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Abstract No. 87

Sustainability of geothermal energy

J. van ‘t Westende et al.

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D. van Nimwegen, J. van ‘t Westende*, P. Shoeibi Omrani
D. Dinkelman, E. Peters

* presenting author

Sustainability of heating in a network

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WARMINGUP
Innovatief Duurzaam Warmtecollectief
towards reliable, sustainable and affordable district heating networks

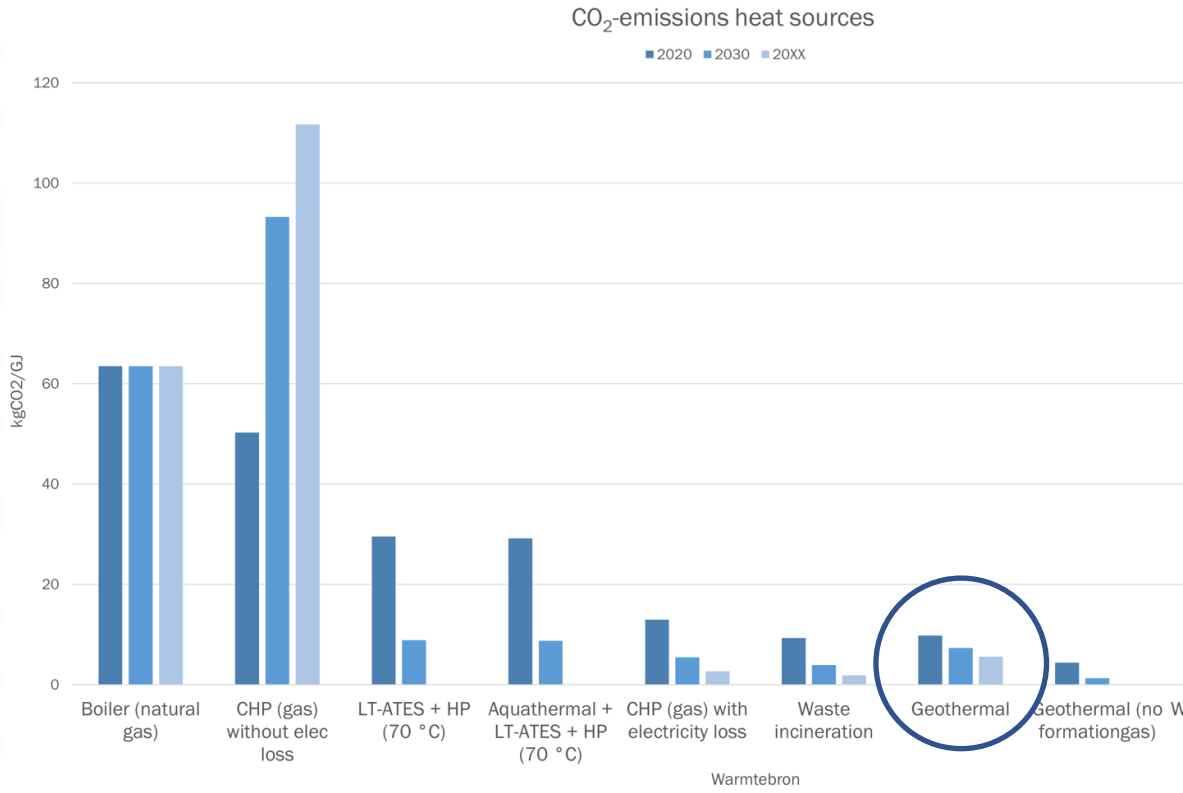
- Dutch National Climate Agreement:
  - 1.5M houses heated sustainably in 2030
  - Emissions of heating network < 18.9 kg CO_2/GJ

- Emissions of heating network
  - Heat source emissions
  - Flow friction losses
  - Seasonal variations
  - Security of heat supply
  - Heat losses

- Low emission heat sources required

- Geothermal heat: ~5 - 10 kg CO_2/GJ

  Boiler : ~60 kg CO_2/GJ
  - Boiler → Geothermal: potentially ~90% lower emissions

