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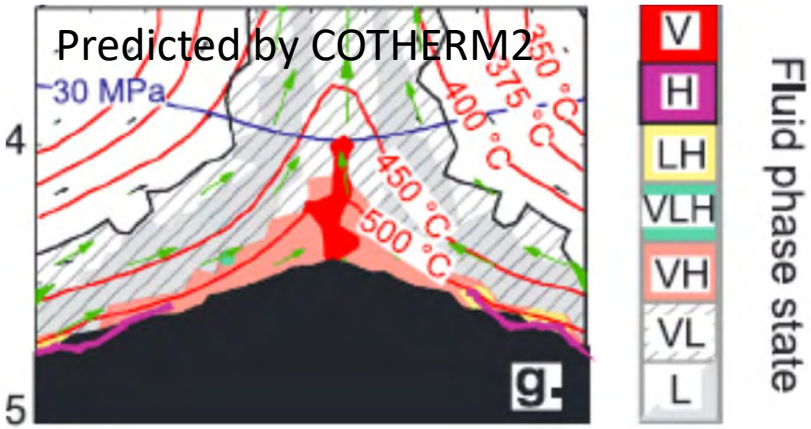
SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

SCCER international collaboration - the example of supercritical (and other) geothermal resources in Iceland

Thomas Driesner, ETHZ



In cooperation with the CTI

Energy
Swiss Competence Centers for Energy Research

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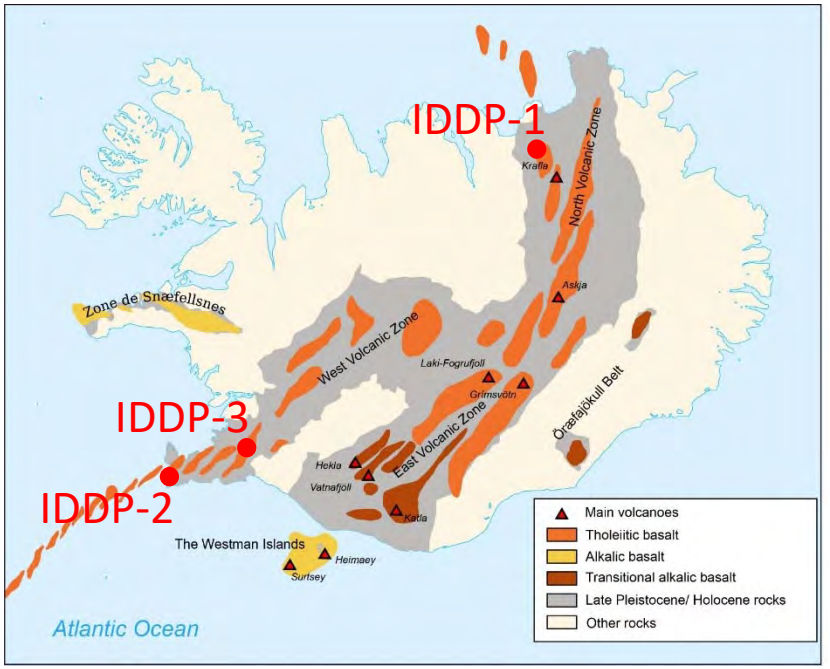
Commission for Technology and Innovation CTI

Collaboration 2013-2018+

- IPGT as umbrella was instrumental
- COTHERM (SNF-Sinergia) – 3 PhD, 1 Postdoc
- Direct interaction with Icelandic DRG (Deep Roots of Geothermal Systems), ISOR, University of Iceland, …
- Direct interaction with FP7 IMAGE (BfE-sponsored field campaign, 2 MSc, SE-Iceland + ISOR + Italian PhD)
- Direct interaction with Iceland Deep Drilling Project, IDDP (workshops, preparatory reports, …), now direct involvement in preparation of IDDP-3

