HOW TO COST EFFECTIVELY ACHIEVE NET-ZERO CO_2 EMISSIONS FOR CEMENT INDUSTRY WITH CCS

Sina Hoseinpoori *, Rahul Anantharaman, Luca Riboldi, Simon Roussanaly, David Pallares, Filip Johnsson

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Motivation:

- CCS is deemed necessary for reaching climate change mitigation targets

- The benchmark CCS is MEA scrubbing with capture rate of 90% which leaves 10% residual emissions

- Residual emissions can be mitigated through higher capture rates or offsetting via CDR

- Direct air capture is CDR technology can offset emissions at high price and energy demand

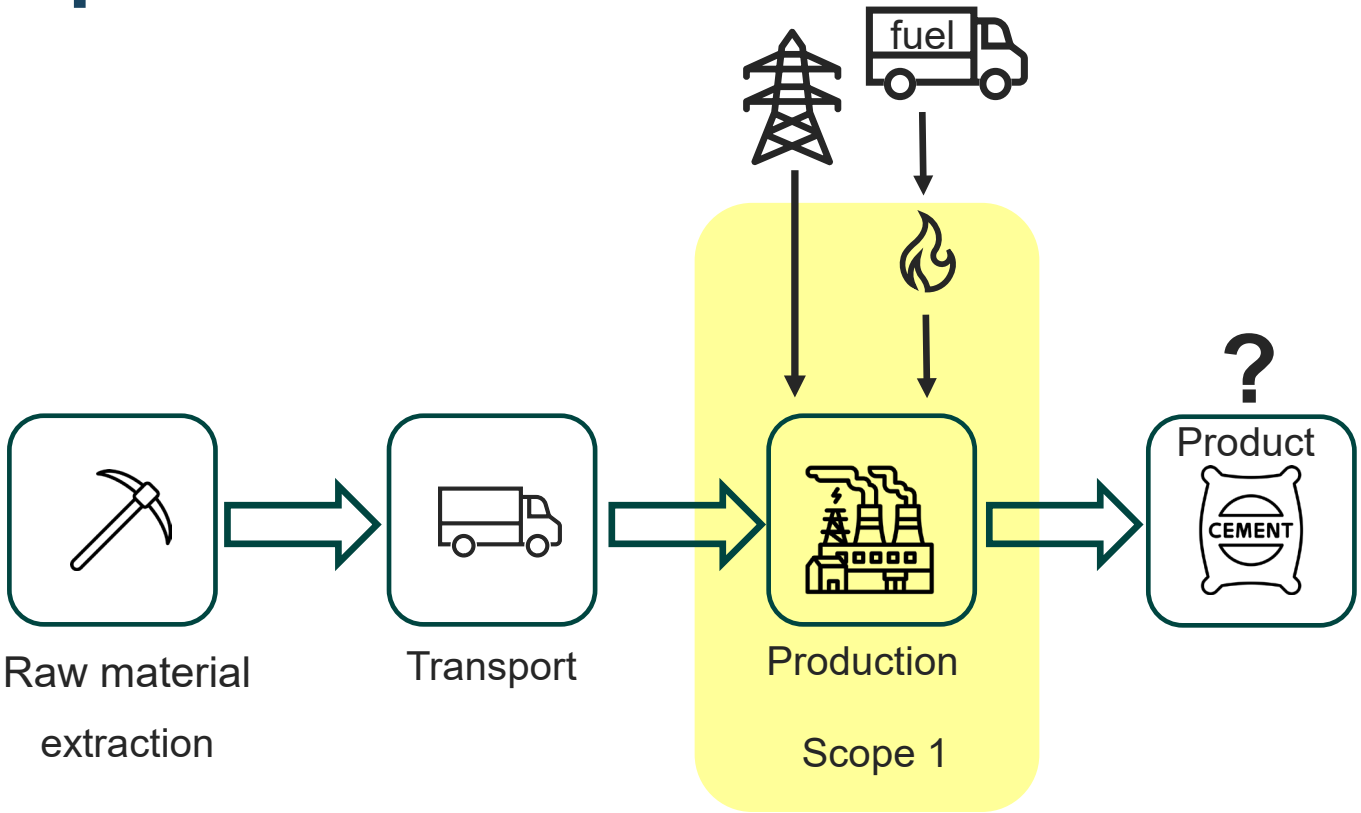
Aim:

- **To investigate the role of direct air capture technologies in decarbonizing carbon intensive industries**

