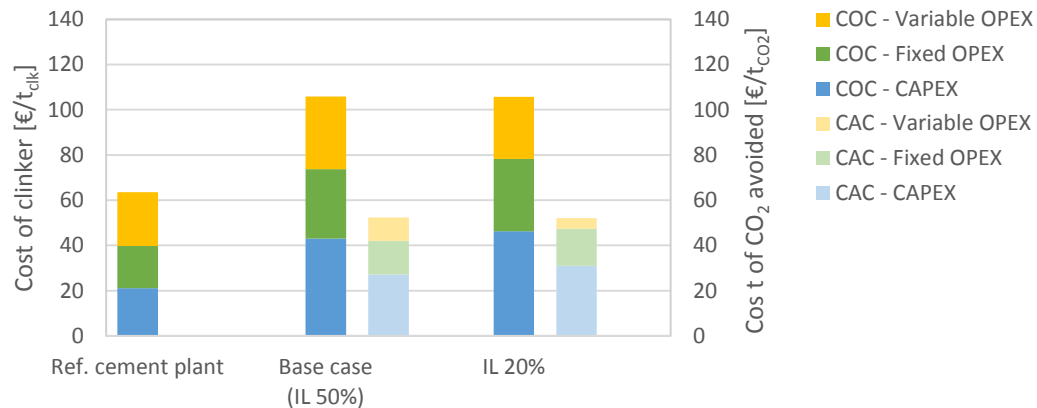
Retrofitability

- 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

Calcium looping – tail-end

Techno-economic evaluation

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



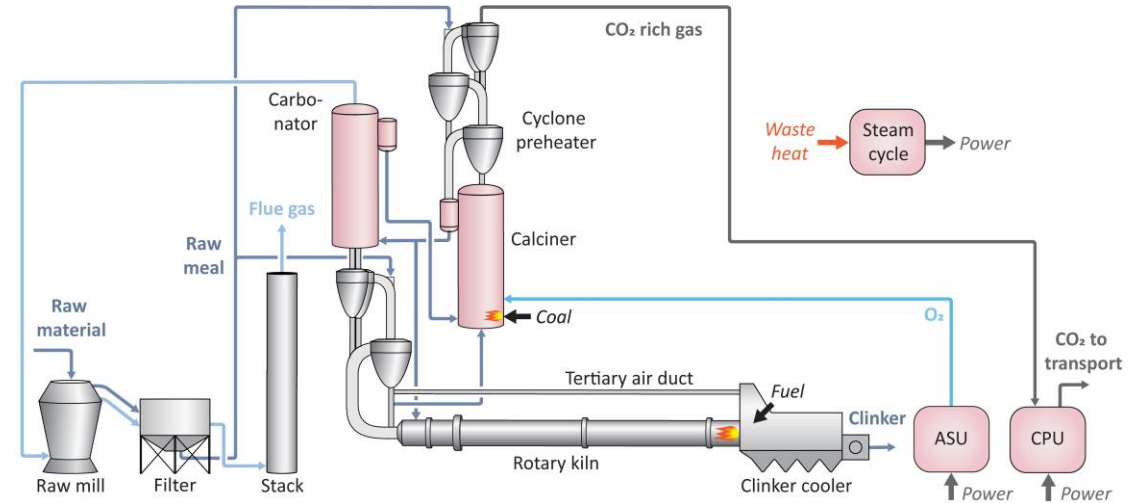
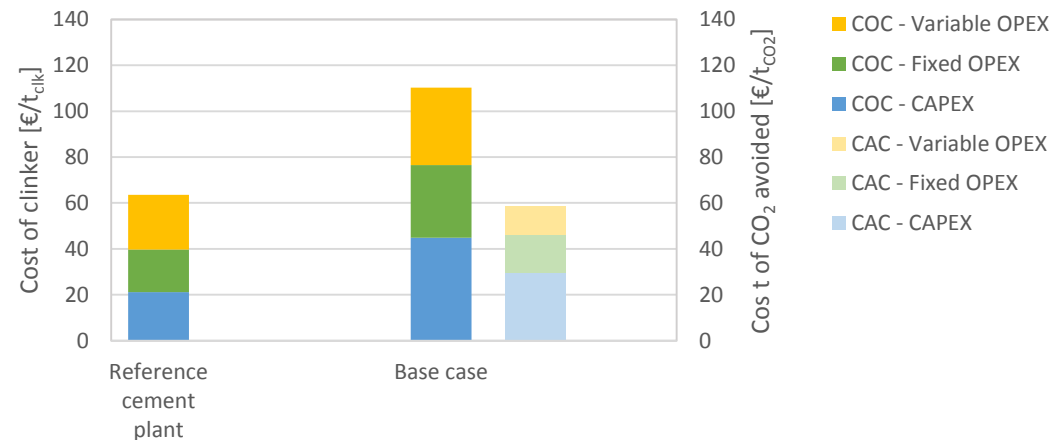
Retrofitability

