SCCER SoE

SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

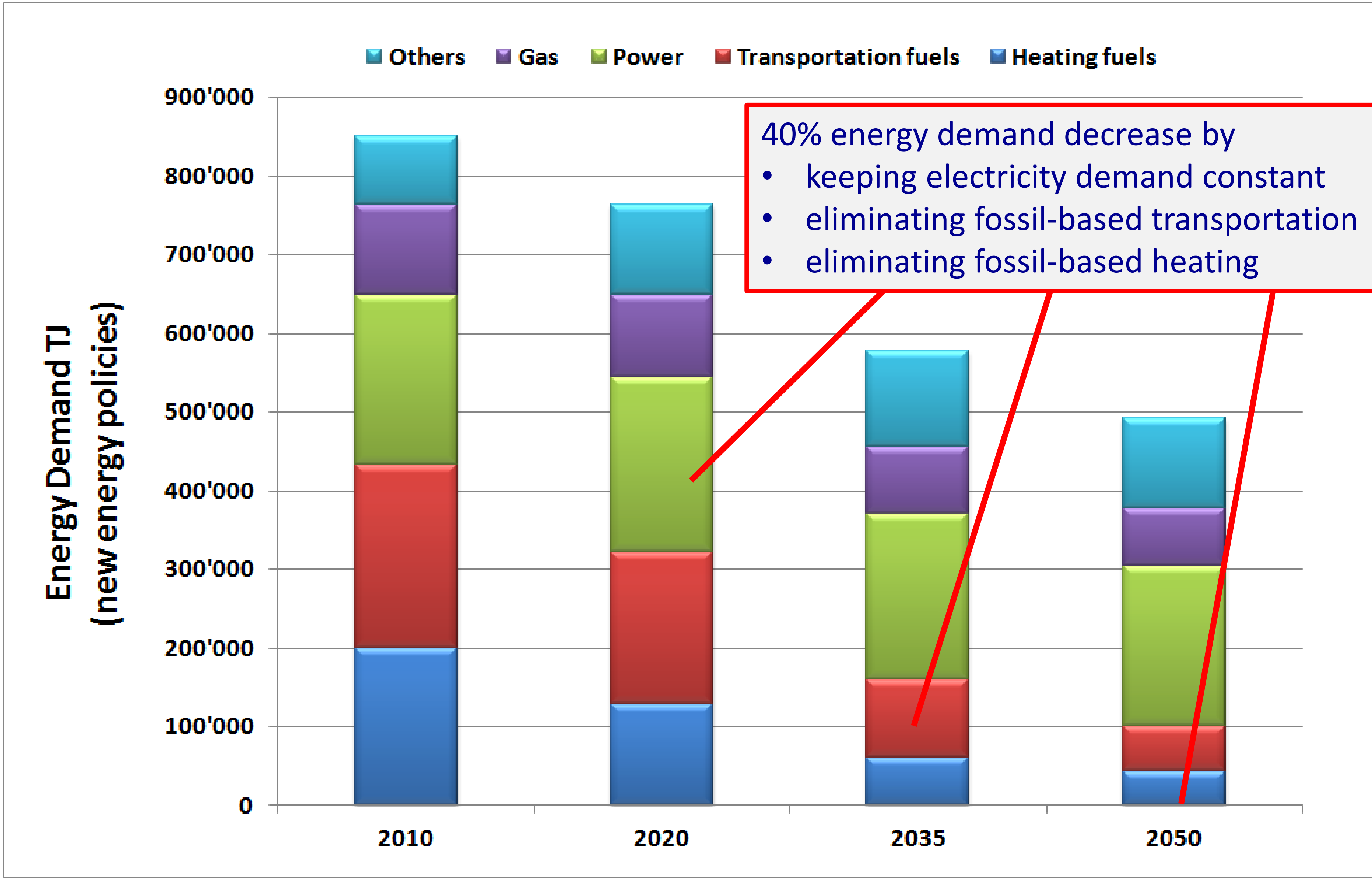
A new Deep-UnderGround Laboratory infrastructure in Switzerland to validate the safe extraction of Deep Geothermal Energy