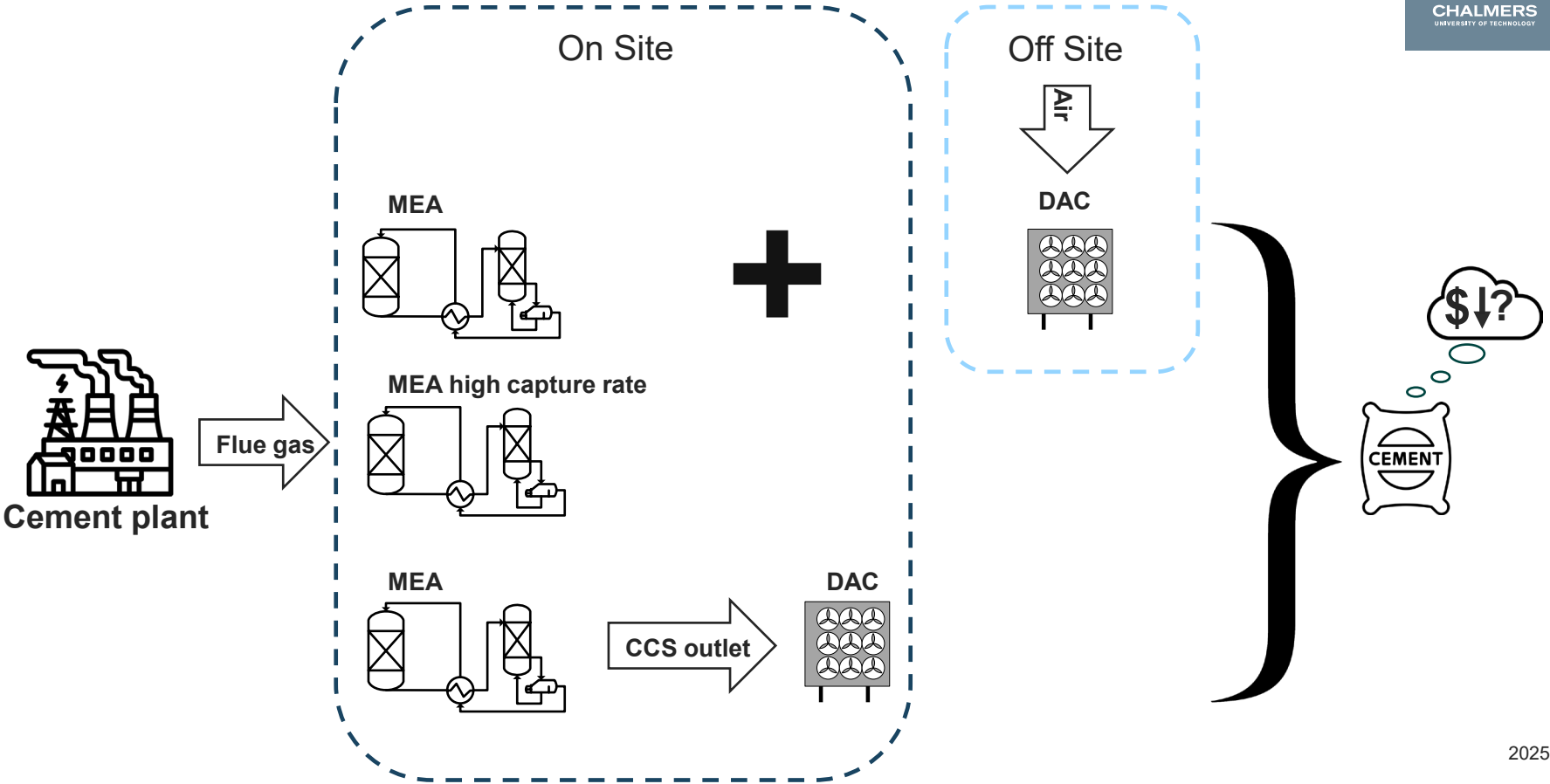
- **To determine the cost-effective extent of carbon capture on site**

Assessing Cost of CO2 Capture From Flue Gas Streams With Low CO2 Concentration by Sina Hoseinpoori, Filip Johnsson, David Pallarès :: SSRN

