BOKU
Institut für Verfahrens- und Energietechnik

Continuous Temperature Swing Adsorption for Carbon Dioxide Capture in Industry

NEFI Conference October 2026

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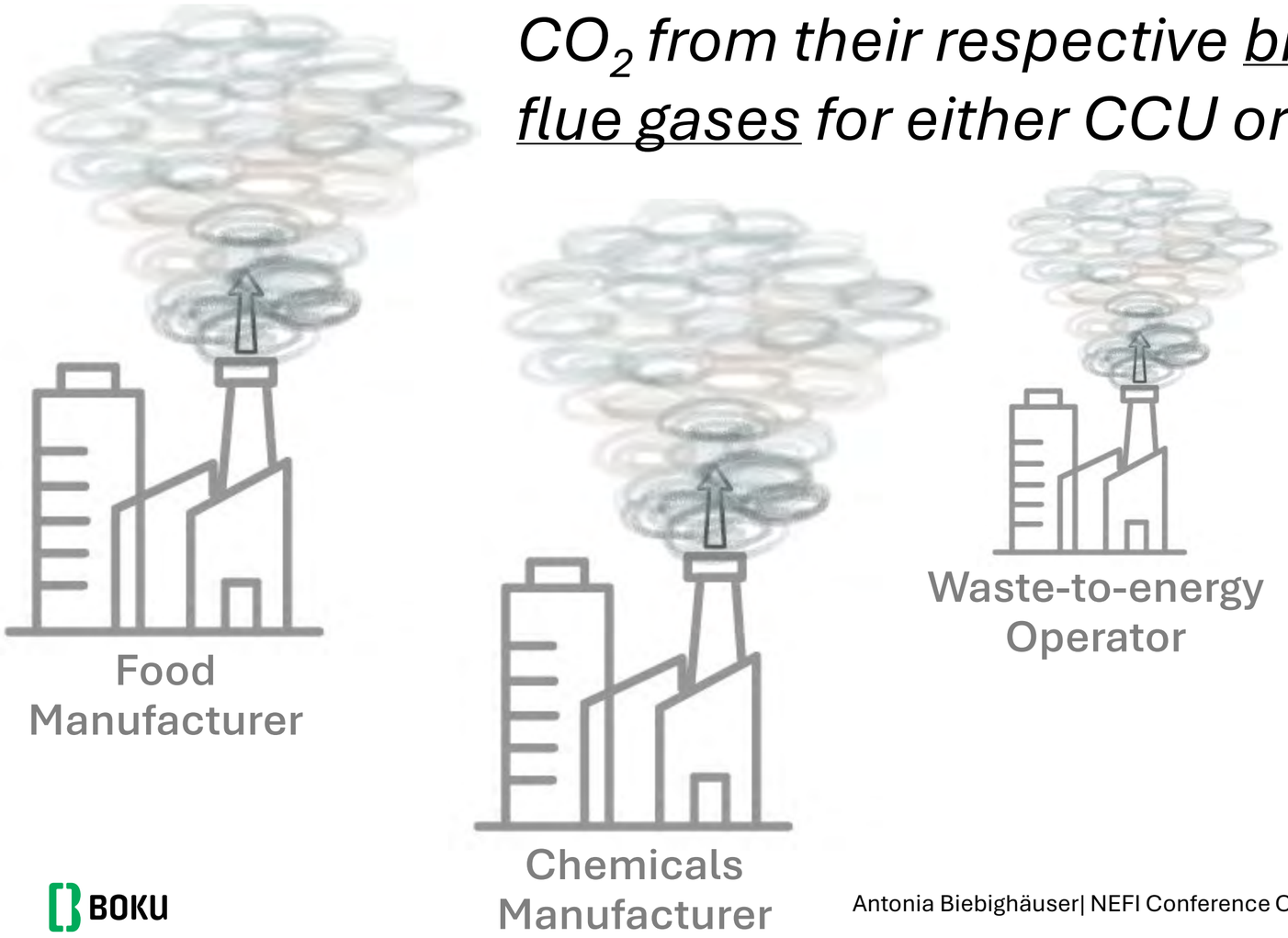
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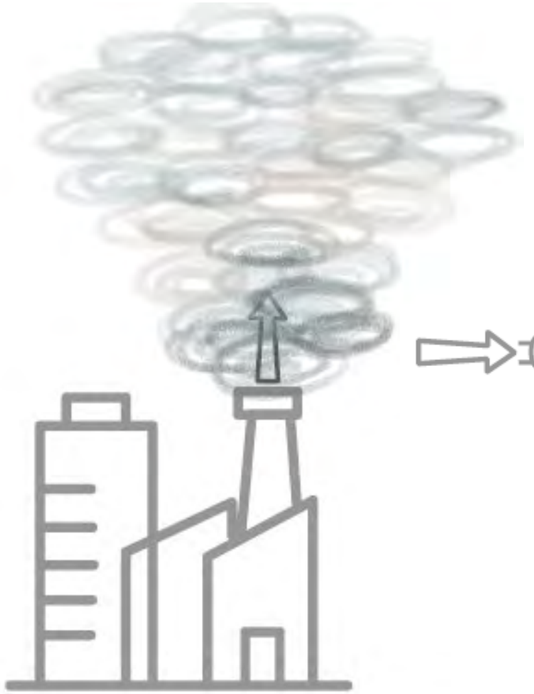