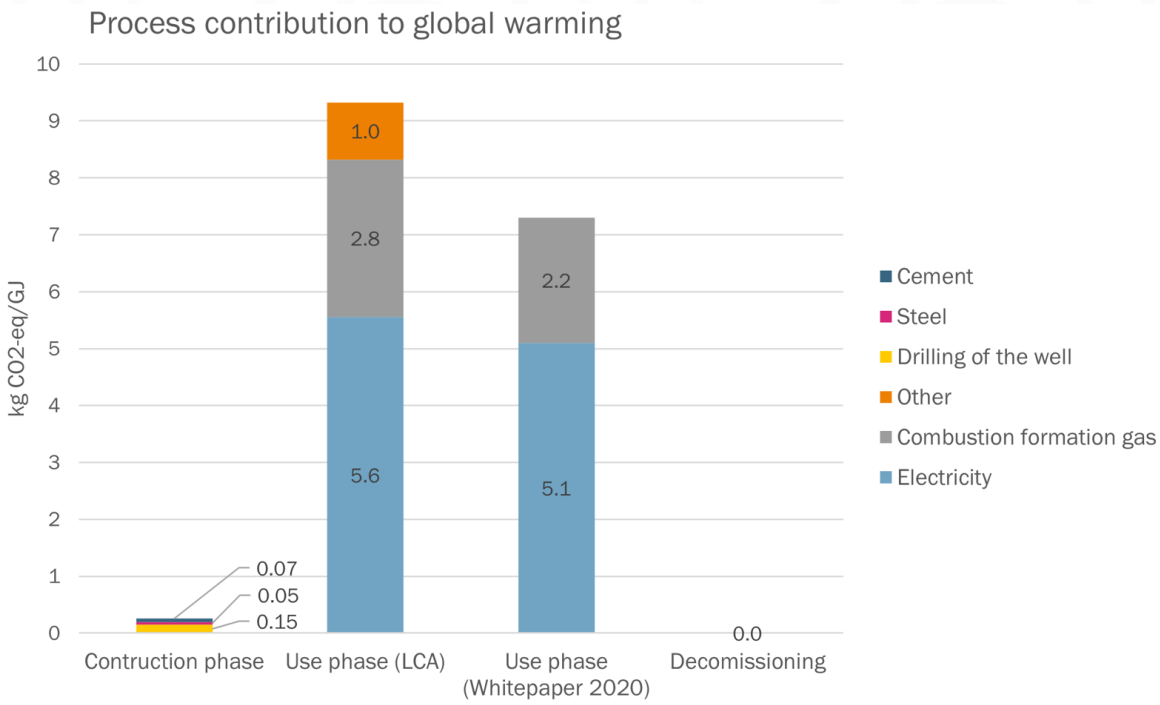


Sustainability of heating in a network

- ~30% of geothermal emissions: formation gas during operations

- Dutch geothermal formation gas: mainly CH_4 & CO_2
  - CH_4: used in CHP
    → heat + electricity + CO_2
  - CO_2: used in greenhouses or vented

- Increase sustainable heating:
  - Formation gas handling
  - Increase geothermal contribution



Formation gas handling

- Goal: decrease GHG emissions from geothermal heat

- Assess viability of three options
  - Pressurise system to keep gas in solution
  - Use CH_4, Capture CO_2 & Reinject
  - Sell CH_4 & reinject CO_2

- Assessment via techno-economic evaluation

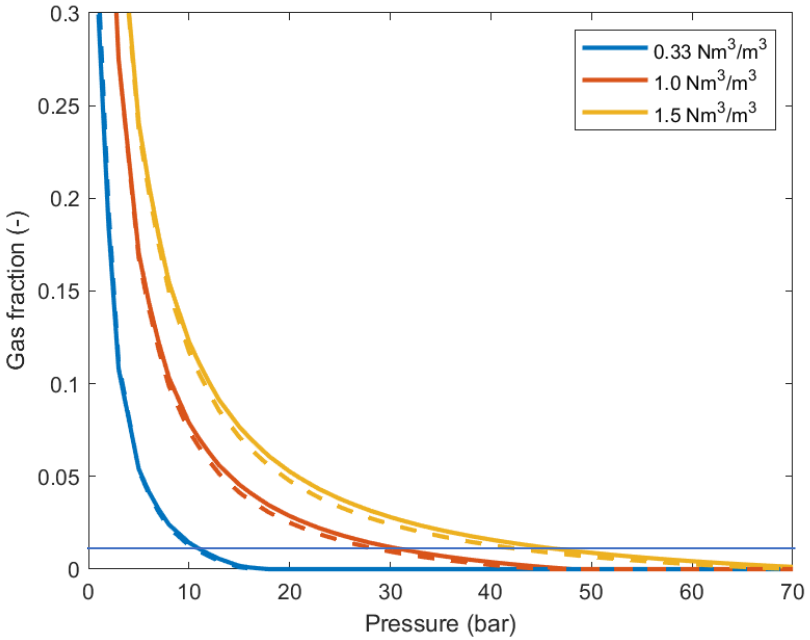
- Elaboration of Work of M. de Wild (2020, MSc TU Delft)

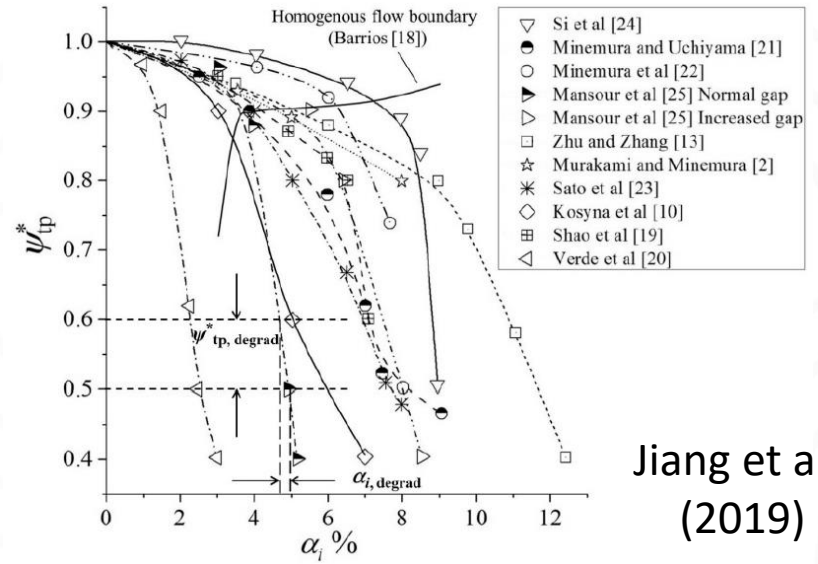
Pressurize system to keep gas in solution

