CO2-Plume Geothermal: evaluating the potential

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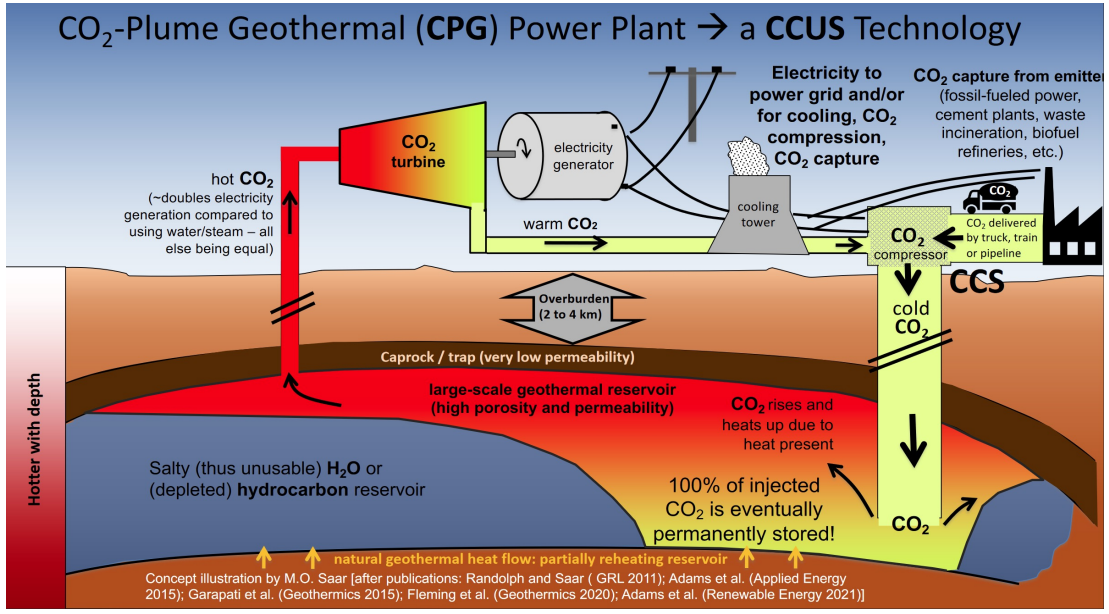
Content of this slide pack:

- CO2 Plume Geothermal (CPG) concept
- CPG Consortium
- Canadian CPG potential evaluation

CO2-Plume Geothermal (CPG)

- CO2-Plume Geothermal (CPG) systems use **naturally permeable reservoirs** at 2-5 km depth, targeted for CO2 Capture and (geologic) Sequestration (CCS) to reduce climate change and to expand the resource base of renewable geothermal energy
- These reservoirs include **depleted oil/gas reservoirs and deep saline formations**
- **CPG turns CCS into CO2 Capture, Utilization and Sequestration (CCUS)**, as CPG's use of subsurface CO2 to extract geothermal energy **doubles to triples** the geothermal energy extraction rate compared to water, while ultimately geologically sequestering 100% of the CO2