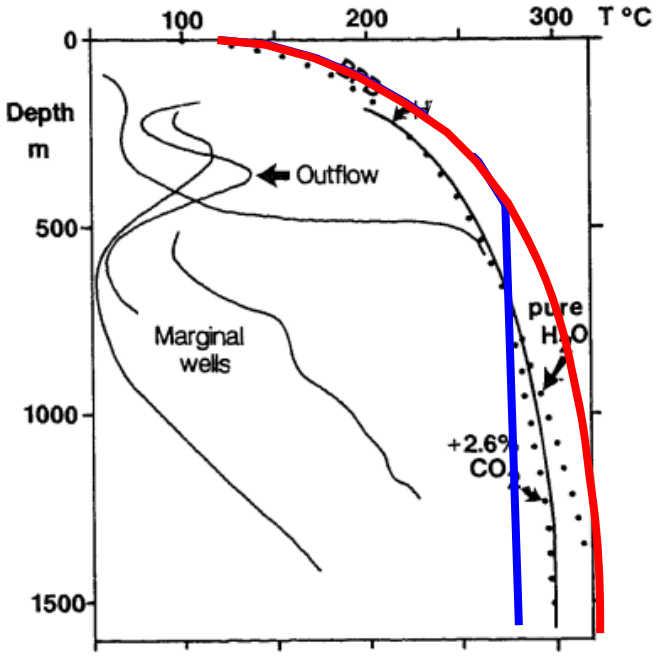
Iceland Geothermal

- >50% of primary energy production (heat and power) geothermal!
- 5 geothermal power stations, ca. 650 MW_{el} total
- Reykjavik district heating completely geothermal (low enthalpy resources plus hot water pumped 30+ km from power stations)
- Plenty of low-/medium-enthalpy resources
- Highly innovative
  - Iceland Deep Drilling Project for supercritical resources
  - Innovative use of waste-water & heat: Blue Lagoon, high-tech yeast, …
  - Very active and successful in acquiring EU grants



Background: high-enthalpy resources

- Driven by magmatic heat, boiling
- Heat transfer to geothermal system controlled by
  - Host rock permeability
  - Temperature dependence of permeability
- Typically exploited at 1 – 2.x km depth and 250 to 300°C



modified from Hedenquist, 1992

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  - Hotter resource, can it be utilized and how?
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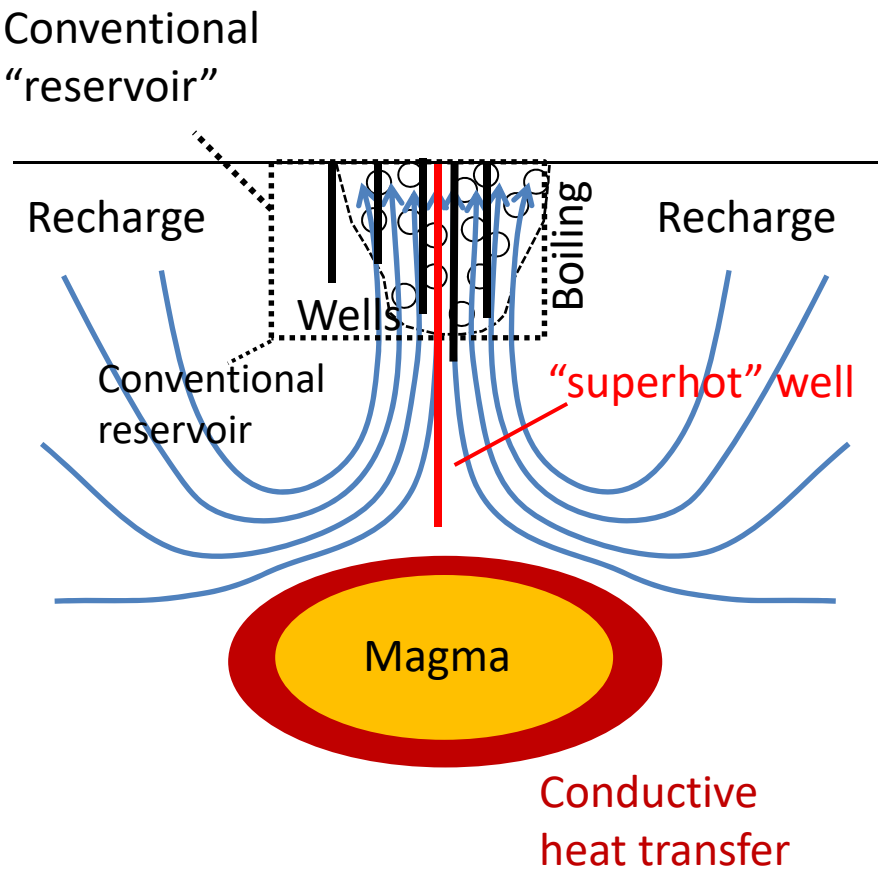