The BioFizz Project

3 Stakeholders that wish to separate CO_2 from their respective <u>biogenic flue gases</u> for either CCU or CCS

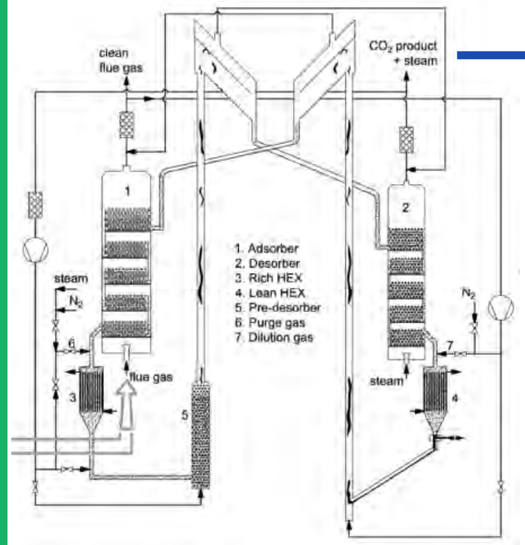


The BioFizz Project

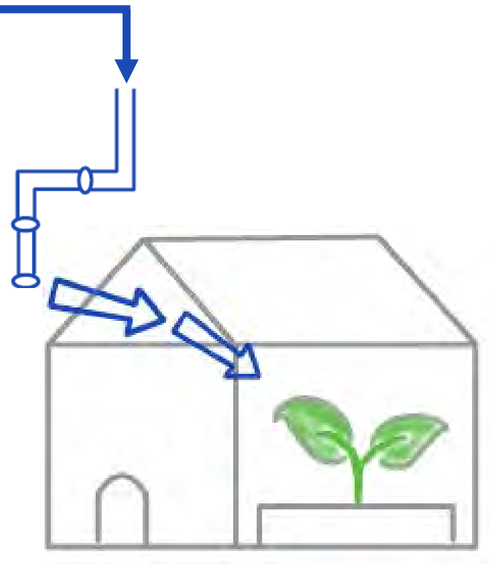


Food Manufacturer

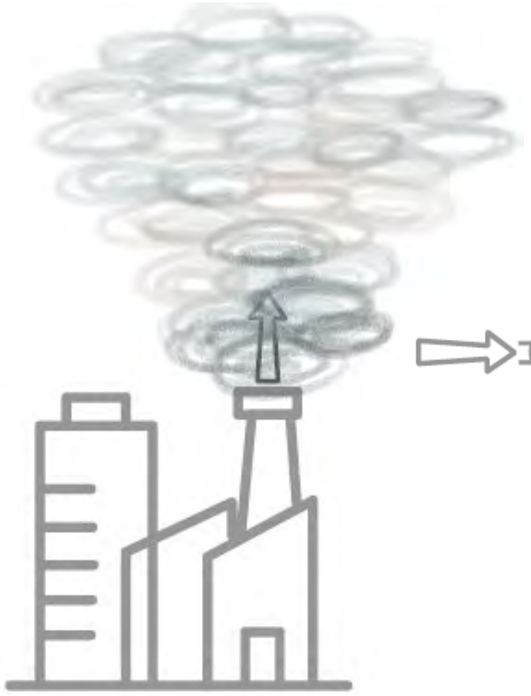
Temperature Swing Adsorption



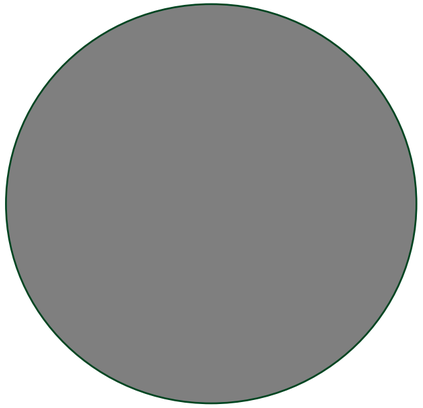
[van Paasen et al., International Journal of Greenhouse Gas Control 109 (2021)]



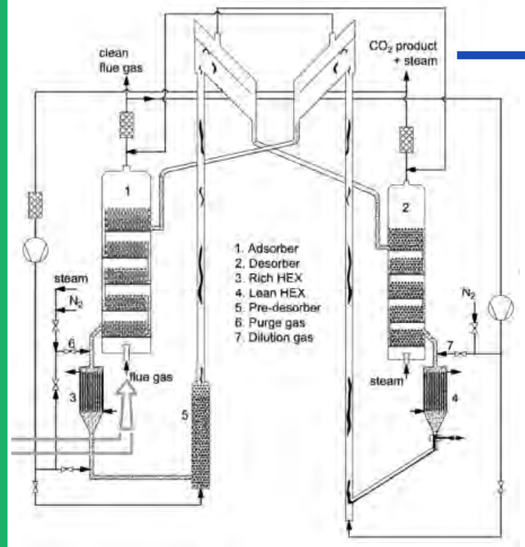
The BioFizz Project



Chemicals Manufacturer



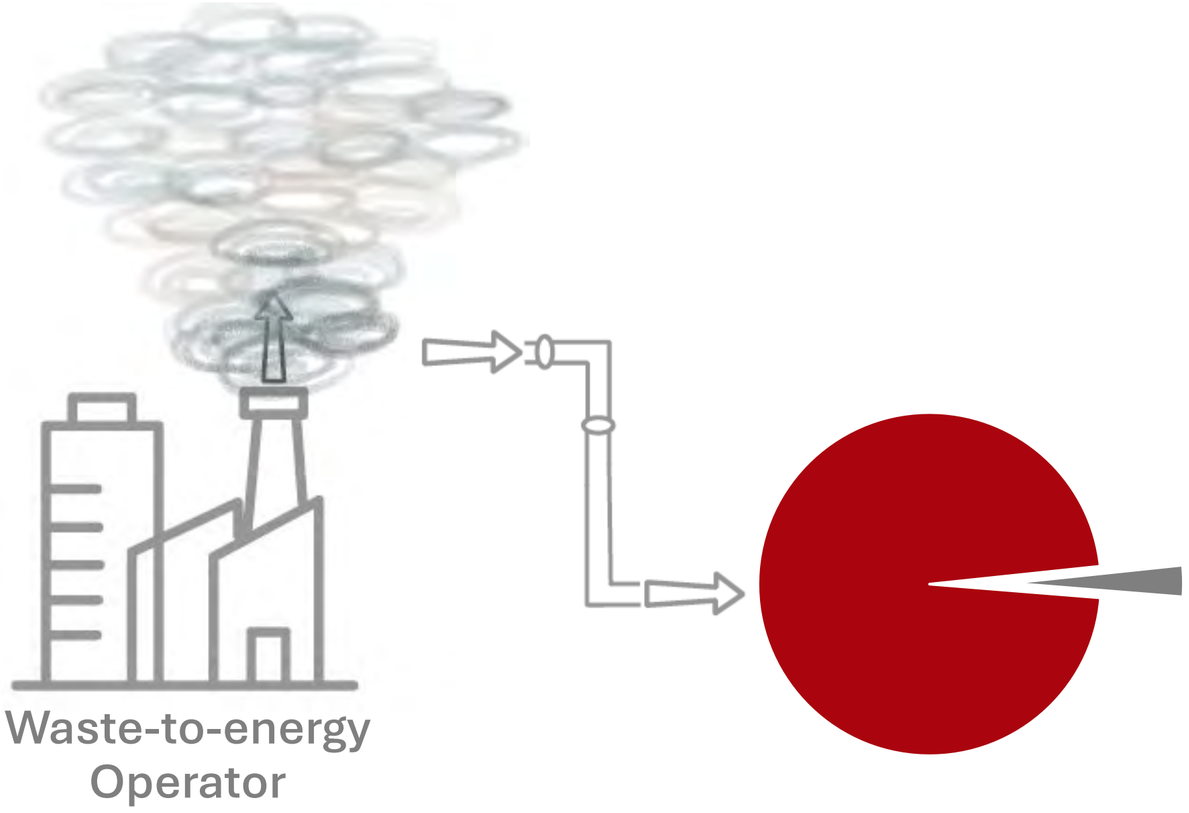
Temperature Swing Adsorption





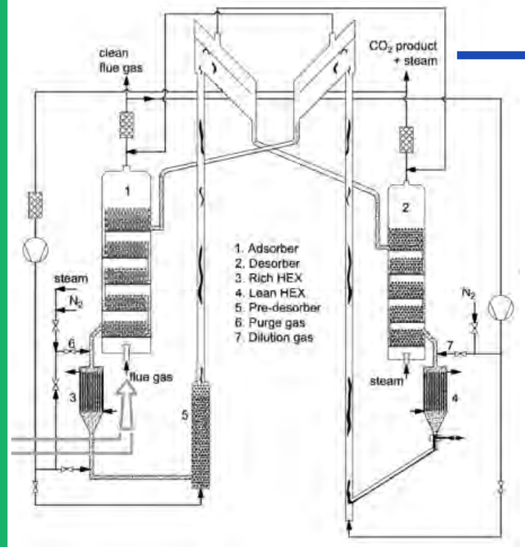
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The BioFizz Project