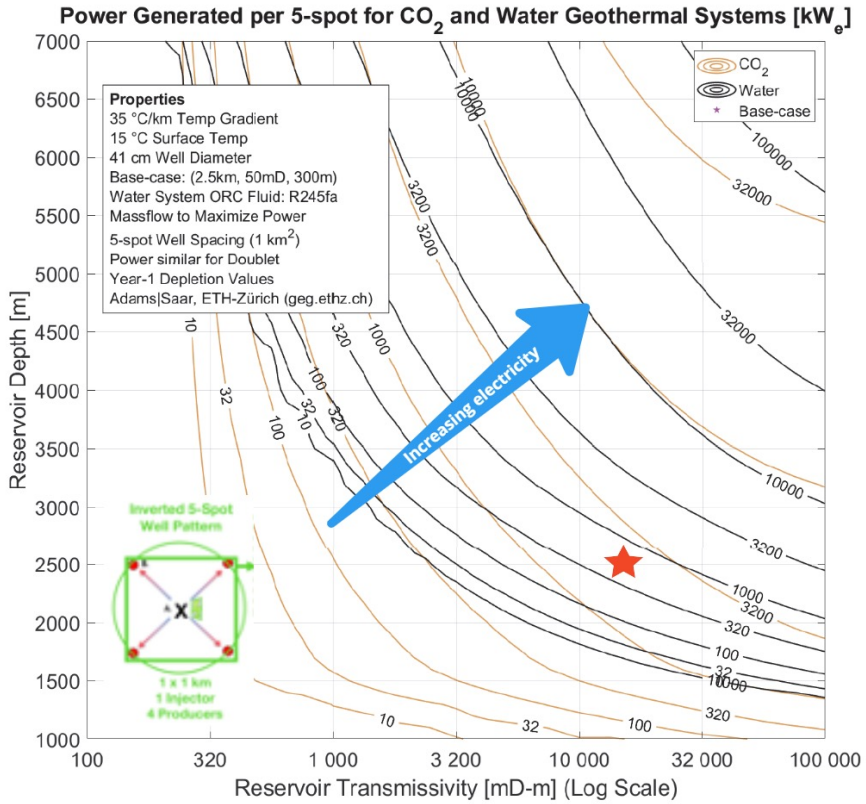
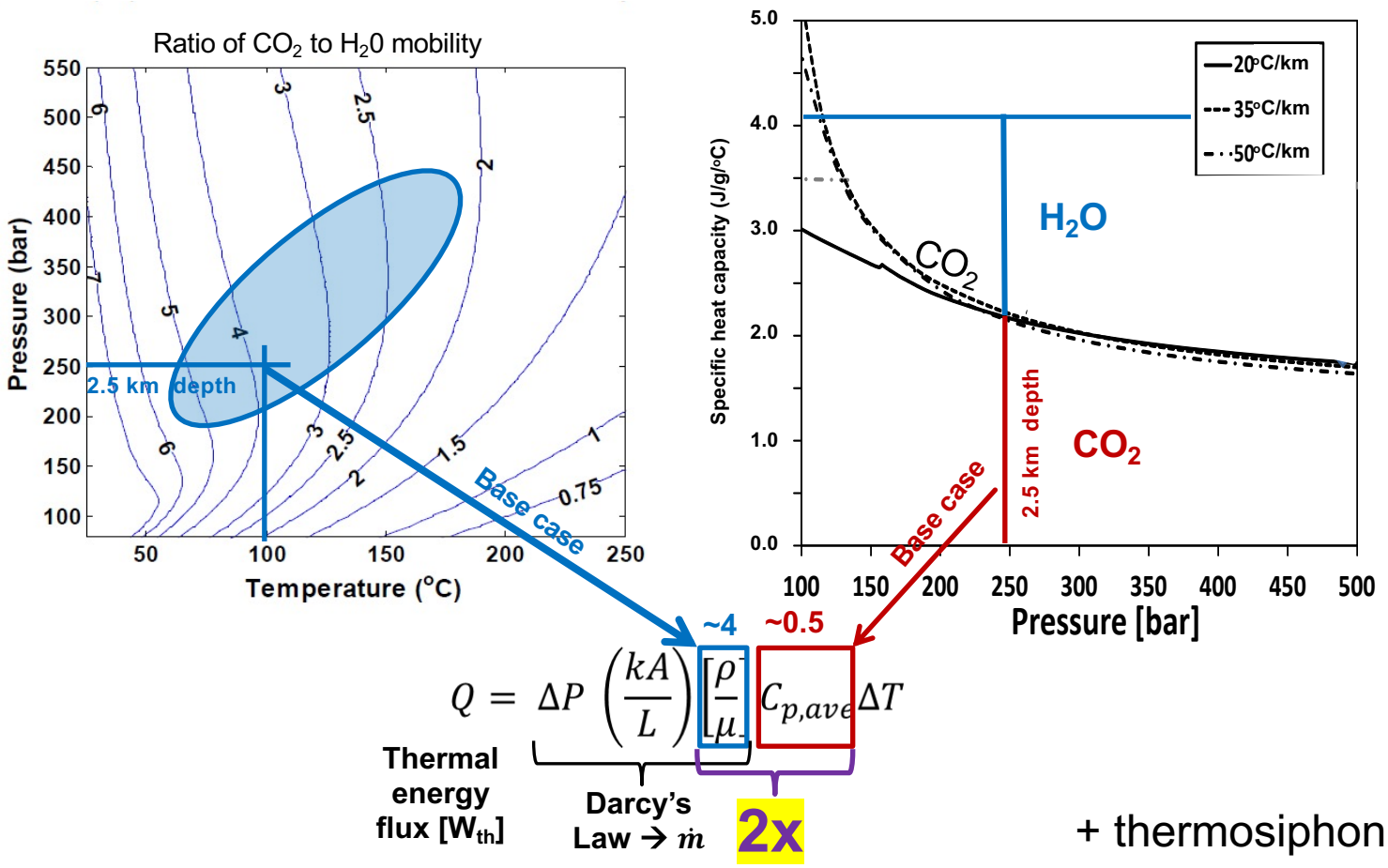