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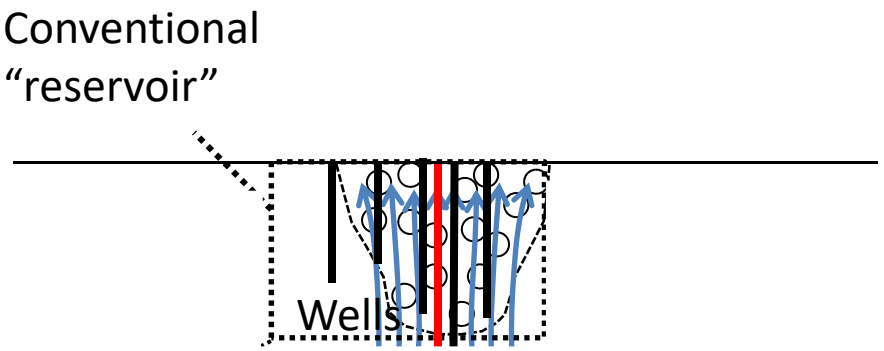
- How has industry looked at this before?
- So: what’s the TRL?



Project IDDP-1: Krafla, N-Iceland
(Landsvirkjun Power Company)

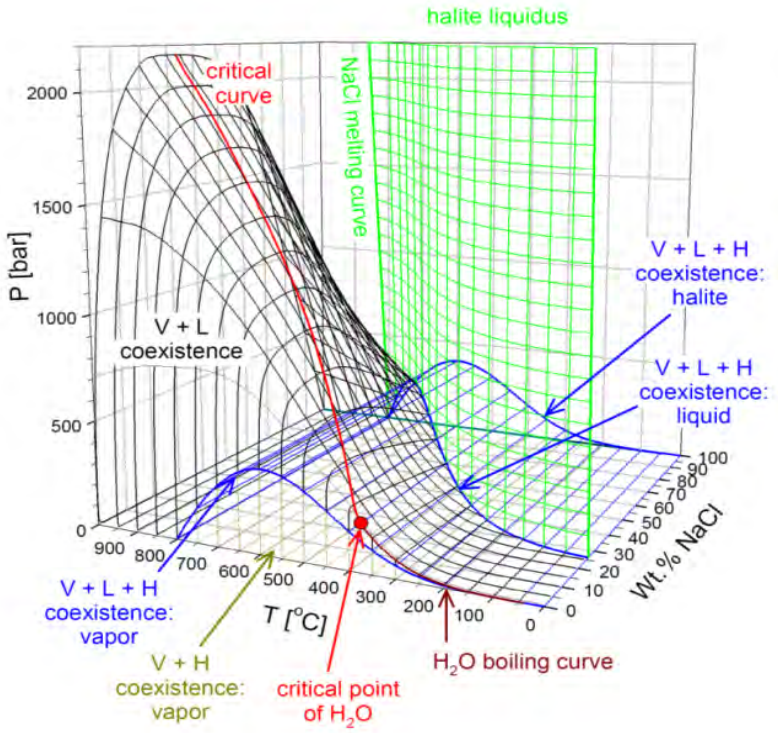
- Hit magma at 2 km depth
- Well head: 450°C, 14 MPa
- Flow tests showed that up to 35 MW_{el} possible from a single well
- However: massive technical problems (scaling, corrosion, thermo-mechanical instability of casing etc.)
- Science involvement mostly AFTER problems encountered …
- Unique learnings and insights but well now abandoned

