Swiss Centre of Competence
for Deep Geothermal Energy
for power and heat production

GEOTHERMAL IN SWITZERLAND OVERVIEW ON ACTIVITIES IN: RESEARCH, INDUSTRY PROJECTS & THE NEW ENERGY LAW

UNECE – SPE SWISS JOINT LECTURE HELD IN OCCASION OF THE UNECE RESOURCE CLASSIFICATION WEEK 2017

PALAIS DE NATIONS, SALLE XXI, GENEVA, 26TH OF APRIL 2017

Dr. Peter Meier,
CEO Geo-Energie Suisse and IGA, chair information committee
p.meier@geo-energie.ch, www.geo-energie.ch

Introduction

- Status of geothermal energy in Switzerland
- Resources difficult to develop, therefore
  - Research
  - Pilot projects
  - Politics provide very interesting incentives

Acknowledgements:

Gunter Siddiqi from the Swiss federal office of energy and the Swiss Competence Center for Energy Research – Supply of Electricity provided many slides

Only heat is generated from geothermal, but ambitious target is set for electricity

Electricity		Direct Use	
Total Installed Capacity (MW_e)	0	Total Installed Capacity (MW_{th})	26.7
New Installed Capacity (MW_e)	0	New Installed Capacity (MW_{th})	-3.9
Total Running Capacity (MW_e)	0	Total Heat Used (PJ/yr) [GWh/yr]	0.78 (215.9)
Contribution to National Capacity (%)	0	Total Installed Capacity Heat Pumps (MW_{th})	1925.5
Total Generation (GWh)	0	Total Net Heat Pump Use [GWh/yr]	2320.2
Contribution to National Generation (%)	0	Target (PJ/yr)	N/A
Target 2050 (GWh/yr)	4'400	Estimated Country Potential (MW_{th} or PJ/yr or GWh/yr)	N/A
Estimated Country Potential (GWh/yr)	N/A		

Katharina Link & Gunter Siddiqi, 2016 Switzerland Country Report, IEA Geothermal, March 2017

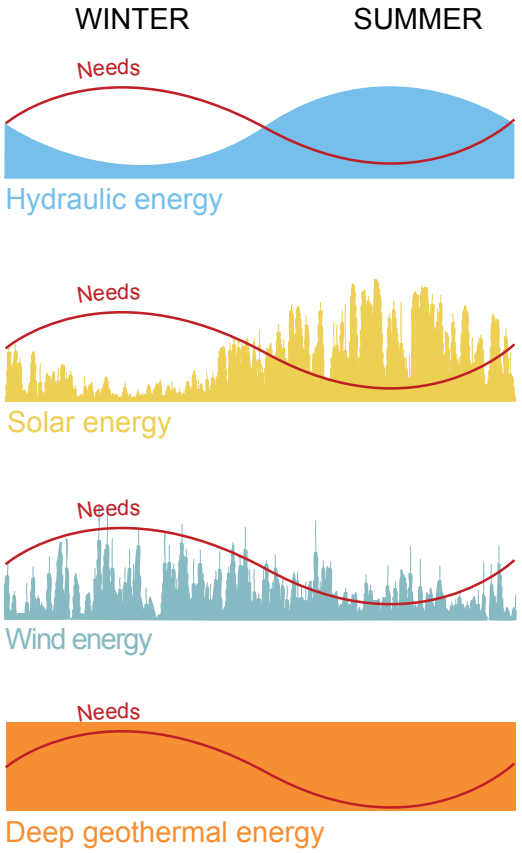
Motivation

- Local and renewable

- Clean and CO_2-free

- Low impact on the environment and the landscape

- Base-load energy – available 24/24



Motivation

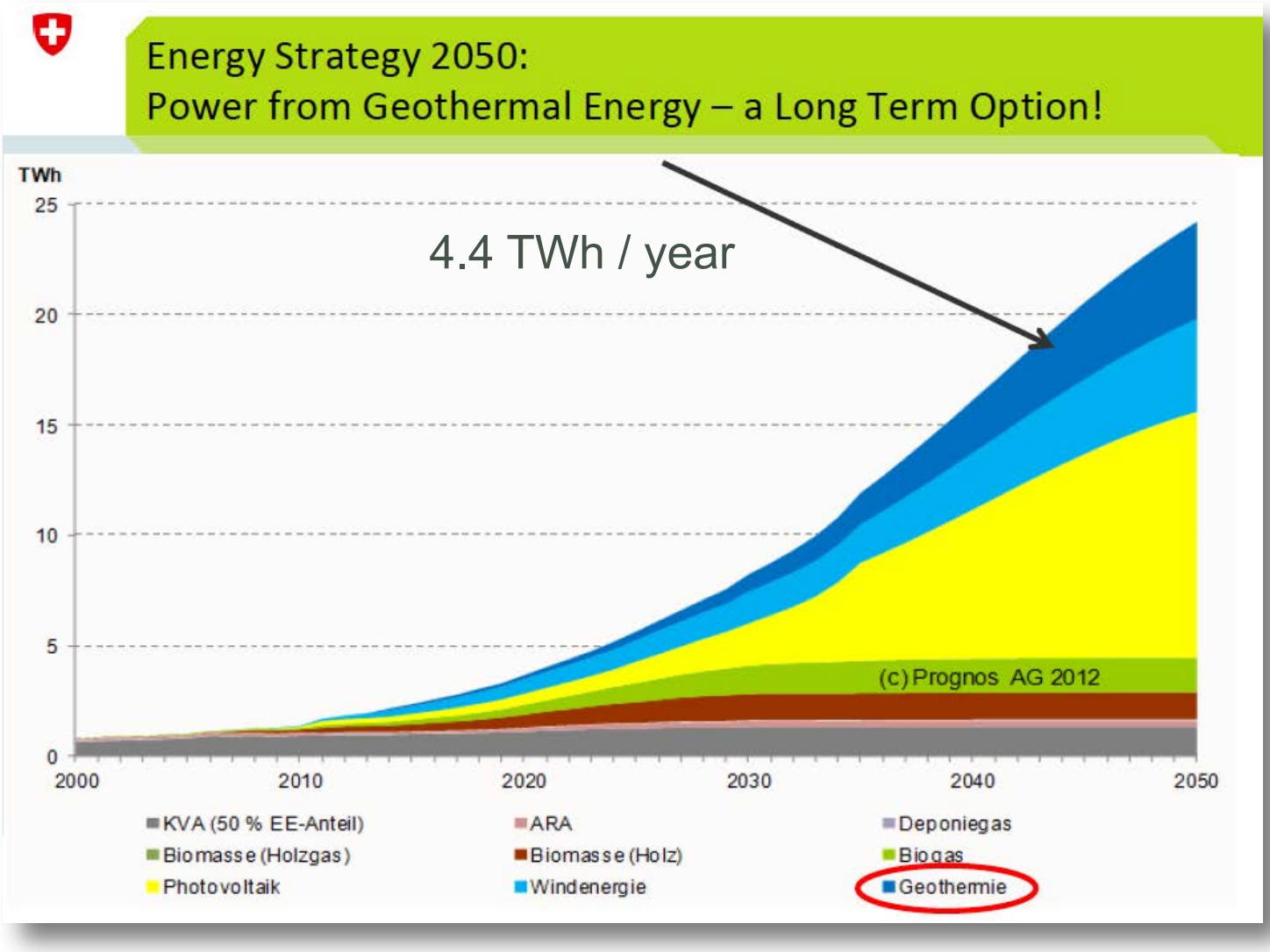
Grünwald

Success story –
Munich, Germany

Unterhaching

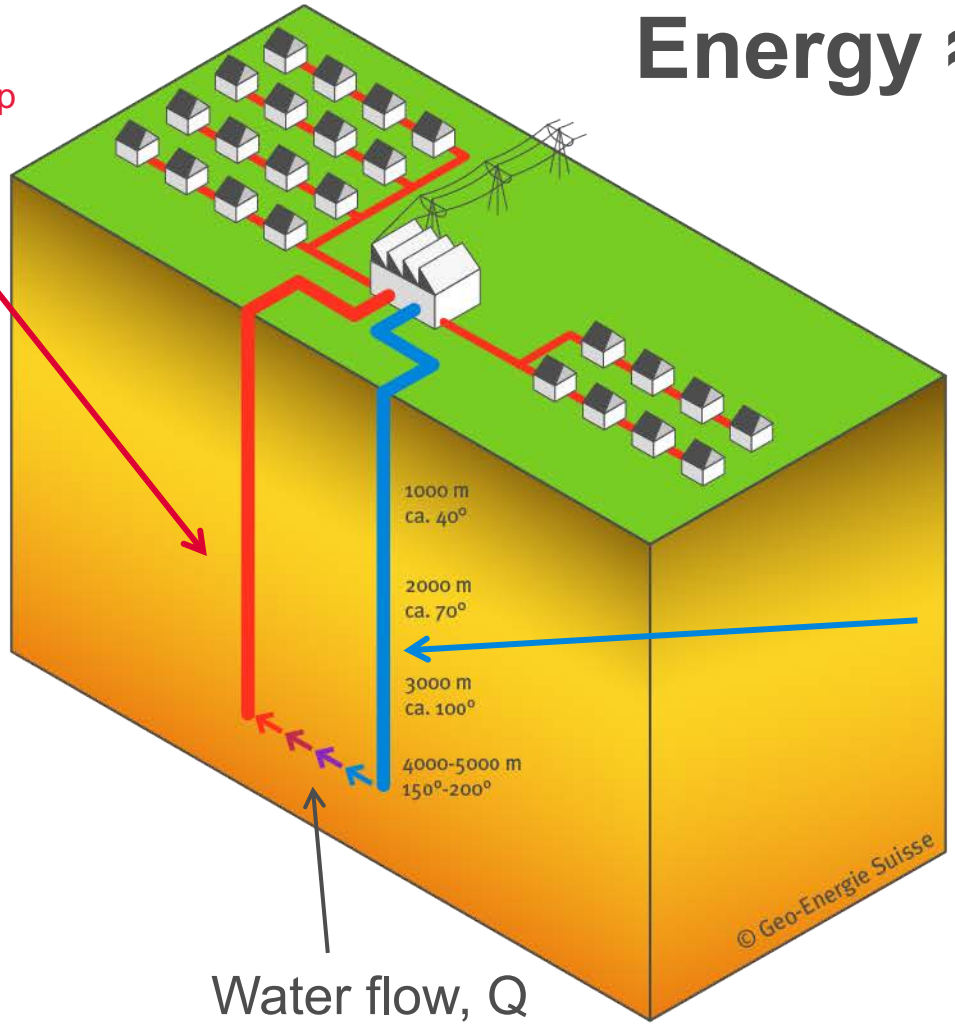
10 power plants produce electricity and heat with an installed electric power of 35 MW

Motivation


Energy Strategy 2050:
Power from Geothermal Energy – a Long Term Option!
TWh
25
20
15
10
5
0
4.4 TWh / year
(c) Prognos AG 2012
2000
2010
2020
2030
2040
2050
KVA (50 % EE-Anteil)
ARA
Deponiegas
Biomasse (Holzgas)
Biomasse (Holz)
Biogas
Photovoltaik
Windenergie
Geothermie