Figure 1: Estimate of electric power generation (in kWe), calculated with genGEO, for groundwater (black lines) and subsurface CO2 (orange lines) of a single inverted 5-spot well pattern (see green drawing) with 1 km² footprint area, or well-doublet, as a function of reservoir depth and reservoir transmissivity. Multiple 5-spot well patterns (or well-doublets) can typically be placed in a reservoir and the power output needs to be multiplied accordingly. The red star indicates the base case where ~2 MWe are generated with CPG and only 0.8 MWe with traditional water as the subsurface geothermal working fluid (based on Adams et al., 2015).

CO_2 : typically **2x** power out compared to H_2O

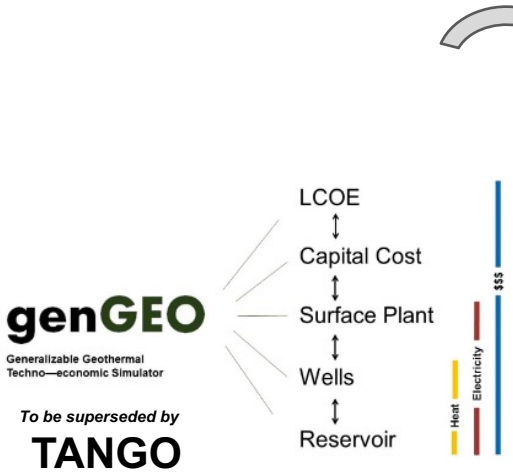


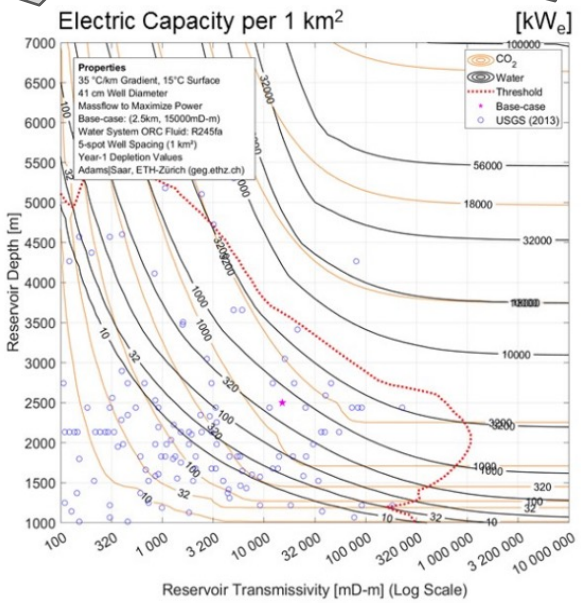
+ thermosiphon effect

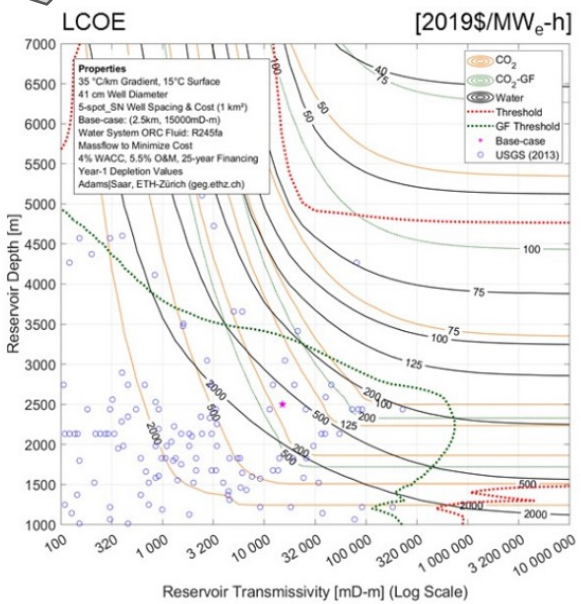
see also: Adams et al. and Saar (Energy, 2014)

The potential of CPG

With the GEG group's genGEO both power output and costs (such as LCOE), can be estimated. We have Identified a CPG potential of 200 GWe in USA saline aquifers alone below 100 $/MWh.