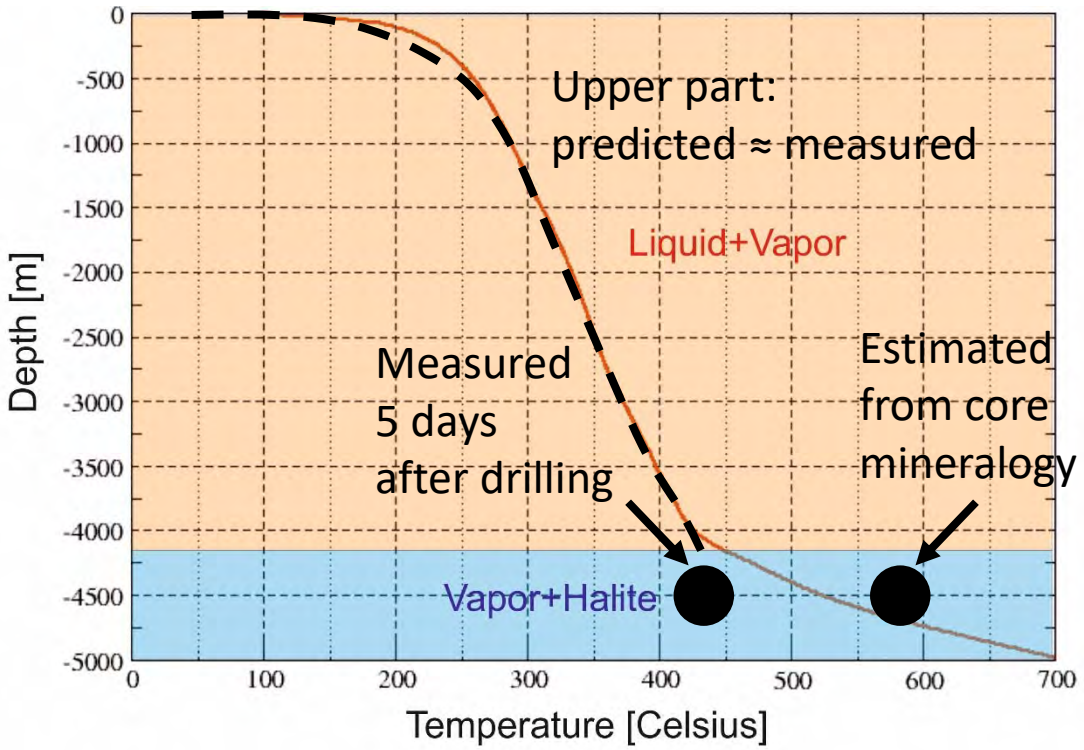
IDDP-2: Reykjanes, SW-Iceland

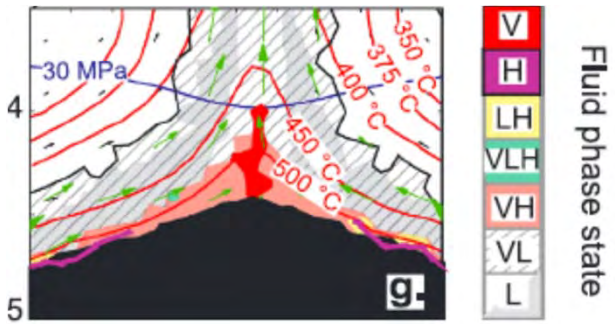
(HS Orka Power Company)

