Annual Performance Profiles of CO_2-Plume Geothermal (CPG) Systems: Impact of the Ambient Conditions

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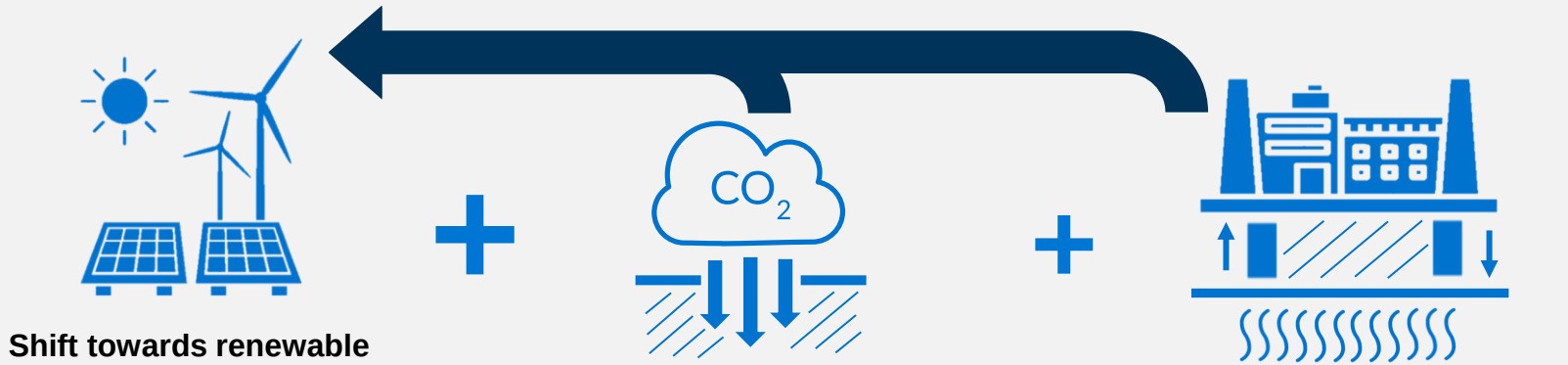
Outline

1) CO_2-Plume Geothermal Systems (CPG): general working principle
2) General system characteristic
3) Operational characteristic
4) Impact of the ambient temperature & comparison of different locations
5) Summary & Outlook

General Motivation

- Ongoing transformation towards renewable energy sources
- Nevertheless**, CCS might be pivotal to limiting global warming** to 1.5 or at least 2.0°C

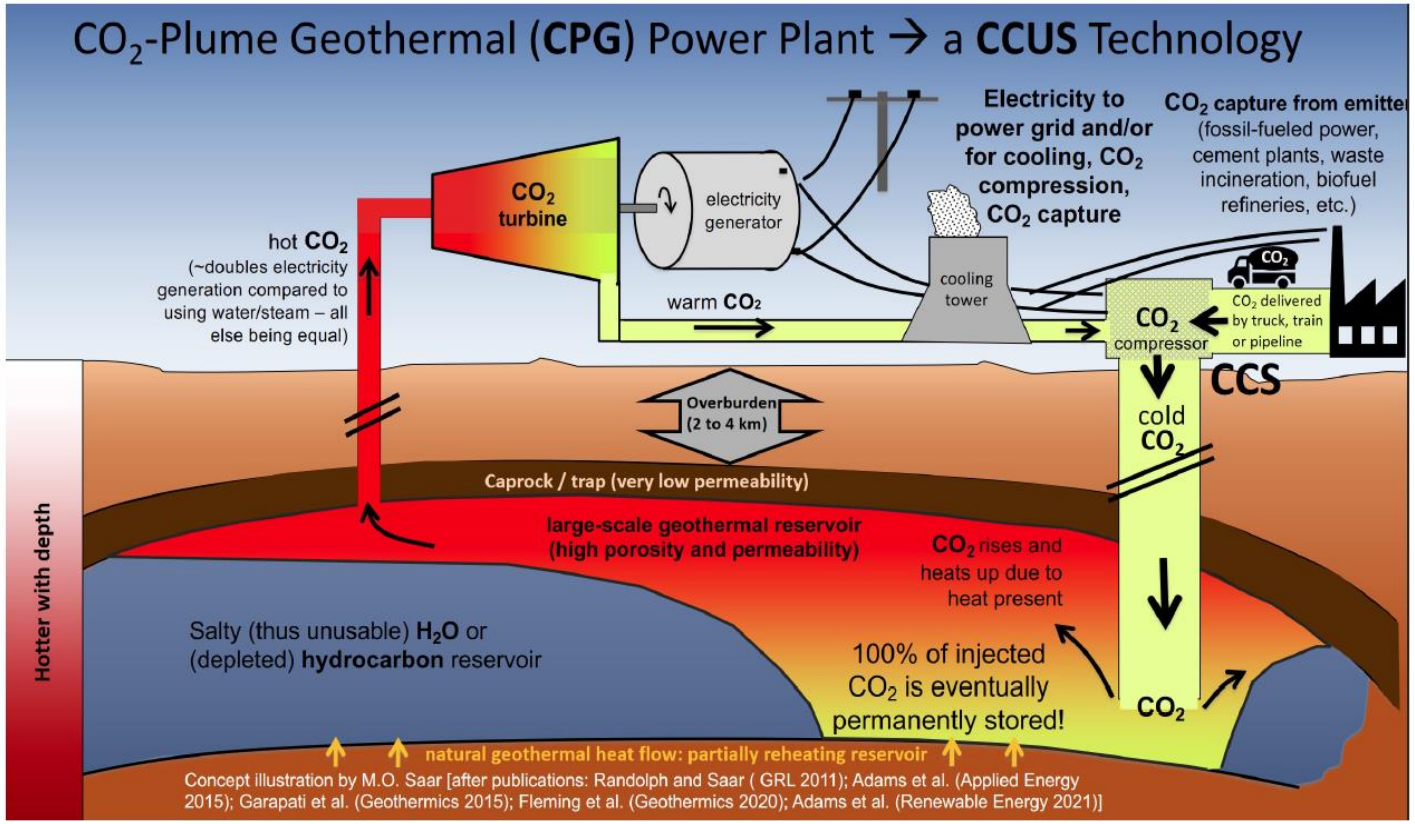


CO_2-Plume Geothermal (CPG) Systems

CPG:

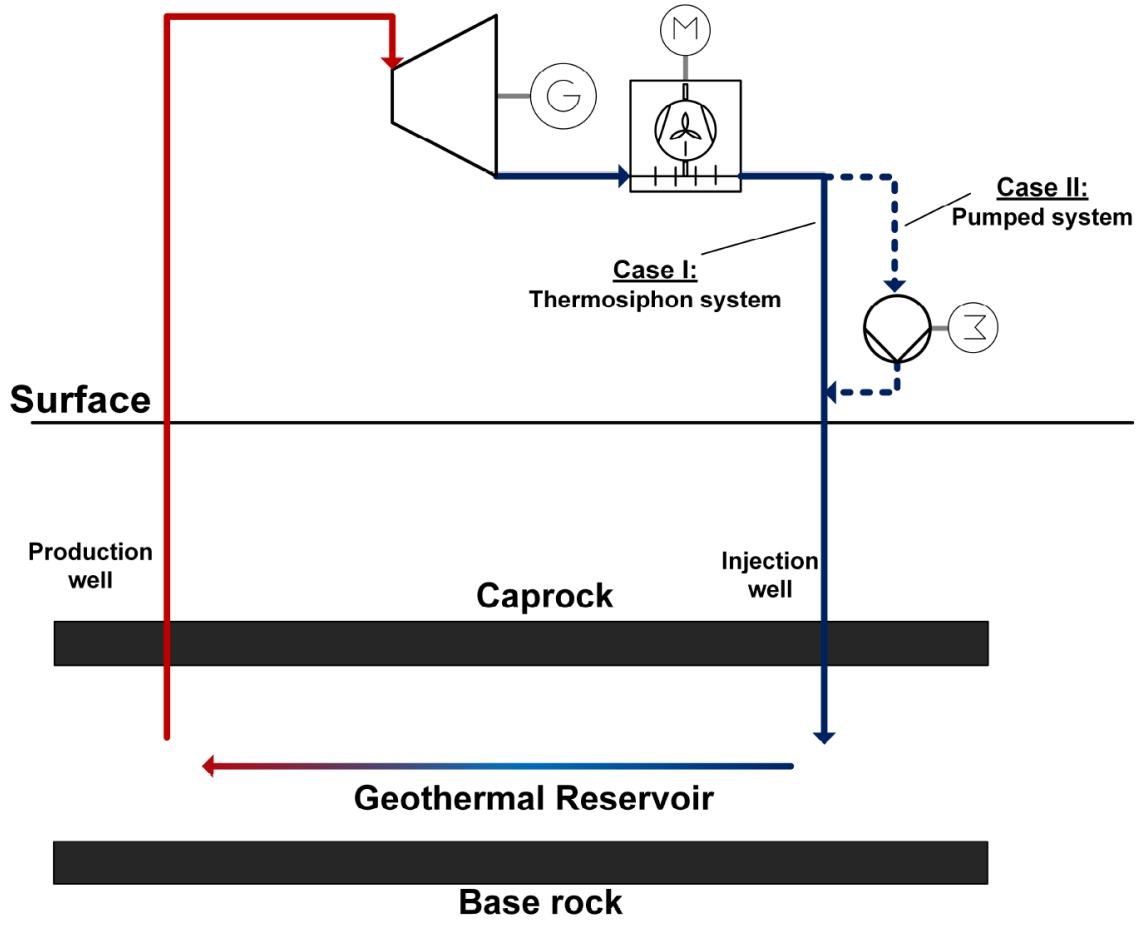
- combines CCS with geothermal energy utilization
- uses the CO_2 for power generation, while storing the CO_2 permanently
- can significantly increase the power output of a geothermal system compared with the traditional system using water/brine
- can improve the economics of CCS

➔ **It is a true CCUS technology**



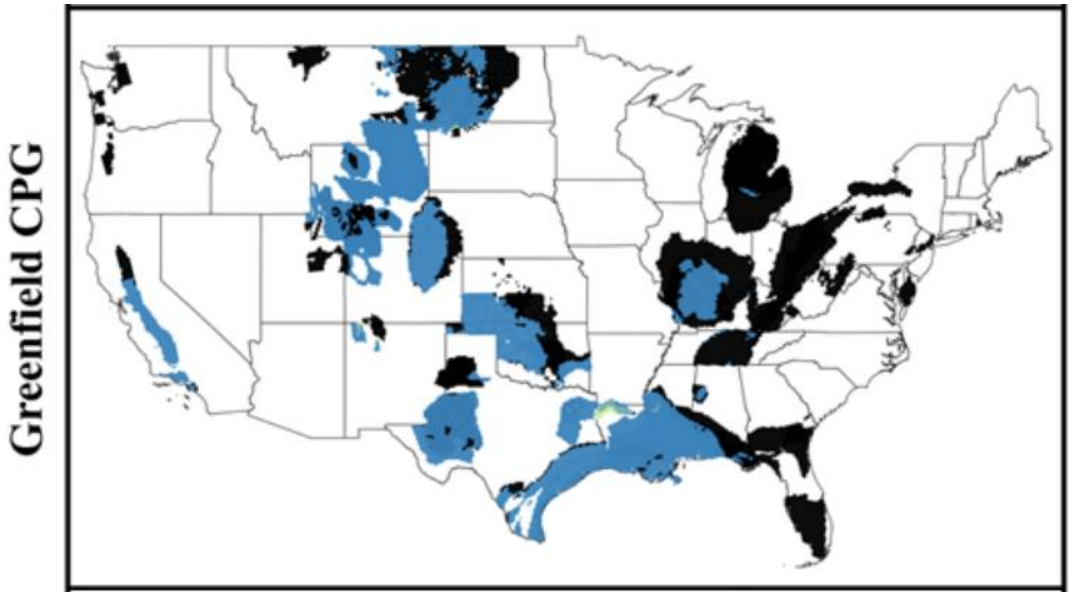
CO_2-Plume Geothermal (CPG) Systems

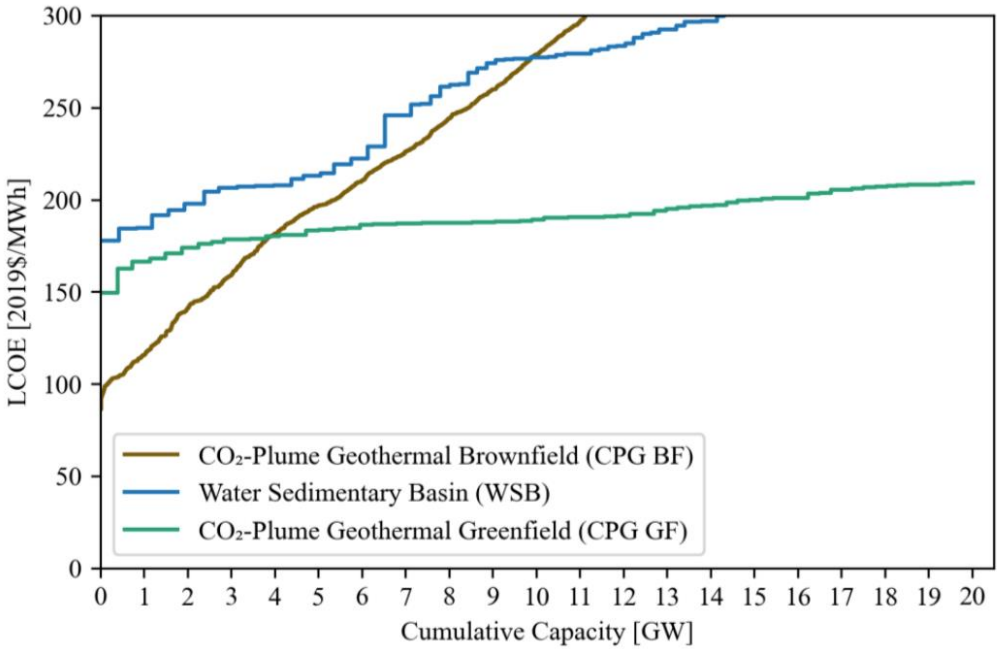
- Can be applied in naturally permeable reservoirs at 2-5 km depth
- These reservoirs include typically depleted oil/gas reservoirs and deep saline formations
- Direct expansion of the CO_2 within a turbine for power generation
- Condensation of the CO_2 before the reinjection well to ensure a sufficient density difference
- In the case of a thermosiphon system, no compressor is necessary
- The additional application of a pump compressor is a promising option to increase the power output



Application potential – recent numbers for the U.S.