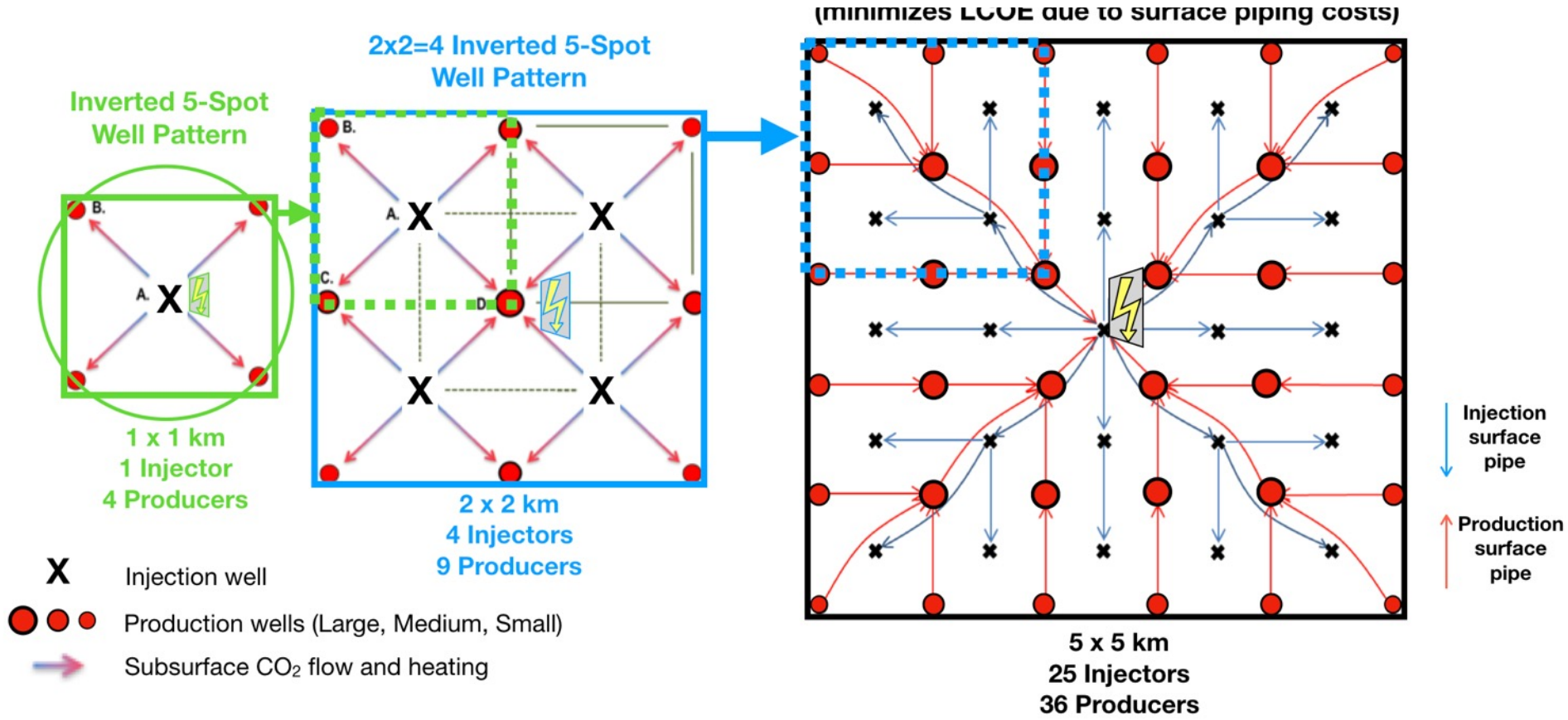






Adams, B.M., J.D. Ogland-Hand, J.M. Bielicki, P. Schädle, and M.O. Saar, *Estimating the Geothermal Electricity Generation Potential of Sedimentary Basins using genGEO (the generalizable GEOthermal techno-economic simulator)*, ChemRxiv: https://doi.org/10.26434/chemrxiv.13514440.v1

CPG upscaling



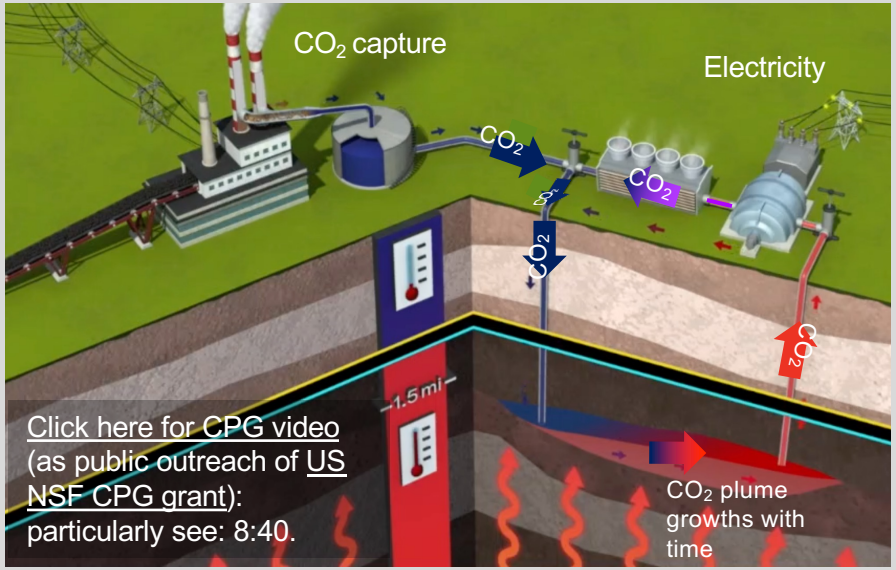
Results in 100-150 MWe geothermal power plant

[under base case conditions: standard geothermal gradient and 2.5 km deep CCS reservoir]

Most relevant **CO_2-Plume Geothermal (CPG)** papers / videos by Saar / GEG Group

CPG:

- combines CCS with geothermal energy extraction/use
- ~doubles geothermal power generation compared to water
- still stores all CO_2 eventually permanently
- can subsidize CCS with heat, electricity and/or revenue
- is a true CC**US** technology → does both **U** and **100% S**