- 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 CO₂ avoided (CAC): 55 €/t_{CO2}
- Less coal consumption than tail-end
- Less heat recovery/power generation
- Low technology maturity -> High contingency



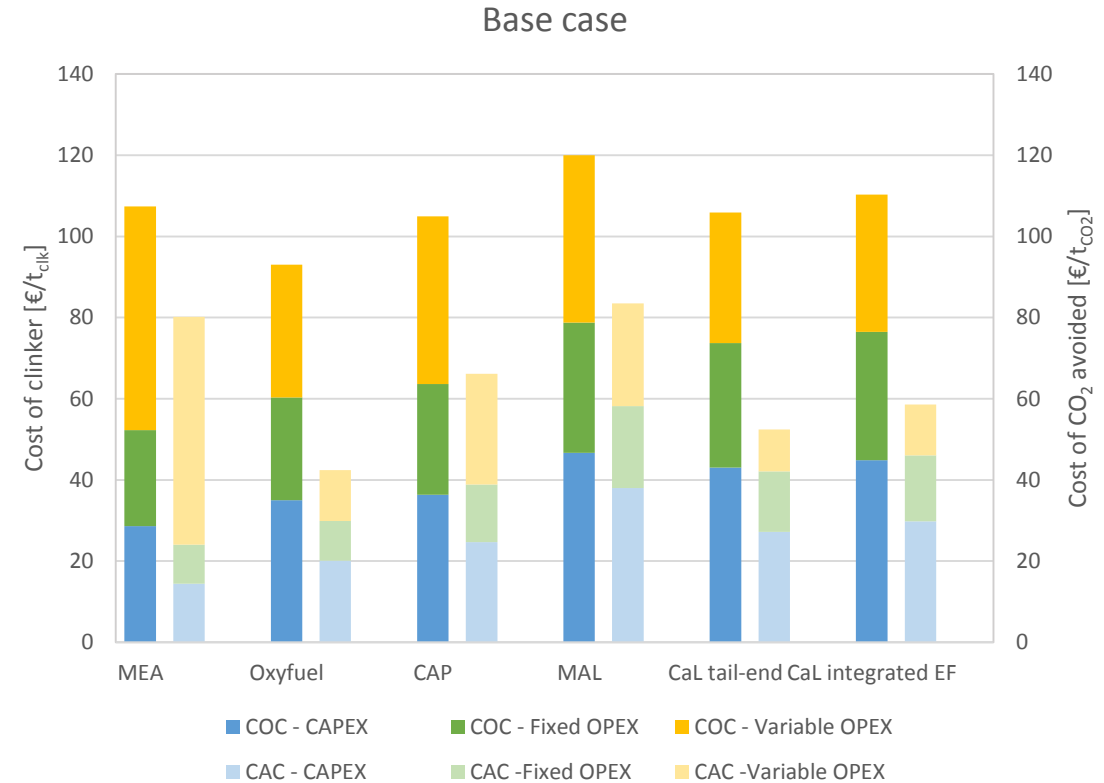
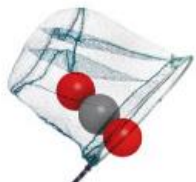
Retrofitability