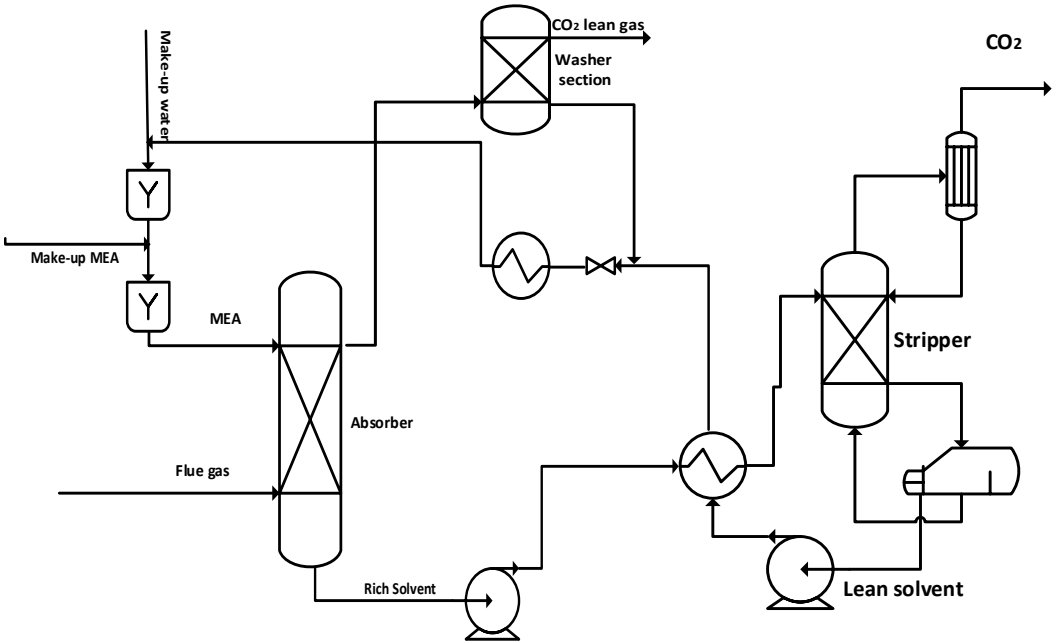
Scope:


fuel
?
Product
CEMENT
Raw material
extraction
Transport
Production
Scope 1

Method: Capture paths



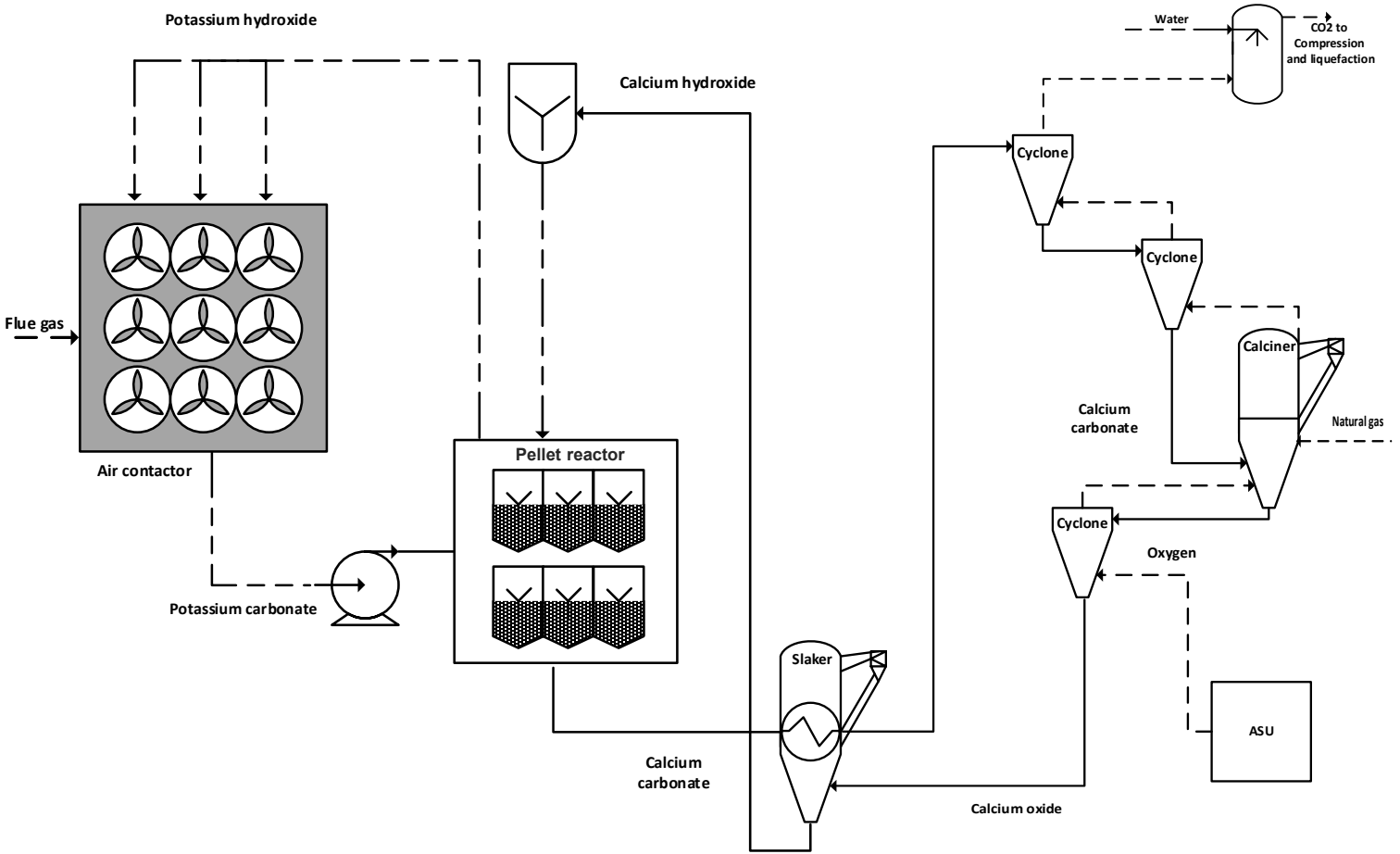
Method: MEA process



Parametric SRD optimization:

1. Lean loading
2. Column height
3. Column diameter

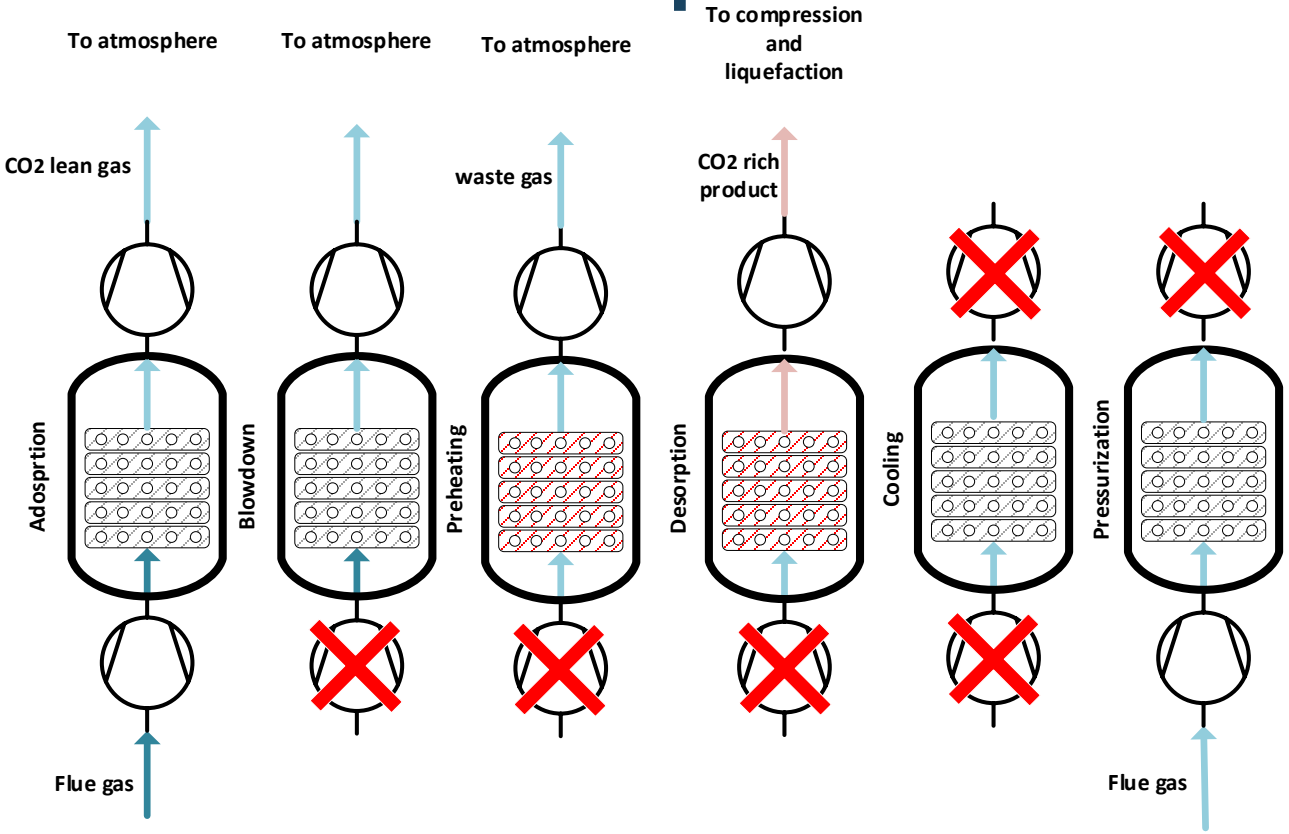
Method: ALK-ABS process



Sizing parameters:

- # Air contactor
- # Pellet reactor
- Calciner and slaker load
- Fuel and oxygen demand