Induced seismicity Workshop, Schatzalp, 13.3.2015

Domenico Giardini, Florian Amann & the DUG-Lab group

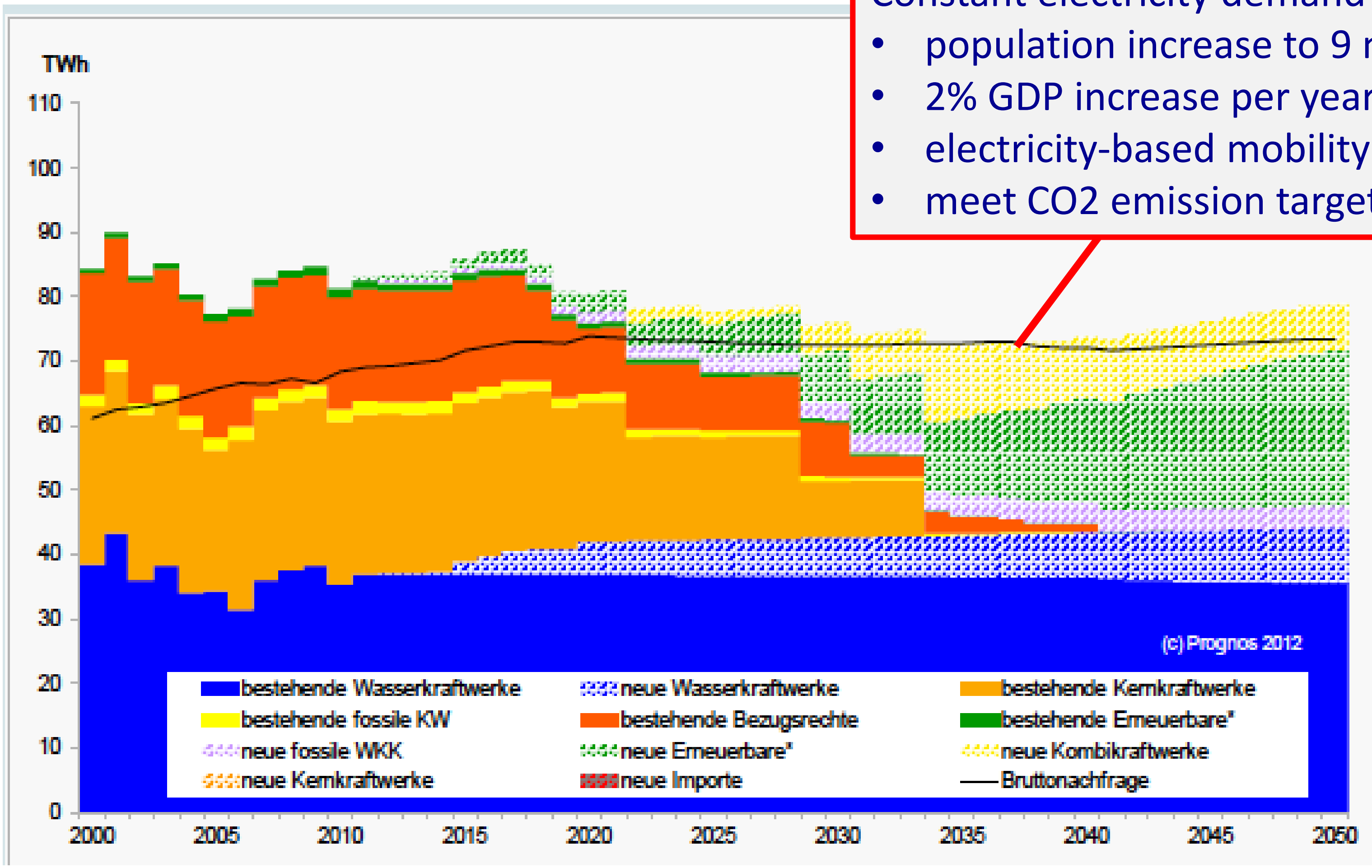
Swiss Competence Center for Energy Research –
Supply of Electricity