- Free gas results in loss of performance in topside equipment (pumps, heat exchangers, filters) → avoid/remove it

- What pressure is required to avoid free gas?
  - PHREEQC: Vapour Liquid Equilibrium
  - High pressures required to avoid any free gas
  - Considered: 1%Vol free gas allowed in topside equipment

- Pressure ↑ : Increased CAPEX & OPEX



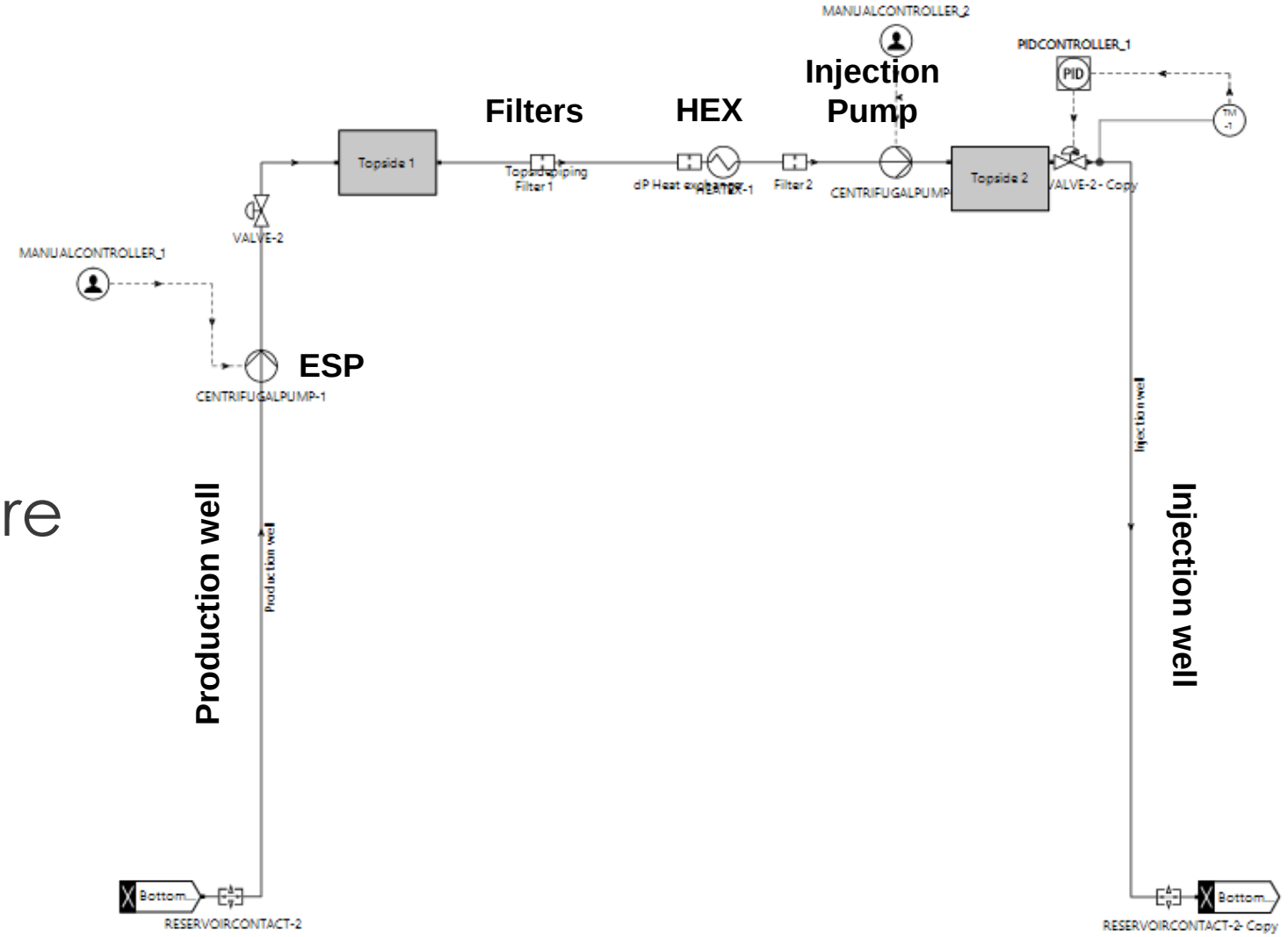


Jiang et al., (2019)

Pressurize system to keep gas in solution

- OLGA-PHREEQC
  - gas release
  - pump performance

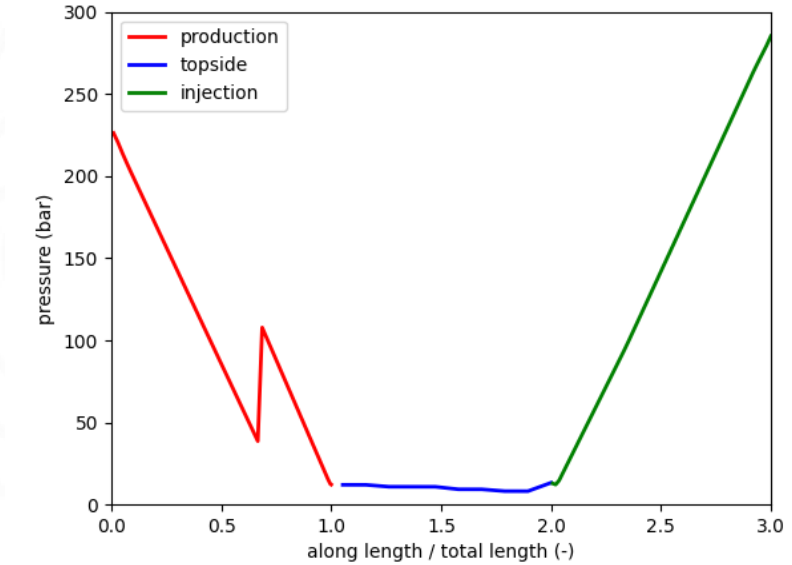
- OLGA: SLB software
- PHREEQC: USGS software