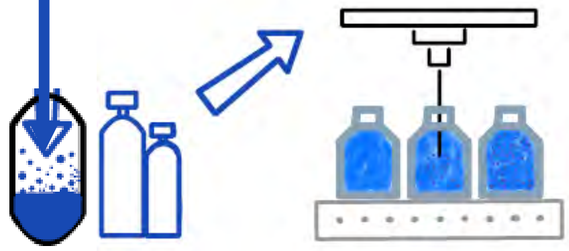


Waste-to-energy Operator

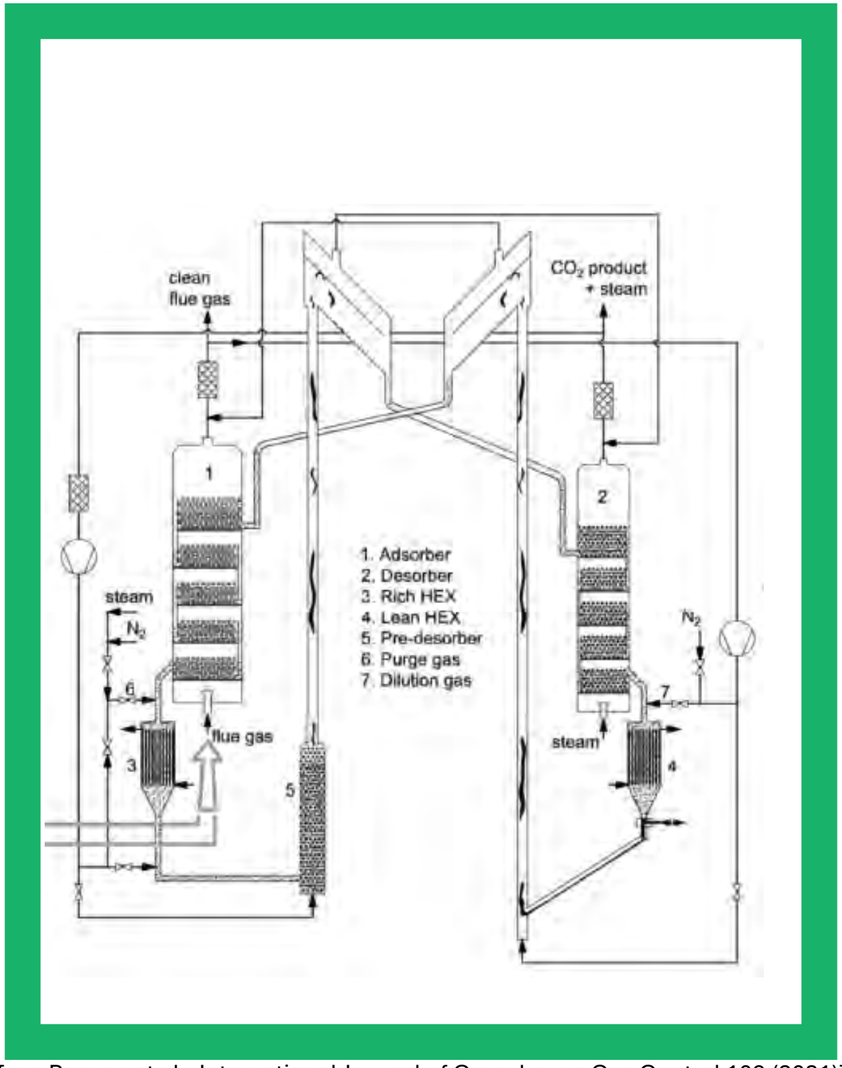
Temperature Swing Adsorption



[van Paasen et al., International Journal of Greenhouse Gas Control 109 (2021)]



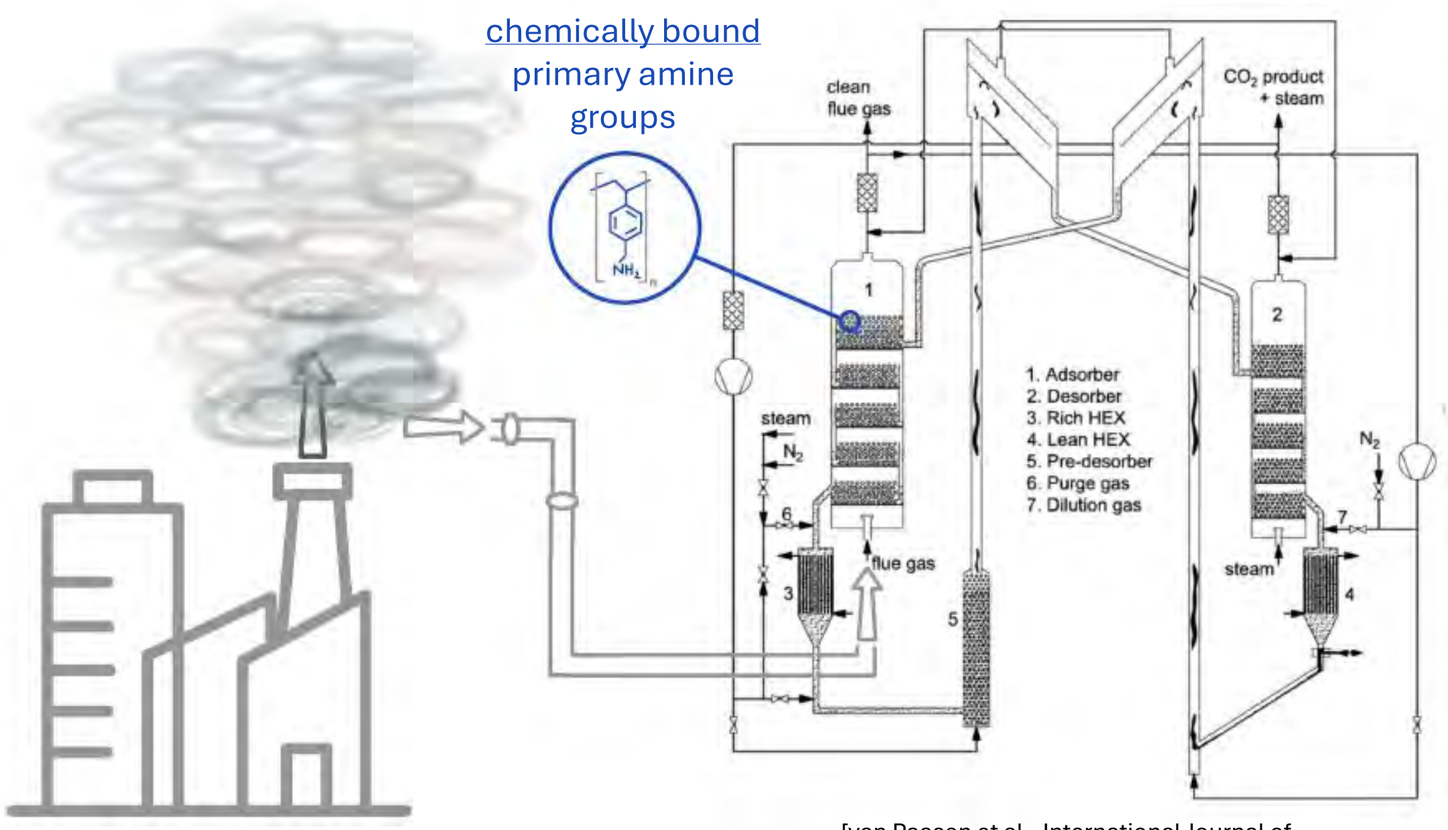
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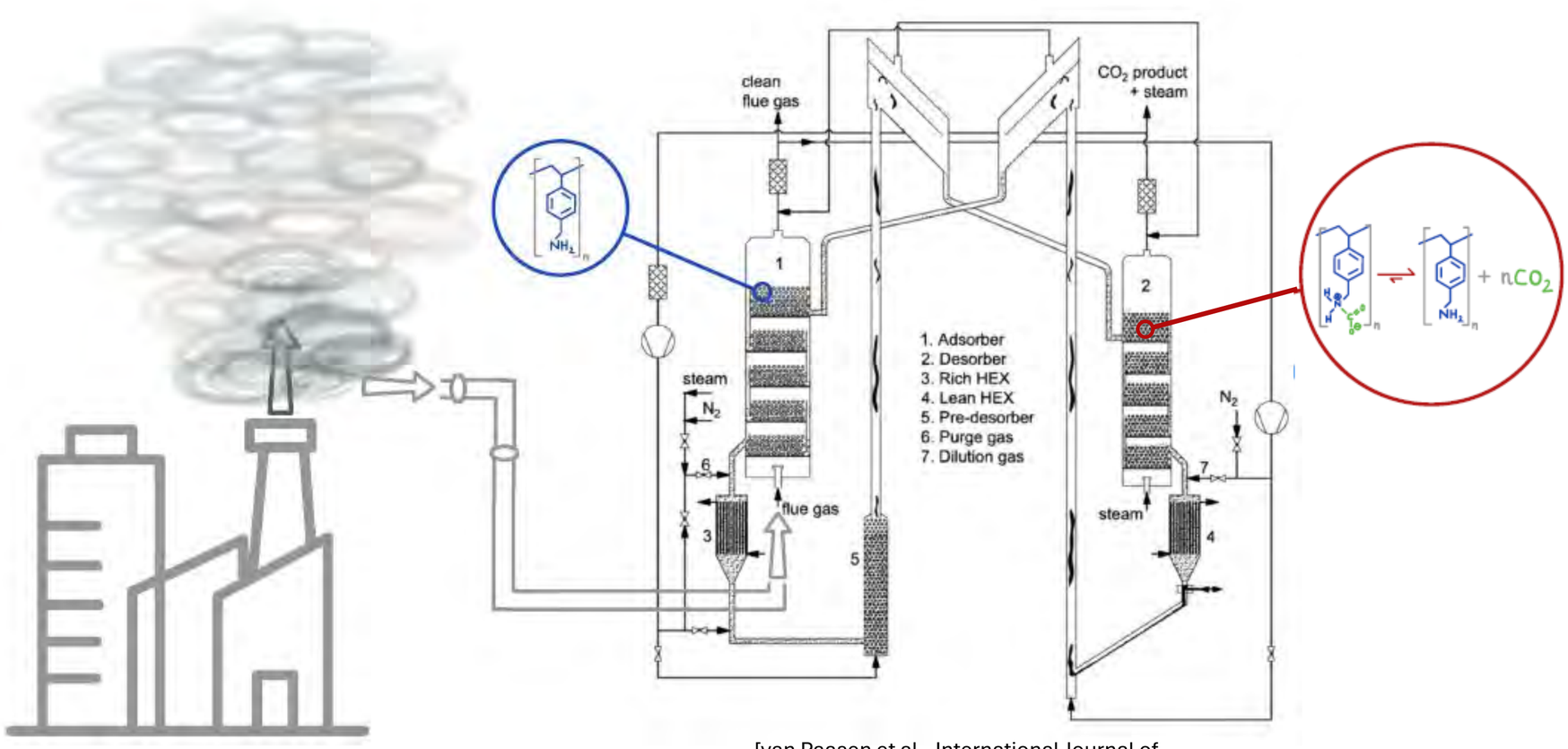
Temperature Swing Adsorption