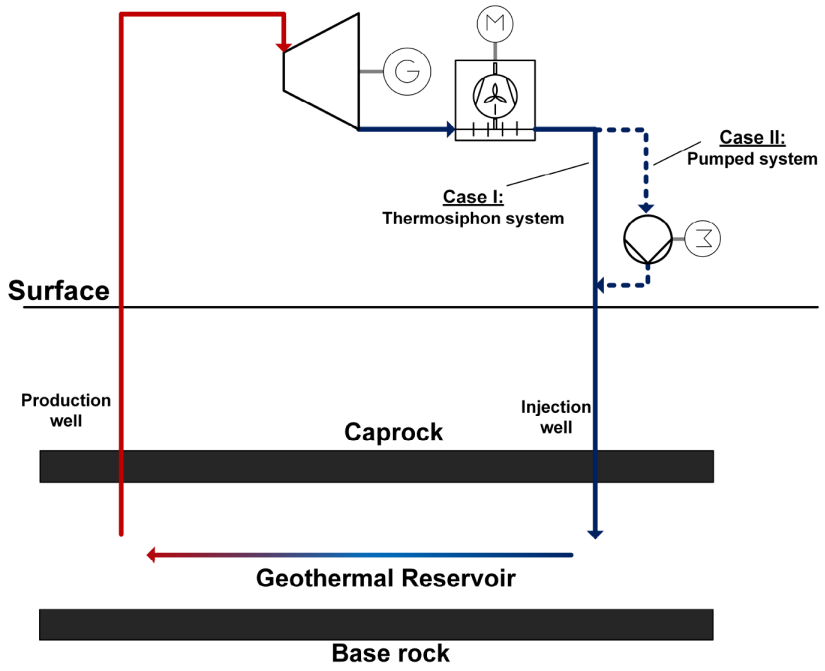
- Recent publication at the Stanford Geothermal Workshop by Ogland-Hand et al. (2024)
- Evaluation of the cost and capacity of sedimentary basin geothermal power
- Applying a CPG system would result in lower LCOE for most of the suitable regions

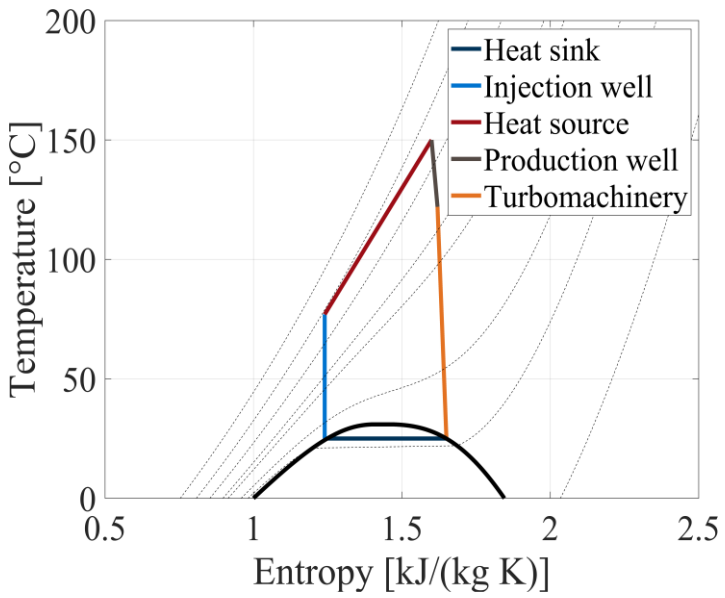


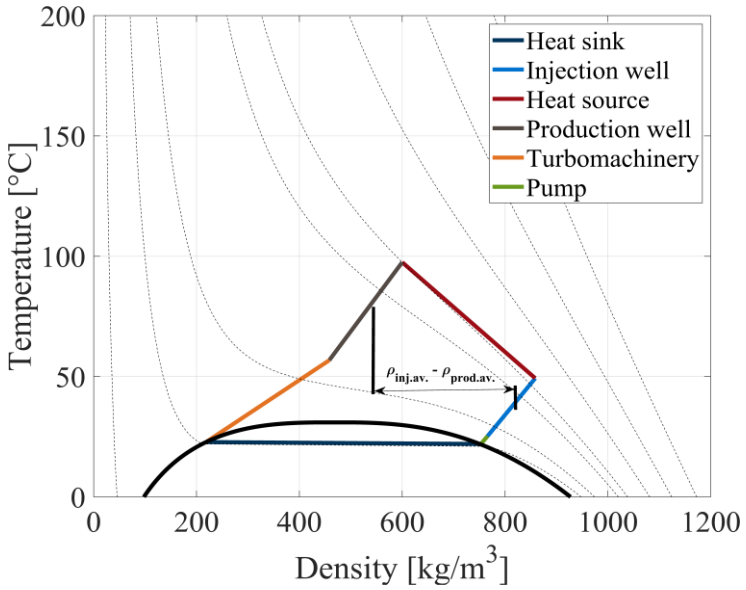


Figures taken from Ogland-Hand et al. (2024)