Method: TVSA process

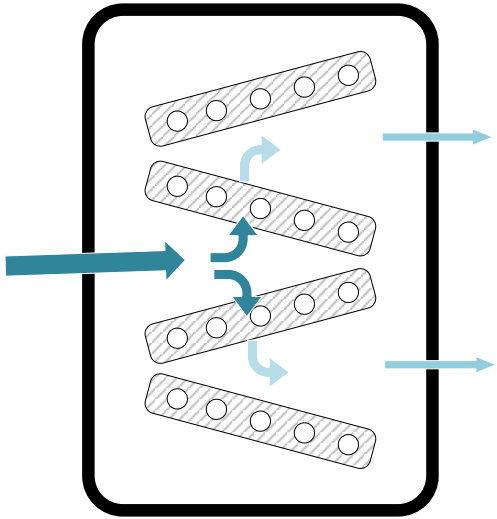


Mapping parameters:

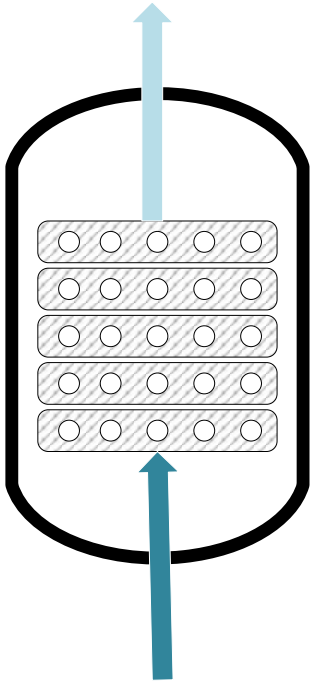
- Inlet flow rate of flue gas
- Column height
- Molar fraction of water in flue gas
- Time of adsorption
- Time of preheating
- Time of desorption