Swiss Energy Strategy 2050: energy demand

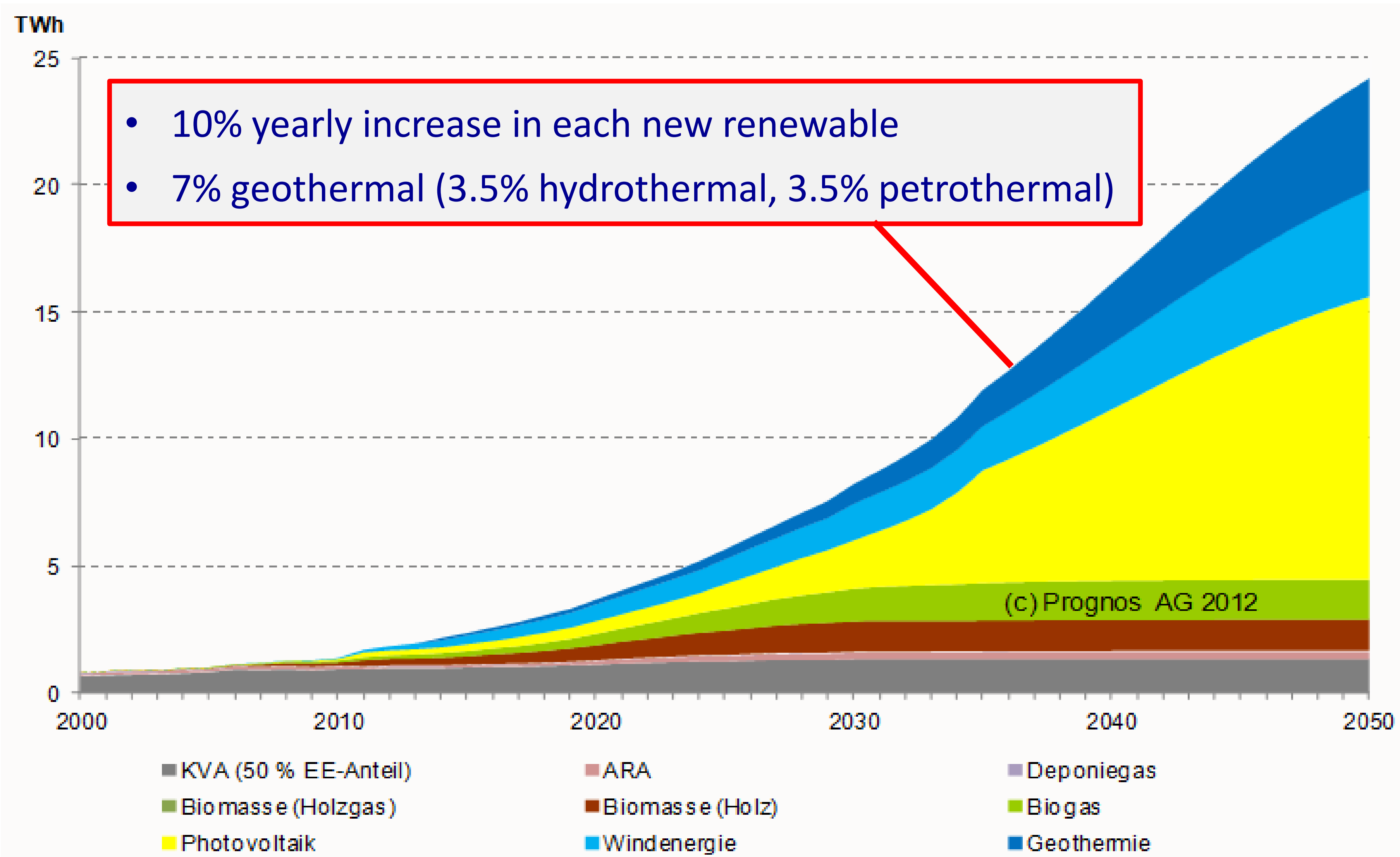


Swiss Energy Strategy 2050: electricity demand and supply

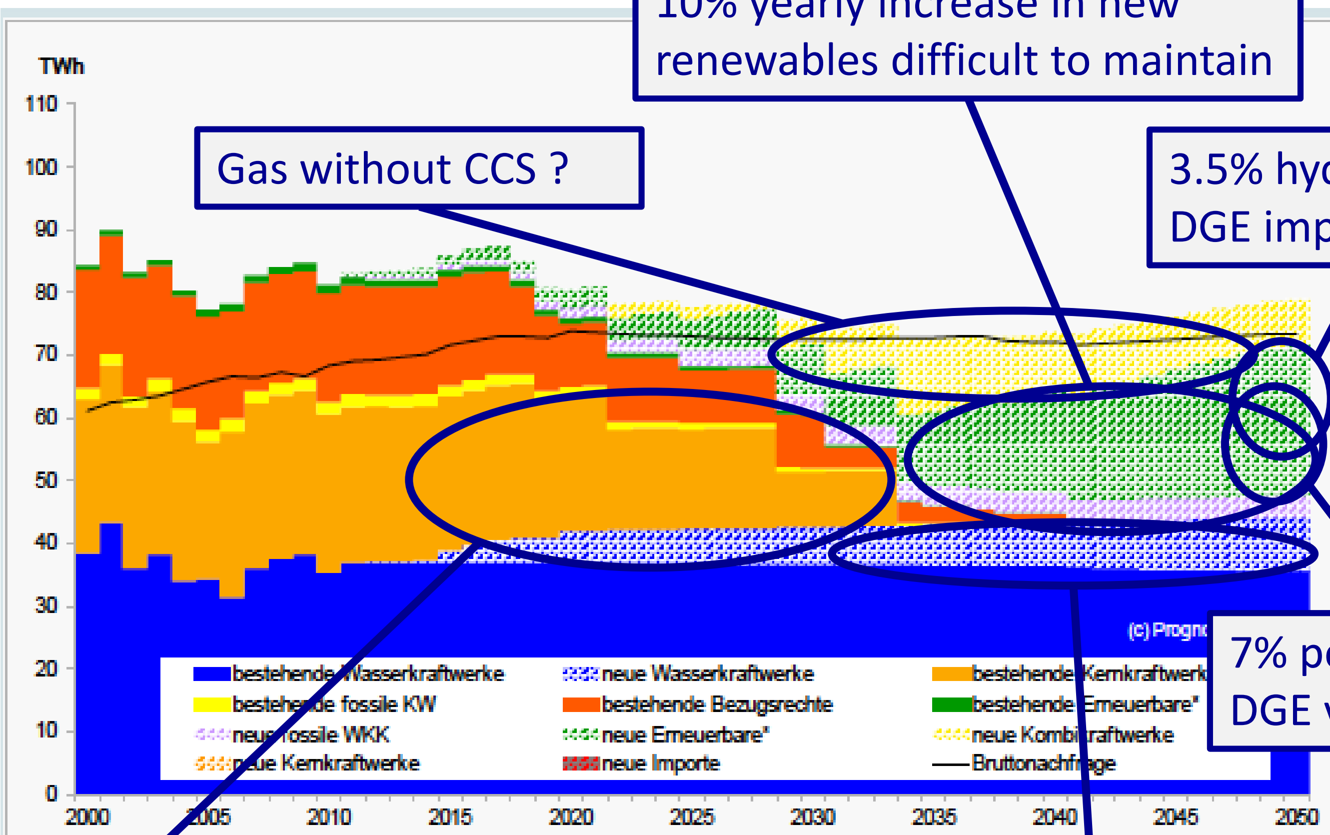
Constant electricity demand with
- population increase to 9 mil
- 2% GDP increase per year
- electricity-based mobility
- meet CO_2 emission targets



Swiss Energy Strategy 2050: Targets for supply of band-electricity



Energy Strategy 2050: Issues for supply of electricity



Gas without CCS ?