General operational characteristic

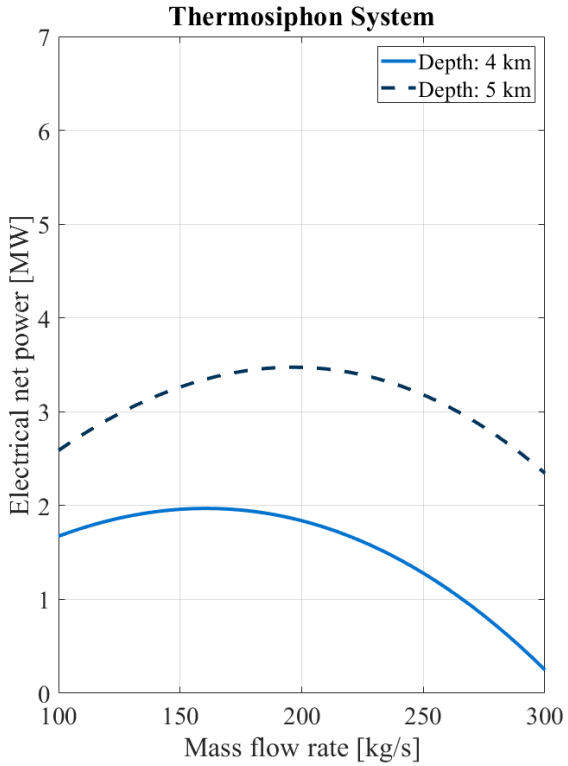


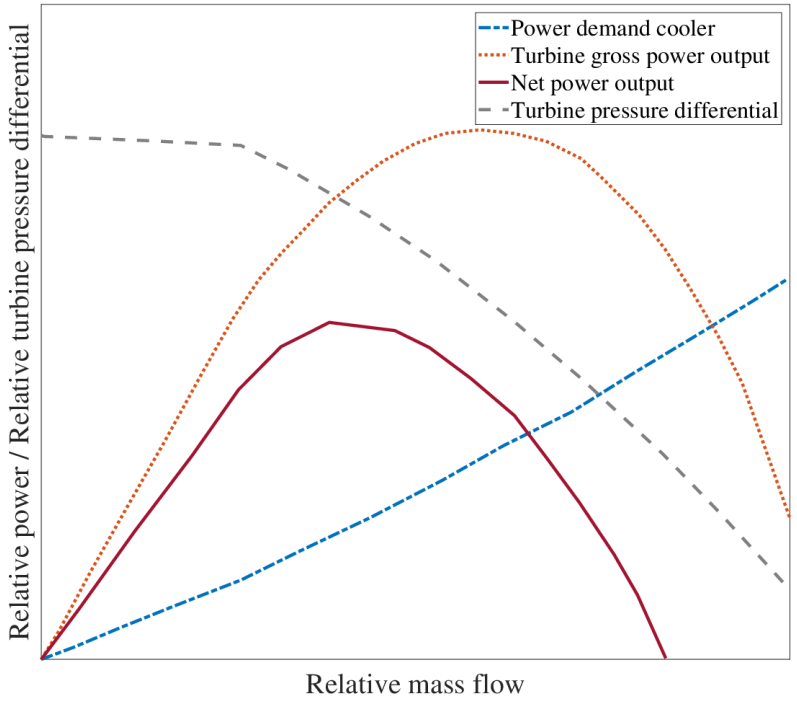




General operational characteristic

- Optimal mass flow rate for each depth and system type
- Increasing net power output for deeper reservoirs
- Actual power output depends mainly on the system's number of wells and depth