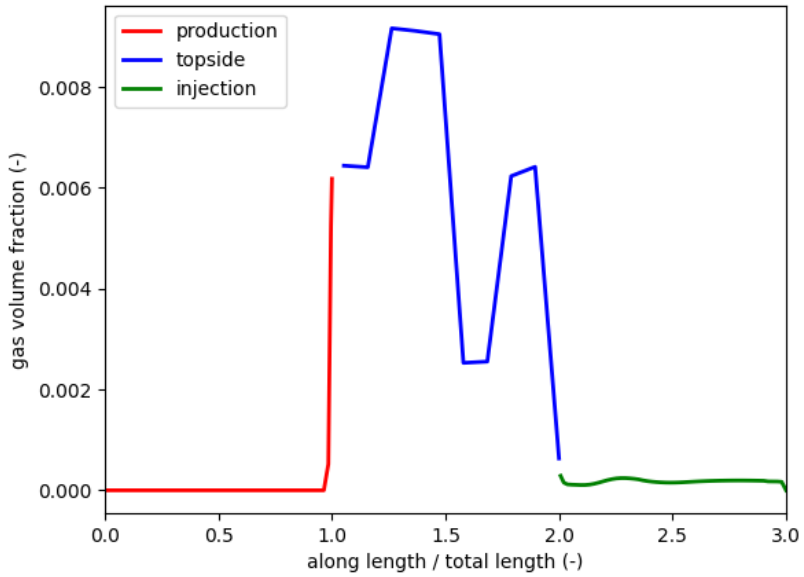


Pressurize system to keep gas in solution

- OLGA-PHREEQC simulations to compute gas release and pump performance

- Example simulation:
  - with separator: ~1.9 MW pump
    9.4 ton CO_2/y
  - Pressurised: ~2.1 MW pump
    no emissions
  - Power increase: 120 k€ /y
    ~160 €/ton CO_2