The Geothermal Energy

Production Temperature, T_p

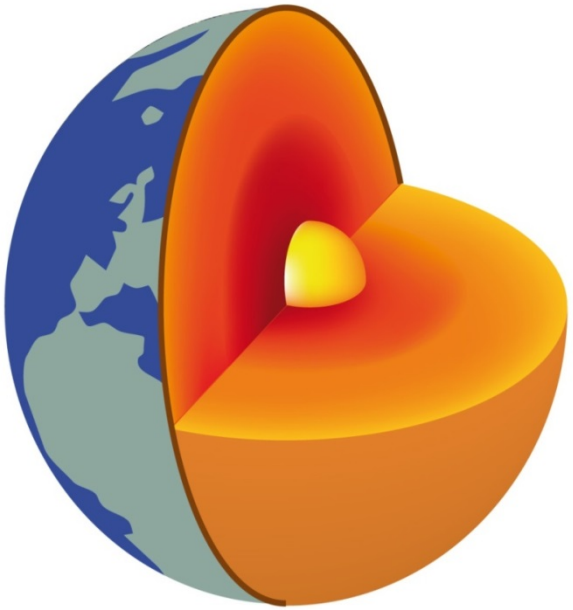


$$\text{Energy} \approx Q^*(T_p - T_i)$$

Re-injection Temperature, T_i

Water flow, Q

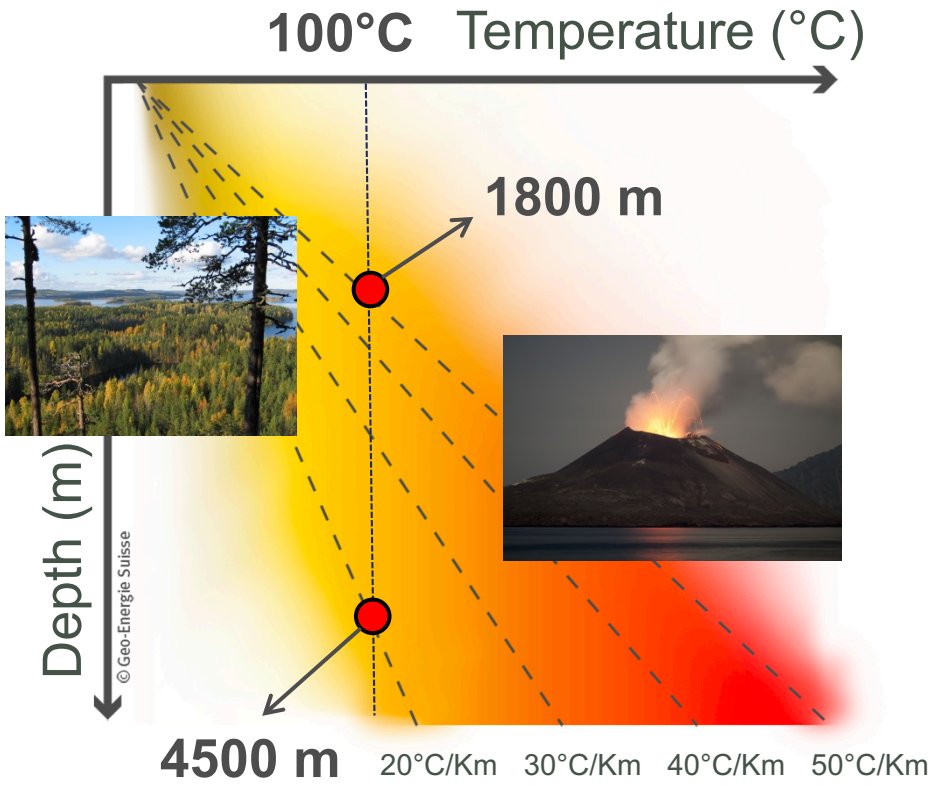
The Heat



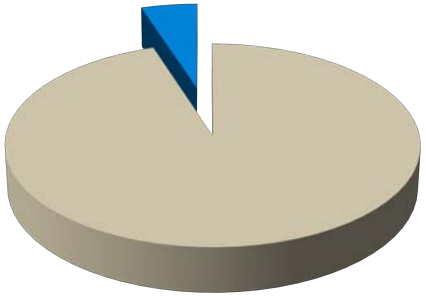
99%

of its volume is above 1000° C

The geothermal gradient



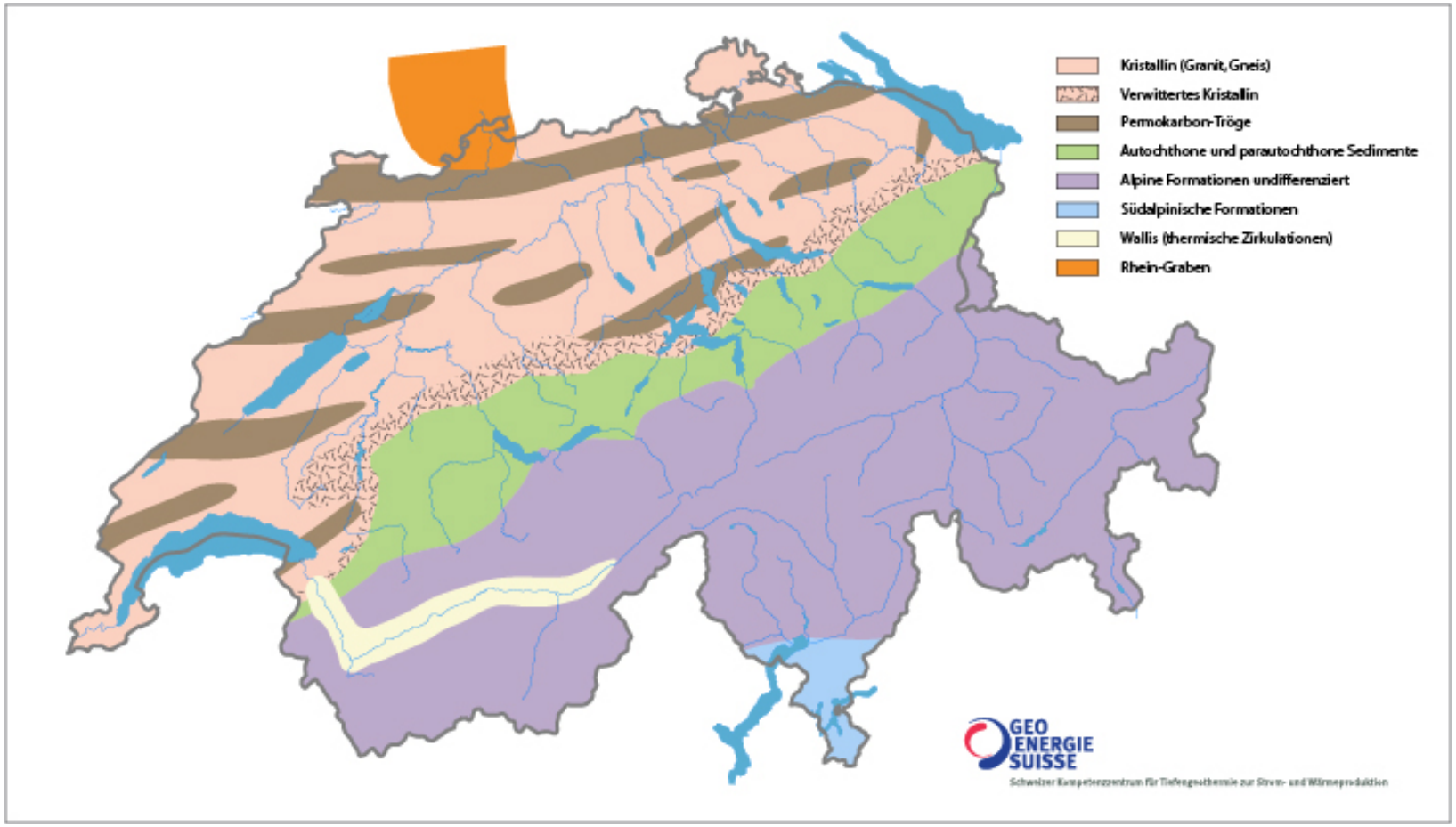
The Water Flow



Message

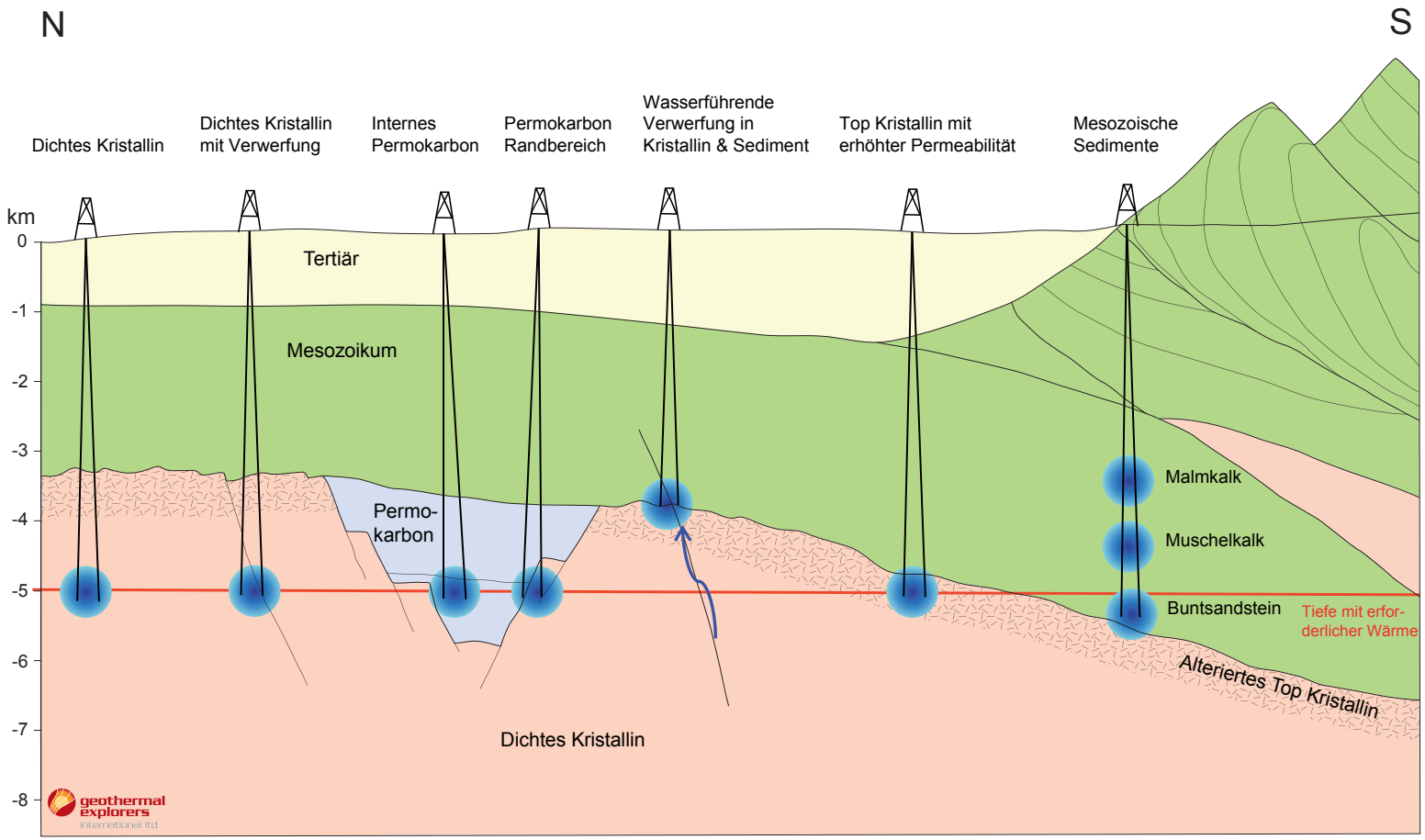
- Sufficient temperature will always be found. It is only a matter of depth (and costs)
- Large water flows at depth are rare. **Technology is therefore required to extract the heat in most cases**

Schematic representation of geology



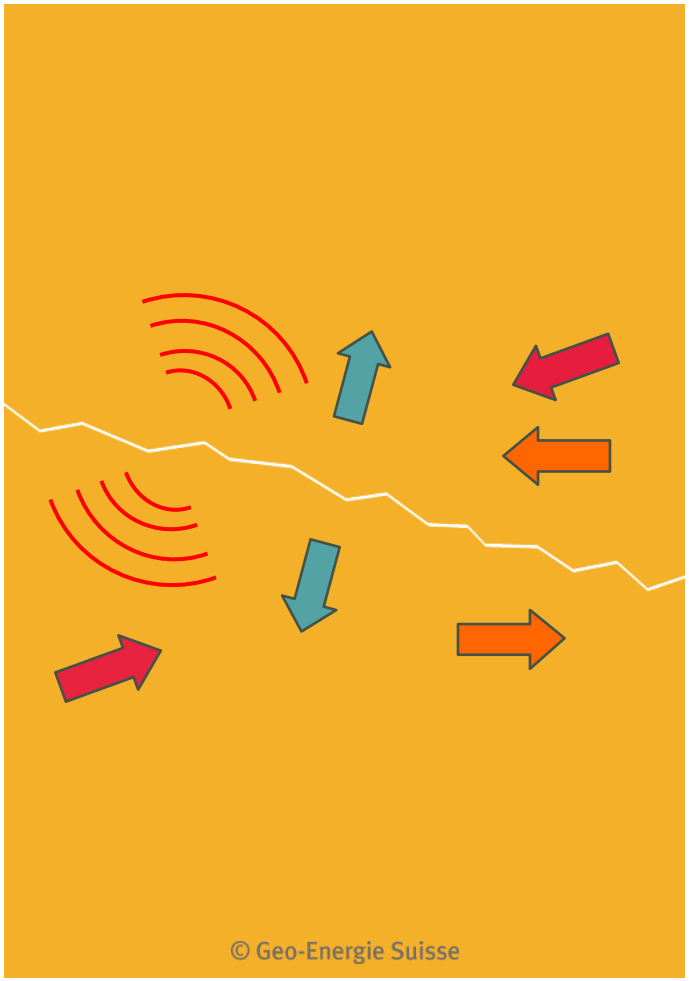
Geothermal plays in Switzerland

Schematischer Schnitt durchs Mittelland



- Only few deep boreholes existing => more exploration needed
- Until now only low permeability rocks were found => R&D in EGS

EGS – Principle of hydraulic stimulation



- Natural fissures represent weaknesses in the rock mass.
- Differential stresses permanently apply on them.
- The injection of water in a fissure reduces the friction preventing it from slipping.
- This causes a displacement along the fissure.
- Seismic energy is released, which allows the event to be located.
- The walls of the fissure don’t match anymore. The permeability has been permanently enhanced.

Lessons of Basel as basis for a new concept.

Deep Heat Mining Basel

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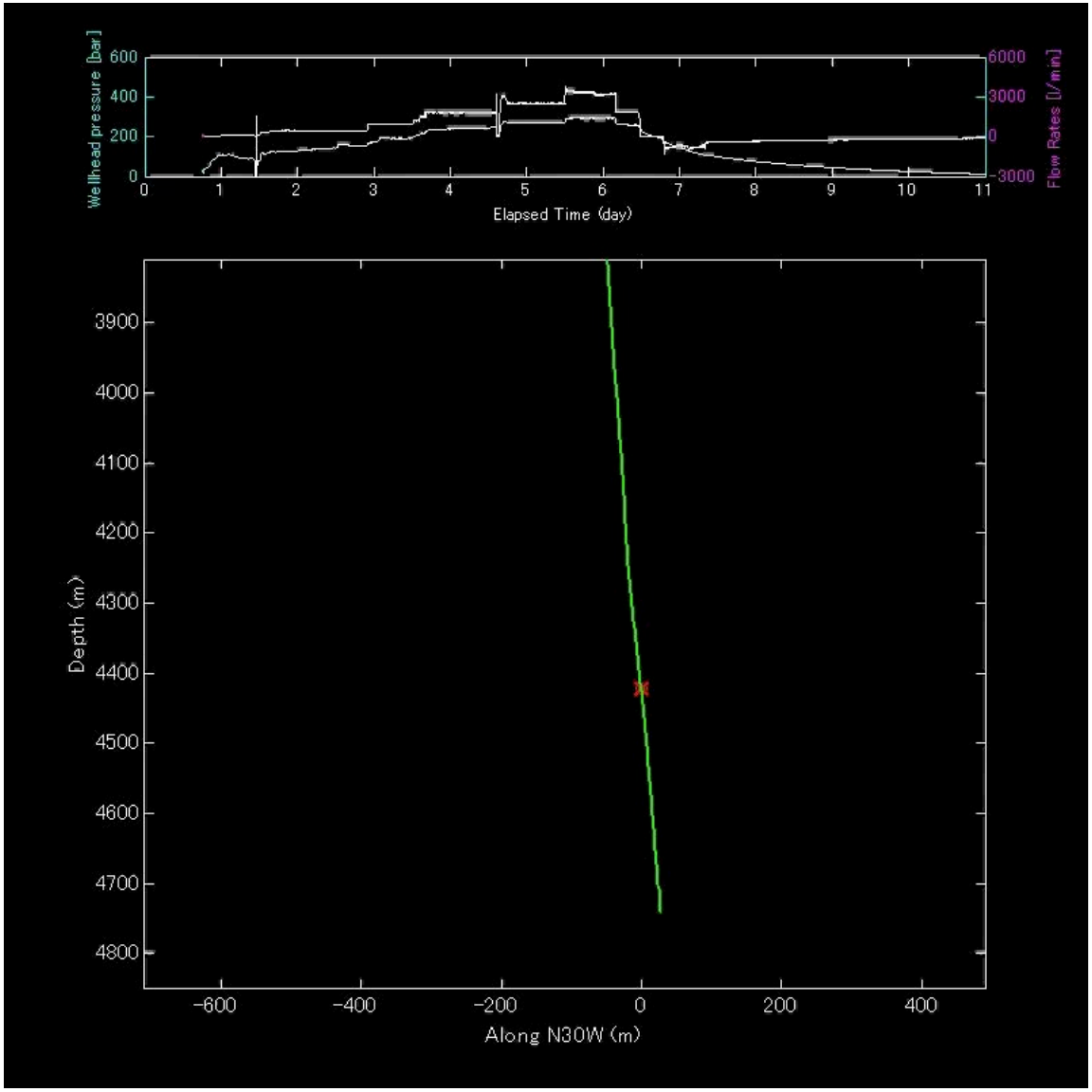
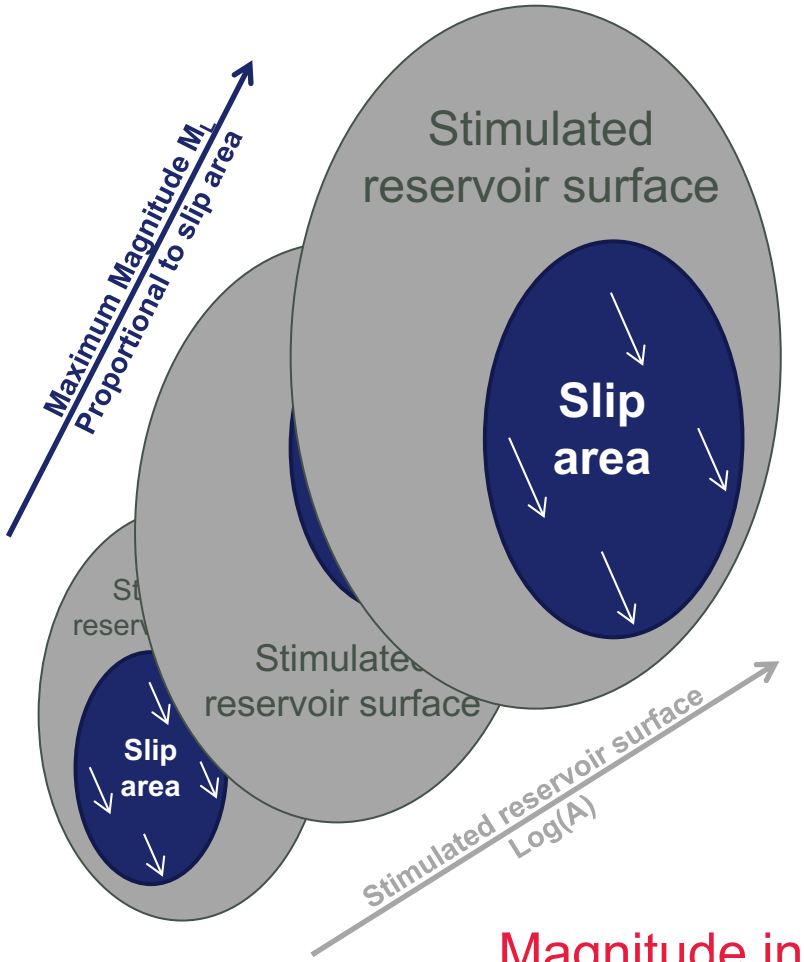
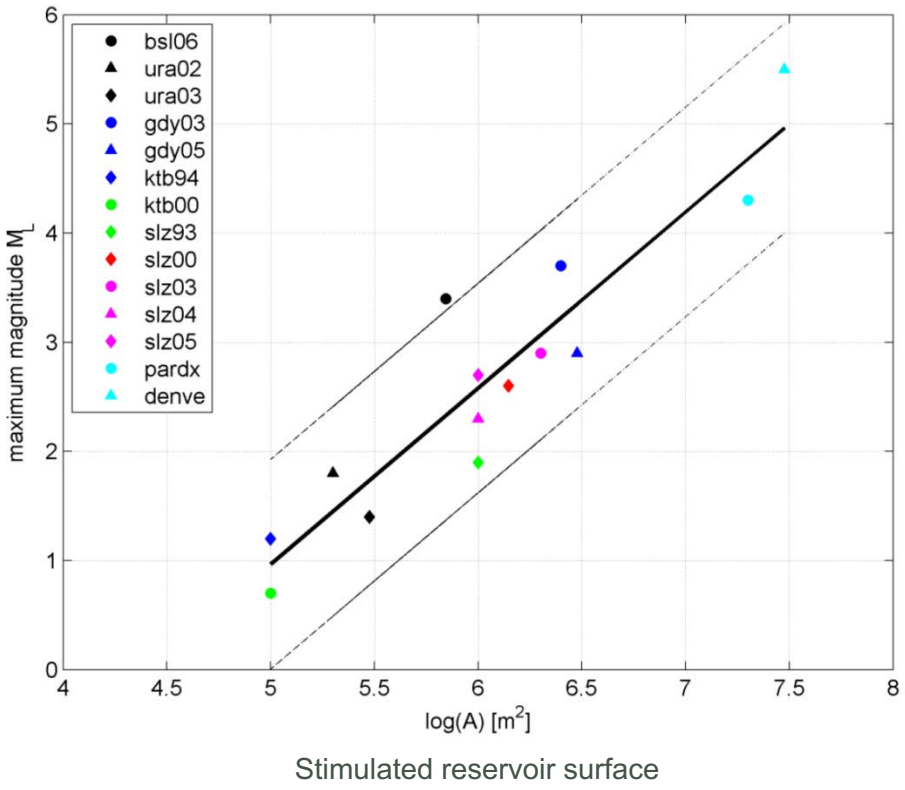
Seismic dataset from the Basel project during the massive stimulation in large open wellbore section



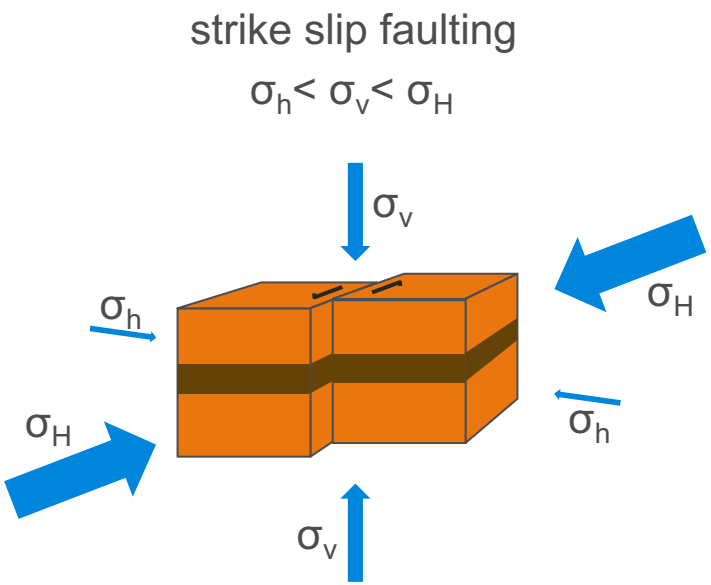
Basel: Key findings on induced seismicity

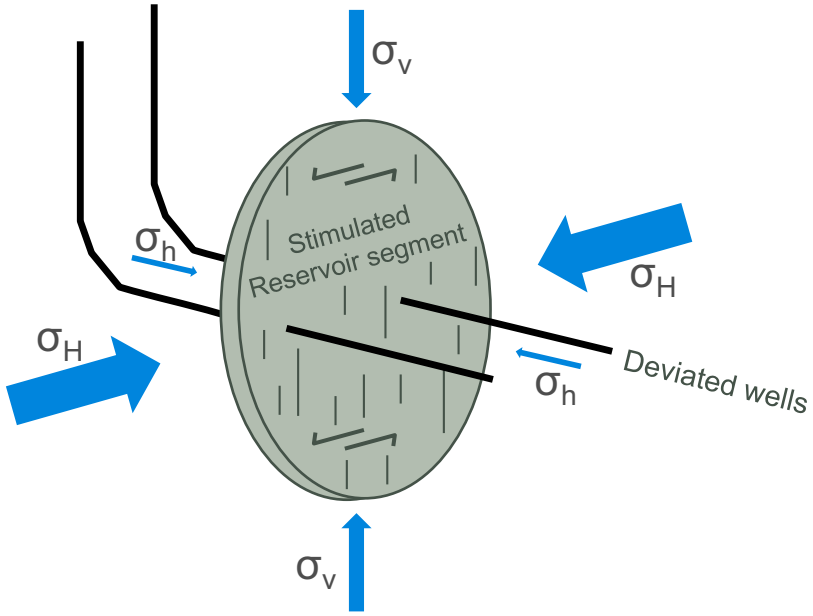




Magnitude increases with stimulated reservoir area (Serianex, 2009)