General operational characteristic

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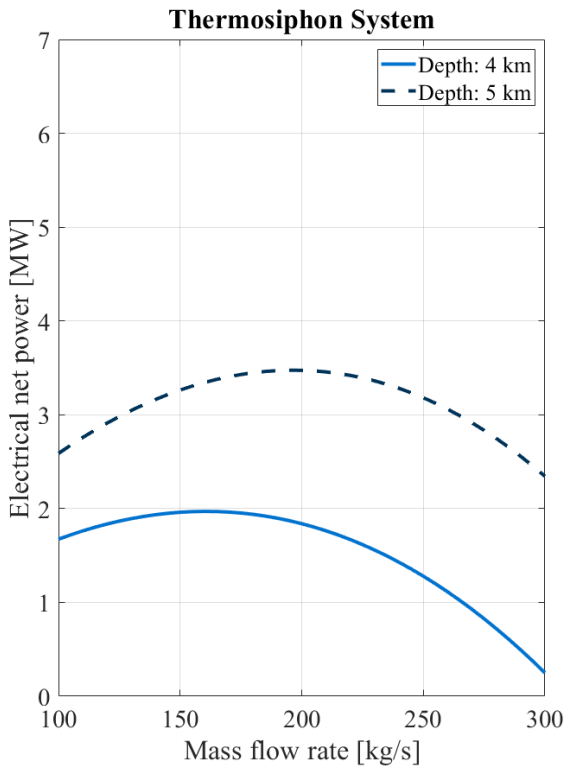
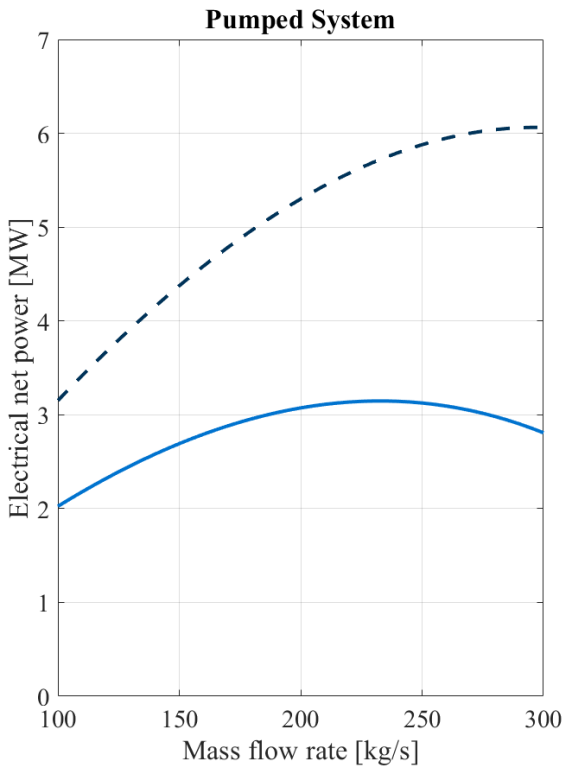
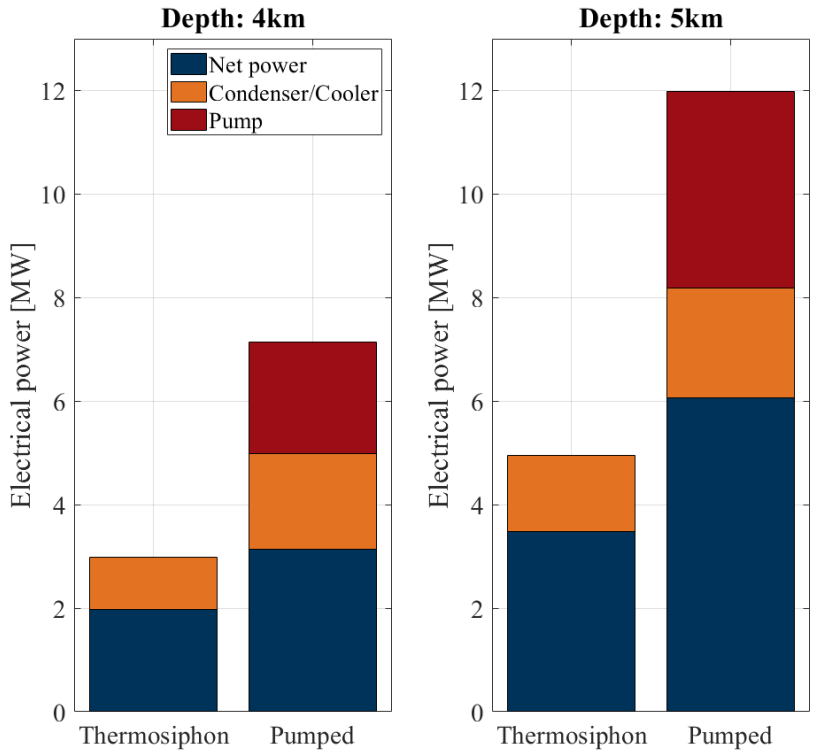
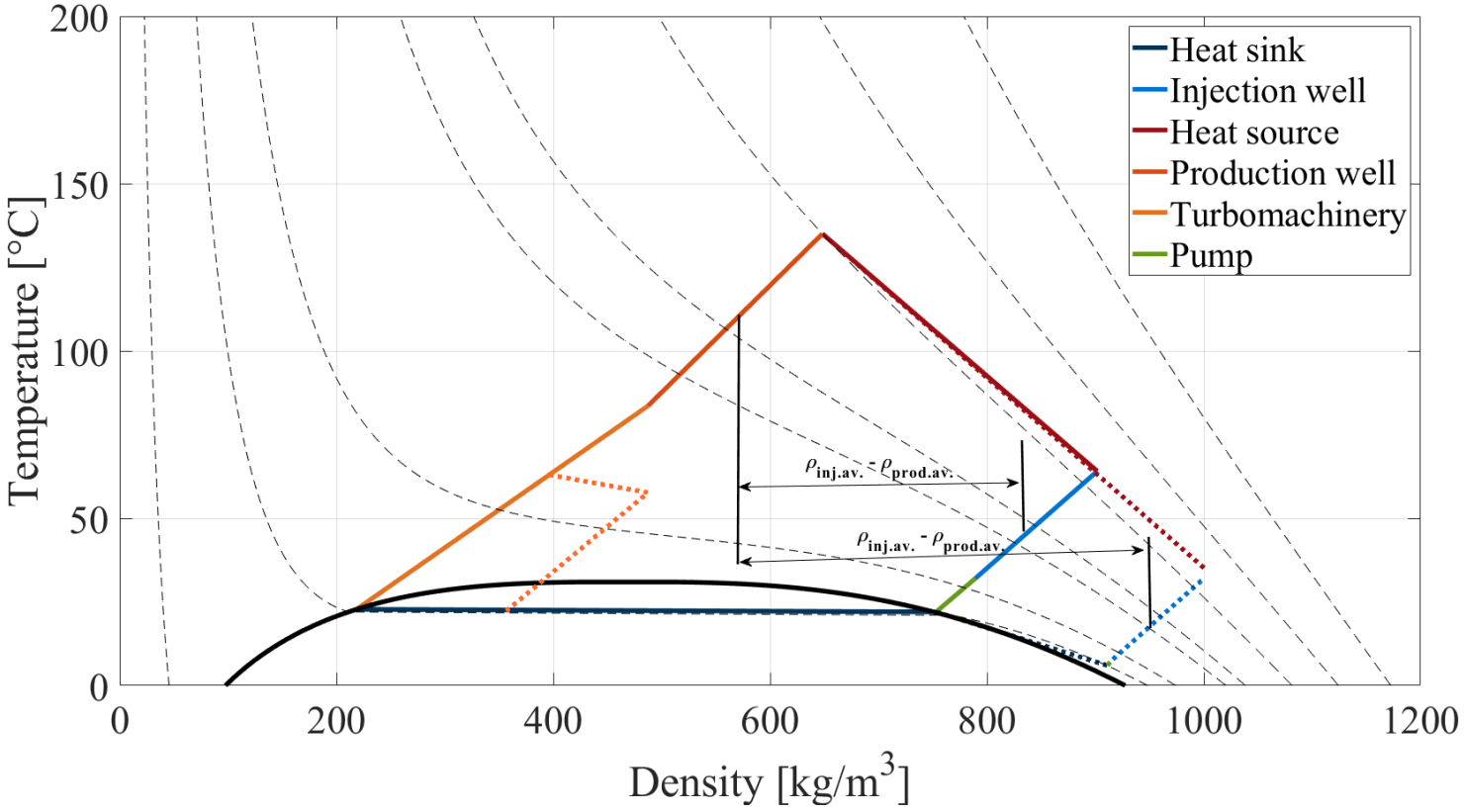
- Higher net power output by the pumped system, but lower thermal efficiencies for a pumped system