- Well drilled to 4.6 km
- Geothermal fluid = seawater
- Total fluid loss below ca. 3.6 km
- Casing problem at about 3.4 km
- 2019: well testing etc.
- We were approached by Equinor (formerly Statoil) to develop scenarios to be tested in the characterization phase
- Within few months, this sparked already two significant, industry-driven proposals (H2020 and Norwegian research council)

IDDP-2: Our Predictions vs. Reality



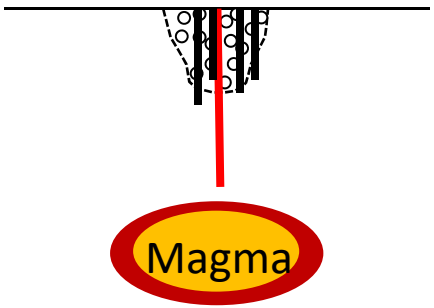




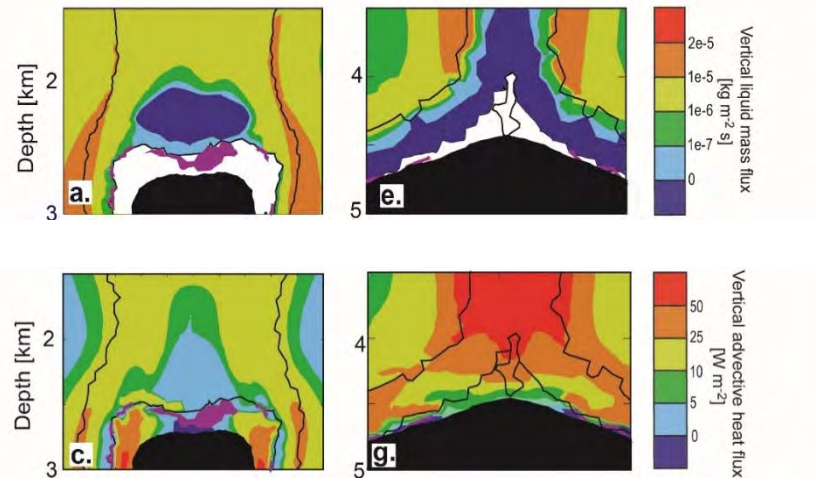
- COTHERM PhD work in 2016 BEFORE drilling predicts +/- exactly the best estimates obtained AFTER drilling (i.e., in 2017/18)

Why are the results interesting for industry?

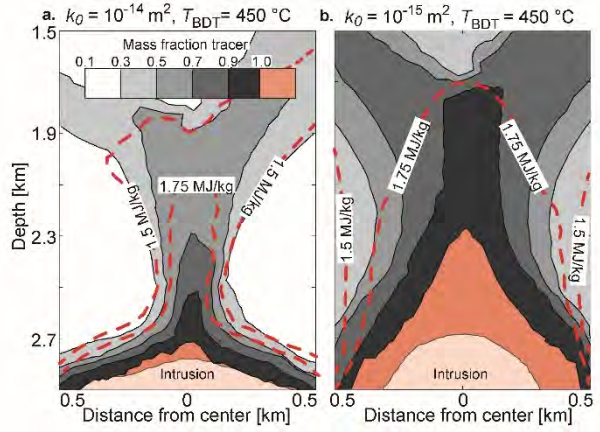
- Developing adequate exploration models and strategies
- Targeting/vectoring:
  - best location for well
- Scenario development:
  - How to test the well for characterizing the resource?
  - How to operate the deep well: production or injection?



Saline systems: heat source depth is key!



Non-saline systems: enthalpy distribution is vector to supercritical resource!