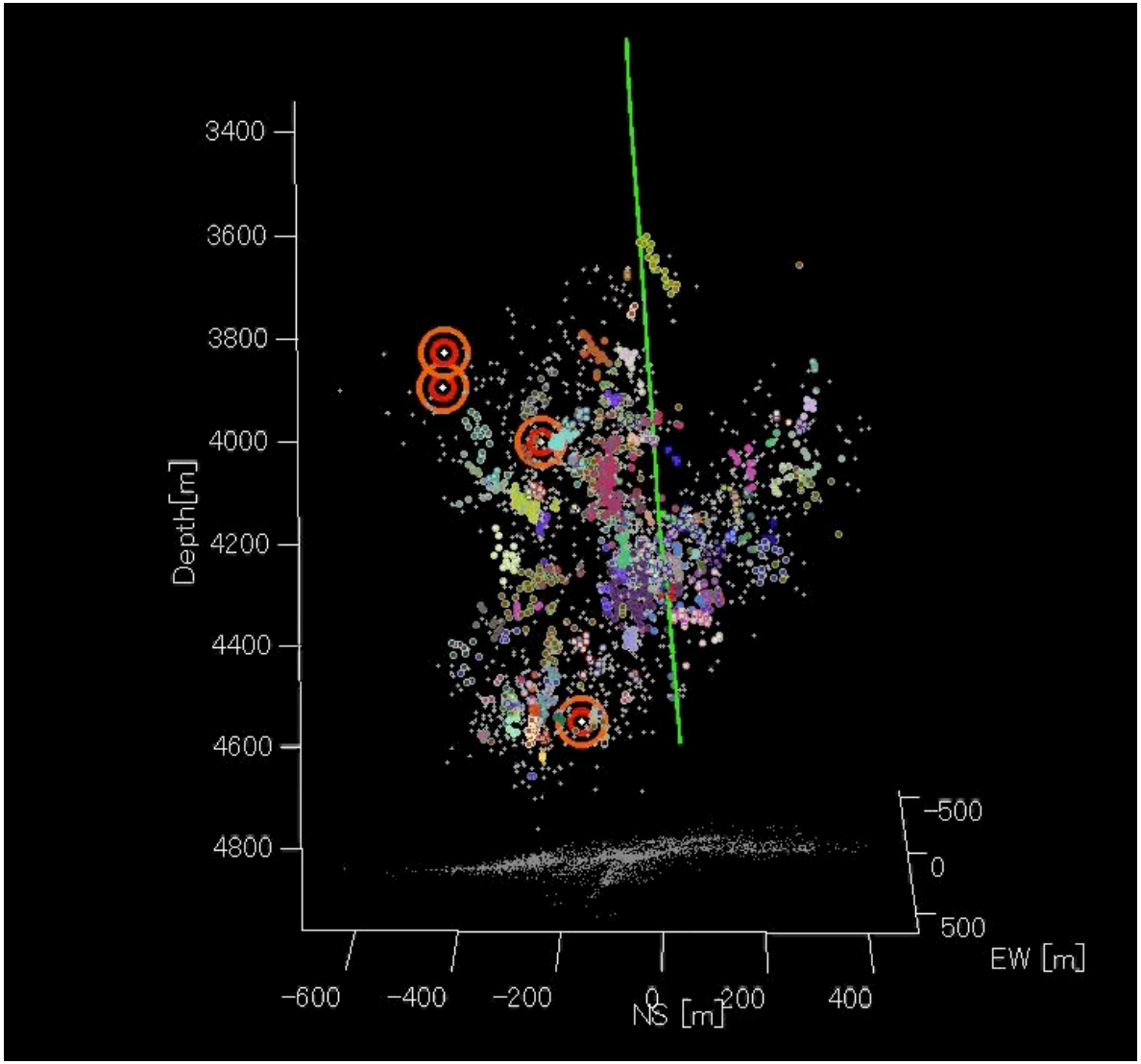
EGS – Orientation of the stimulated reservoir



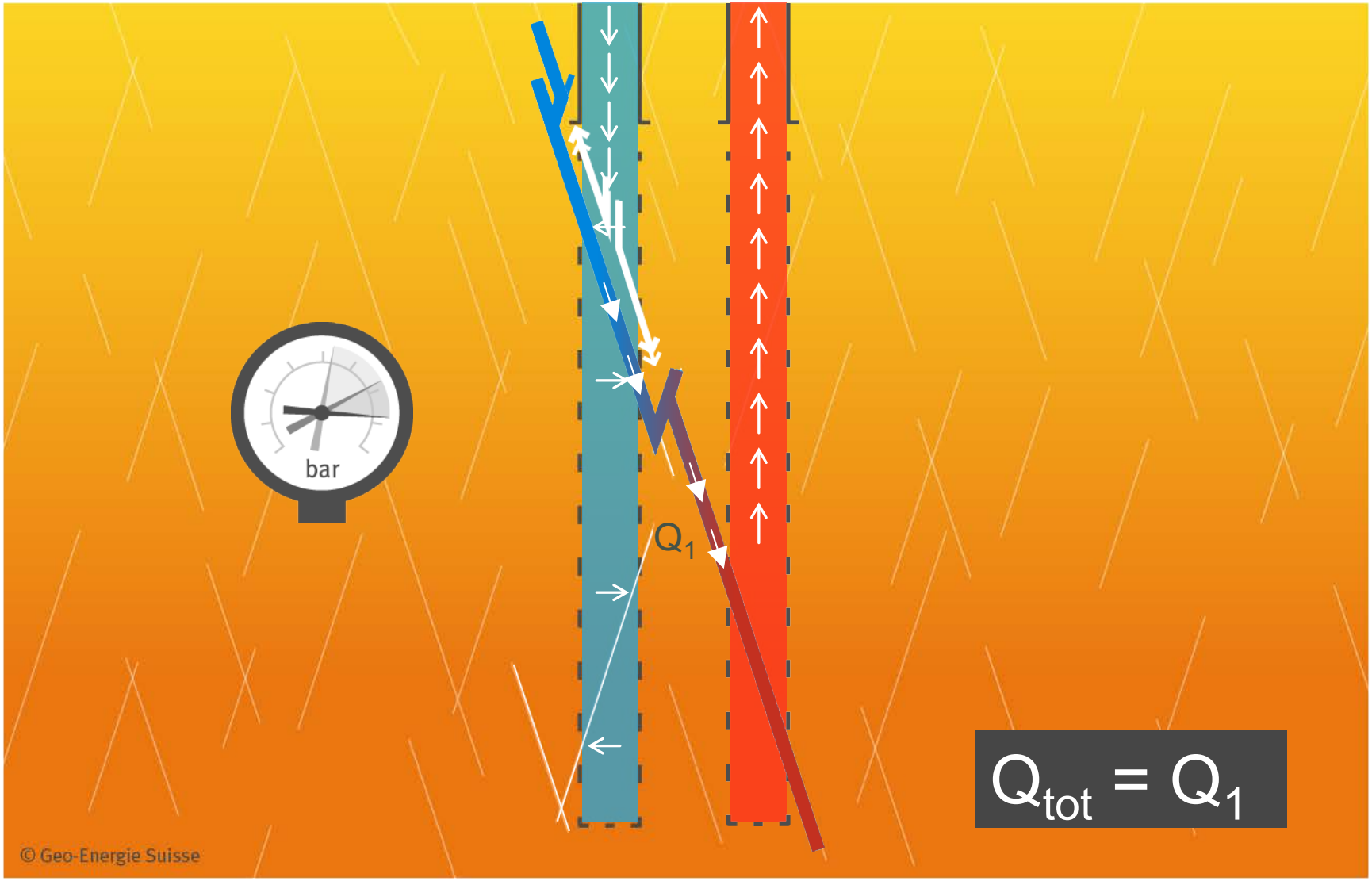


- In a strike-slip stress regime, a vertical disked-shaped reservoir develops during stimulation
- **→ In such stress regimes, the drilling of deviated wells is required**

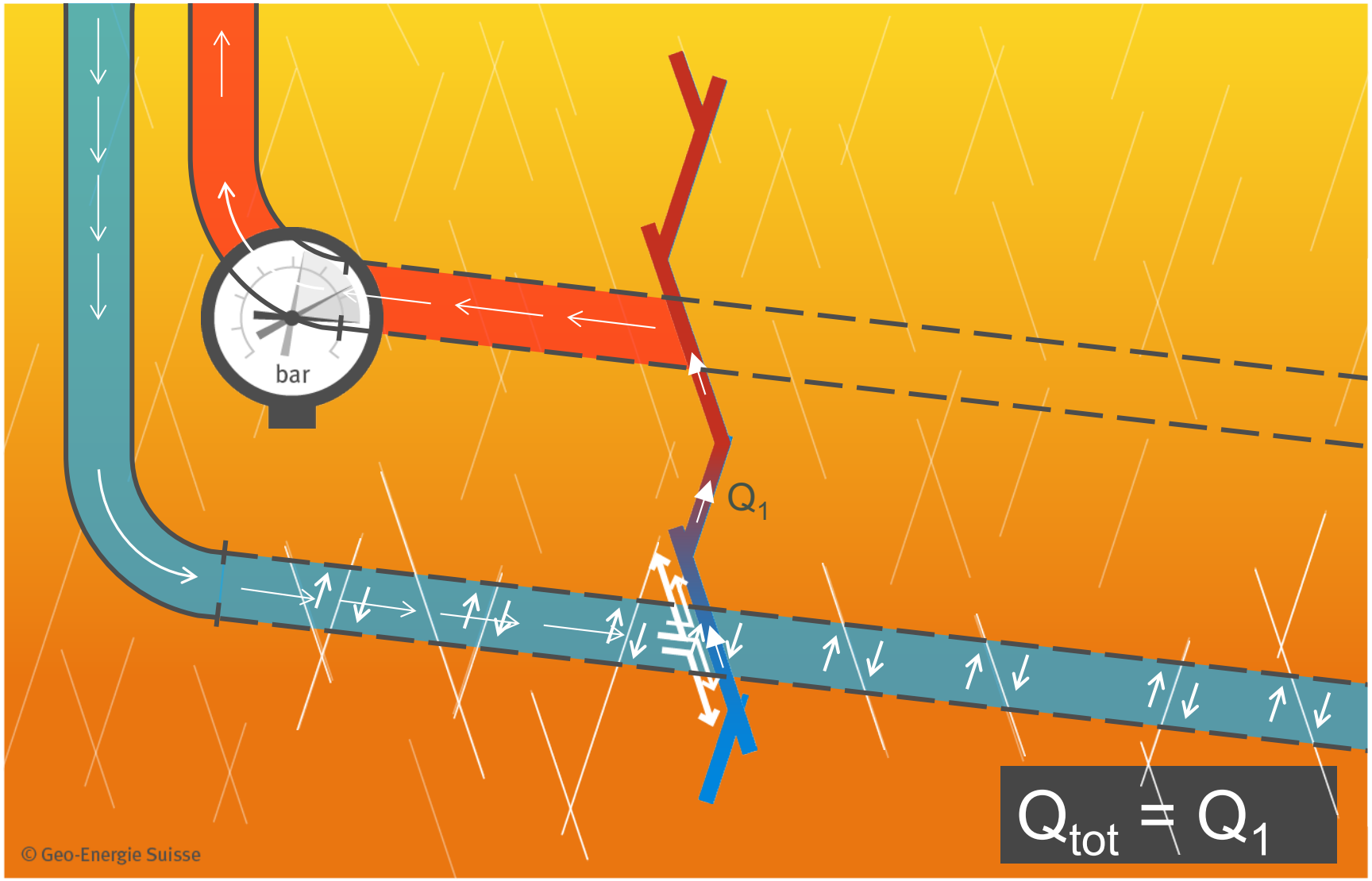
Seismic dataset showing the 3D geometry of the Basel reservoir after 3 months



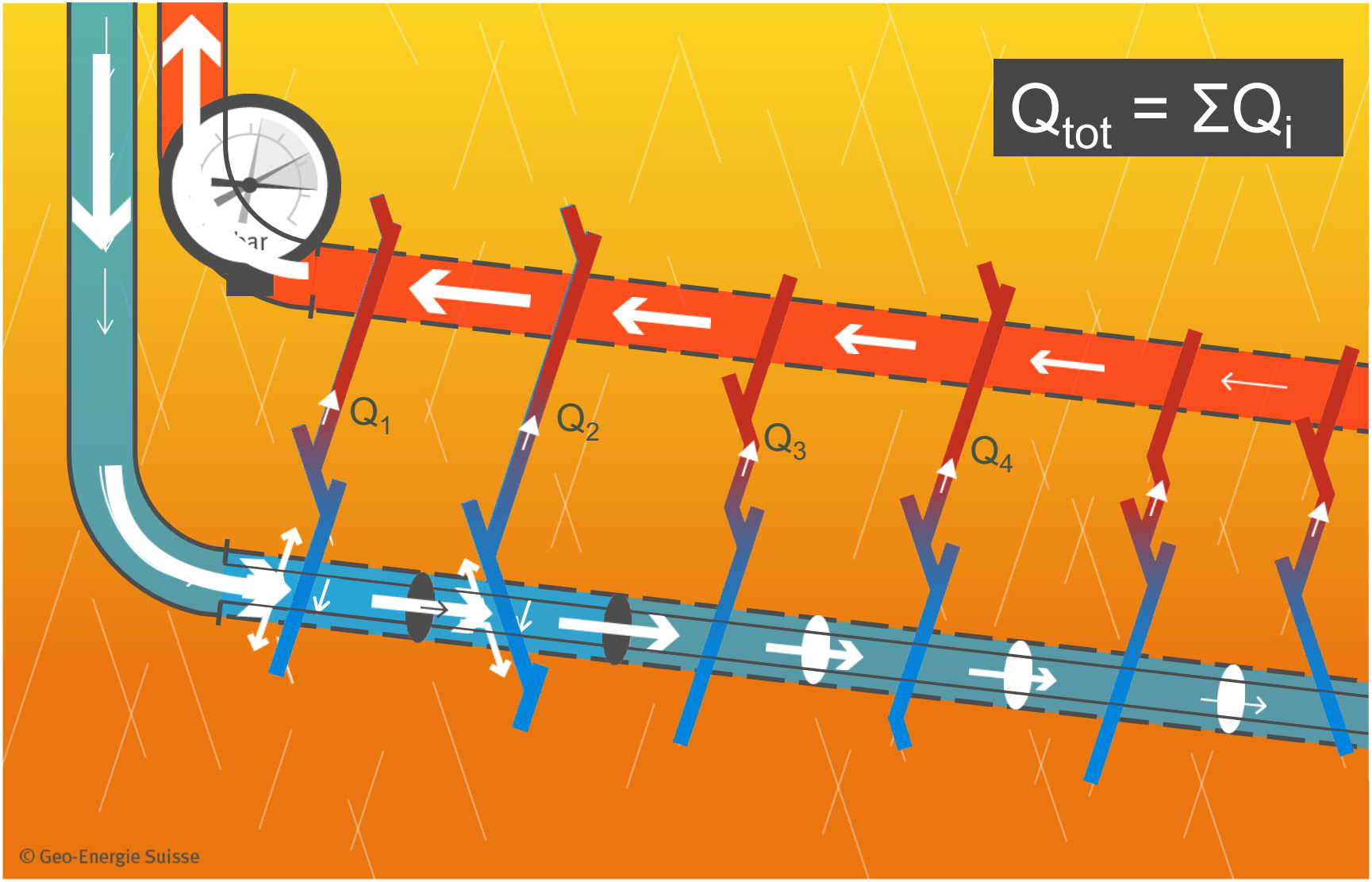
Stimulation of an open-hole vertical well



Stimulation of an open-hole deviated well

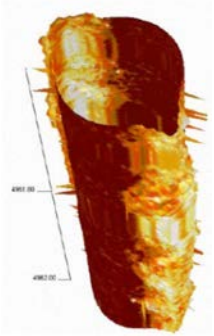


Multi-stage stimulation of isolated segments



Project DESTRESS / EU-Horizon 2020
Multi-stage and cyclic stimulation

Objectives
Demonstration of soft stimulation treatments of geothermal reservoirs.



Project description
16 Partners from research and industry from 6 European countries and South Korea will demonstrate soft stimulation in existing or planned boreholes at up to 7 sites in sedimentary and crystalline rocks.