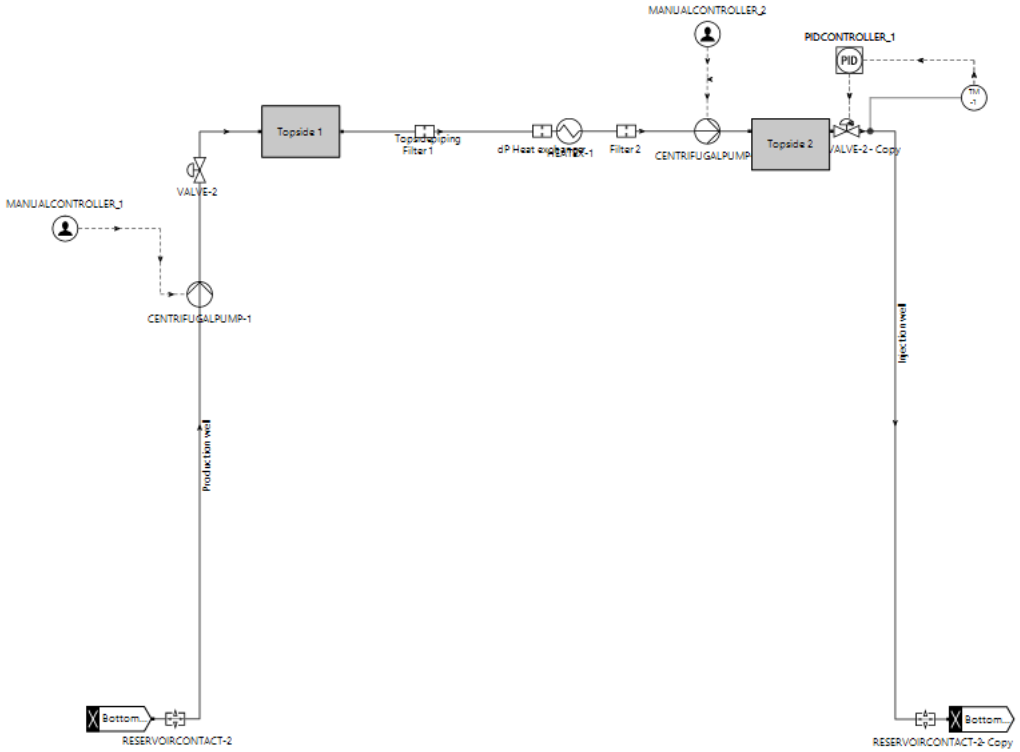




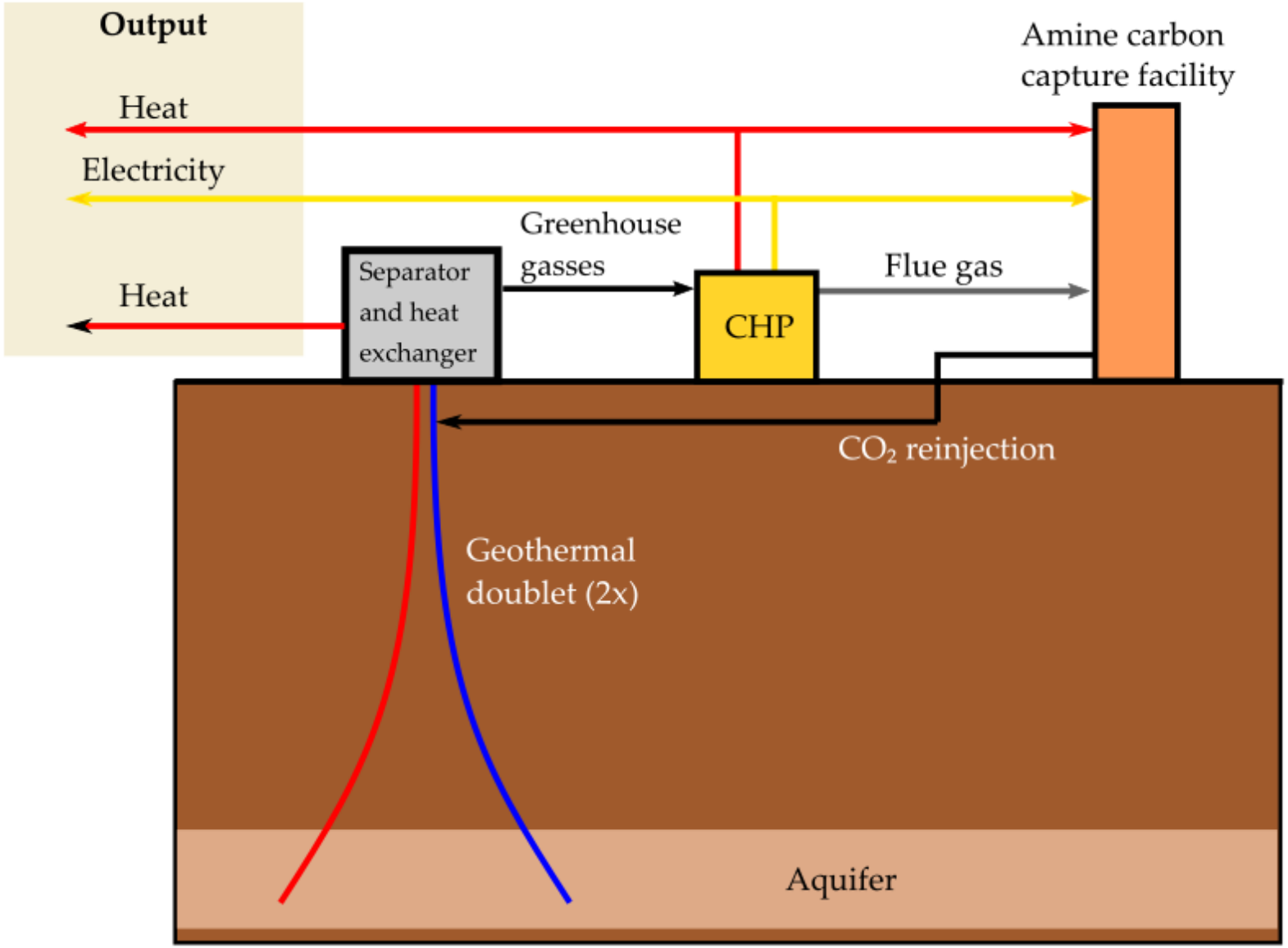
Pressurize system to keep gas in solution

- Effects that require higher ΔP_{ESP} → increase OPEX
  - Higher brine density
  - Higher brine temperature
  - Lower $P_{reservoir}$
  - Higher GLR
  - (Lower CO_2 content)

- Other operational considerations
  - Corrosion risks
  - Scaling
  - Complex operations