10% yearly increase in new renewables difficult to maintain

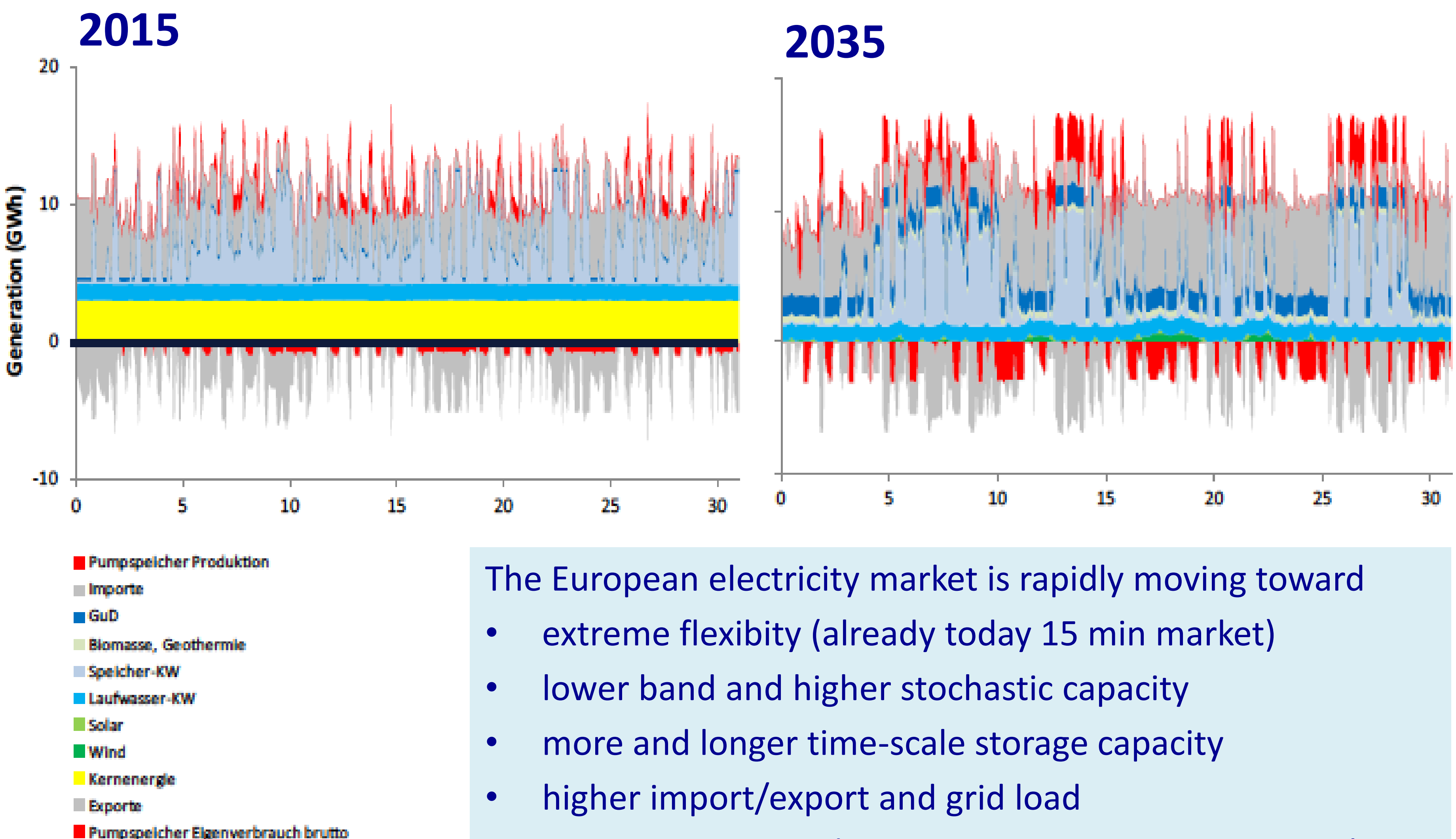
3.5% hydrothermal DGE impossible

7% petrothermal DGE very difficult

Global nuclear industry is very vulnerable and would not survive another Fukushima

- We don't know what water we will have in 2050
- Market conditions are very unpredictable and industry today is unable/unwilling to invest for long-term M&O and new large/small HPP

Band vs stochastic electricity



Quelle: VSE, «Vorschau 2012»

The European electricity market is rapidly moving toward

- extreme flexibity (already today 15 min market)
- lower band and higher stochastic capacity
- more and longer time-scale storage capacity
- higher import/export and grid load
- excess capacity and negative prices in summer months
- up to 50% deficit in winter months

Strategic energy R&D

To reach the goals of the Energy Strategy 2050 and enable the exit from nuclear energy, the Swiss Government approved a new plan for strategic energy R&D:

- ✓ Capacity development
- ✓ Research infrastructures
- ✓ National coordination with 8 new centers of competence (SCCER) on supply, mobility, efficiency, grids …
- ✓ Project funding (doubled funding for energy R&D, new high-risk projects)
- ✓ First phase 2013-2016 ongoing, second phase 2017-2020 under approval
- ✓ Industry participation
- ✓ Involving all relevant academic partners
- ✓ Integration across the whole energy domain
- ✓ Strong anchoring to federal offices and national planning
- ✓ P&D projects
- ✓ Specific targets for 2050