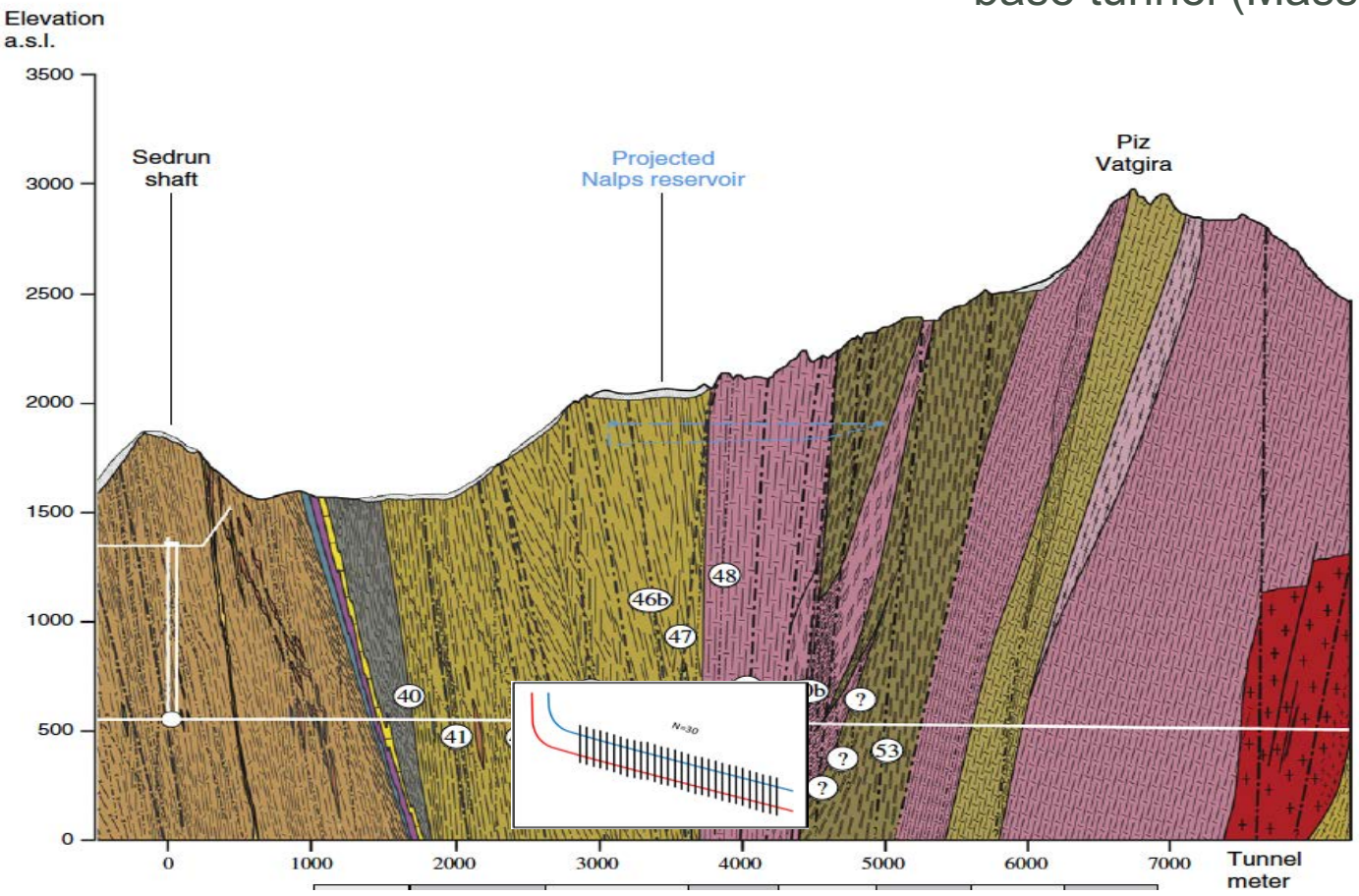
Significance
Geo-Energie Suisse focuses on the development and testing of zonal isolation techniques and multi-stage shear stimulation treatments at the Haute-Sorne site.

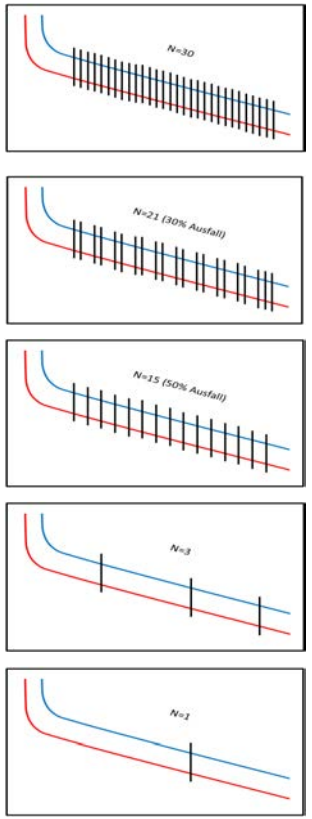
Budget
Total budget Euro 25 Mio., Geo-Energie Suisse CHF 5.6 Mio.

Project duration
March 2016 – February 2020

MC simulations to show chances of success

assuming rock conditions of the Gotthard base tunnel (Masset & Loew, 2013)





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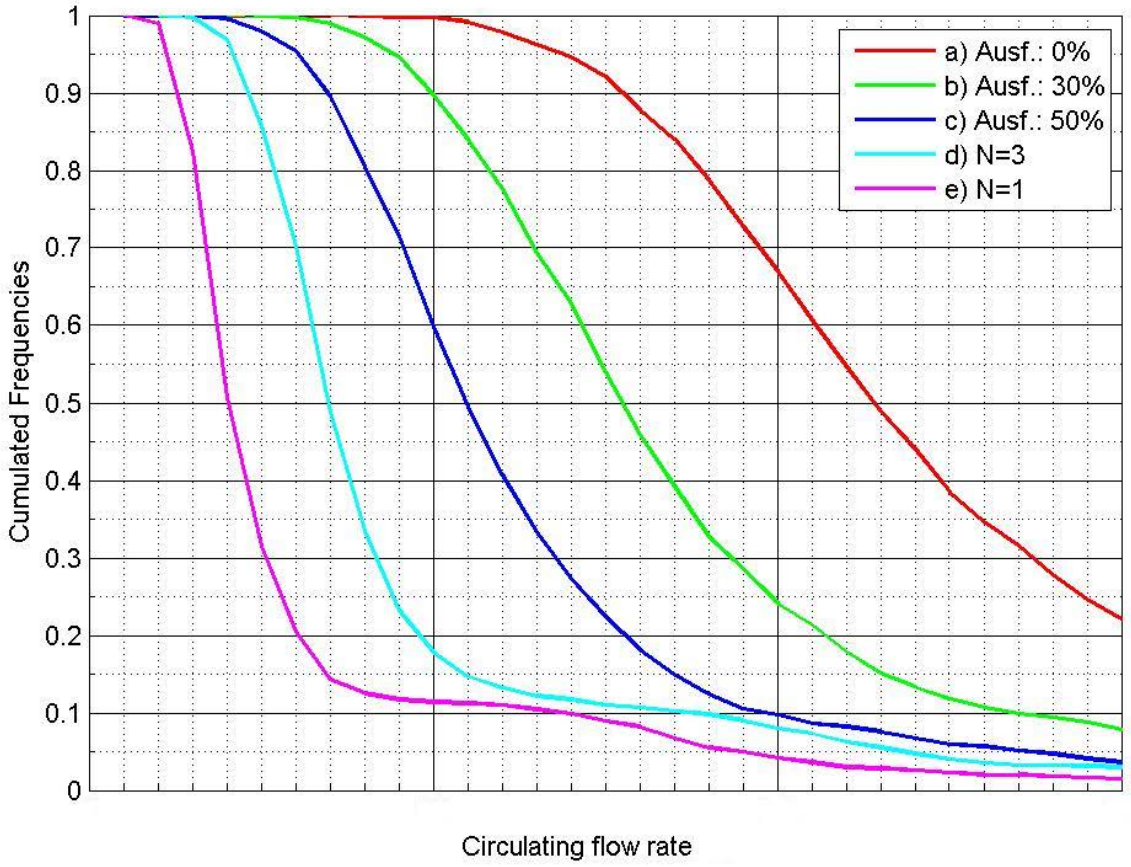
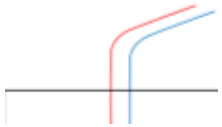
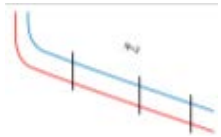
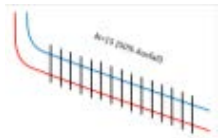
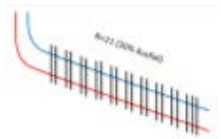
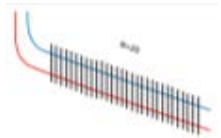
MC simulations demonstrate the improvement of circulation rates using a multi-stage stimulation system instead of a stimulation in an open borehole



GEO ENERGIE SUISSE

What are the economics?

Utilisation System		Increase Factor of: El. Power	Increase Factor of: Costs
	**Vertical Single-Open-Hole-System**, 1 fracture	**1**	**1**
	Single-Open-Hole-System, 3 fractures	1.8	1.2
	Multi-Stage-System; 50% failure rate of stages	2.9	1.6
	Multi-Stage-System; 30% failure rate of stages	4.2	1.6
	**Multi-Stage-System**; 0% failure rate of stages	**6.2**	**1.6**

Advantages of the multi-stage EGS concept compared to massive open-hole stimulation

Multi-stage stimulation

↓

High total reservoir permeability

↓

High water flow through the reservoir

↓

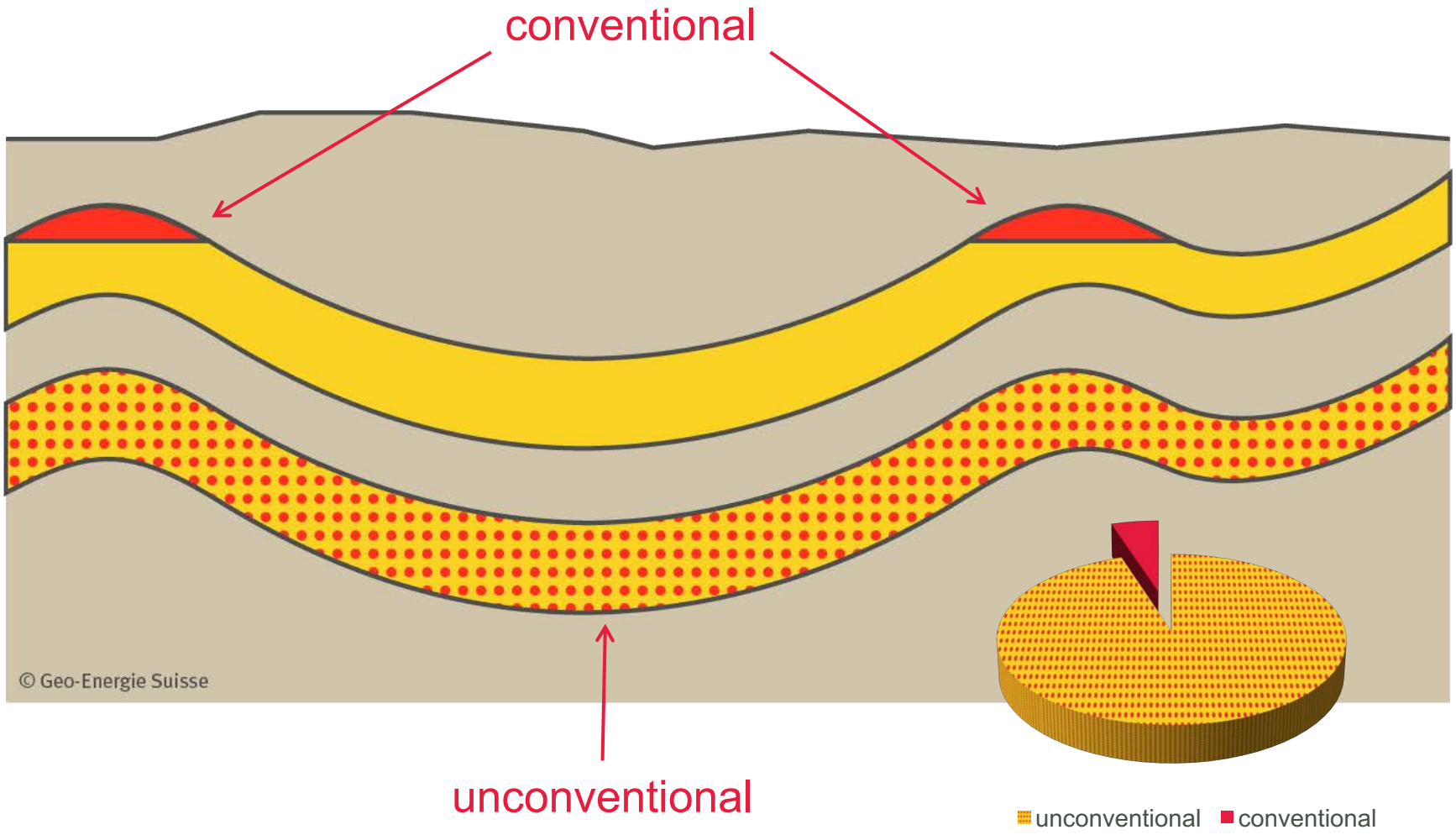
High energy yield of the reservoir

(up to a factor 10 compared to open-hole stimulation)

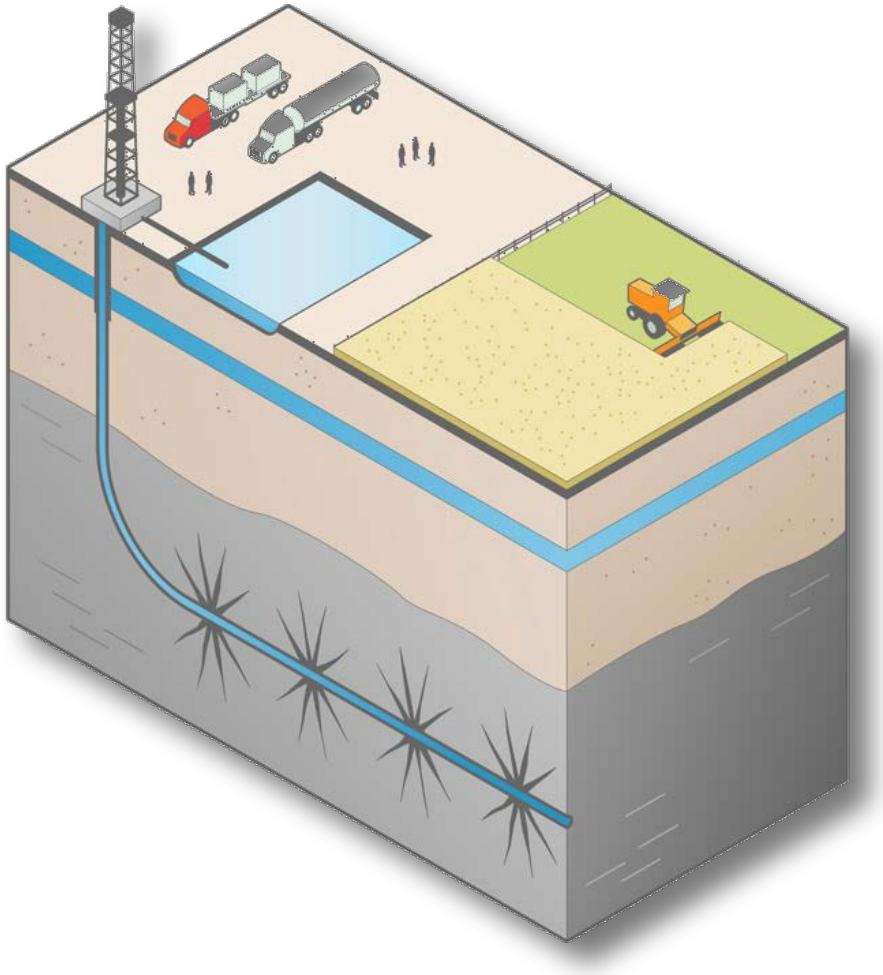
↓

High economic output

Analogy to the oil and gas exploration



Analogy to the oil and gas exploration



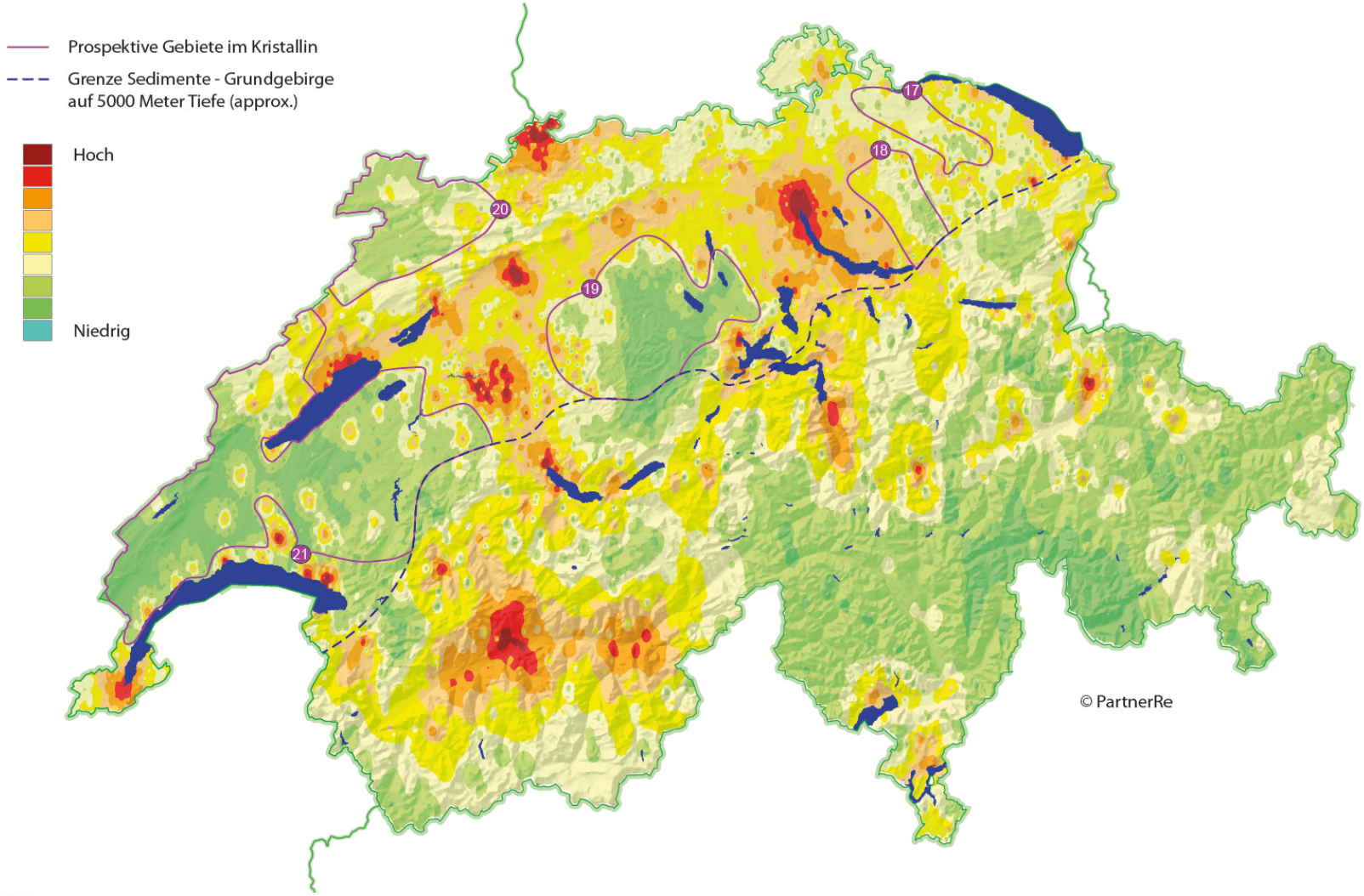
Message

- Similar to the oil and gas exploration, most of the geothermal potential is spread out throughout the underground and is not concentrated in the few places with high natural permeability.
- And similar to the oil exploration, new technologies make it now possible to tap into this tremendous reserve of energy.