Method: TVSA

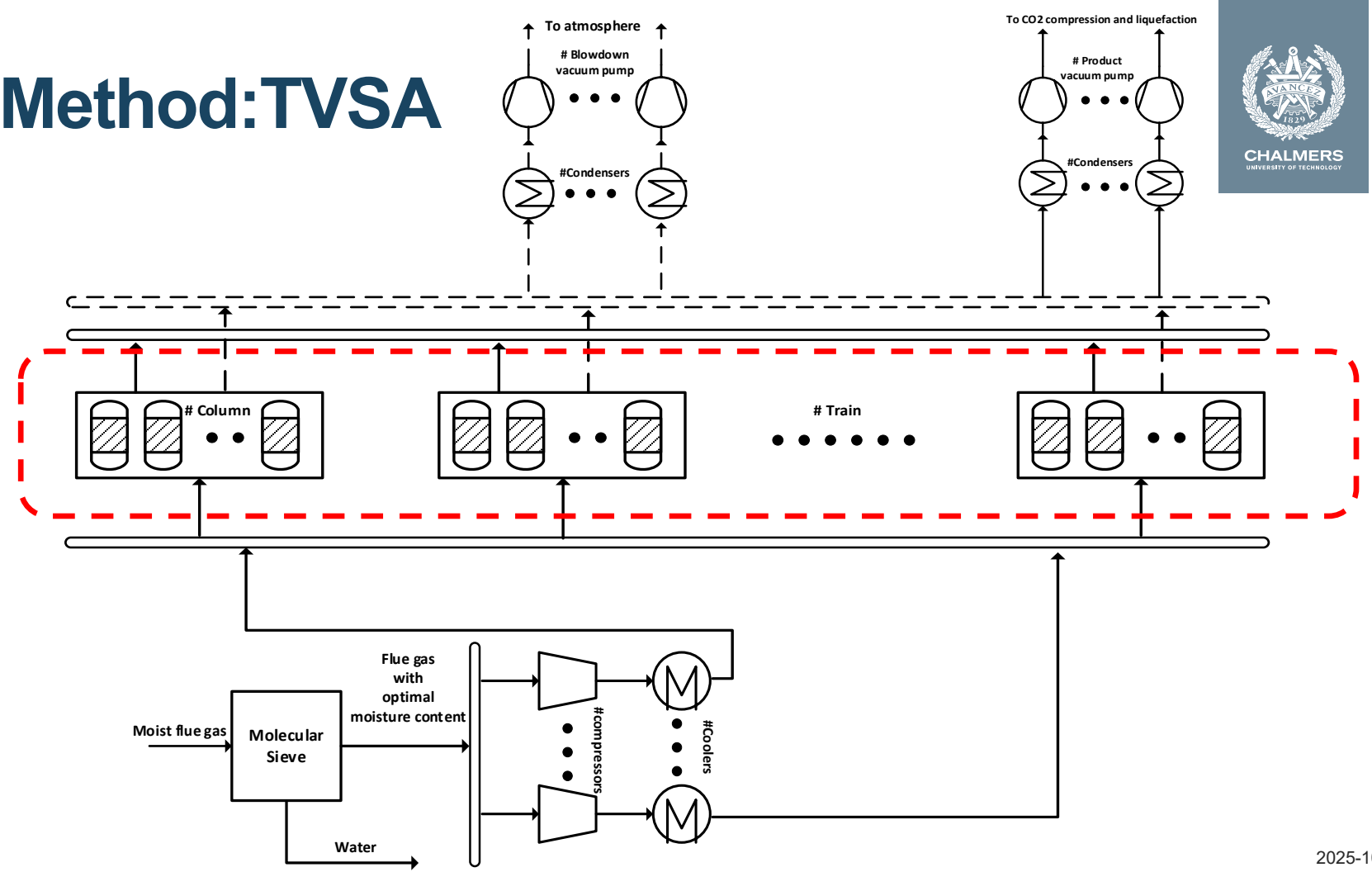
Climeworks DAC design



This work



Method:TVSA


To atmosphere
Blowdown vacuum pump
#Condensers
To CO2 compression and liquefaction
Product vacuum pump
#Condensers
Column
Train
Flue gas with optimal moisture content
Moist flue gas
Molecular Sieve
Water
#compressors
#Coolers

Case study:

- Cement plant with 1 Mtpa clinker production
- CO_2 concentration 18 %mol
- Flue gas flow rate 380 t/h
- Temperature before absorber 40℃
- The cost of TVSA and ALK-ABS are assessed assuming 1Mtpa cumulative deployed scale and applying learning rates

Results: MEA column sizing

Capture rate	90%	95%	96%	97%	98%	99%	99.77%
Lean loading [Mol CO_2 / mol MEA]	0.24	0.23	0.21	0.21	0.2	0.17	0.2
Absorber packing height [m]	18.5	19	19	19.5	20.5	21.5	22
Stripper packing height [m]	7.5	8	9	9	9.5	12.5	12.5
SRD [MJ/ Kg CO_2]	3.45	3.499	3.506	3.529	3.573	3.709	4.927
Power demand [KWh/Kg CO_2]	0.145	0.1443	0.1437	0.1437	0.1436	0.1433	0.1611

Results: ALK-ABS and TVSA costs