SCCER-SoE Research Partners

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

eawag
aquatic research

UNI BASEL

BKW

Hes·so

unine
UNIVERSITÉ DE NEUCHÂTEL

GEO ENERGIE SUISSE

EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

PAUL SCHERRER INSTITUT
PSI

axpo

ALPIQ

Lucerne University of Applied Sciences and Arts
HOCHSCHULE LUZERN

UNIVERSITÉ DE GENÈVE

sarmap

HSR
HOCHSCHULE FÜR TECHNIK RAPPERSWIL
FHO Fachhochschule Ostschweiz

Unil
UNIL | Université de Lausanne

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office of Topography swisstopo
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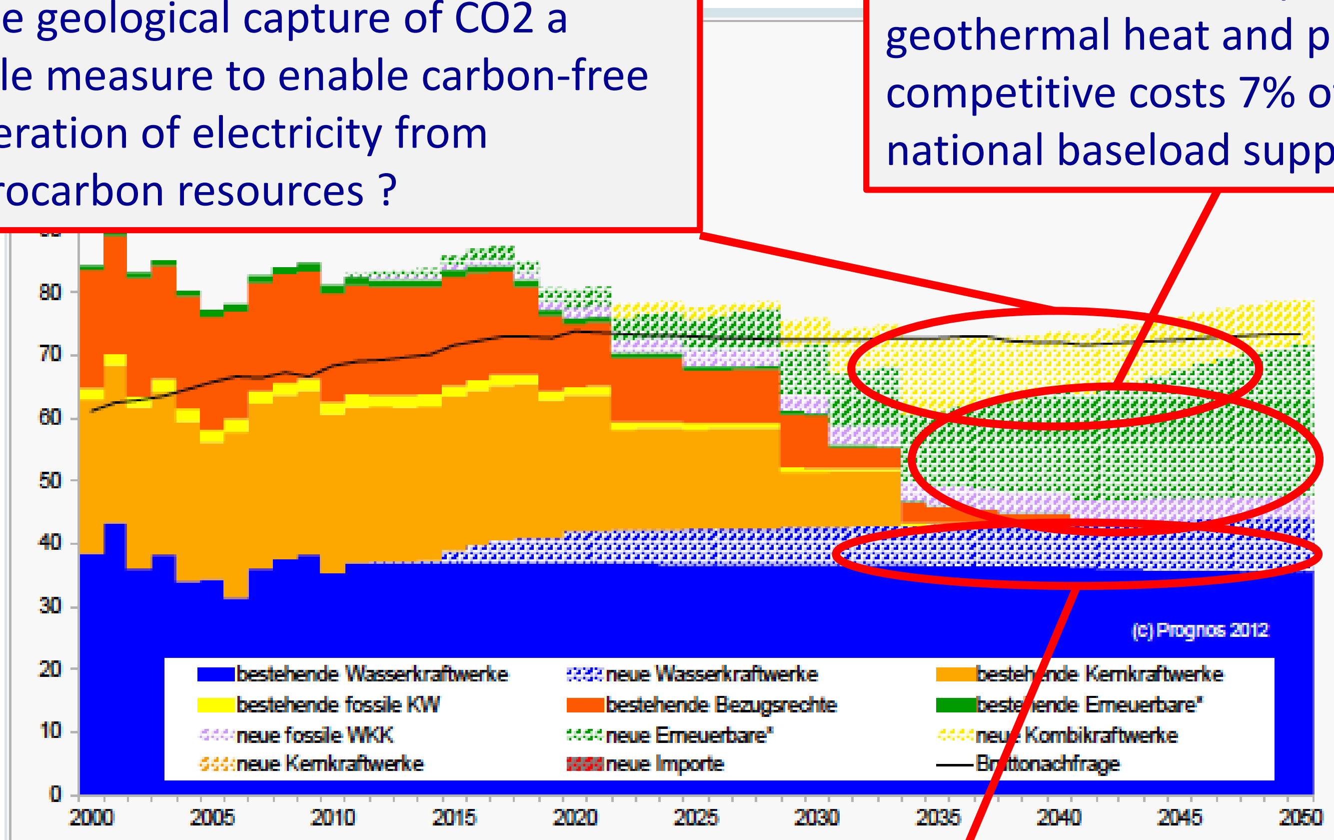
WSL

Swiss Energy Strategy 2050: Targets for supply of band-electricity

Is the geological capture of CO2 a viable measure to enable carbon-free generation of electricity from hydrocarbon resources ?

Can we extract safely the deep geothermal heat and produce at competitive costs 7% of the national baseload supply ?



Can we increase (i.e. by 10%) the present hydropower electricity production under changing demand, climate and operating conditions ?