Conclusion

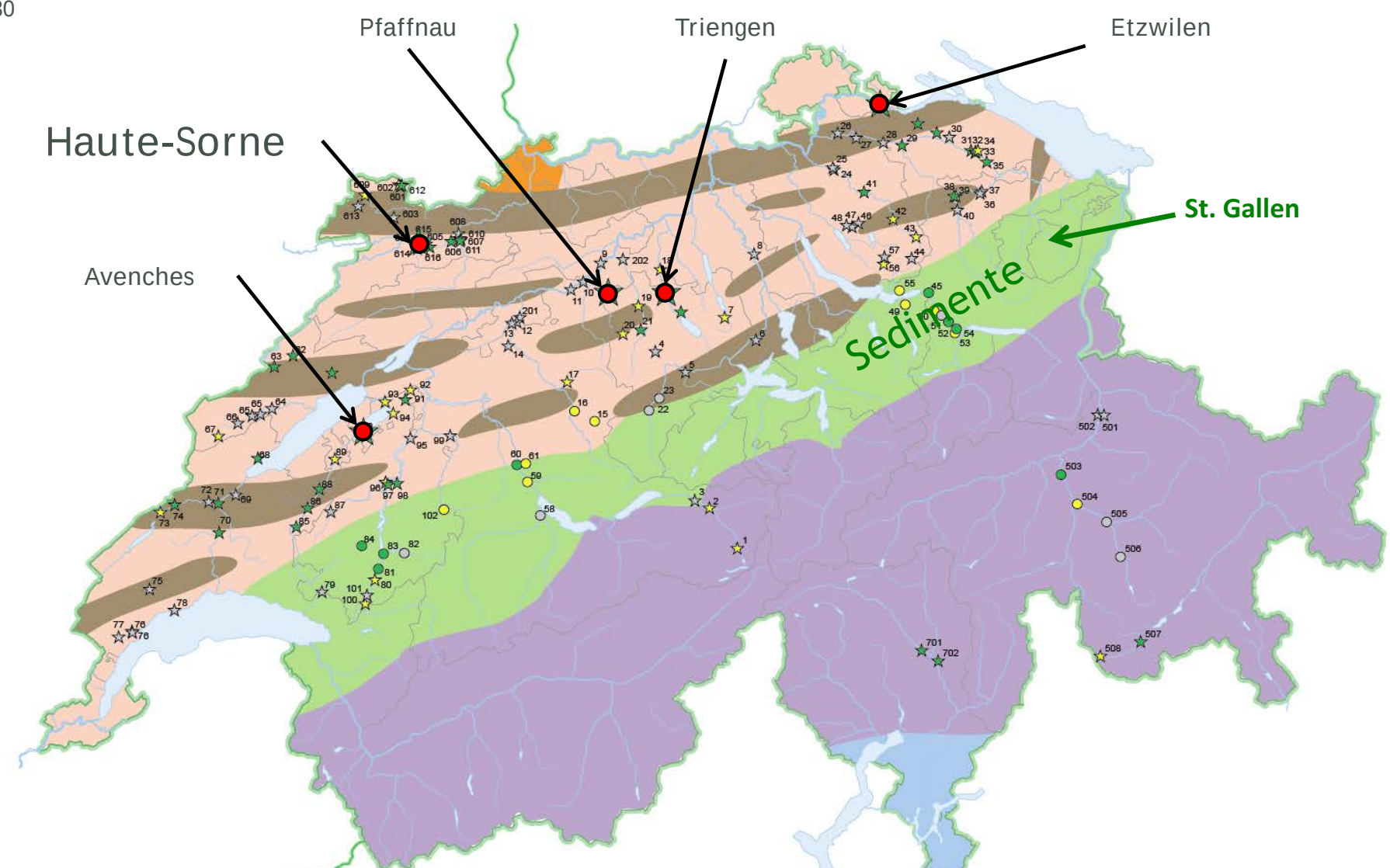
- Large geothermal potential resides in Switzerland, but also worldwide in low permeability rocks.
- New advances in technology make it now possible to tap into this abundant, indigenous, clean and renewable energy.
- The new multi-stage stimulation concept of Geo-Energie Suisse enhances the hydraulic output while reducing the seismic risk.
- R&D is needed and the concept has to been demonstrated in pilot projects.
- Do you consider multi-stage stimulation worth thinking about for geothermal reservoirs in your country?
- We are open to share our ideas and expertise!

Site selection EGS pilot plants: Low risk areas for first pilot projects and safety distance to large fault zones



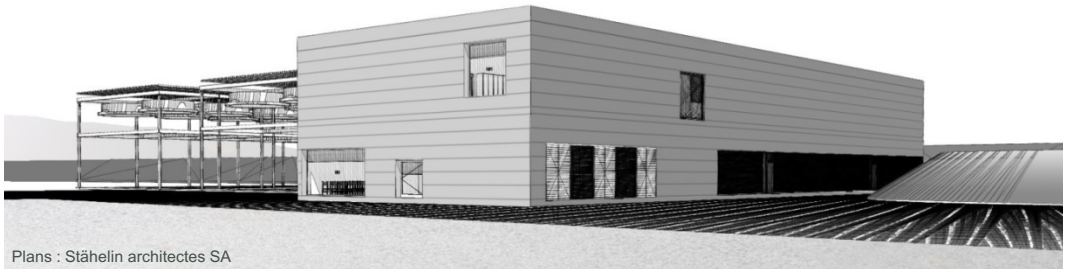
GEO ENERGIE SUISSE

130 potential sites for pilot projects were evaluated within different plays within crystalline basement and sediments



Haute-Sorne, Canton Jura

The Haute-Sorne EGS Pilot Project

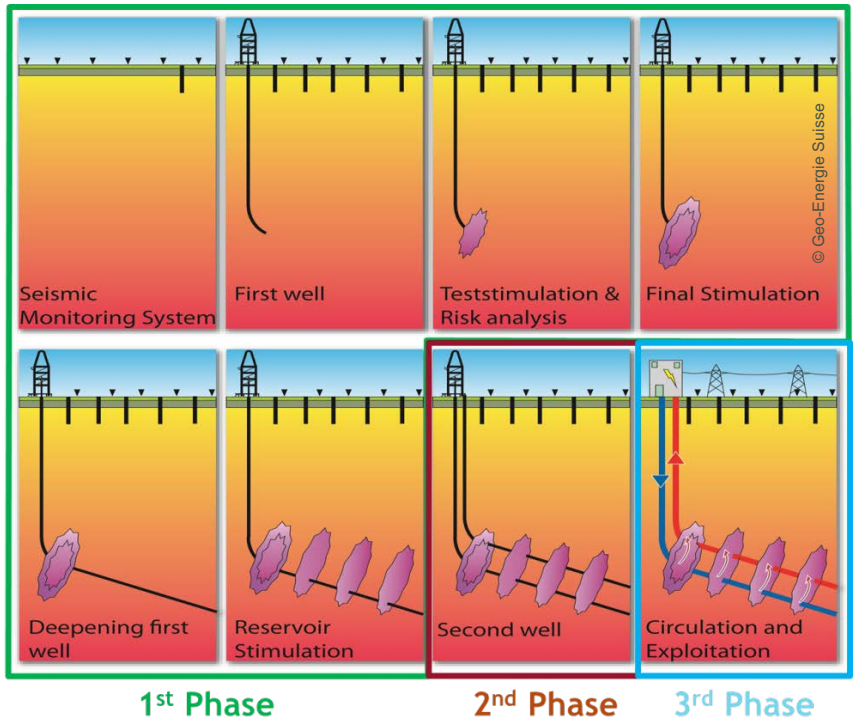

Plans : Stähelin architectes SA

Agenda

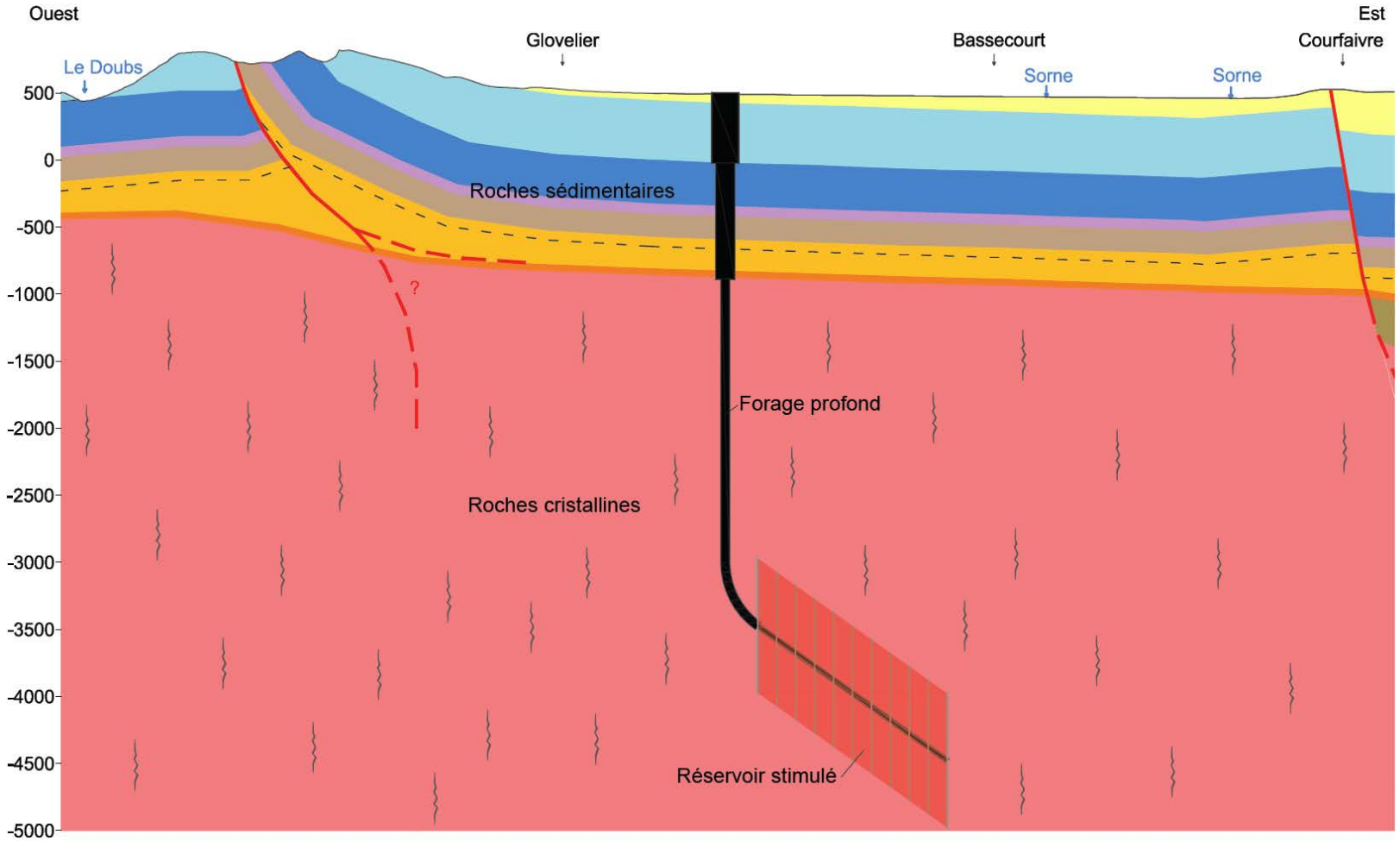
- 1st Phase: 2016-2018
- 2nd Phase: 2018-2019
- 3rd Phase: 2019-2020

Project Summary

- The Haute-Sorne pilot project in Canton Jura, Switzerland, is the first project worldwide that foresees multistage stimulation to achieve water circulation between two deep boreholes drilled trough the crystalline basement.
- The project is in the final phase of obtaining the risk guarantee from the State that covers up to 60% of the exploration costs in case of failure.
- As a pilot and demonstration project, subsidies from the State can be expected.



Geological cross section



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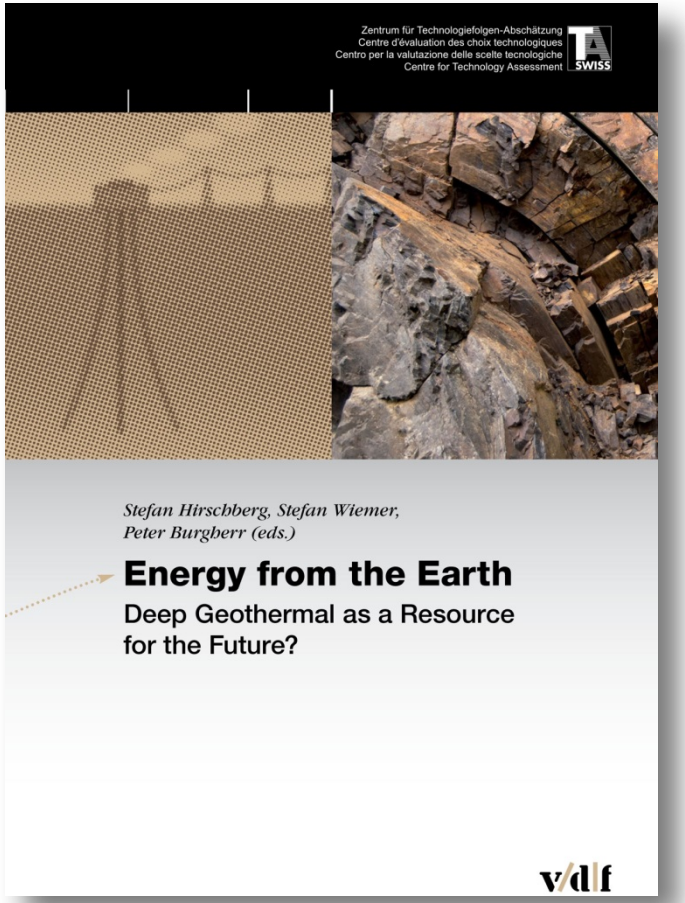
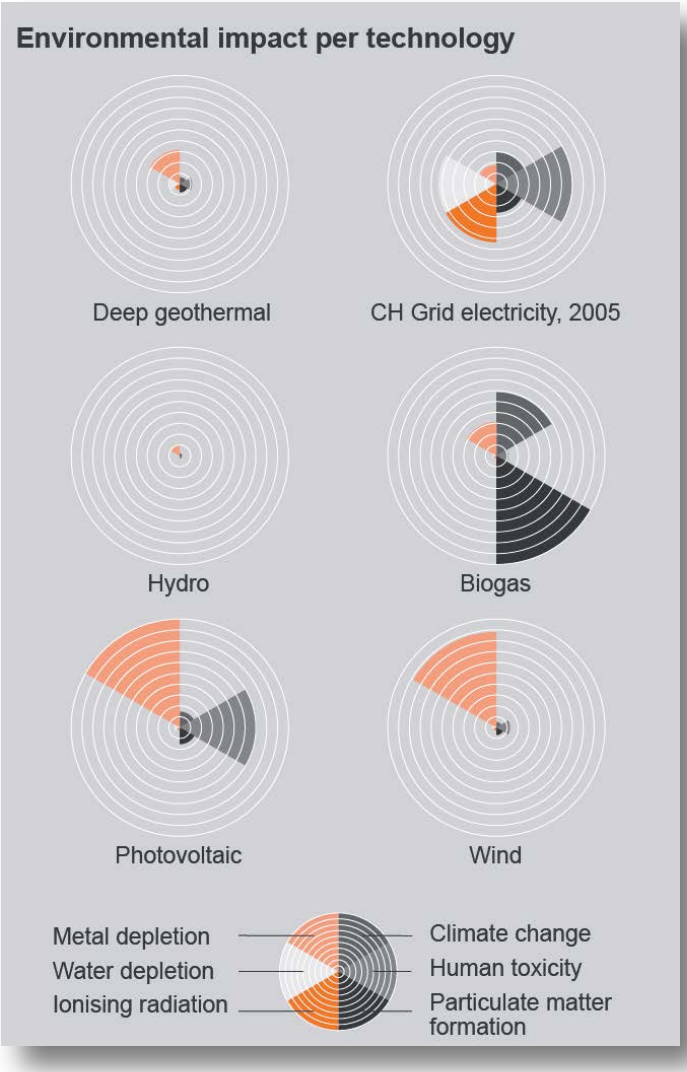
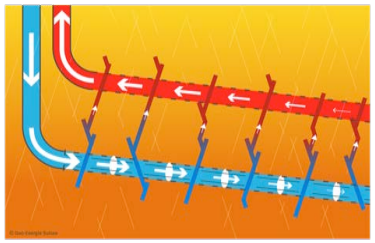
What's about the environmental impact?



https://www.ta-swiss.ch/en/projects/mobility-energy-climate/deep-geothermal-energy/



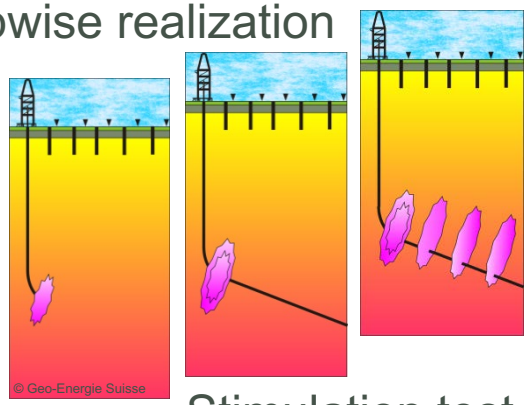
What's about the seismic risk?