Use CH_4, Capture CO_2 & Reinject

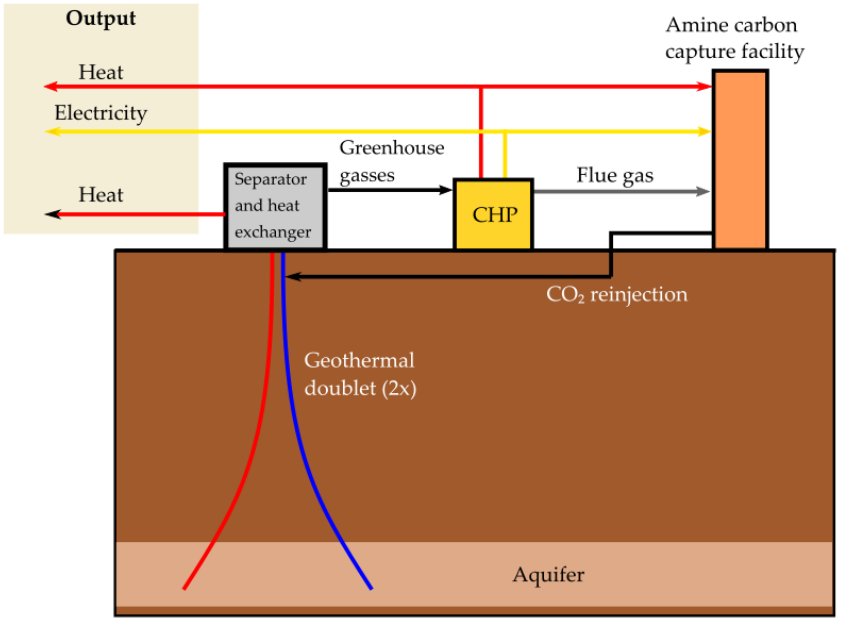


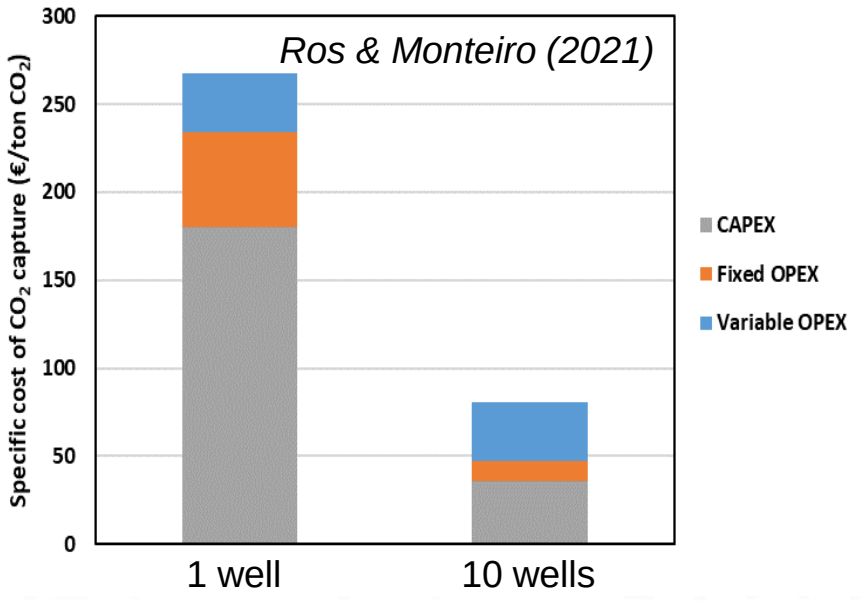
Use CH_4, Capture CO_2 & Reinject

- Processes:
  - Separate gas @ topside
  - Burn CH_4 with air in CHP/boiler
    - Heat, (electricity), CO_2
  - Capture CO_2 & reinject in aquifer

- Ros&Monteiro (2021) showed capture not economical viable for single well, but with >10 wells it is
  (economics of scale)

- Addition of CO_2 from boiler during cold season improves the case?