Crosslinked polymer in spherical bead form with chemically bound primary amine groups



[van Paasen et al., International Journal of Greenhouse Gas Control 109 (2021)]

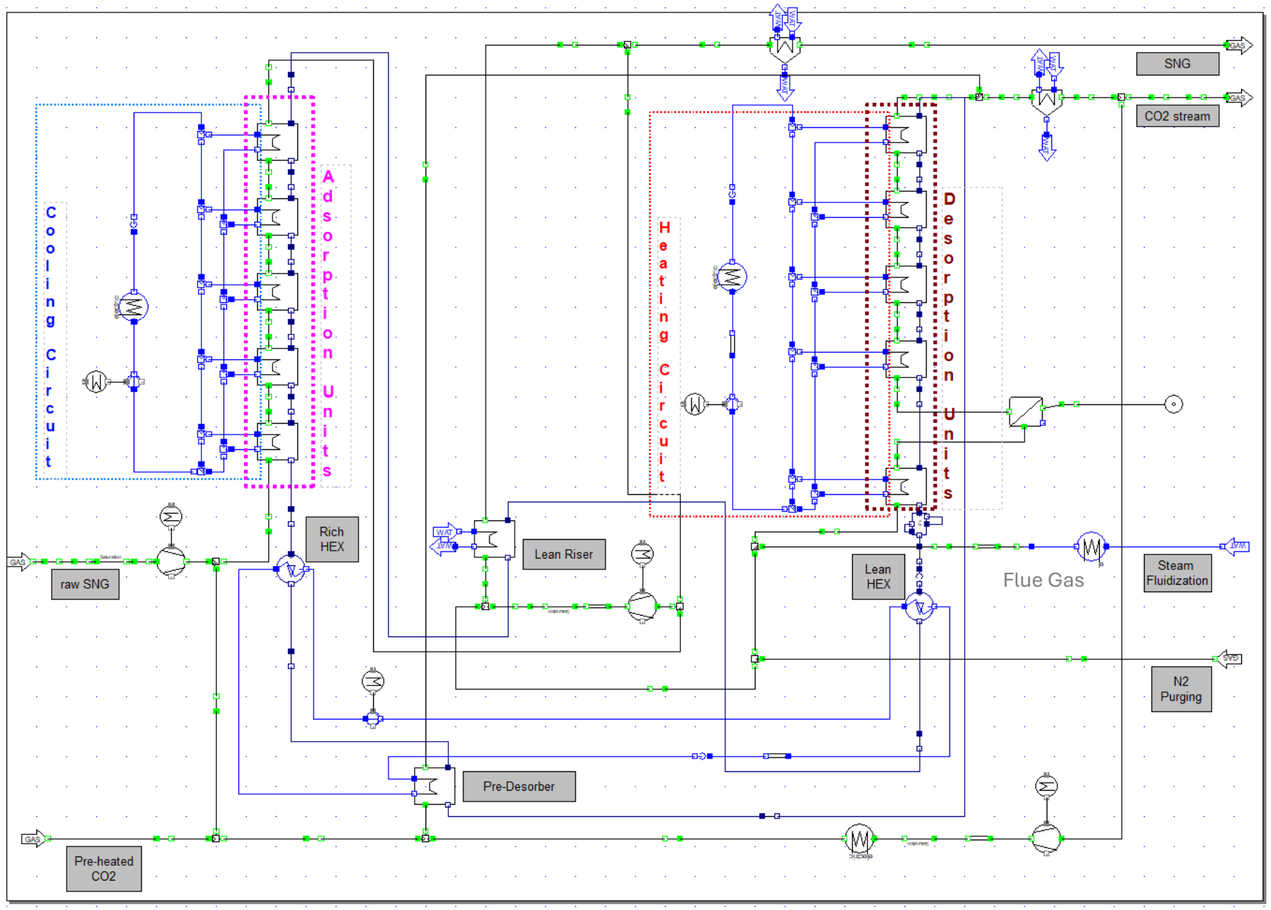
Temperature Swing Adsorption



Reverse reaction allows for regeneration of adsorbens

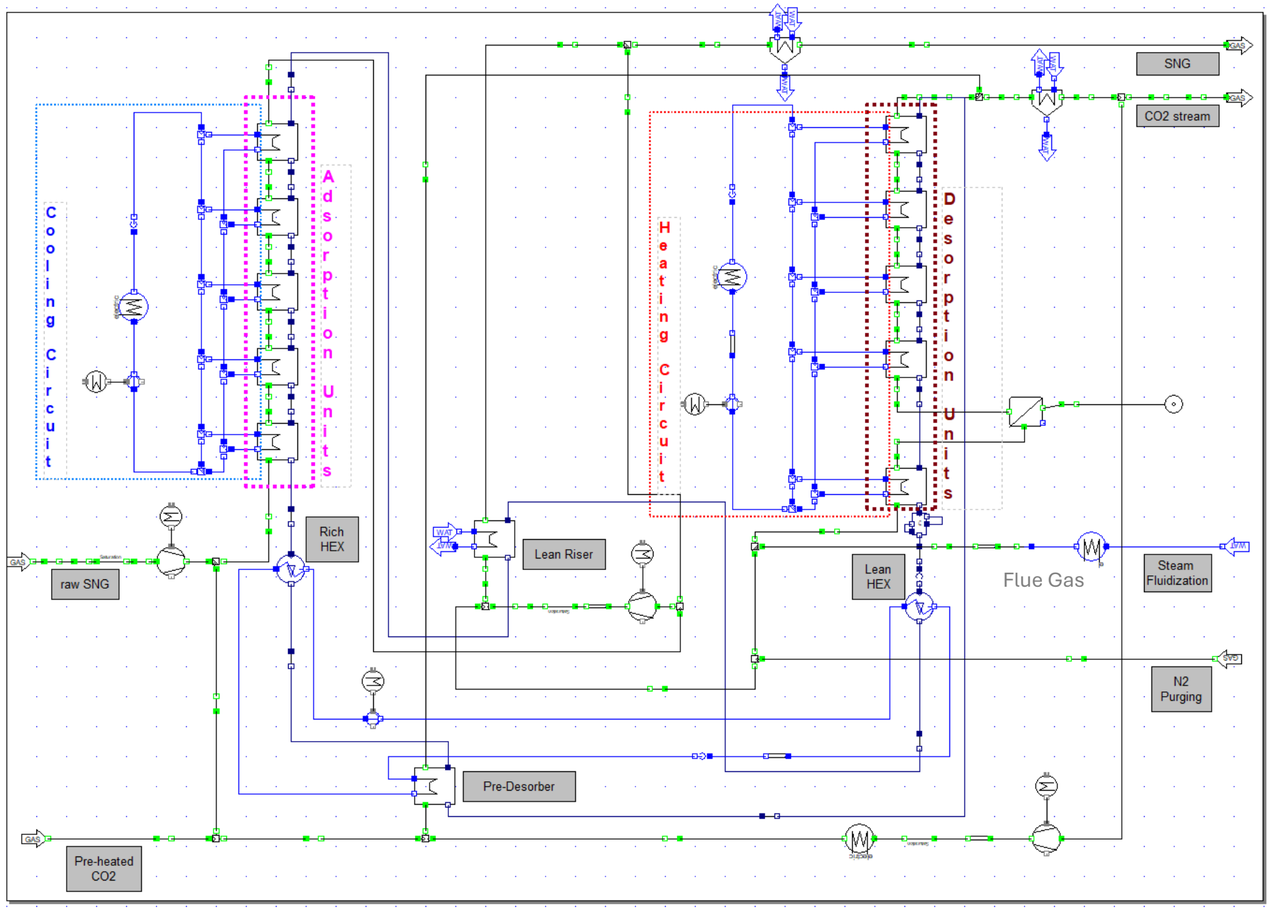