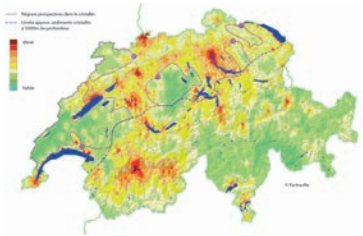
Safer concept

Risk studies

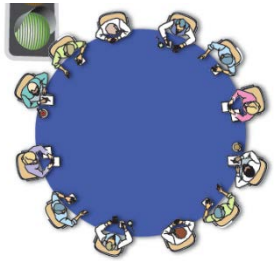
Stepwise realization



Stimulation test



Site selection



Continuous risk evaluation

Conservative traffic light system

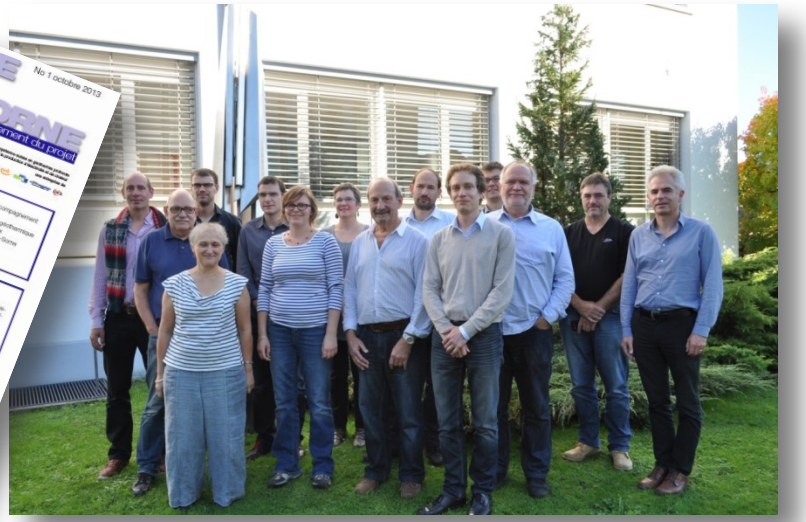
Real-time monitoring

Communication: Information Meetings

- Several information meetings organised for the population
- Specific information meetings for the political authorities
- Publication of 4 information bulletins

Communication: Accompanying group

- Representatives of cantonal and communal authorities, NGO's and Geo-Energie Suisse
- Information and discussion platform during planning and filing phases of the project
- Information relay for the population
- Regular meetings, publication of information bulletins



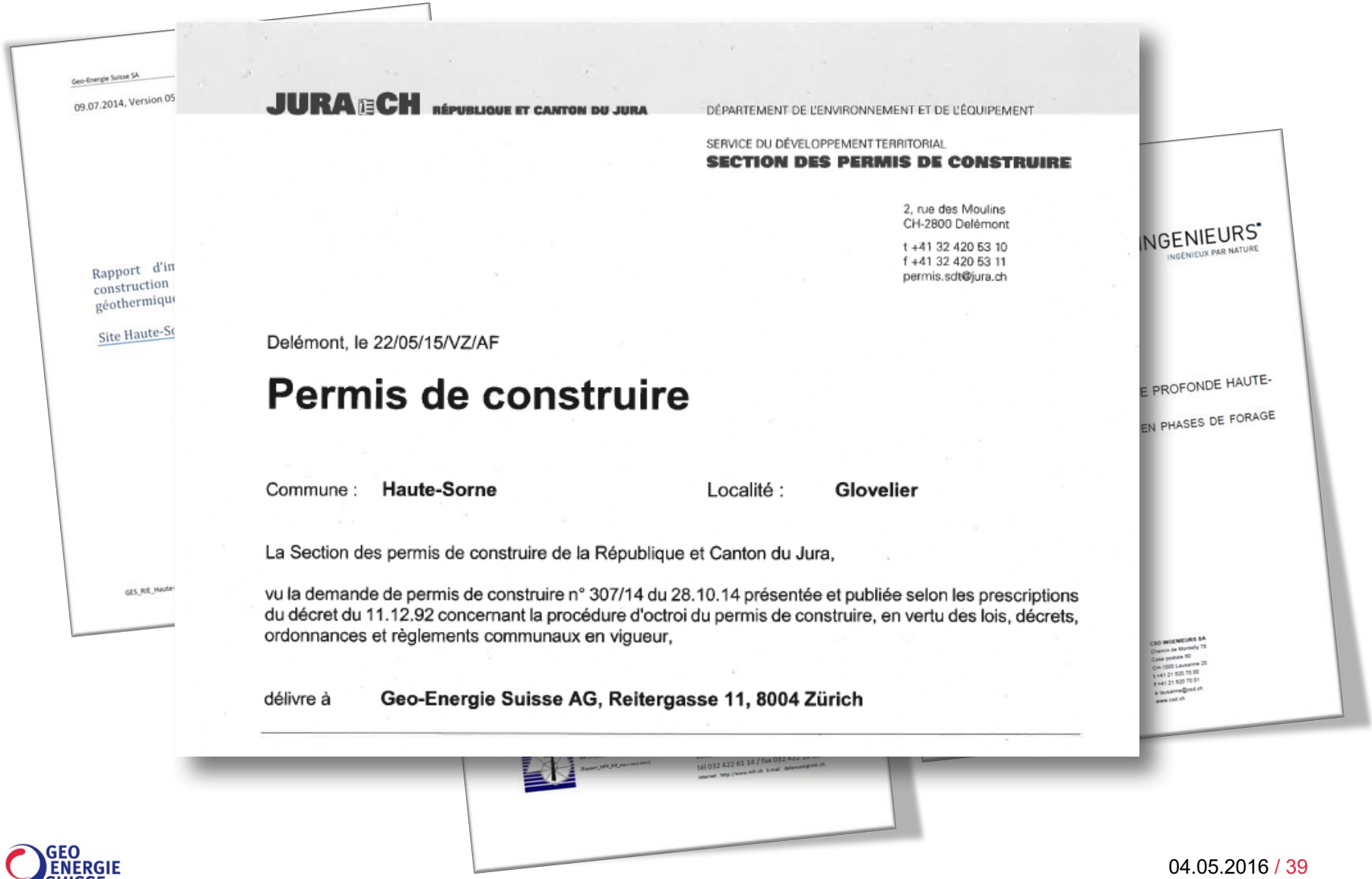
Permit delivered June 15, 2015

Peter Meier,
CEO
Geo-Energie Suisse

Philippe Receveur,
Minister
Canton of Jura

Jean-Bernard Vallat,
President
Commune of Haute-Sorne

What's about the environmental impact?



JURA CH RÉPUBLIQUE ET CANTON DU JURA

DÉPARTEMENT DE L'ENVIRONNEMENT ET DE L'ÉQUIPEMENT

SERVICE DU DÉVELOPPEMENT TERRITORIAL

SECTION DES PERMIS DE CONSTRUIRE

2, rue des Moulins
CH-2800 Delémont

t +41 32 420 53 10
f +41 32 420 53 11
permis.sdt@jura.ch

Delémont, le 22/05/15/VZ/AF

Permis de construire

Commune : **Haute-Sorne** Localité : **Glovelier**

La Section des permis de construire de la République et Canton du Jura,

vu la demande de permis de construire n° 307/14 du 28.10.14 présentée et publiée selon les prescriptions du décret du 11.12.92 concernant la procédure d'octroi du permis de construire, en vertu des lois, décrets, ordonnances et règlements communaux en vigueur,

délivre à **Geo-Energie Suisse AG, Reitergasse 11, 8004 Zürich**

Time plan Haute-Sorne

2012

Preliminary impact and risk studies

-Accompanying groups / public information

-Application of construction permit and main environmental impact and risk studies

2013

Examination by authorities

Permit 15.6.2015

2014

Risk guarantee BFE/Swissgrid (Dec 2016)

2015

Appeal cantonal administrative court (Dec 2016)

2016

Tendering drilling contractor for R&D (April 2016)

Vote on New Energy Law (May 2017)

Appeal Federal court (Summer 2017-Spring 2018)

2018

Decision cantonal initiative against geothermal (?)

2019

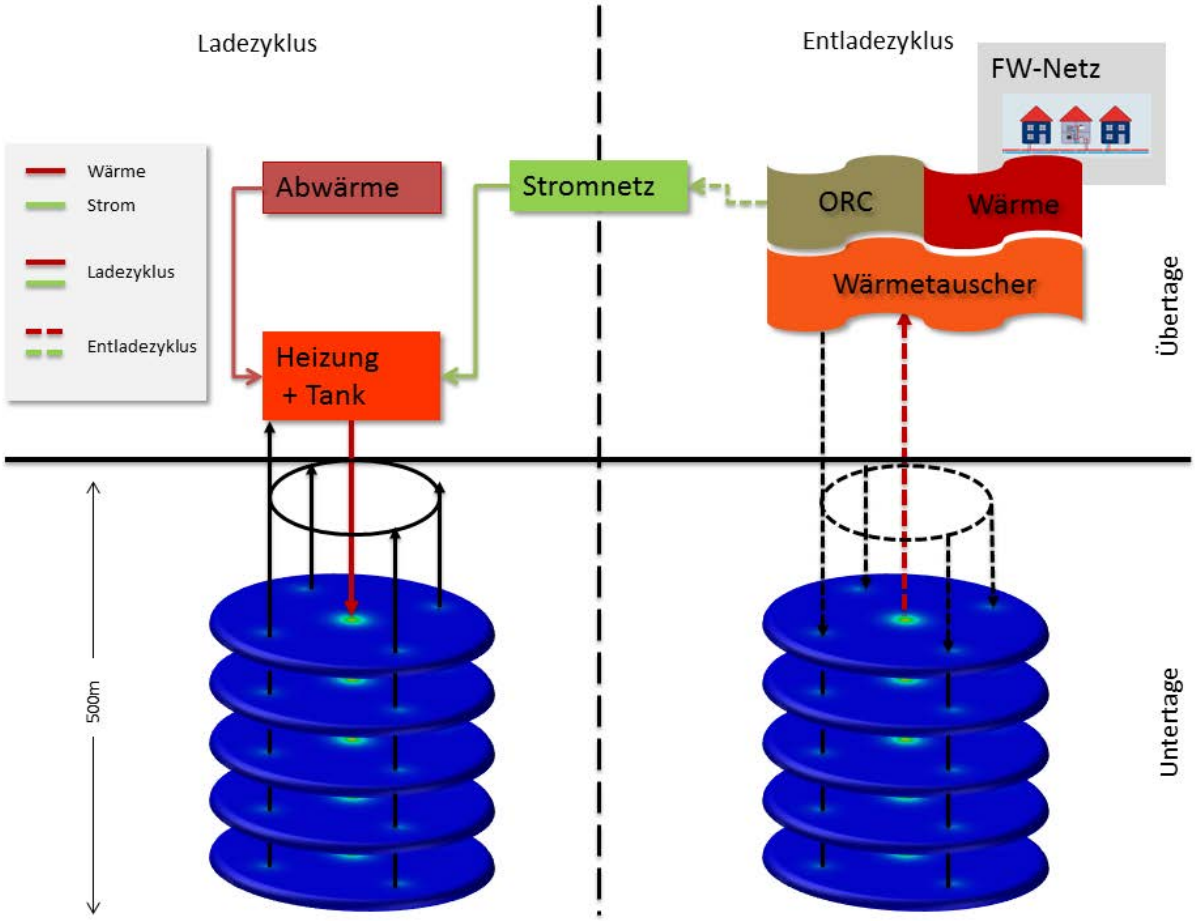
Drilling (180 days), Completion & Stimulation (150 days)