Cost [$/tCO2]/ CO_2 Concentration [%]	2.3 % After(90%)	1.15% After(95%)	0.92% After(96%)	0.7% After(97%)	0.48 After(97%)	0.2% After(99%)
ALK-ABS	342	374	387	405	435	504
TVSA	198	274	317	378	532	802

- There is a cross over between the cost of TVSA and ALK-ABS in the CO_2 concentration range 0.48-0.7%
- Cost of ALK-ABS and TVSA for capturing CO2 from air has been estimated 544 and 840 $/tCO$_2$ respectively.

Next steps:

- Finalize technoeconomic assessment to compare marginal cost avoidance with the cost of DAC
- Apply the same methodology for other industries and concentrations.
- Considering intercooling in the MEA model.

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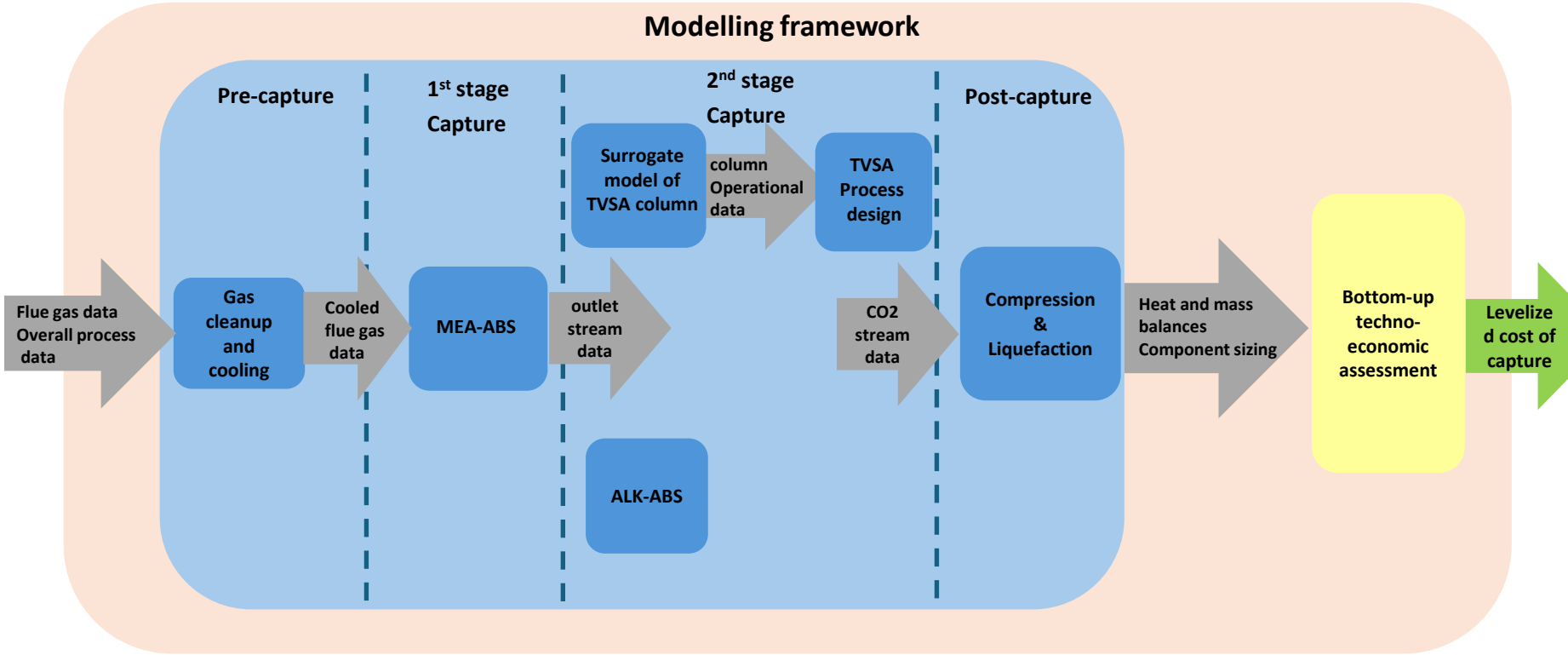
Modelling framework
Pre-capture
1st stage Capture
2nd stage Capture
Post-capture
Flue gas data Overall process data
Gas cleanup and cooling
Cooled flue gas data
MEA-ABS
outlet stream data
Surrogate model of TVSA column
column Operational data
TVSA Process design
ALK-ABS
CO2 stream data
Compression & Liquefaction
Heat and mass balances Component sizing
Bottom-up techno-economic assessment
Levelized cost of capture