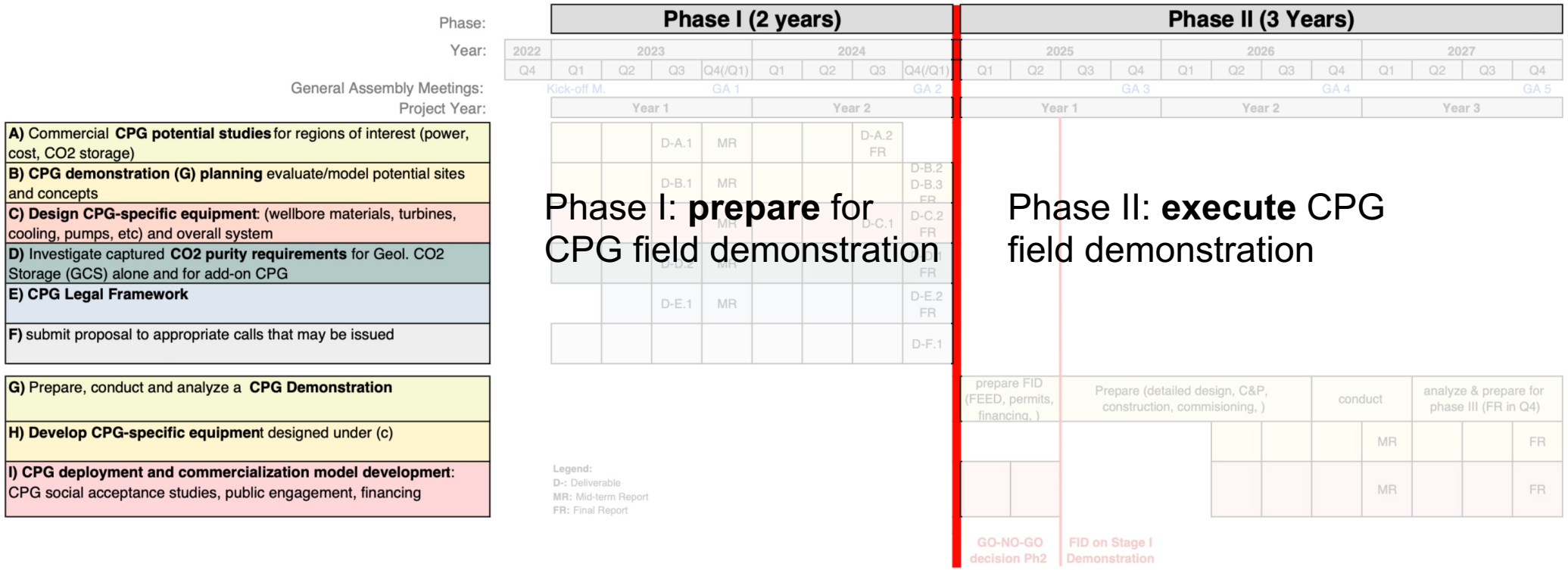


CPG and CPG Consortium talk, given by Saar online at Schlumberger (SLB) in April 2022 (shared with permission by SLB): https://vimeo.com/708207444 (Password: **CPG-April2022)**