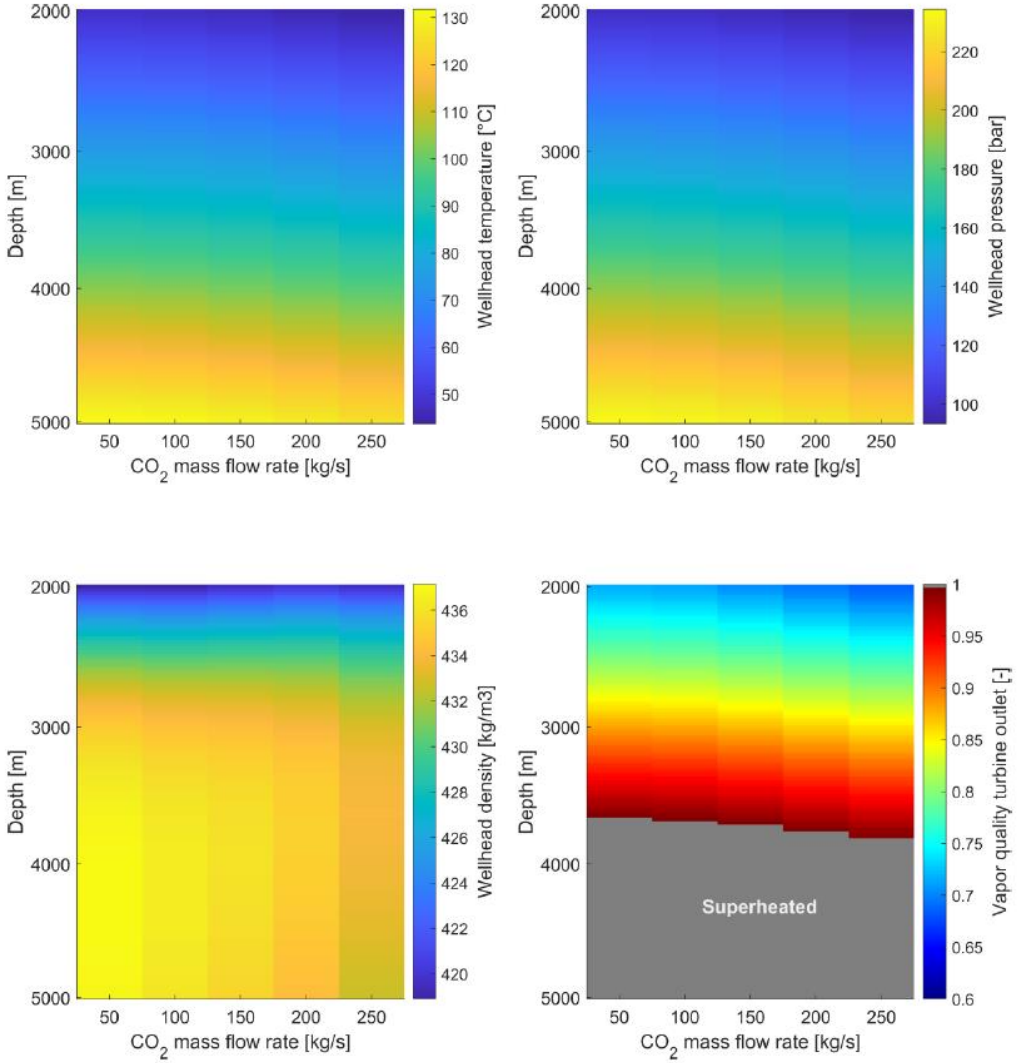


Impact of the injection temperature



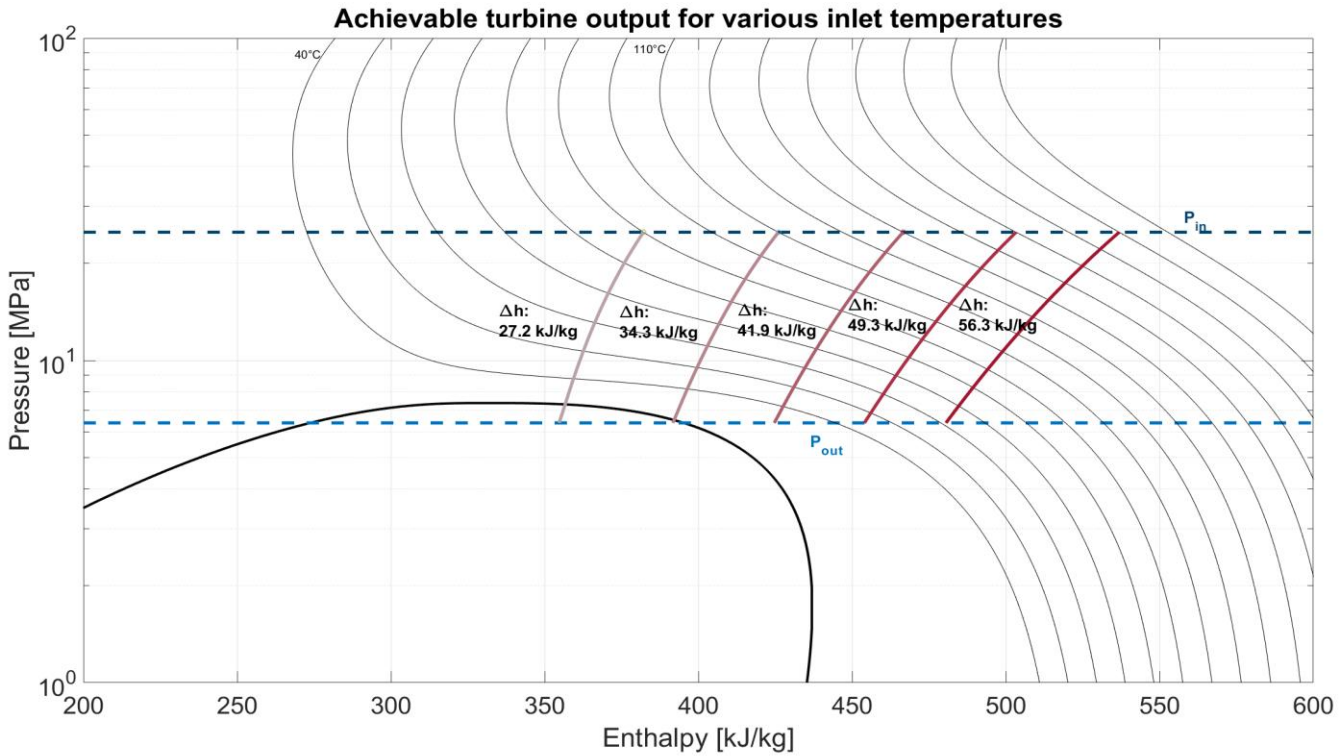
- A lower injection temperature increases the density variation between the CPG's production and injection well
- The higher optimal mass flow rate and the lower required pump power demand increase the net power output
- E.g. lowering the injection temperature by 5 K, might increase the theoretical achievable net power output by 20 %

Turbine inlet and outlet conditions



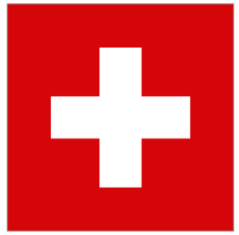
- Significant variations of the turbine inlet temperature and pressure with the system's depth
- Both temperature and pressure levels are lower than for other sCO_2 applications (e.g. waste heat recovery)
- Rather constant inlet density
- Potential state at the turbine outlet depends also on the system's depth and flow rate (might require a certain reheating for lower depths)

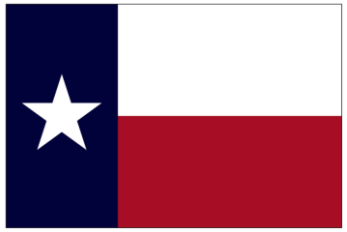
Impact of the injection temperature

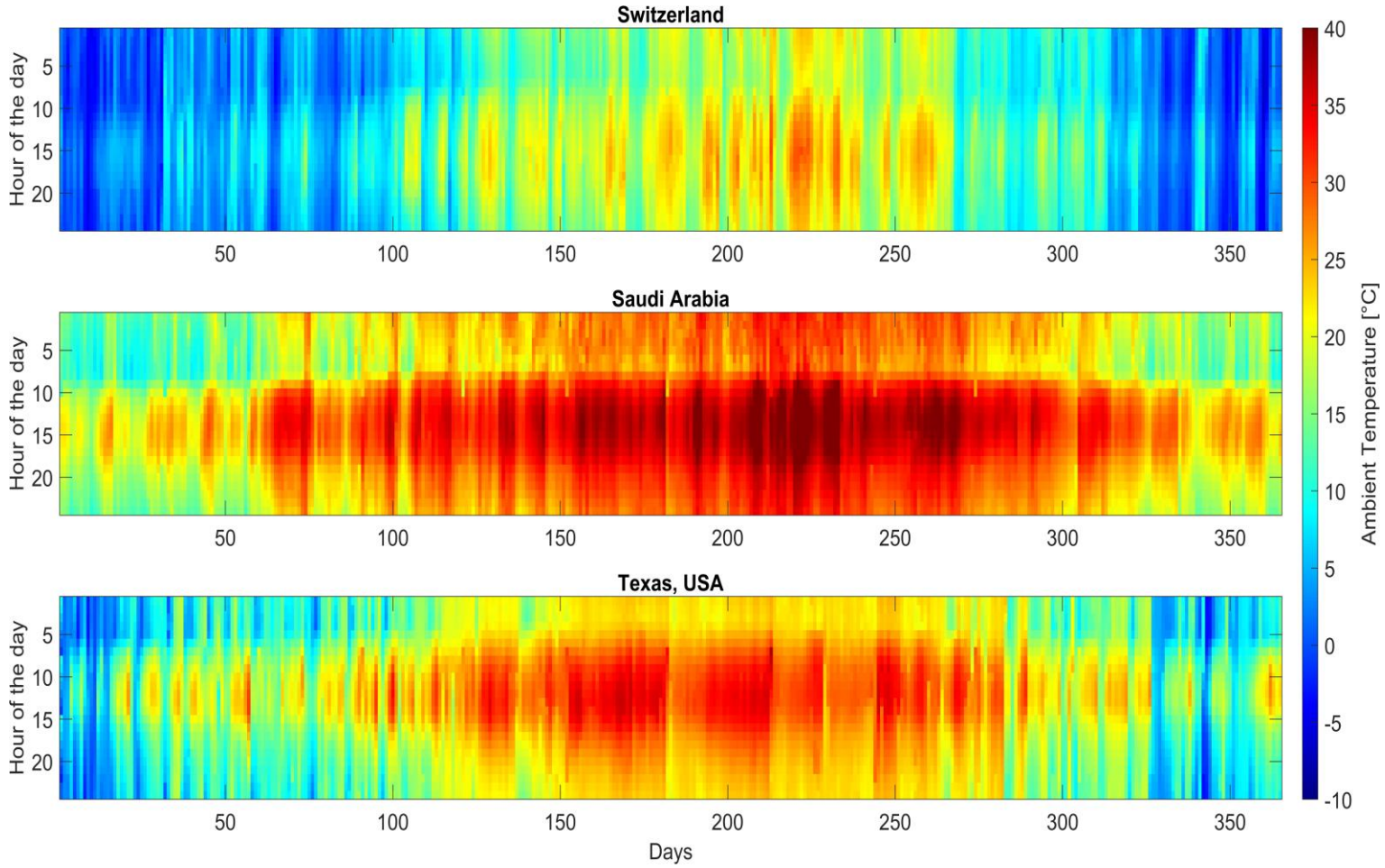


- For the same turbine in- and outlet pressures, the turbine inlet temperature has a significant impact on the achievable mass-specific power output