- 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

Retrofitability vs cost

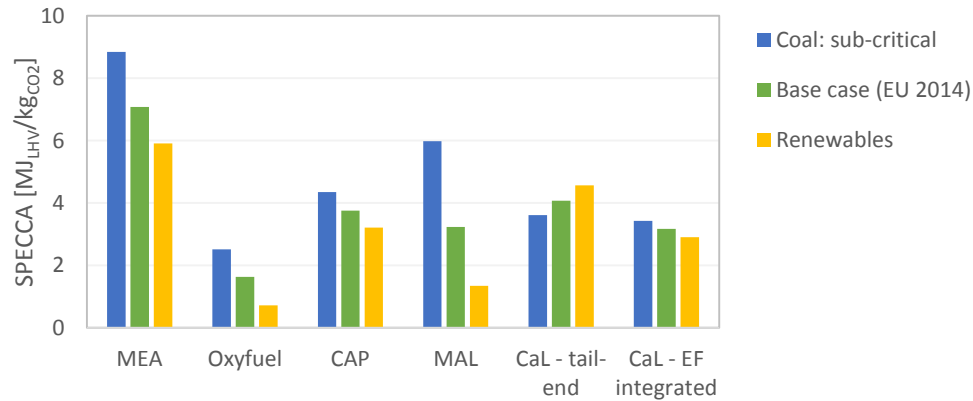
	Criteria	MEA	Oxyfuel	CAP	MAL	CaL (tail-end)	CaL (integrated)
1	Impact on cement production	✓	!!	✓	✓	✓	!
2	Equipment and footprint	!	!!	!	!	!	!!
3	Utilities and services	!	!	!	!	!	!
4	Introduction of new chemicals/subsystems	!	!	!	✓	!	!
5	Available experiences	✓	?	!	?	!	?