2022	Fleming, Adams, Bielicki, Kuehn, Saar, **Flexible CO2-Plume Geothermal (CPG-F): Using Geologically Stored CO2 to Provide Dispatchable Power and Energy Storage**, Energy Conversion and Management, 253/115082, **2022**. [Download PDF] How, with the addition of a "shallow" reservoir, CPG can be used to store energy.
2022	Ezekiel, Adams, Ebigbo, **Numerical analysis and optimization of the performance of CO2-Plume Geothermal (CPG) production wells and implications for electric power generation**, Geothermics, 98/102270, **2022**. [Download PDF] When liquid loading may occur in CPG production wells and how to avoid it.
2021	Ezekiel, Kumbhat, Ebigbo, Adams, Saar, **Sensitivity of Reservoir and Operational Parameters on the Energy Extraction Performance of Combined CO2-EGR–CPG Systems, Energies**, 14/6122, **2021.** [Download PDF] Parameter sensitivity study on CPG power output performance.
2021	Adams, Vogler, Kuehn, Bielicki, Garapati, Saar, **Heat Depletion in Sedimentary Basins and its Effect on the Design and Electric Power Output of CO2 Plume Geothermal (CPG) Systems**, Renewable Energy, 172, pp. 1393-1403, **2021**. [Download PDF] Reservoir heat depletion during CPG and CPG parameter analysis and reservoir cooling, where the well design is varied.
2020	Garapati, Adams, Fleming, Kuehn, Saar, **Combining brine or CO2 geothermal preheating with low-temperature waste heat: A higher-efficiency hybrid geothermal power system**, Journal of CO2 Utilization, 42, **2020**. [Download PDF] When to use geothermal systems in general and in particular CPG as a preheater.
2020	Hefny, Qin, Saar, and A. Ebigbo, **Synchrotron-based pore-network modeling of two-phase flow in Nubian Sandstone and implications for capillary trapping of carbon dioxide**, International Journal of Greenhouse Gas Control, 103/1031642, **2020**. [Download PDF] CCS and CPG after EOR.
2020	Fleming, Adams, Kuehn, Bielicki, Saar, **Increased Power Generation due to Exothermic Water Exsolution in CO2 Plume Geothermal (CPG) Power Plants**, Geothermics, 88/101865, **2020**. [Download PDF] How exothermic exsolution of water from CO_2 in the CPG production well can significantly increase CPG-based power generation.
2020	Ezekiel, J., A. Ebigbo, B. M. Adams, and M. O. Saar, **Combining natural gas recovery and CO2-based geothermal energy extraction for electric power generation**, Applied Energy, 269/115012, **2020**. [Download PDF] Adding CPG after EGR.
2017	Walsh, Garapati, Leal, Saar, **Calculating thermophysical fluid properties during geothermal energy production with NESS and Reaktoro**, Geothermics, 70, pp. 146-154, **2017**. [Download PDF] How different (subsurface) fluid properties affect power generation and how to calculate the properties of geothermal working fluids.
2015	Adams, Kuehn, Bielicki, Randolph, Saar, **A comparison of electric power output of CO2 Plume Geothermal (CPG) and brine geothermal systems for varying reservoir conditions**, Applied Energy, 140, pp. 365-377, **2015**. [Download PDF] Calculating electric power output from thermal output for CPG systems and comparing it also to indirect systems such as ORCs.
2015	Garapati, Randolph, Saar, **Brine displacement by CO2, energy extraction rates, and lifespan of a CO2-limited CO2-Plume Geothermal (CPG) system with a horizontal production well**, Geothermics, 55, pp. 182-194, **2015**. [Download PDF] CO2-limited CPG systems → How much CO2 is needed. Plus use of horizontal wells and brine displacement by CO2.
2014	Adams, Kuehn, Bielicki, Randolph, Saar, **On the importance of the thermosiphon effect in CPG (CO2-Plume geothermal) power systems,** Energy, 69, pp. 409-418, **2014**. [Download PDF] CO_2-thermosiphon effect in CPG.
2011	Randolph, J.B., and M.O. Saar, **Combining geothermal energy capture with geologic carbon dioxide sequestration**, Geophysical Research Letters, 38, L10401, **2011**. [Download PDF] Main first CPG publication. Comparing thermal power output of CPG to CO2-EGS and to hydrothermal.

CPG Consortium: started March 2023

- Following extensive theoretical research, a **CPG field demonstration** is now required to de-risk this technology
- End-to-end integrated joint academic and industry project: Oil & Gas companies, CO2 equipment manufacturers, CO2 emitters as well as universities



Evaluation of Canadian Potential

- Proposed ETH + University of Alberta + University of Calgary joint project (late 2023 – early 2025)