Future of DGE

Many reasons to doubt:

- ✓ DGE failed in Basel, St.Gallen
- ✓ Too risky (induced earthquakes, water table pollution, ...)
- ✓ Too costly (St.Gallen, 160MFr for 4MWel)
- ✓ To be relevant, we need LOTS of it in Europe → so far, no real strategy
- ✓ Domino effect: all geoenergy sources are in trouble – shale gas, gas and oil extraction, EOR, DGE, CCS, gas storage – due to induced seismicity
- ✓ Governments will not finance DGE
- ✓ Licensing too lengthy and cumbersome
- ✓ NIMBY
- ✓ The electricity market is wild and industry has little money
- ✓ Impossible to predict 2050 conditions and prices

→ **DGE is doomed, we should stop talking about it**

Future of DGE

… but …

- ✓ All DGE plays provide very valuable information, we need more detailed knowledge on our underground and validation of the DGE technologies
- ✓ We are learning what to do and what not to do
- ✓ Licensing underway in several countries
- ✓ Large international effort underway
- ✓ DGE is not an off-the-shelf mature technology, needs RD&D
- ✓ Costs are high and efficiency low, but large gains are possible
- ✓ Long-term horizon → Energy Strategy 2050
- ✓ We sit on an unlimited reserve of energy !

→ DGE electricity has a great future, but we need a coordinated strategy

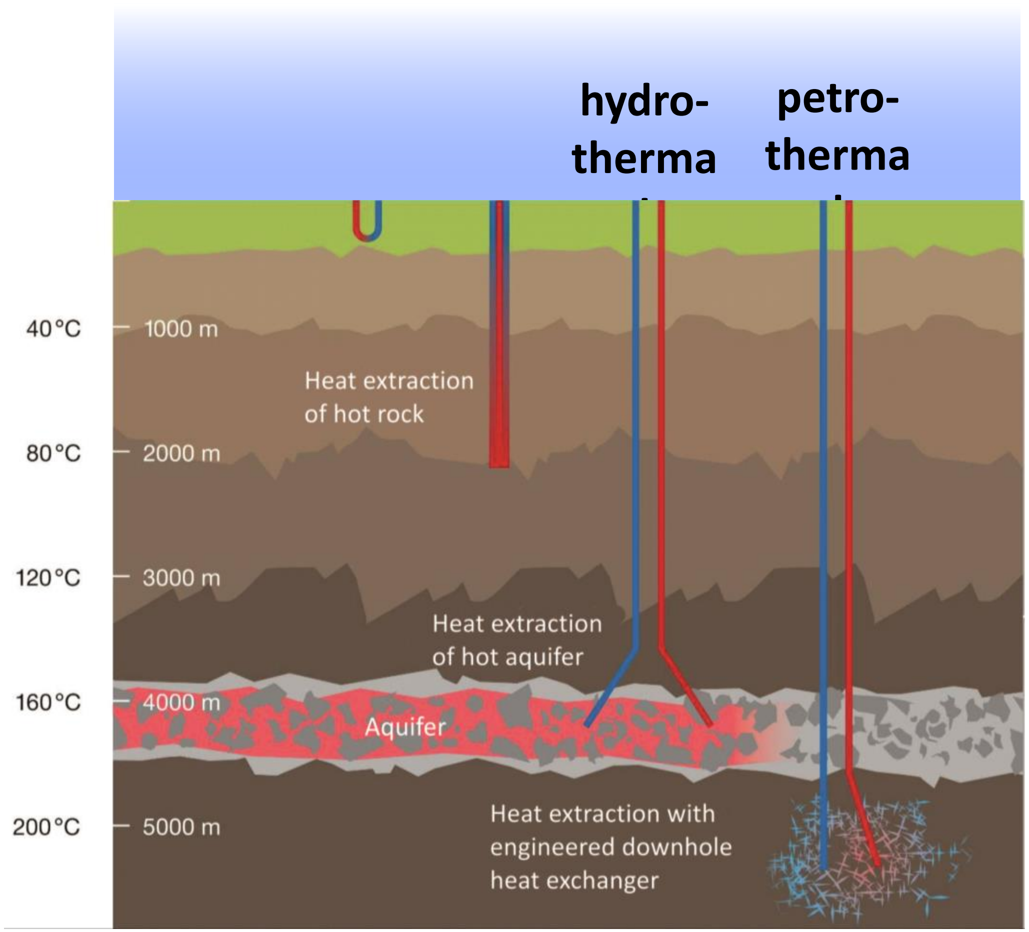
Challenge: efficiency, scaling up

- ✓ Cooling 1 cubic km of 200° C hot granite by 20° C could deliver heat sufficient to generate >10 MWel for 20 years → resource is unlimited
- ✓ The Carnot efficiency of the system is low compared to most other sources of electricity; the overall net efficiency of the conversion of heat to electricity in a DGE plant is expected to be (today) around 13-15%
- ✓ Under normal conditions, in Europe we find 170-190° C in crystalline basement rocks at 4-6 km depth
- ✓ A sustained water flow of 220 l/s at 180° C is required to generate 20 MWel
- ✓ The Swiss ES2050 target for DGE is 7% of Swiss electricity supply → 4.4 TWh/yr, >500 MWel installed
- ✓ The EU-28 area consumes 3'200 TWh/yr of electricity; a 5% share of DGE would correspond to an installed capacity of the order of 20 GWel