[van Paasen et al., International Journal of Greenhouse Gas Control 109 (2021)]

Simulative evaluation
based on Scheuch plant





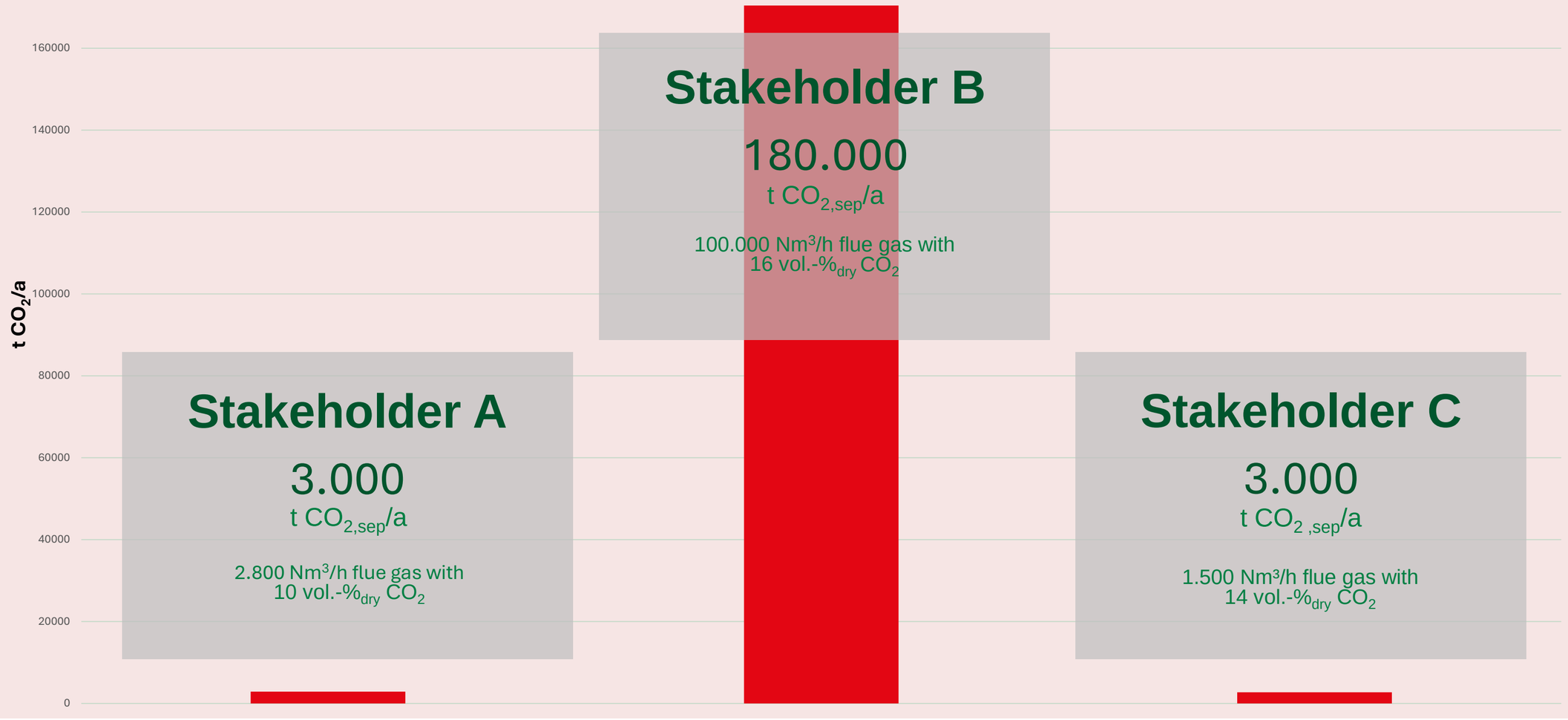
Simulative evaluation
based on Scheuch plant





- Does the separated CO_2 meet Stakeholder requirements?
- CAPEX?
- Energy Demand?
- CO_2 Footprint?