✓	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

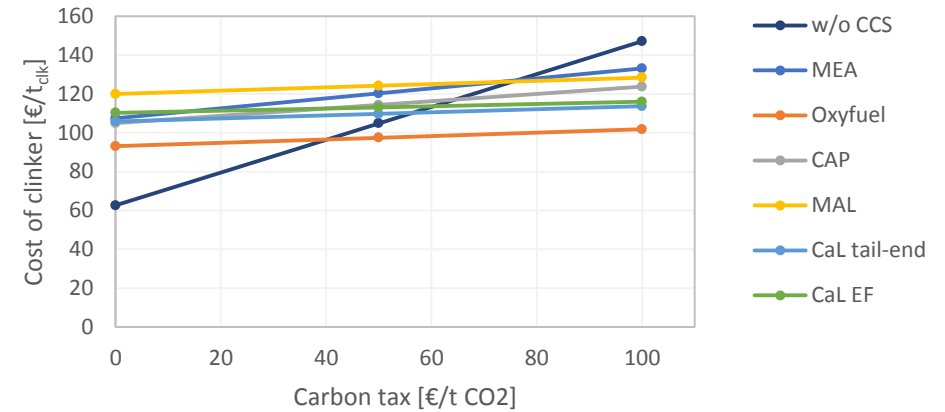


Sensitivity analysis

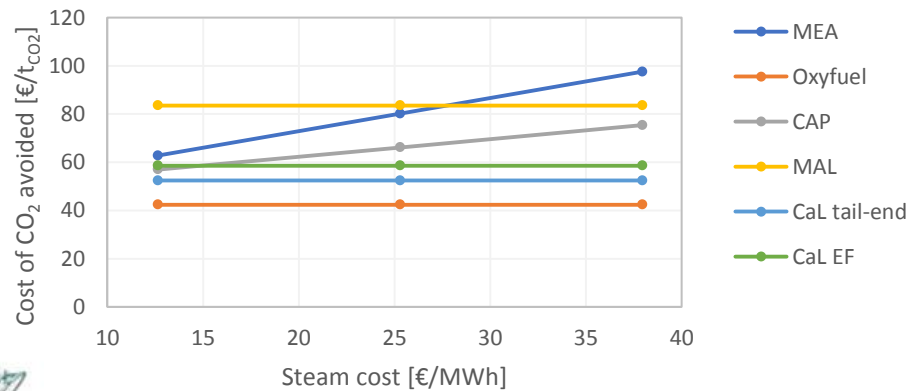
SPECCA and electricity mix



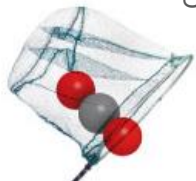
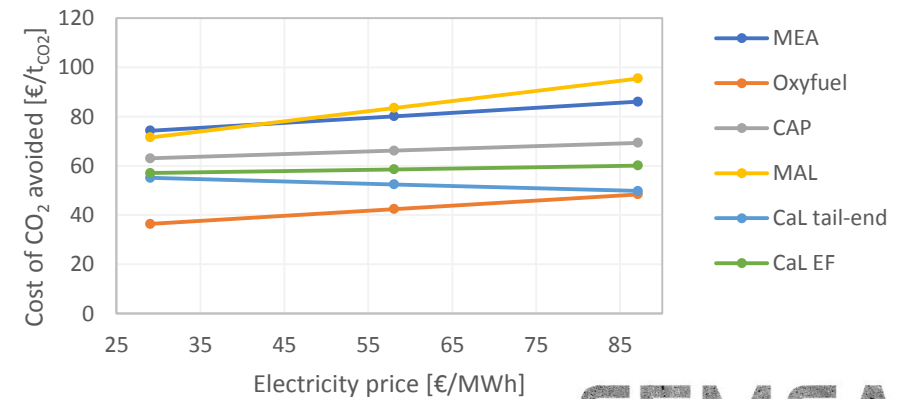
Cost of clinker and carbon tax



CO₂ avoided and steam cost

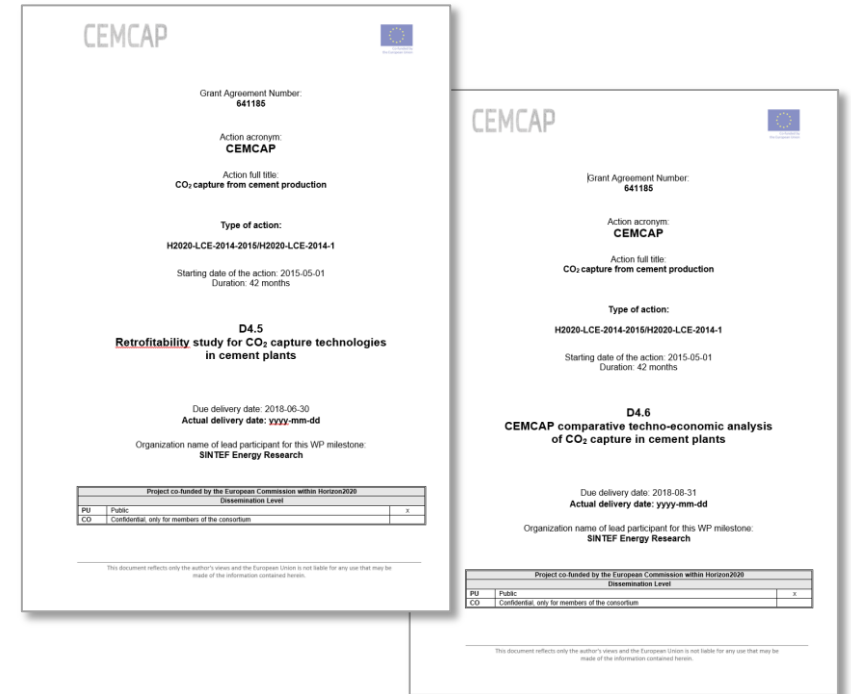
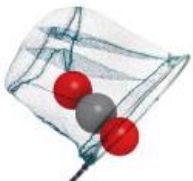


CO₂ avoided and electricity price



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 CO₂ capture in cement plants

To be shared in:

<https://zenodo.org/communities/cemcap/>

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Cement Producers



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Technology providers



R&D providers

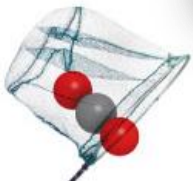


ETH zürich



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Coordinated by SINTEF



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