2020+

Power plant working

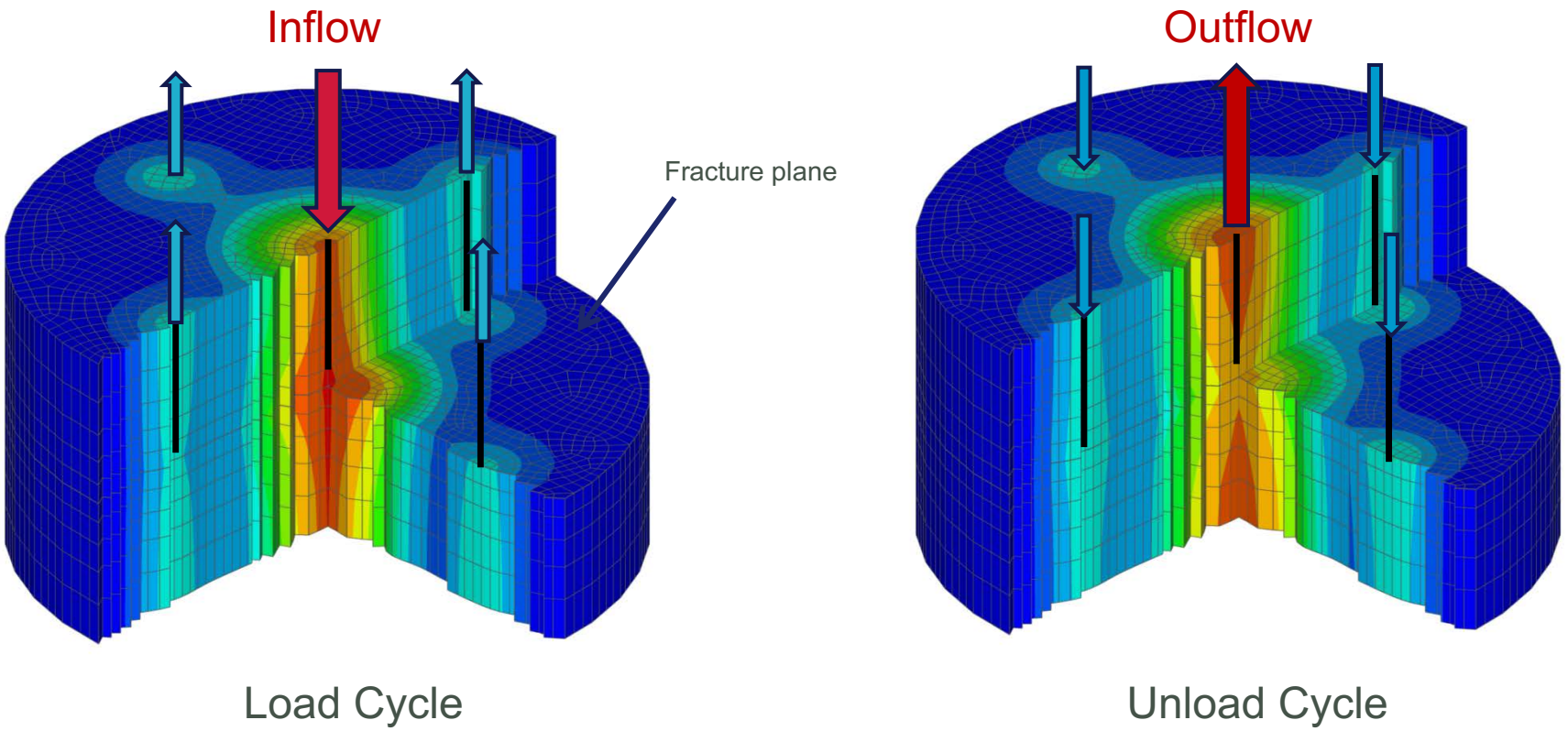
GEO ENERGIE SUISSE

Other applications using EGS / fracturing technology: Underground heat storage

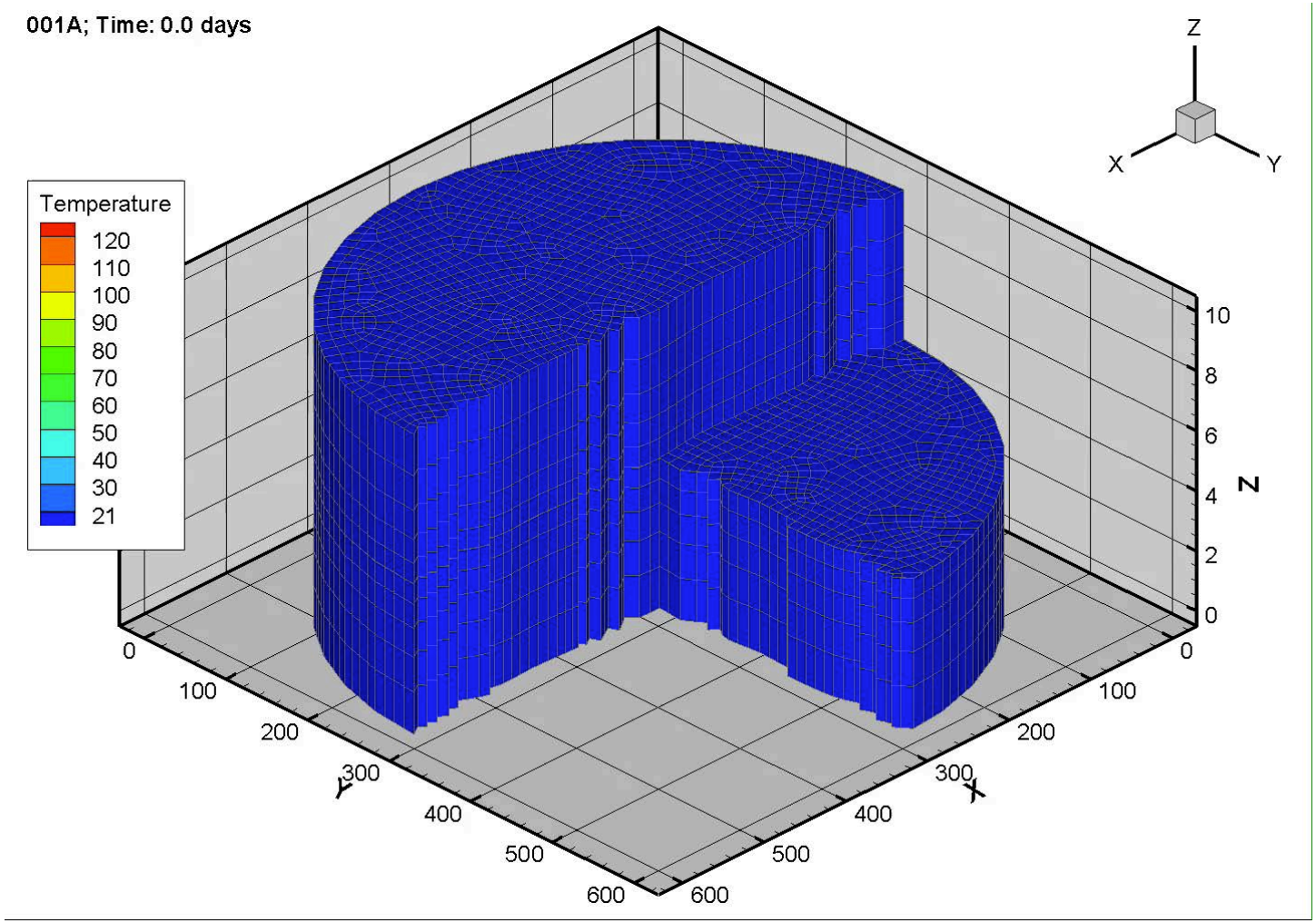


GEO ENERGIE SUISSE

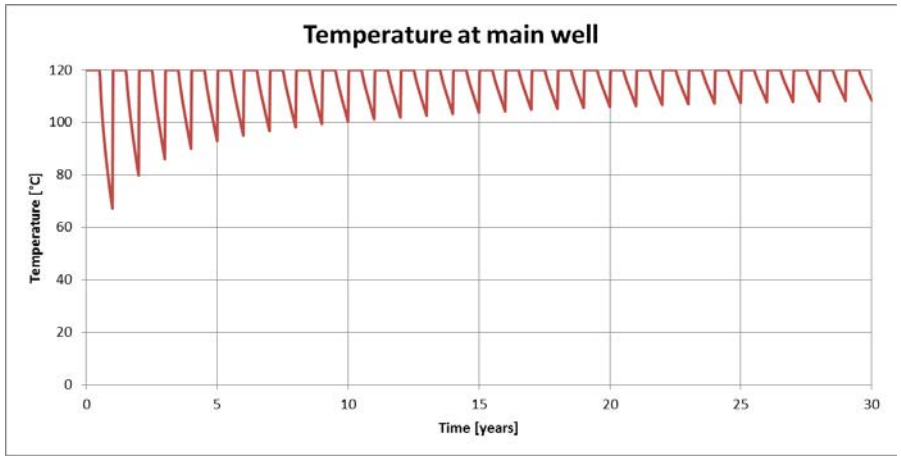
Loading / unloading of single fracture

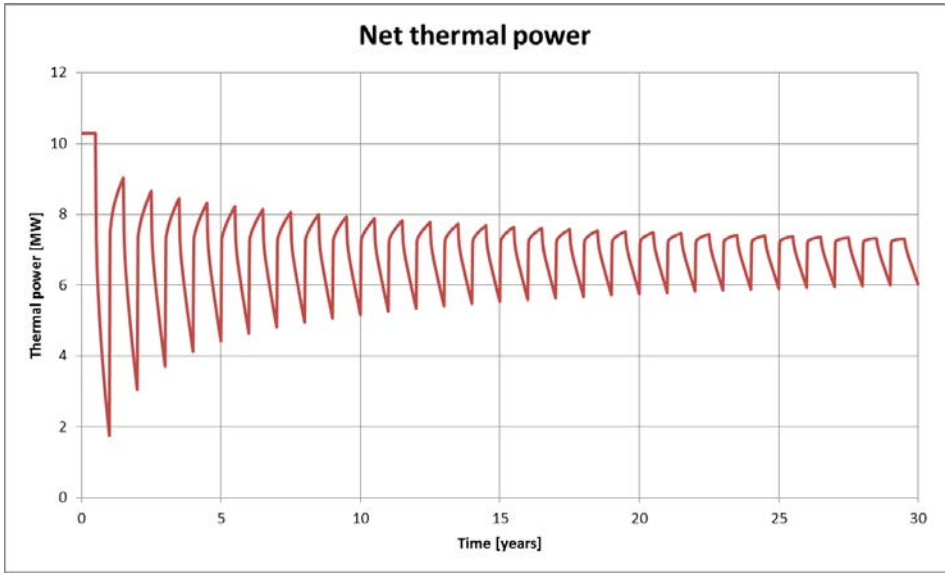


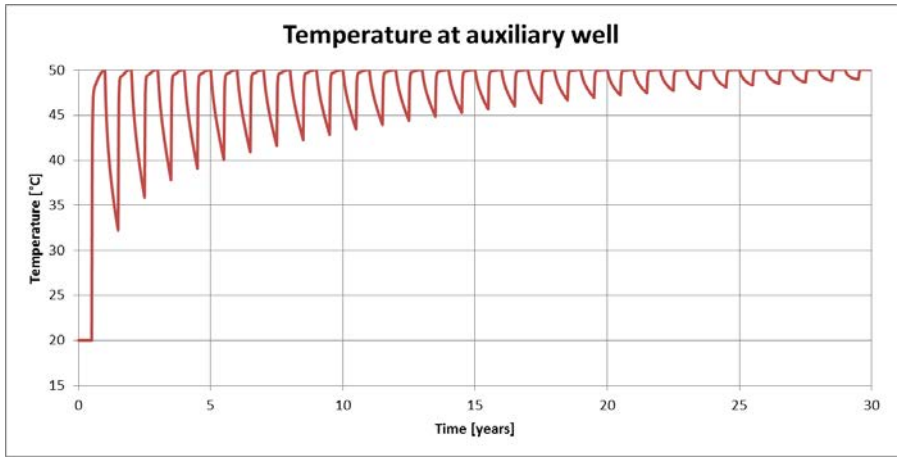
Loading / unloading of a single fracture



Temperature and power







SWISS COMPETENCE CENTER FOR ENERGY RESEARCH – SUPPLY OF ELECTRICITY/ENERGY (2013-2020)

Cooperative national programs:
- SFOE GEOSIM, GEOBEST
- CCES GEOTHERM-2
- SNF COTHERM

National research infrastructures:
- Deep Underground Laboratory
- Rock deformation laboratories
- NAGRA GTS, MontTerri
- Valais EPFL campus

WP1 Geo-energies: DGE & CO2 Sequestration

WP2 Hydropower: usage & infrastructures

WP3 Innovation agenda

WP5 Pilot & Demonstration projects

WP4 Future supply of electricity

Capacity building, Technology Transfer, Outreach

Integration with other SCCERs:
- Joint SCCER Scenario & Modeling Initiative
- Energy system analysis
- Risk and socio-economic drivers (CREST)
- Storage

NRP 70-71

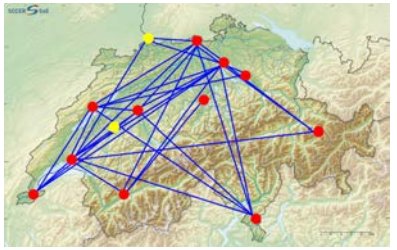
- Swiss Geological Survey@Swisstopo
- FOEN
- SFOE

Input from additional energy resources: biomass, WP, SP, nuclear, oil&gas

International programs:
- IPGT (AU, IS, NZ, US, CH)
- EERA, ERA-NET, IEA
- DOE FORGE, IDDP, DRG
- ICOLD
- ICDP

- EU FP7 projects: STREST, IMAGE, HYPERBOLE, GEISER, NERA, EPOS-PP
- EU H2020 projects: CONSENT, EPOS-IP, DESTRESS, SERA, CHALM
- ESFRI RI: EPOS, ECCSEL

55 FTEs working on geothermal energy



http://www.sccer-soe.ch/
Leading House ETH Zurich

ETH zürich

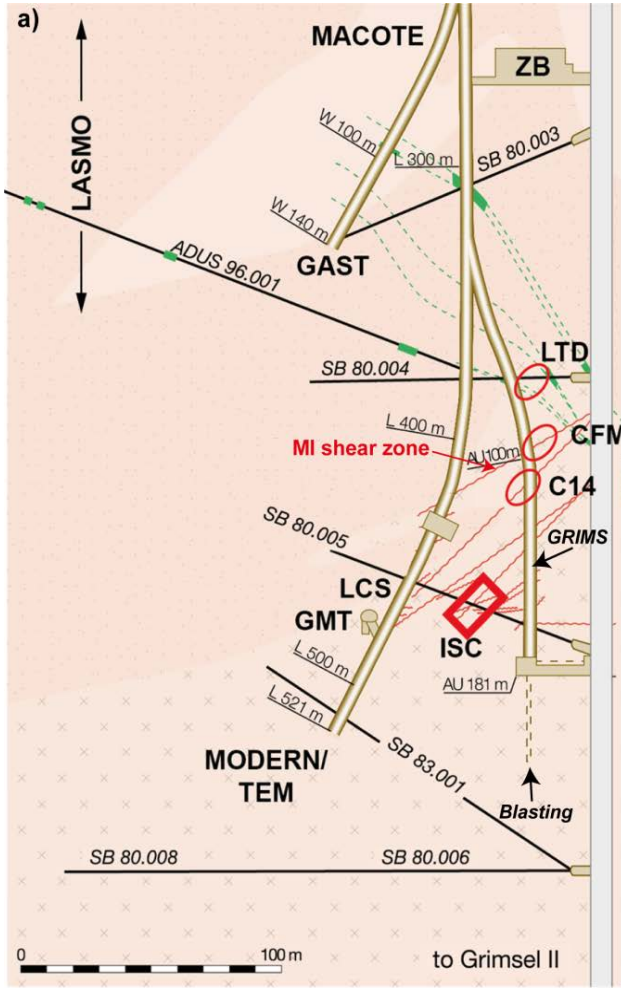
Flagship stimulation experiment in the deep underground laboratory, risk study

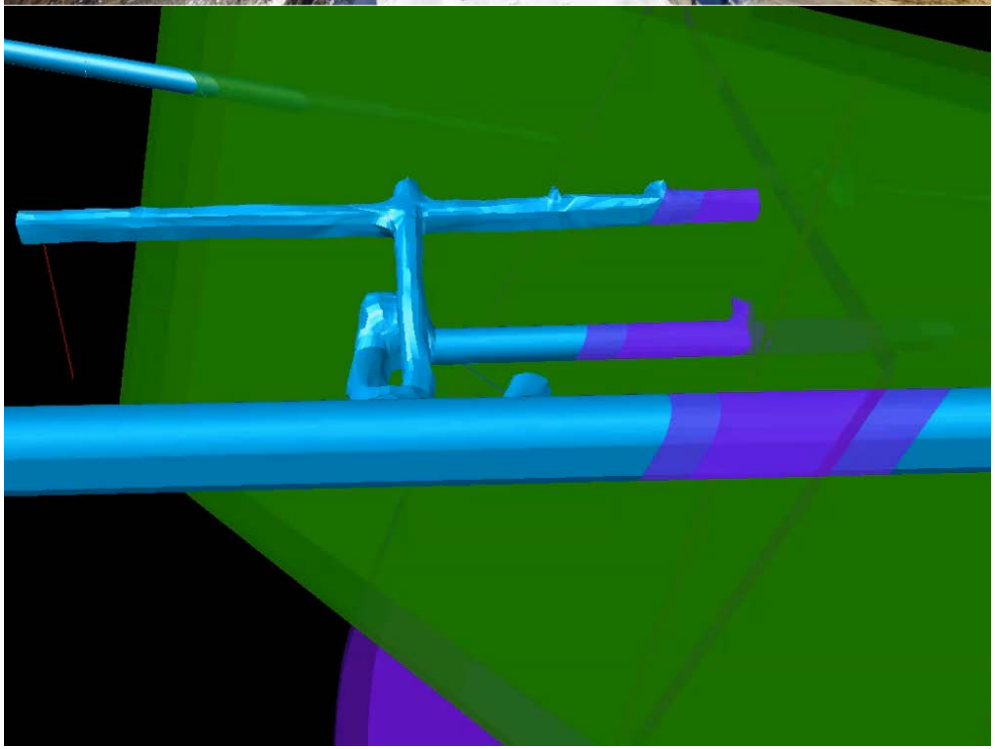
SCCER Annual meeting 12 – 13.09.2016, Sitten, Switzerland

F. Amann, V. Gischig, J. Doetsch, M. Jalali, M. Broccardo, S. Esposito, H. Krietsch, B. Valley, C. Madonna, M. Nejati, M. Klepikova, K. Evans, A. Kittlilä, C. Jordi, L. Villiger, B. Brixel, N. Dutler D. Giardini, HR. Maurer, M. Saar, S. Löw, S. Wiemer, T. Driesner