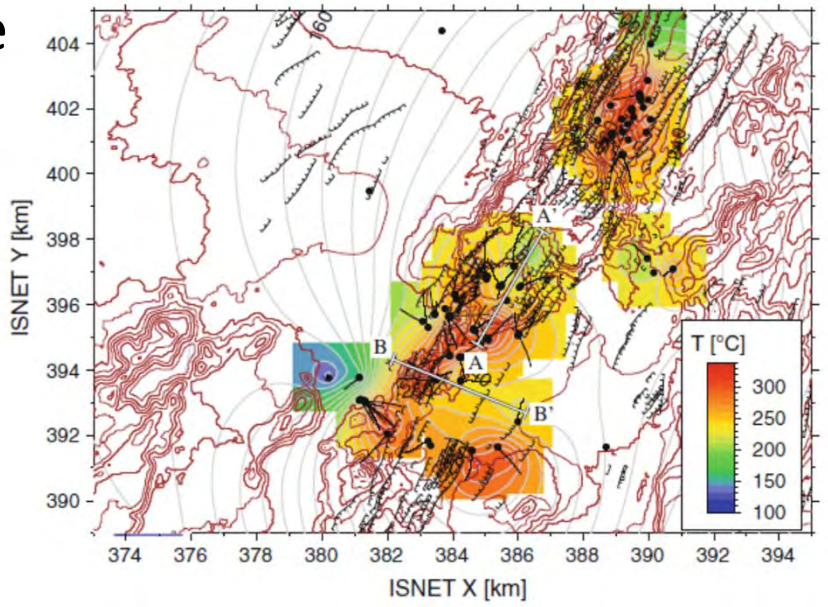


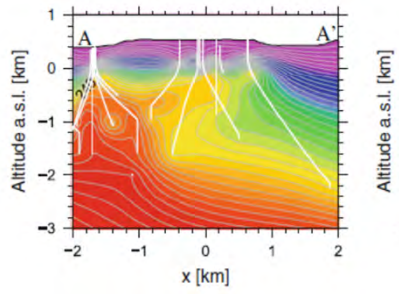
IDDP-3: Hellisheidi-Hengill, S-Iceland
(Reykjavik Energy)

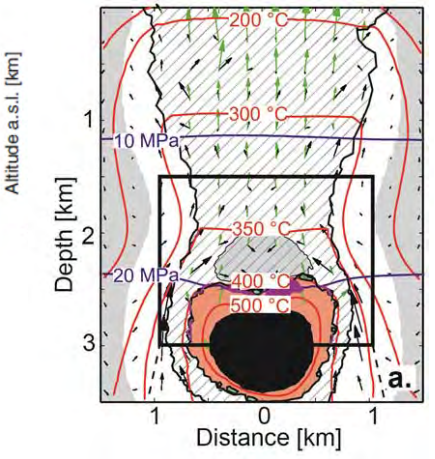
- To be drilled 2020/21
- Try to avoid errors made in IDDP-1 and IDDP-2
  - Pilot hole to 3.5 km planned
  - Involve science early on for developing scenarios
- Try to locate best well site
- Same site that SED works on: synergies!
- Plus: Climeworks direct capture + sequestration …

Interest of Industry in Collaboration

- Make fewer challenging/negative experiences than IDDP-1/2
  - Best well-siting
  - Best characterization strategy
  - Best operation approach
  - Best choice of equipment/technology
- Realized that current workflows and tools don't allow rigorous assessment of their problems …
- Cost/benefit of the exercise …
  - 10^4 - 10^5 EUR to improve a 10^7 EUR project – are we really talking TRL?