Results: MEA column sizing

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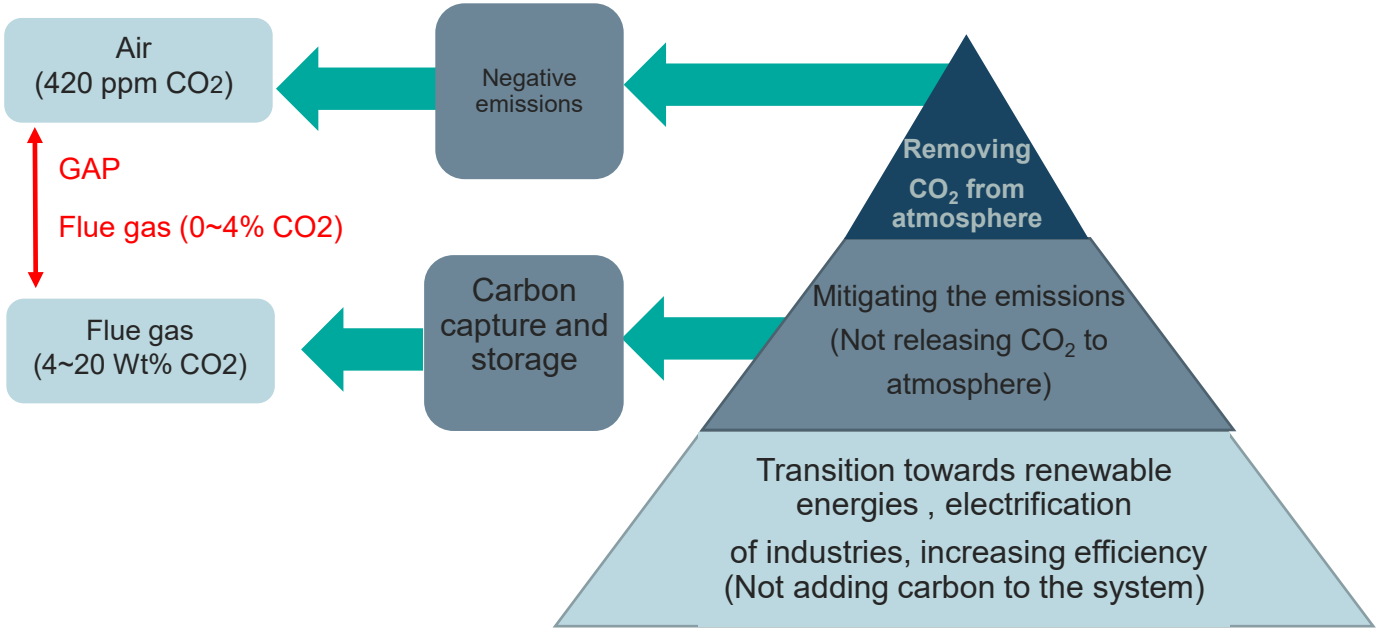
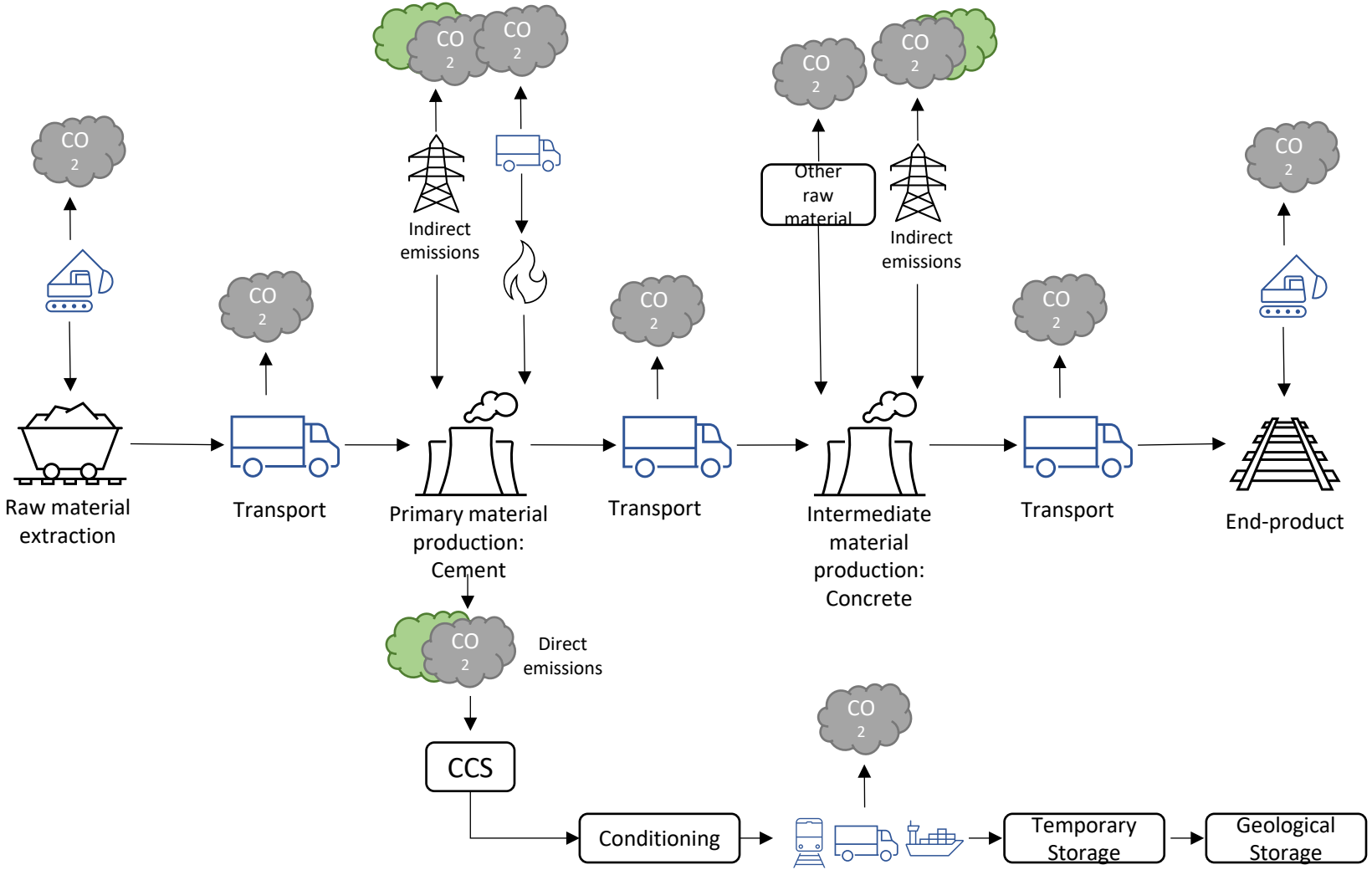
Absorber packing height [m]	18.5	19	19	19.5	20.5	21.5	22
Stripper packing height [m]	7.5	8	9	9	9.5	12.5	12.5
Absorber diameter [m]	8.185	8.308	8.246	8.282	8.28	8.193	7.84
Stripper diameter [m]	4.78	4.9	4.89	4.92	4.94	5	5.82
SRD [MJ/ Kg CO_2]	3.45	3.499	3.506	3.529	3.573	3.709	4.927
Power demand [KWh/Kg CO_2]	0.145	0.1443	0.1437	0.1437	0.1436	0.1433	0.1611

Net-zero Hierarchy




CO2
CO2
CO2
CO2
CO2
CO2
CO2
Indirect emissions
Other raw material
Indirect emissions
Raw material extraction
Transport
Primary material production: Cement
Transport
Intermediate material production: Concrete
Transport
End-product
Direct emissions
CCS
Conditioning
Temporary Storage
Geological Storage