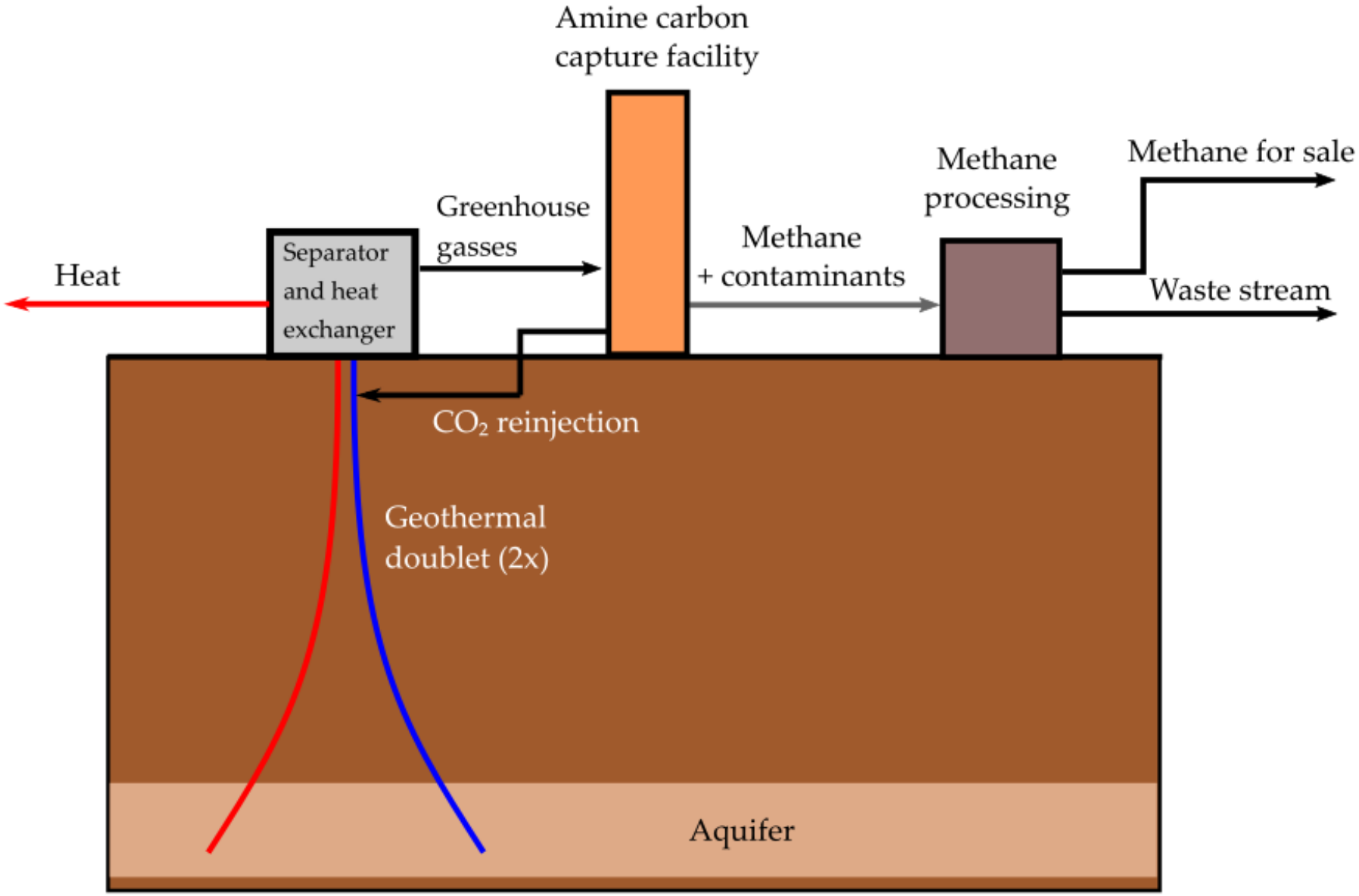
Use CH_4, Capture CO_2 & Reinject

- Scenario's
  - General: 2 geothermal wells, each 200 m^3/h, 1.5 Nm^3/m^3, all gas is burned in CHP/boiler
  - Additional heat required in cold season is covered by:
    - Sc. 1b: purchase from market (cmp Ros & Monteiro work)
    - Sc. 2b: boosting geothermal wells
    - Sc. 3b: burning gas from grid in CHP
    - Sc. 4b: burning gas from grid in boiler

Scenario	1b	2b	3b	4b
CO_2 production (kton/y)	7.1	8.8	19.7	13.0
Emission (kton/y)	*0.7*	*0.9*	*9.6*	*2.9*
Capture (kton/y)	*6.4*	*7.9*	*10.1*	*10.1*
CO_2 Capture cost (*€/ton*)	291.5	365.2	406.4	406.4

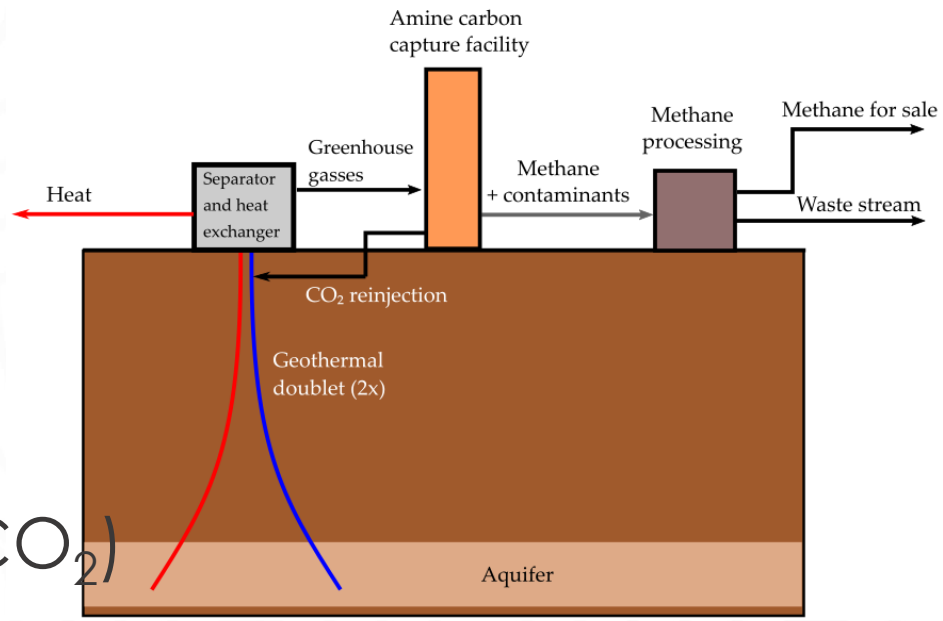
- Capture costs increase
  - Capture plant not utilised 100% in summer season
- Emissions non-zero
  - Efficiency capture plant ~90%
  - Limited dynamic range of capturing

Sell CH_4 & reinject CO_2



Sell CH_4 & reinject CO_2

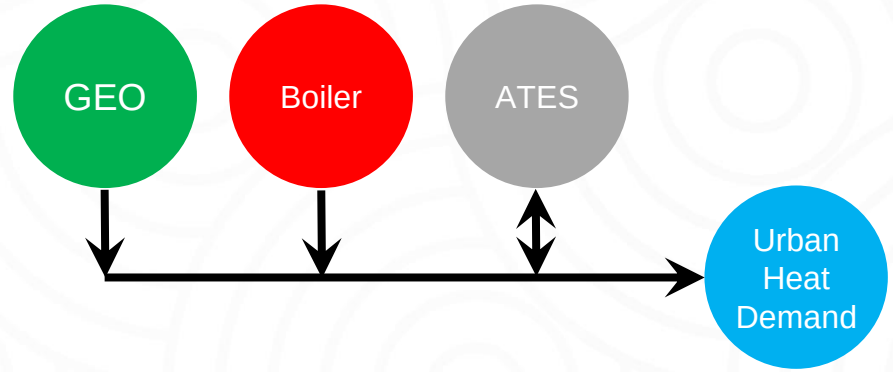
- Processes:
  - Separate gas @ topside
  - Capture CO_2 & reinject in aquifer
  - Obtain quality specs and sell CH_4