SCCER SoE

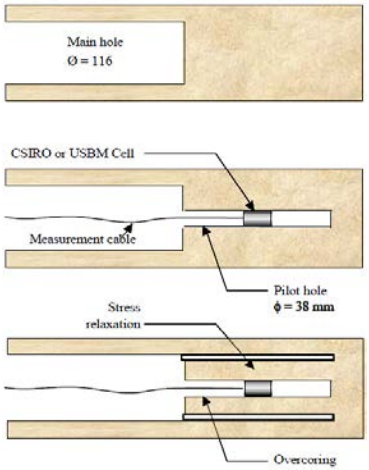
ISC experiment at the Grimsel Test Site

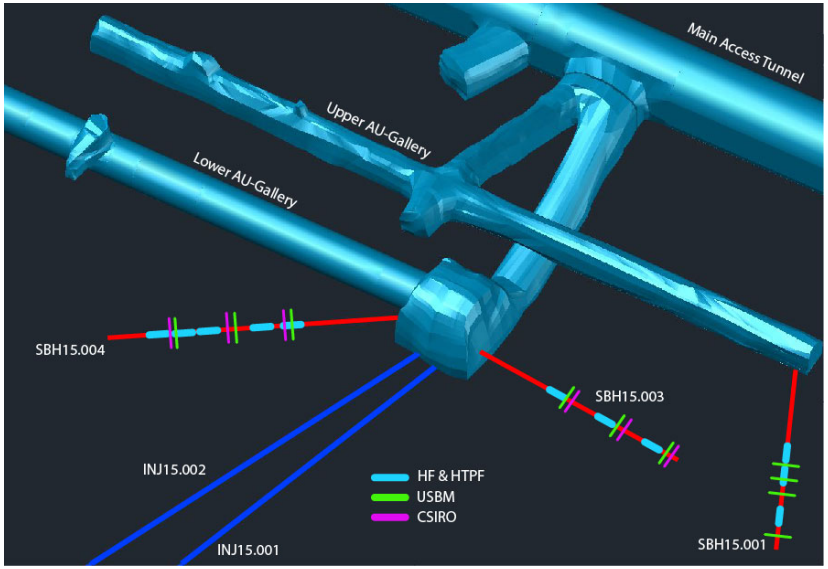


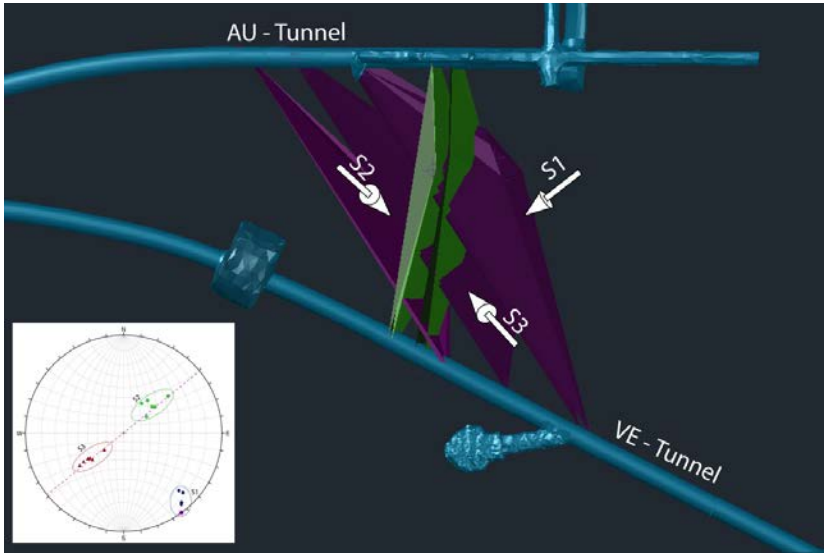


Stress measurements

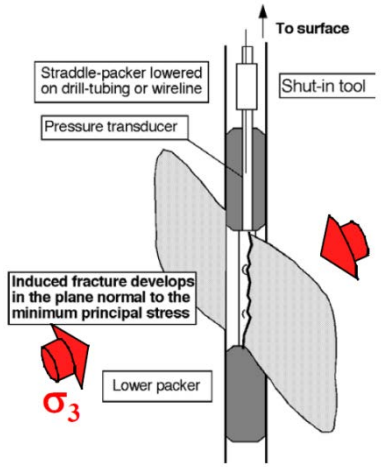
Overcoring





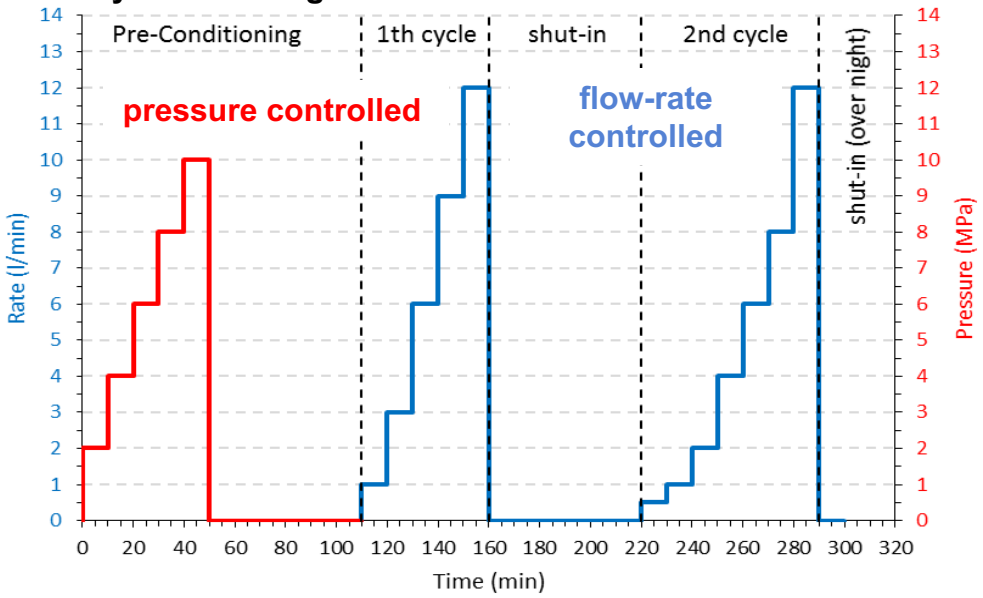


Hydraulic fracturing

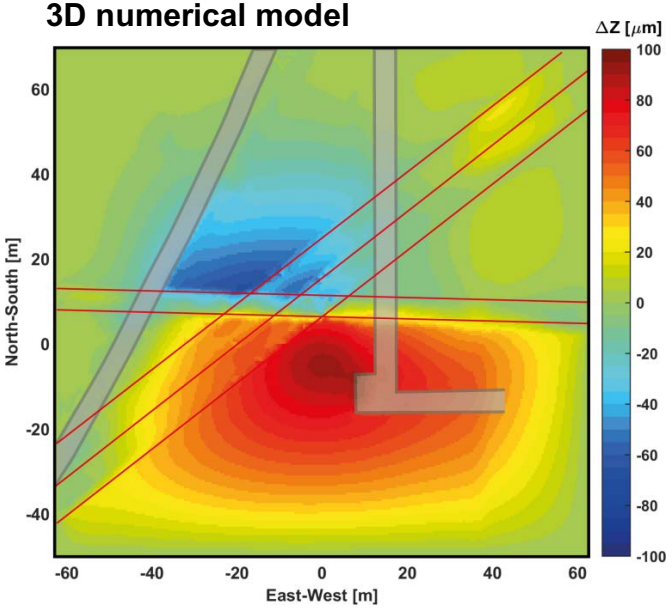


Stimulation phase

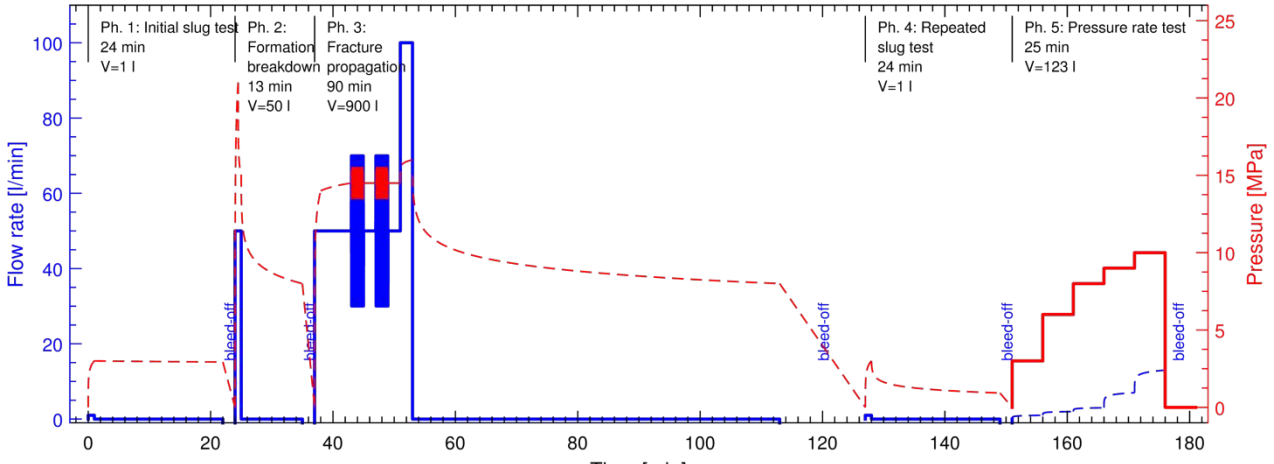
Hydro-shearing



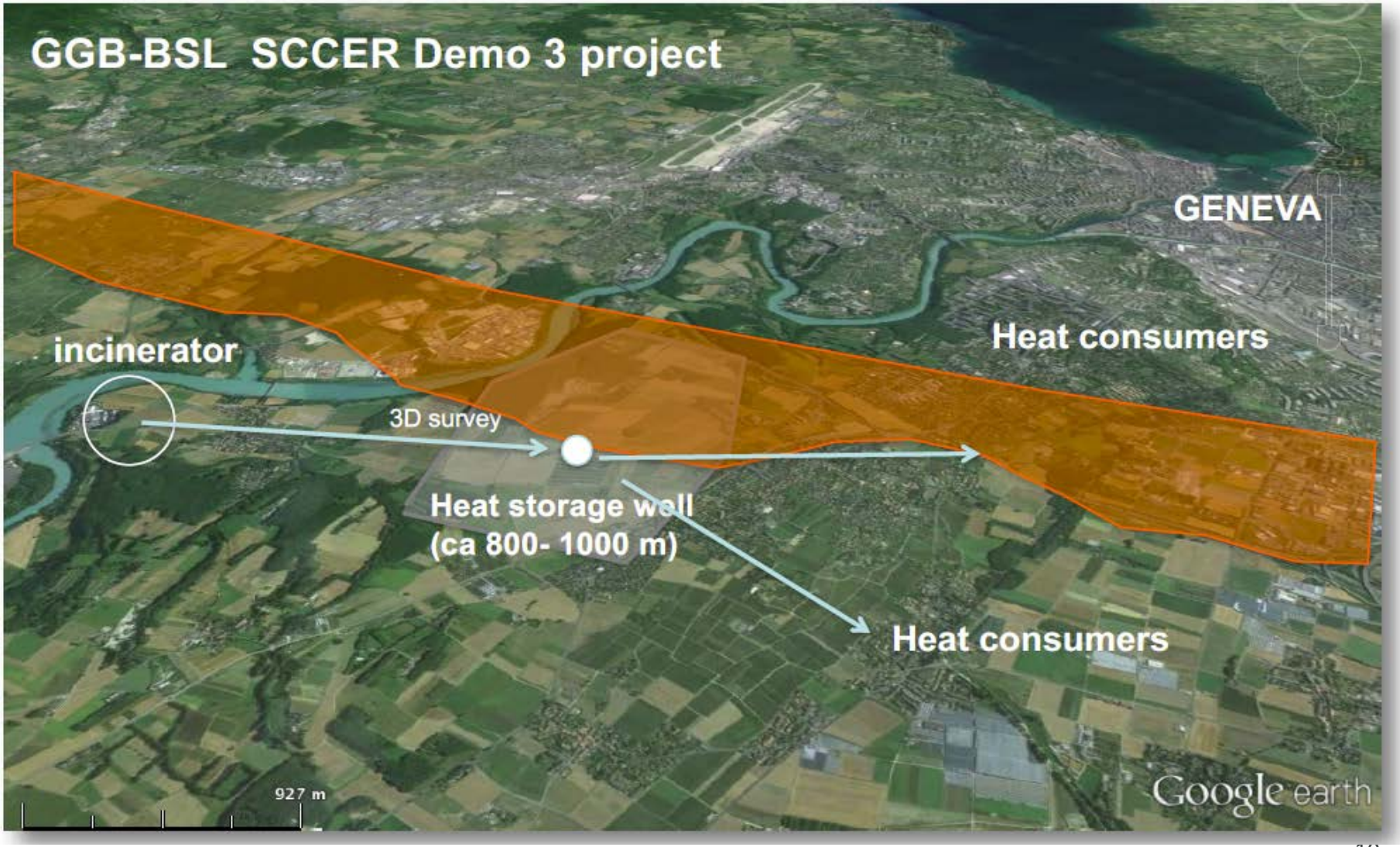
3D numerical model



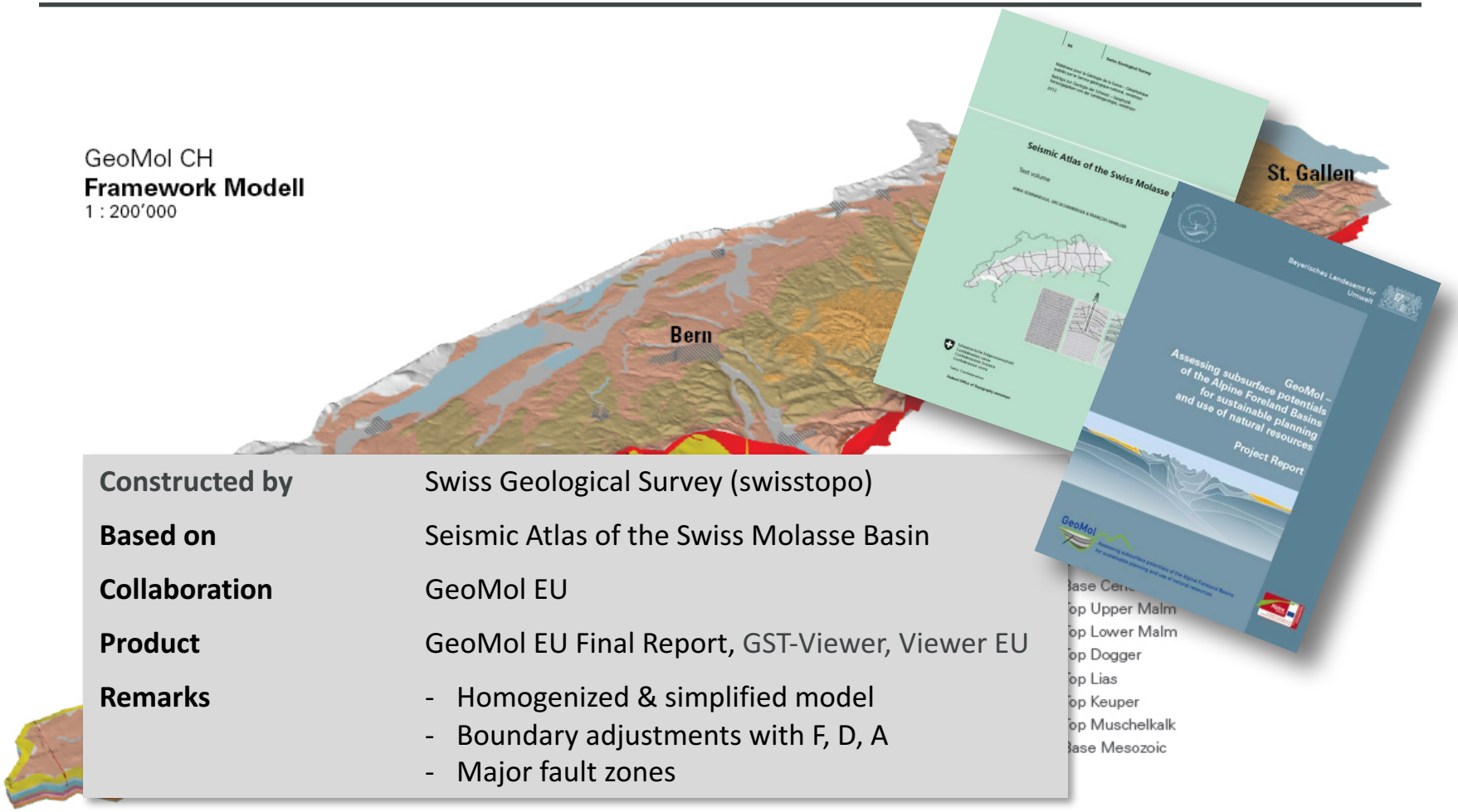
Hydro-fracturing



PROSPECTING EXPLORING FOR HEAT STORAGE AND USAGE IN THE GREATER GENEVA BASIN



GEO-DATA INFRASTRUCTURE AND ANALYSIS



Constructed by	Swiss Geological Survey (swisstopo)
Based on	Seismic Atlas of the Swiss Molasse Basin
Collaboration	GeoMol EU
Product	GeoMol EU Final Report, GST-Viewer, Viewer EU
Remarks	- Homogenized & simplified model - Boundary adjustments with F, D, A - Major fault zones

KEY FOR SUPPORT FOR GEOTHERMAL: REVISIONS OF A NUMBER OF ACTS (ENERGY, CO_2, NUCLEAR ENERGY, ...)

- June 2011: Federal Council (government) with approval of parliament decides to develop a new energy strategy
- Trigger: Fukushima, plus convergent trends (cost reduction renewables, climate change, political instability in Middle East and North Africa...)
- Sept 2013: Gov't sends bills to parliament
- Features: exit nuclear when no longer technically safe, up efficiency & savings, decrease fossils, increase renewables
- 30. Sep 2016: both chambers approve the Acts (optional referendum if 50'000 signatures are collected within 3 months against the Acts)
- Nationalist conservatives launch collection of signatures and collect ~68'000 by 20 Jan 17)
  -> 21 May 2017 Swiss population will vote
- In parallel, a people's initiative (100'000 signatures) calls for shut-down of nuclear after 45 years of operation
- 45 years means that 3 of 5 plants would have had to be shut in by the end of 2017
- Swiss voters reject «accelerated» phase-out vs. «orderly» phase-out on 27 November 2016 with a solid majority of 54%
- In parallel, 1 February 2017: Federal Administration launches the consultation process of ordinances (implementation rules of policy support measures) which are subordinate to the Acts
- Subject to 21 May 2017 results: all will enter into force on 1 January 2018

HEADLINES: 1ST SET OF MEASURES TO IMPLEMENT SWITZERLAND'S ENERGY STRATEGY 2050

No new nuclear (ea. of the 5 existing ones [24 TWh in 2015] retire at end of their technical/safe lifetime)

New renewables (excl. hydro) targets for electricity production:

2015: 2.8 TWh; 2020: 4.4 TWh

2035: 11.4 TWh

Energy consumption relative to the year 2000:

2000: 854 970 TJ, 2015: 838 360 TJ

2020: -16% and 2035: -43% (rel. 2000)

Of which electricity consumption:

2000: 52.4 TWh, 2015: 58.2 TWh

2020: -3% and 2035: -13% (rel. 2000)

CO_2 targets remain unchanged:

-20% by 2020 rel. to 1990

Revision of CO2-Act has been initiated

New target: -50% by 2030 rel. to 1990
-30% domestic and -20% foreign

Geothermal energy policy measures (target enforcement date: 1.1.2018)

Geothermal guarantee scheme (until 2031)

Increase coverage to 60% of total sunk subsurface development cost

Exploration support scheme (until 2031)

Max. 60% towards pre-spud exploration activity and first wells to confirm the presence of a reservoir

Both schemes are funded via a max. 0.1 Rp. per kWh from high voltage grid surcharge (for *all* measures a cap of max. 2.3 Rp per kWh)

Feed-in tariffs continue (until ~2024)

Support scheme for direct use geothermal energy (until 2020, and likely to 2025)

CHF 30 mln p.a. from CO_2-levy on heating oil

Geothermal in the "national interest"

Accelerated planning and permitting

PLANNED POLICY SUPPORT MEASURES FOR GEOTHERMAL – ENERGY ACT / CO2-ACT

Energy Act Art. 33 Contributions to exploration and Geothermal guarantees

- Program financed by a max. CHF 1 per MWh of electricity transmitted via the national high voltage grid (~ 60 TWh) -> at most CHF 60 mln per year

Energy Act Art. 19 Feed-in tariffs for geothermal energy

Installed Capacity	Hydrothermal (CHF / MWh)	Enhanced/Engineered Geothermal Systems (CHF / MWh)
≤5 MW	400.0	475.0
≤10 MW	360.0	435.0
≤20 MW	280.0	355.0
>20 MW	227.0	302.0

Average retail / consumer end price: CHF 150 / MWh
Average annual consumption 4 person single family home: ~ 5 MWh

PLANNED POLICY SUPPORT MEASURES FOR GEOTHERMAL – ENERGY ACT / CO_2-ACT

Energy Act Art. 33 Contributions to exploration and Geothermal guarantees

[1]Prospecting and exploration activities for geothermal power projects may be supported by a financial contribution of up to 60%

[2]Geothermal guarantees may be given to cover investments into exploration and development of geothermal resources for power generation. The guarantee may not exceed more than 60% of the admissible costs.

[3]An exploration project may not receive a geothermal guarantee.

[4]The Federal Council specifies the implementation rules, in particular the admissible costs and the procedures.

CO2-Act Art. 34 § 2

[2]To minimize in the long-term CO_2-emissions in the building sector the Confederation may support projects for direct use of geothermal energy to supply heat. The Confederation dedicates a small part [of the CO2-tax revenues] but no more than CHF 30 million per year. The Federal Council specifies the implementation rules, in particular the admissible costs and the procedures.

1 CHF ~ 1USD
CO_2-tax: levied on fossil fuels used for heating; currently CHF 84 per ton of CO_2 About CHF 900 million in tax revenues, of which CHF 300 million towards the *building program (energy savings, efficiencies and CO_2 emission reductions)* and the remainder towards rebates on health insurance and employer's social insurance premiums

PLANNED SUPPORT FOR GEOTHERMAL IN SWITZERLAND

Estimated Monetary Value of a Project (EMV)
=
Probability of Success (POS) * $NPV_{success}$
+
Probability of Failure * $NPV_{failure}$

Installed Capacity (P_{el})	Feed-in tariff (Rp./kWh)
≤ 5 MW	40.0 / 47.5
≤ 10 MW	36.0 / 43.5
≤ 20 MW	28.0 / 35.5
> 20 MW	22.7 / 30.2

$$EMV = POS*NPV_{success} + (1-POS)*NPV_{failure}$$

Federal exploration grant: 60% prospecting and 60% of proving the reserve (i.e. 1st well)

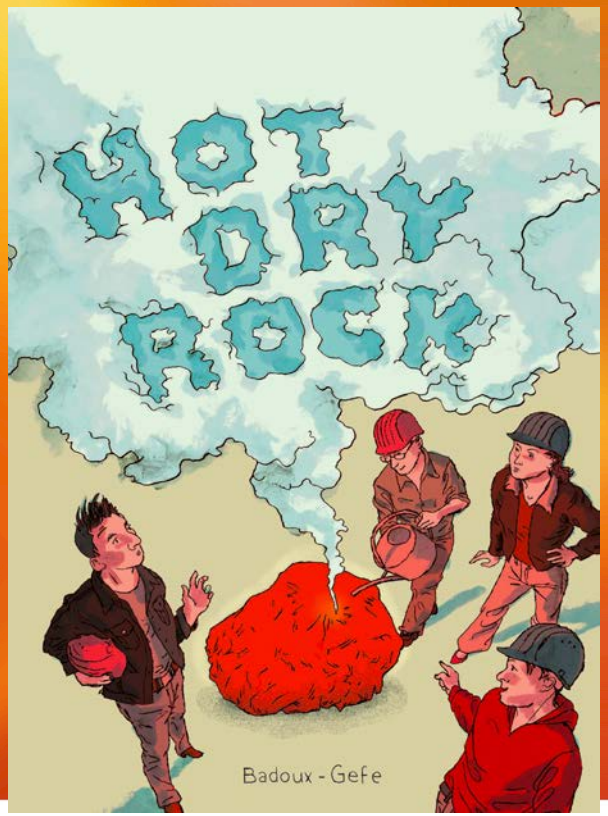
Federal geothermal guarantee: Covers up to 60% of sunk subsurface project development cost

Federally sponsored R&D projects
and funds for pilot and demonstration projects
- Swiss Fed. Office of Energy
- Swiss Nat. Science Foundation
- Swiss Federal Institutes of Technology
- CTI Swiss Innovation Promotion Agency

Improved support measures likely after 2018

Swiss Centre of Competence
for Deep Geothermal Energy
for power and heat production

GEO ENERGIE SUISSE



Thank you for your attention!