Basal Cambrian Sandstone CO_2 Storage Potential

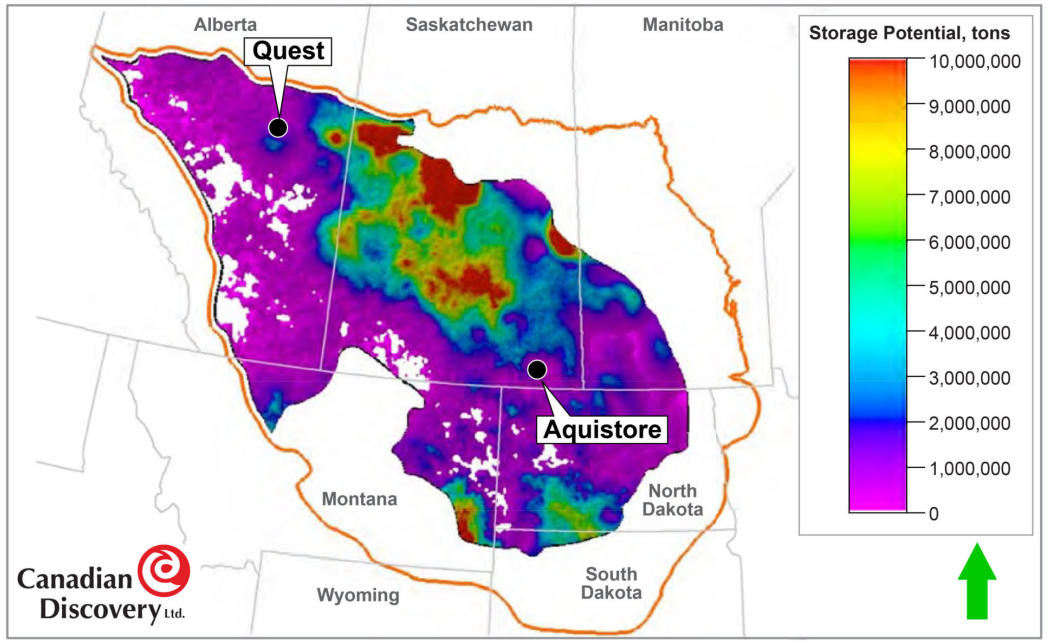
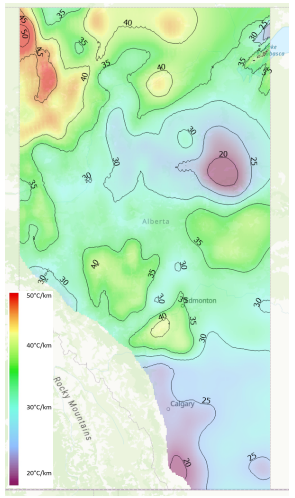
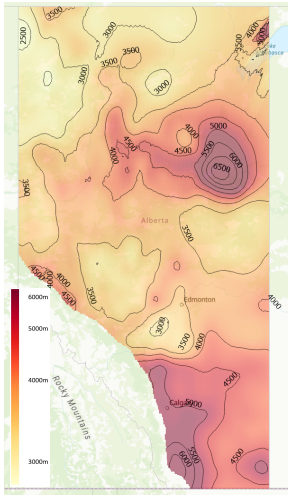


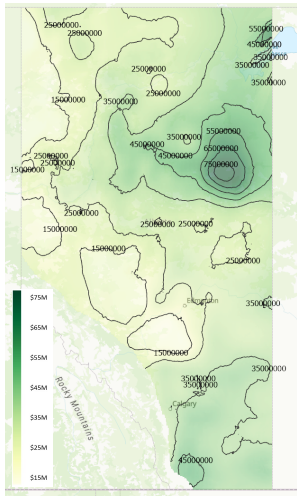
Figure 1 Modified from Peck et al., 2014



Geothermal Gradient (°C/km) map of Alberta. From Majorowicz (2018)



Estimated depths (m) to achieve subsurface temperatures of 120°C



Estimated costs to drill a doublet to subsurface temperatures of 120°C

How I get involved?

- If you have a current or planned CO_2 storage project, or are operating a CO_2-based enhanced oil or gas recovery system, CPG could be a potential add-on.

- Join the CPG consortium at ETH and shared data (under NDA) on potential fields for evaluation for a demonstration project
  - Contact Jasper (adereus@ethz.ch) or Martin (saarm@ethz.ch)

- Share data with the U of A / U of C teams once the joint project is initiated
  - Potential target reservoirs or current operations

GEG.ethz.ch