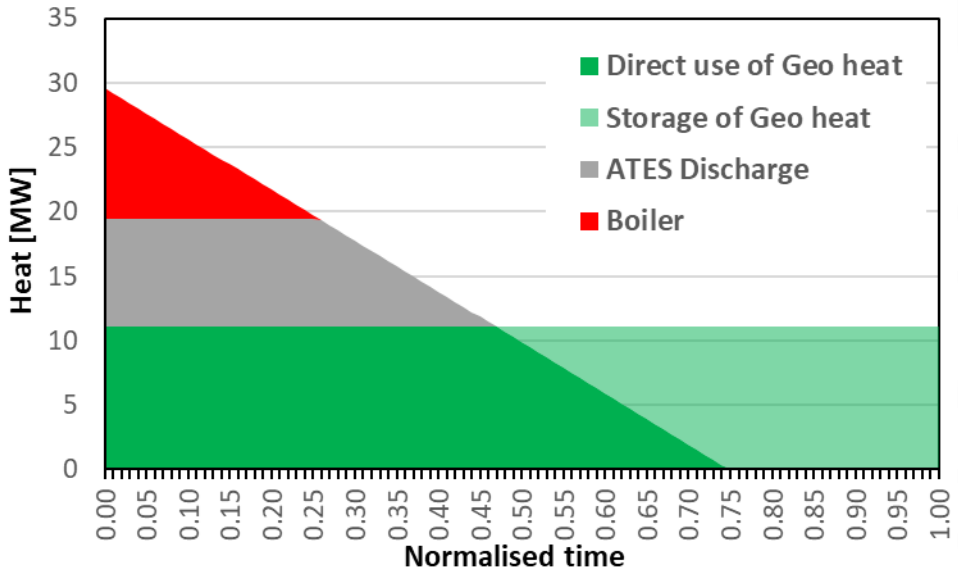


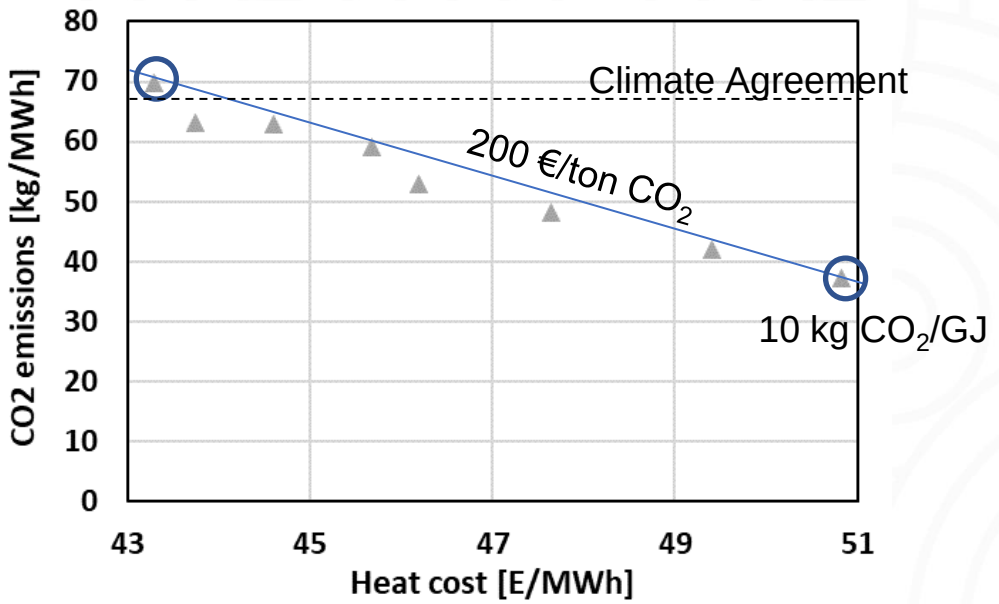
- Small volumes for capturing plant
  → relatively expensive (up to ~1000 €/ton CO_2)
- ….., but revenues from CH4 sales are high
- Money making if CH_4 content and GLR are high enough
- ….., but how does end-user handles combustion gasses?
  (emissions may not be reduced, but redirected)

Boosting Geothermal usage by HT-ATES

- Decrease emissions by boiler by increased operational hours of Geothermal
- How to handle the **variability** in urban heat demand, considering:
  - Security of heat-supply
  - Cost (constant production)
  - Emissions







Summary

- Climate agreement: drive to improve sustainability of heating
- Geothermal heat itself can be more sustainable → formation gas handling
  - High GLR & high CH_4 content : **Selling CH_4** is preferable,
    … but truly sustainable?
  - Otherwise: keep system **under pressure**
  - Use of CH_4, **capture CO_2** & reinject: most expensive option & emissions non-zero
- Geothermal heat can make the heating mix more sustainable
  → boosting geothermal usage (e.g. via HT-ATES) can decrease emissions
- Significant uncertainties in costs exists,
  … CO_2 reduction is expensive or very expensive (> ~160 €/ton CO_2)

  Rennert et al. (Nature 610, 2022) : ~185 $/ton CO_2
- EU Carbon prices: ~80 €/ton CO_2 !!

Acknowledgements / Thank You / Questions

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WARMINGUP
Innovatief Duurzaam Warmtecollectief

TNO innovation for life

EU Carbon prices

https://ember-climate.org/data/data-tools/carbon-price-viewer/