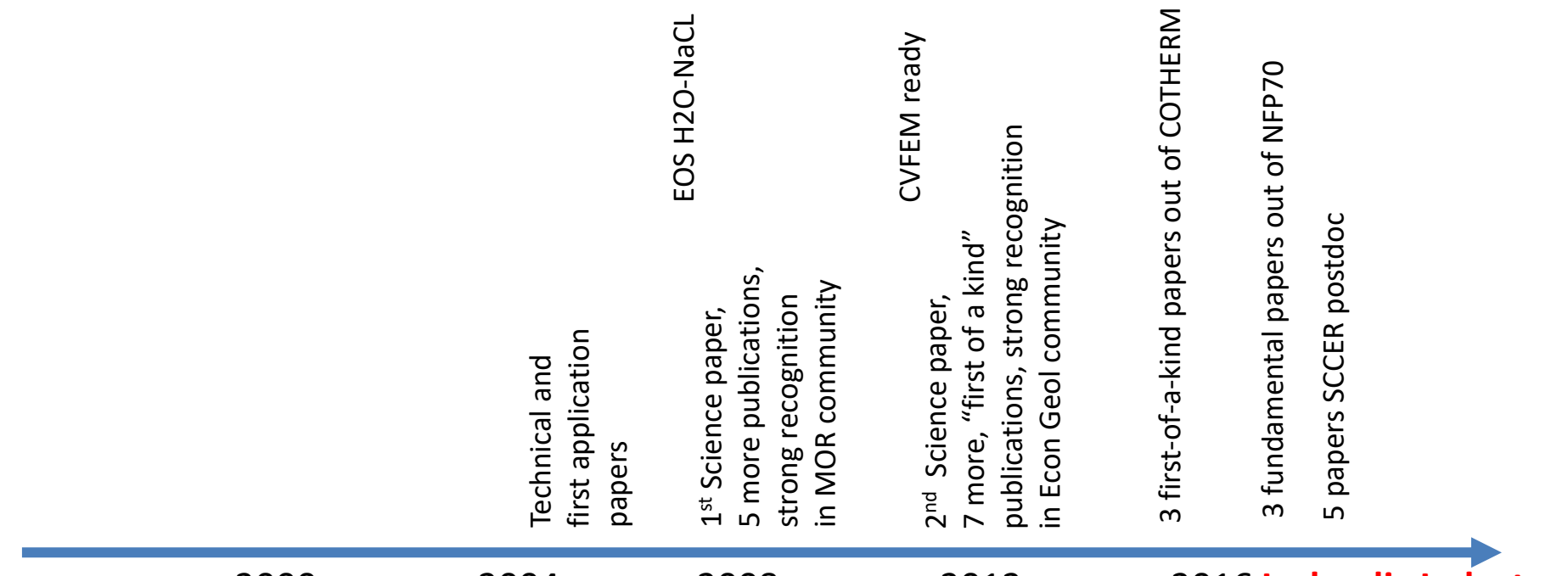




What sparked the interest?

- COTHERM/IPGT/SCCER
- Previous work advertised repeatedly on personal meetings in Iceland, presentation and language tuned to have impact
- Personal connections (outcome of interaction during BfE-sponsored workshop at Castasegna, 2012; 18kCHF, 15 people from CH, US, NZ, ICE, AUS) from IPGT countries, shaped US benchmarking initiative, ETH: published high-enthalpy benchmarking standard …). This was a bargain!
- Scientific messages need time and repetition to trickle in PLUS the curiosity and reception of industry but:
- Why does it work so well on an IPGT level and supposedly not in CH? Is this really a TRL question? Or one of trust in people and their expertise and commitment and will to interact?

About the time aspect …



Successful interaction is a matter of time and communication

- Academics do not naturally/automatically know the industrial questions, workflows and approaches (e.g. “flow assurance”), i.e., two-way communication is key!
- Have precise questions, then we can most probably provide value-adding advice or answers (applies also within SCCER …)!
- If we can’t provide the answer yet, we can do it within a limited number of years!

Beyond Supercritical: HEATSTORE

- Reykjavik heating is +/- 100% geothermal (=2/3 of population)
- Mixed low-/medium-enthalpy resources (with smelly H_2S) and piped (>30 km) hot water from a power station
- 2017/18: cold winter followed by cold summer plus massive increase in tourism (one new hotel permit application per week) -> resource reaching its limit
- Seasonal heat storage as possible way to mitigate this problem (power station runs baseload all year)
- Collaboration with Reykjavik Energy in HEATSTORE