Three Industrial Stakeholders and their CO_2 demand

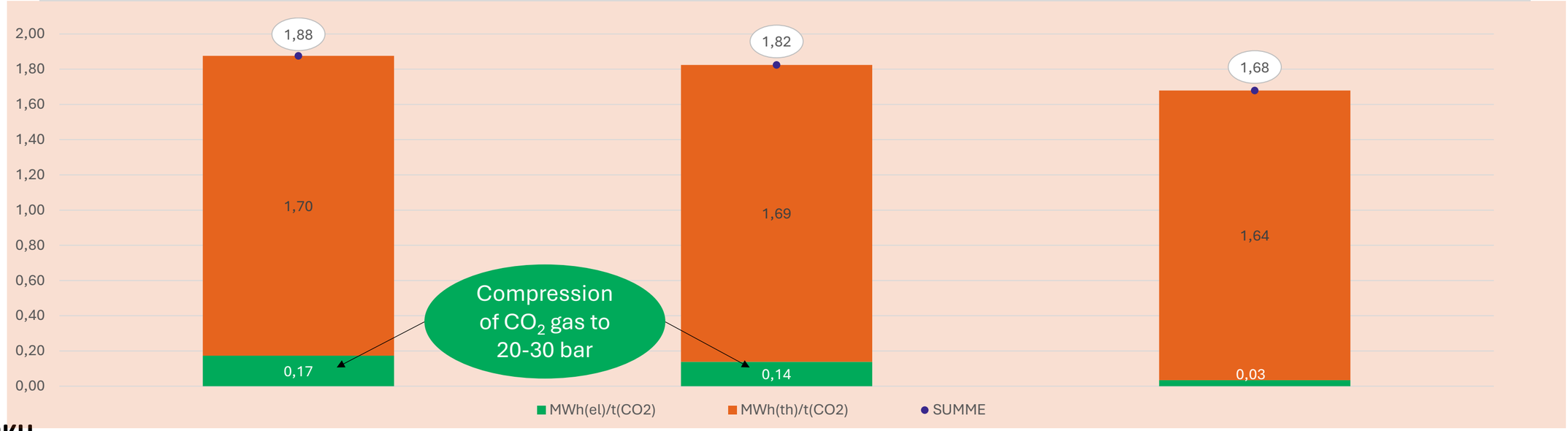


Energy Demand

Tons of CO_2 separated in each process

Stakeholder A	Stakeholder B	Stakeholder C
3.000	180.000	3.000
t $CO_{2,sep}$/a	t $CO_{2,sep}$/a	t $CO_{2,sep}$/a
For beverage carbonization	For CCS	For greenhouse fertilization

Scale-Up results based on Scheuch plant with side specific energy integration

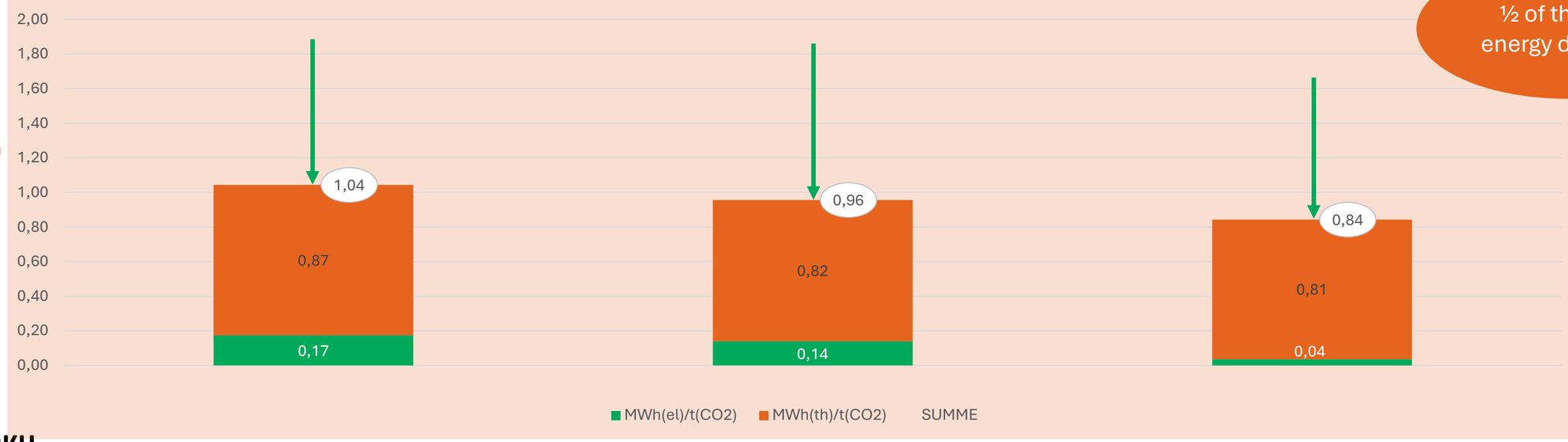


Optimised Energy Demand

Tons of CO_2 separated in each process

Stakeholder A	Stakeholder B	Stakeholder C
3.000	180.000	3.000
t $CO_{2,sep}$/a	t $CO_{2,sep}$/a	t $CO_{2,sep}$/a
For beverage carbonization	For CCS	For greenhouse fertilization

Optimized energy demand (steam) based on Zerobin & Pröll (2020)) in MWh/tCO_2



½ of thermal energy demand.

Assumptions for techno-economic assessment

- Lifetime of plant = 20 years
- Opterating hours per year = 8.000
- OPEX
  - Thermal energy = 52 €/MWh
  - Electrical energy = 12 ct/kWh
  - Adsorbens costs: = 69 € (Lewatit® VP OC 1065)
    24 € (Purolite A110)
- CAPEX
  - $C_{eq} = Ceq_{,\,base} * \left(\frac{S_{desian}}{S_{base}}\right)^{r} * \left(\frac{CEPCI_{2026}}{CEPCI_{base\ year}}\right)$
  - $C_{eq,base}$ = ViennaGreenCO_2 costs in the year 2015 = 1.454.287 €
  - CEPCIbase year = Chemical Engineering Plant Cost Index in the year 2015 = 556,8
  - r = 0,6 – 0,7
  - CAPEX EIGA for Stakeholder A = 236.000 €