Case study regions: all promising for CPG, but different local climate







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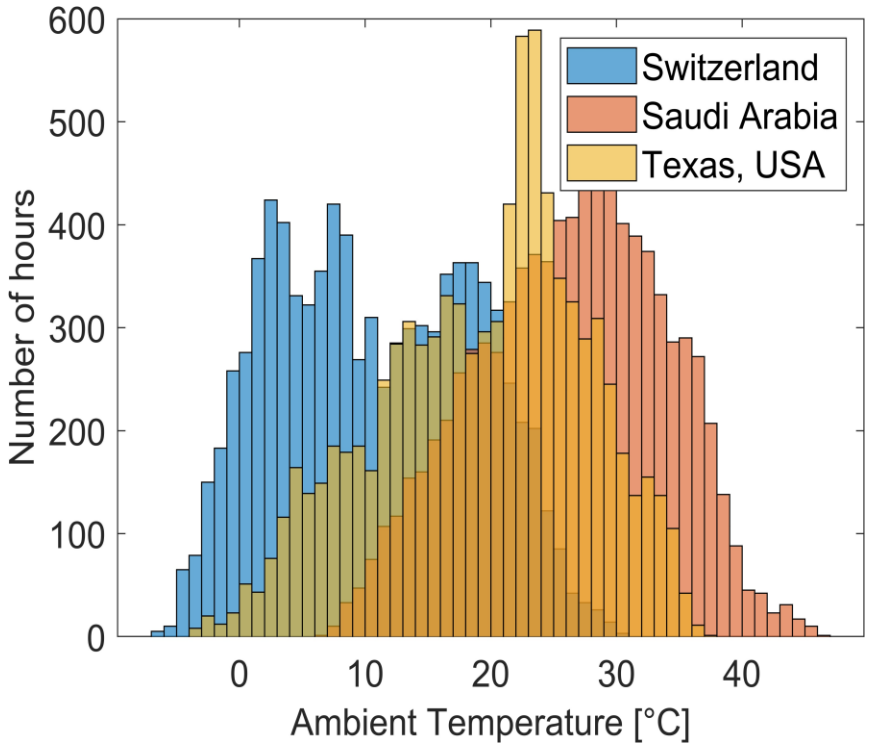

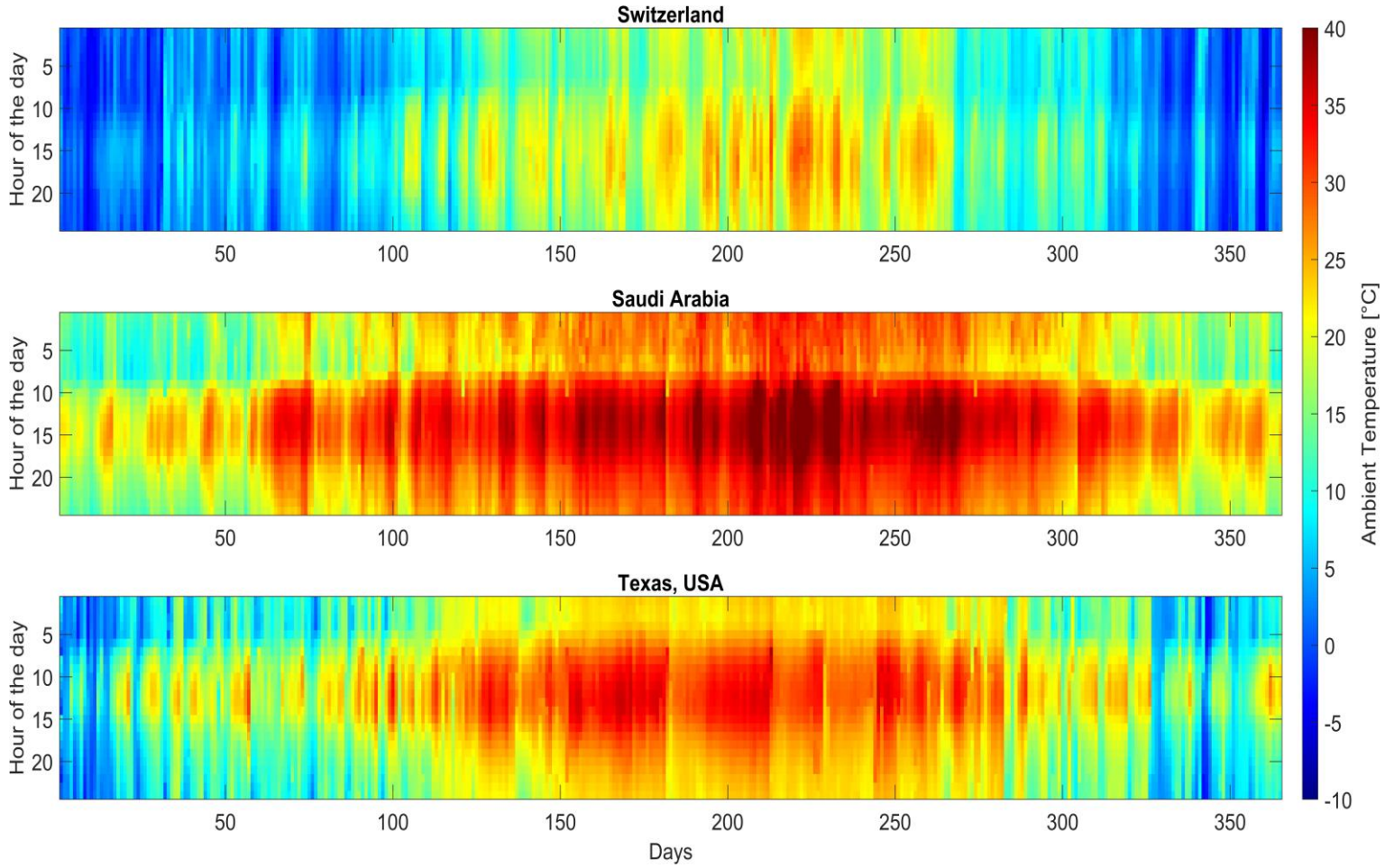

Modeling

Open-source modelling framework from ETH

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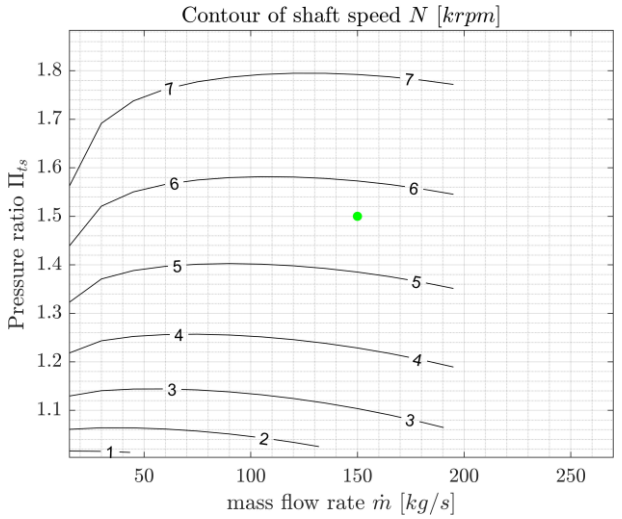
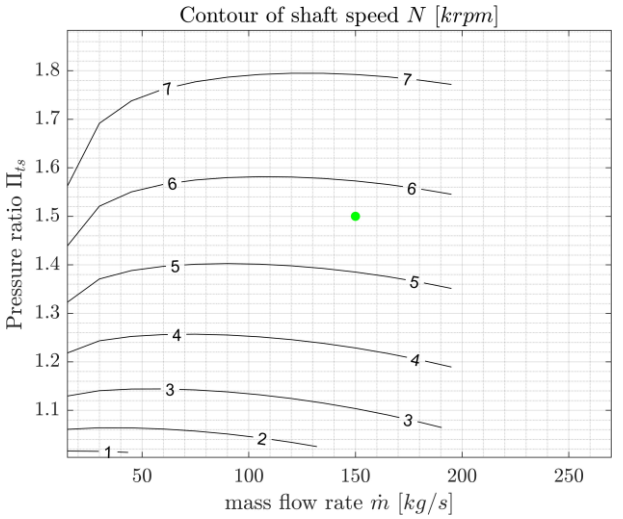
genGEO +

Off-design models





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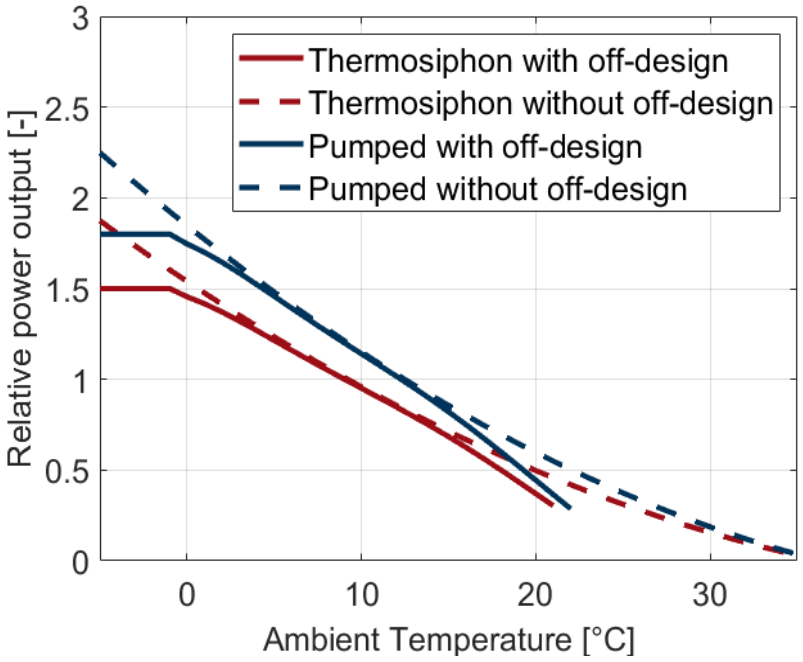
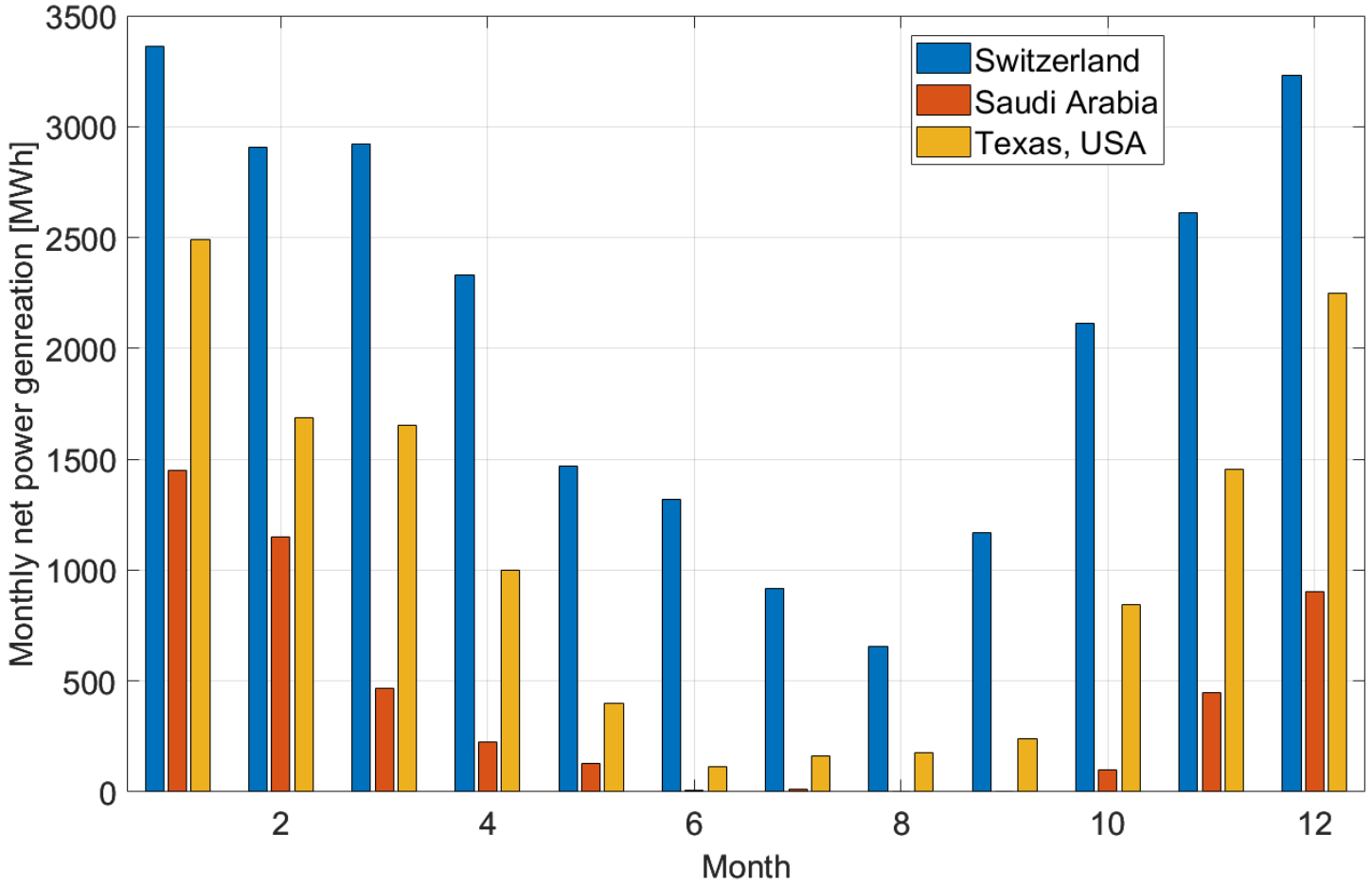
Same boundary conditions

- Depth: 2.5 km
- Same geological conditions
- Power output in the design point at 9°C: 3.4 MW

Annual net power output





Summary & Outlook

Summary

- CPG combines CCS with geothermal energy utilization
- Tremendous market potential for CO_2 equipment manufacturers
- Impact of the ambient temperature and off-design behavior on the achievable net power output
- Significant variations between the different regions and seasons

Outlook

- Thermo-economic optimization also focuses on the optimal design point selection
- Incorporating the effect of the presence of dissolved water and other impurities in the CO_2 stream and its potential changes during the project's lifetime
- Paving the way towards a first large-scale demonstration project

➔ Increasing demand for interdisciplinary research and development

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Thank you for your attention!

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