Techno-economic assessment – Base Case

Tons of CO_2 separated in each process

Stakeholder A

3.000

t $CO_{2,sep}$/a

For beverage carbonization

Stakeholder B

180.000

t $CO_{2,sep}$/a

For CCS

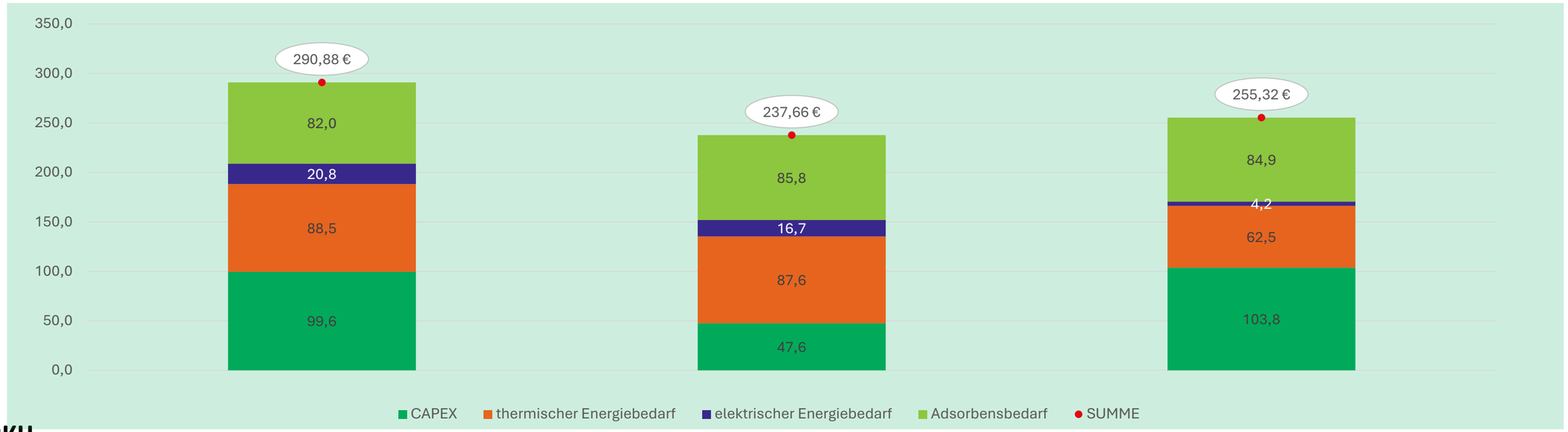
Stakeholder C

3.000

t $CO_{2,sep}$/a

For greenhouse fertilization

Techno-economic assessment
Base case in €/tCO_2



Techno-economic assessment

Tons of CO_2 separated in each process

Stakeholder A

3.000

t $CO_{2,sep}$/a

For beverage carbonization

Stakeholder B

180.000

t $CO_{2,sep}$/a

For CCS

Stakeholder C

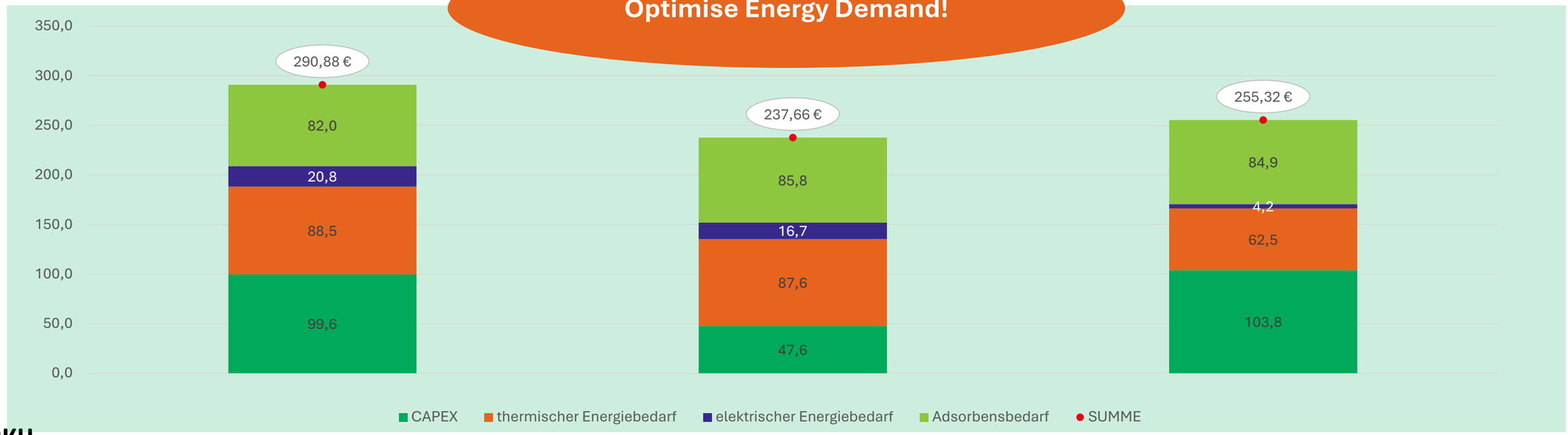
3.000

t $CO_{2,sep}$/a

For greenhouse fertilization

Optimise Energy Demand!

Techno-economic assessment
Base case in €/tCO_2



Techno-economic assessment: optimised energy demand

Tons of CO_2 separated in each process

Stakeholder A

3.000

t $CO_{2,sep}$/a

For beverage carbonization

Stakeholder B

180.000

t $CO_{2,sep}$/a

For CCS

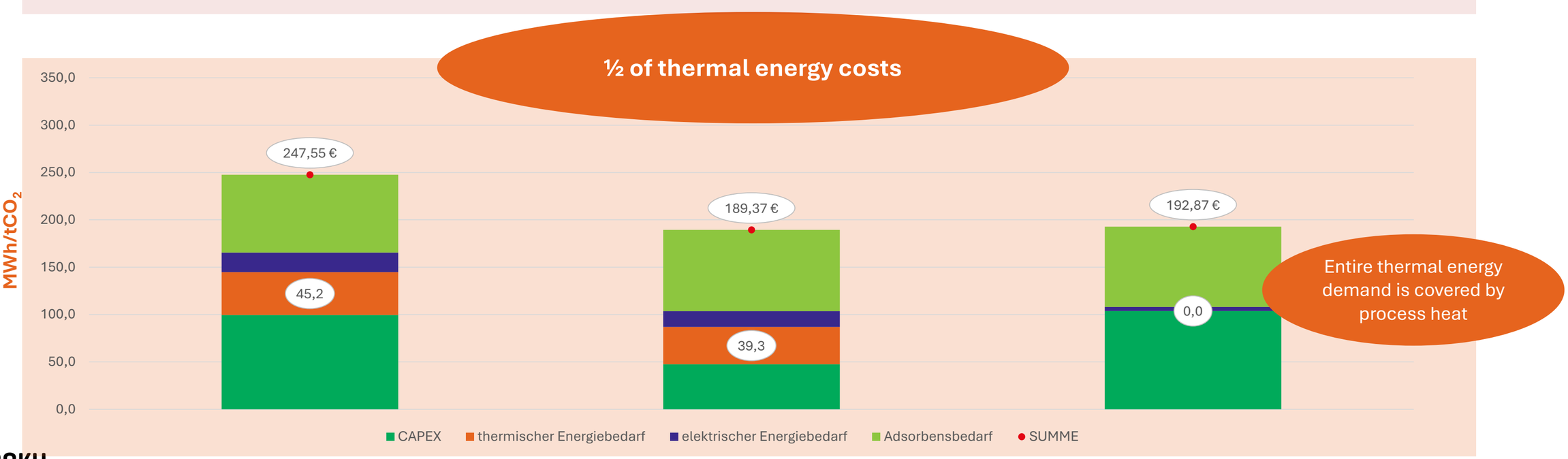
Stakeholder C

3.000

t $CO_{2,sep}$/a

For greenhouse fertilization

Costs for optimized energy demand based on Zerobin & Pröll (2020)) in MWh/tCO_2



Techno-economic assessment

Tons of CO_2 separated in each process

Stakeholder A

3.000

t $CO_{2,sep}$/a

For beverage carbonization

Stakeholder B

180.000

t $CO_{2,sep}$/a

For CCS

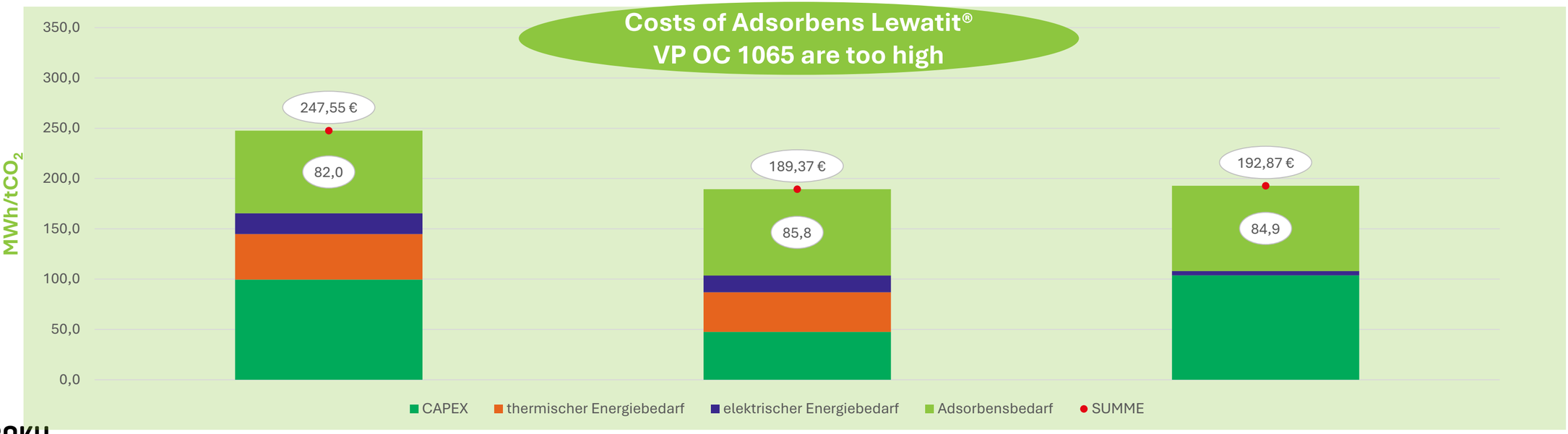
Stakeholder C

3.000

t $CO_{2,sep}$/a

For greenhouse fertilization

Costs for optimized energy demand based on Zerobin & Pröll (2020)) in MWh/tCO_2



Techno-economic assessment: optimised adsorbens costs

Tons of CO_2 separated in each process

Stakeholder A

3.000

t $CO_{2,sep}$/a

For beverage carbonization

Stakeholder B

180.000

t $CO_{2,sep}$/a

For CCS

Stakeholder C

3.000

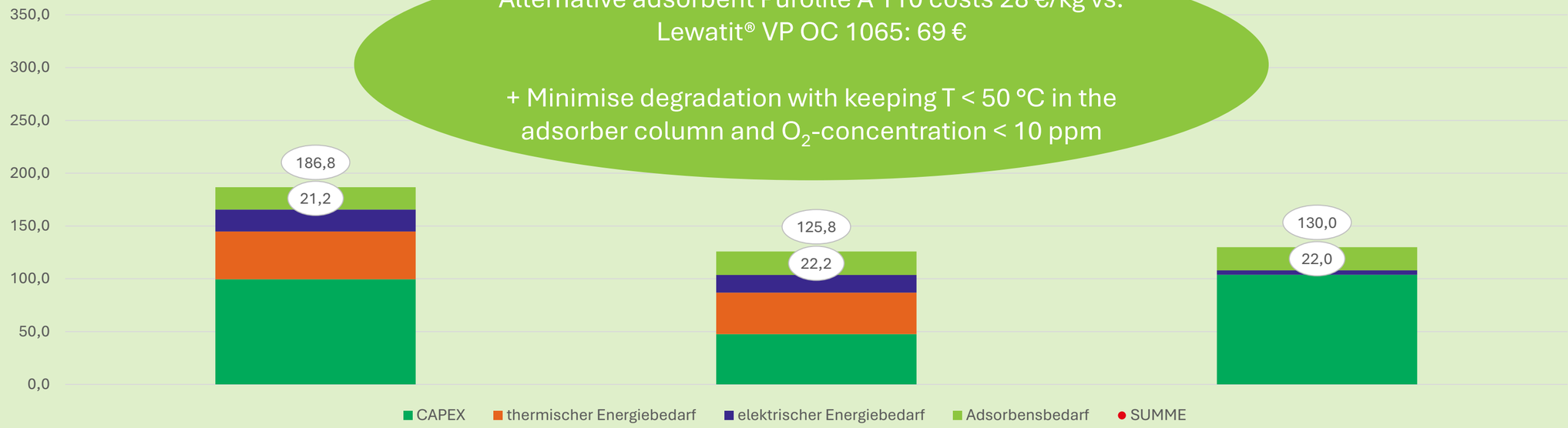
t $CO_{2,sep}$/a

For greenhouse fertilization

Techno-economics: Adsorbens costs

Alternative adsorbent Purolite A 110 costs 28 €/kg vs. Lewatit® VP OC 1065: 69 €

+ Minimise degradation with keeping T < 50 °C in the adsorber column and O_2-concentration < 10 ppm



Summary of techno-economic assessment and energy demand

- **Energy demand**: 0,84 – 1,88 MWh/$tCO_{2,sep}$
  - CO_2 gas compression: 79 % of electrical energy demand
  - Steam generation: 74 % of thermal energy demand
- **Adsorbens costs:** 21,2 – 85,8 €/$tCO_{2,sep}$
  - Degradation in the presence of **O_2** at temperatures > 50 °C
- **CAPEX** is strongly influenced by the scale of the CO_2 separation task
  - ~35-40 % of total costs for 3.000 $tCO_{2,sep}$/a vs. ~20 % for 180.000 $tCO_{2,sep}$/a

Assumptions for Carbon Footprint analysis

- **Thermal energy demand:** Low pressure steam from biomass boiler
  = 19 g CO_2-eq/kWh for wood chips
- **Electrical energy demand:** Austrian electricity grid
  = 83 g CO_2-eq/kWh
- **Steel** for plant construction
  = 2,46 t CO_2-eq/t steel
- Production and periodic replacement of the **adsorbent**
  = 4,93 kg CO_2-eq/kg Lewatit® VP OC 1065
  → 11 % capacity loss after 915 h of operation

Carbon Footprint

Tons of CO_2 separated in each process

Stakeholder A

3.000

t $CO_{2,sep}$/a

For beverage carbonization

Stakeholder B

180.000

t $CO_{2,sep}$/a

For CCS

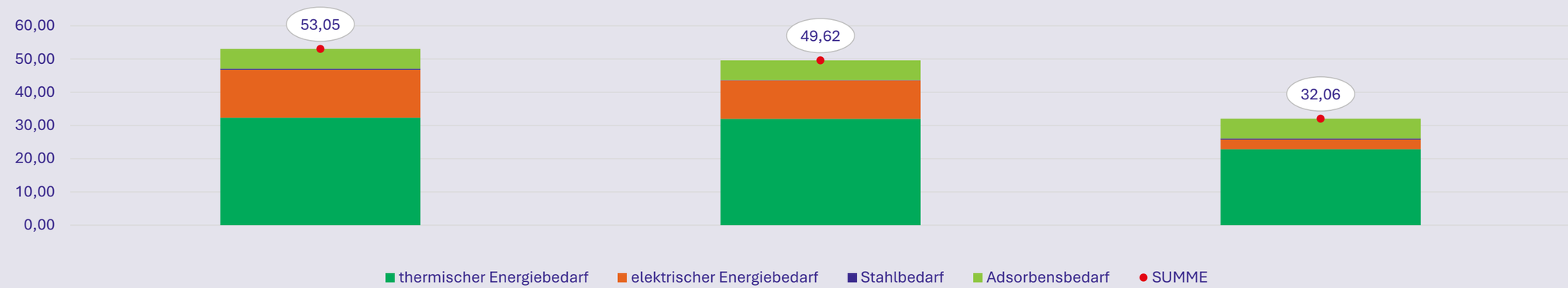
Stakeholder C

3.000

t $CO_{2,sep}$/a

For greenhouse fertilization

Amine Scrubbing reports values between 50 – 250 kg CO_2-eq/a



Net CO_2 capture efficiency: 94,7 %

Net CO_2 capture efficiency: 95,0 %

Net CO_2 capture efficiency: 96,8 %



[Merci BOKU]

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