→ Europe will need 1’000 20MWel plants to meet the 5% quota

→ Switzerland will need 25 20MWel plants to meet the 7% quota

Challenge: water

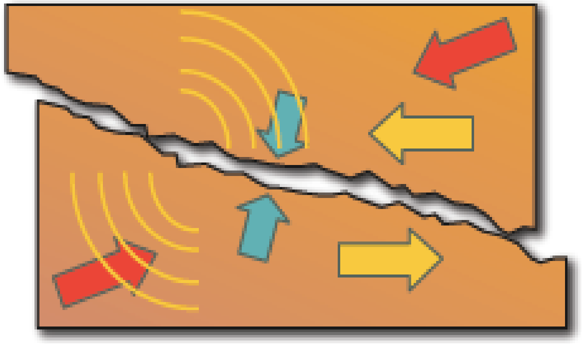


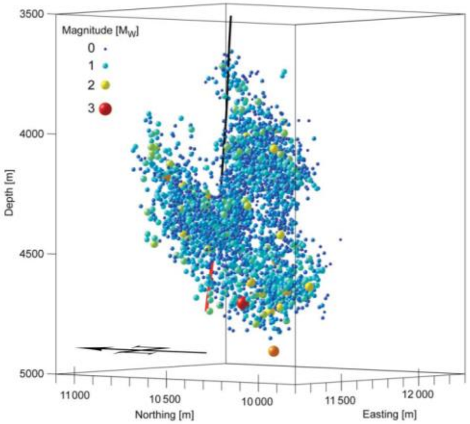
- High-enthalpy volcanic areas are few, limited and far between – Iceland, Italy – and cannot provide electricity to the whole Europe
- In many areas, hydrothermal DGE has great potential for heating, less so for electricity
  → water is scarse and not easily found
- We need to create deep reservoirs in hot rock (EGS) and circulate water from the surface

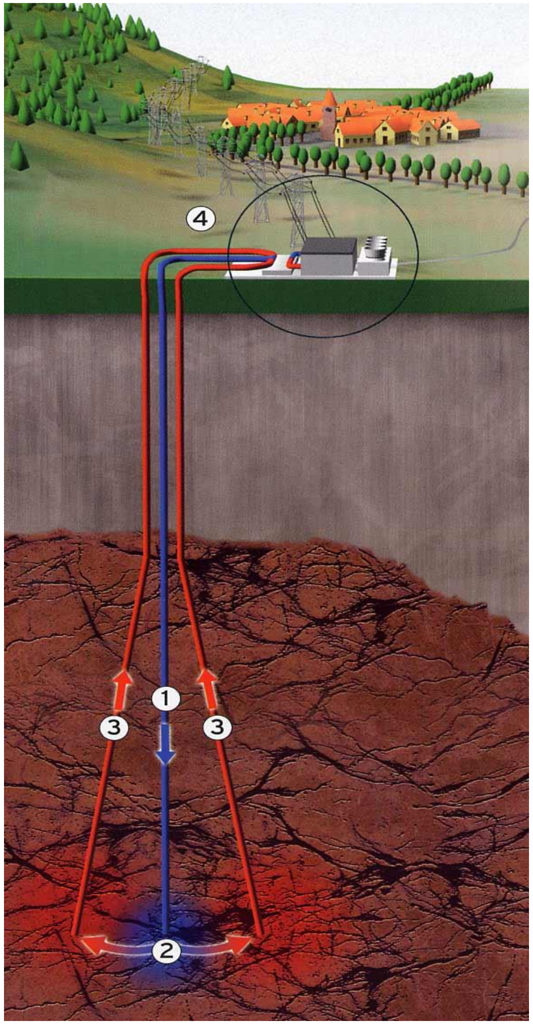
Challenge: engineering the reservoir

The main challenge is to create a sustainable heat exchanger at depth, a system that will operate for 20-40 years with no or minimal loss in flow, temperature and efficiency.

New approaches are required to enhance rock permeability, with optimal distribution of micro-cracks and porosity to maximize heat exchange, swept area and water circulation.







Challenge: induced seismicity

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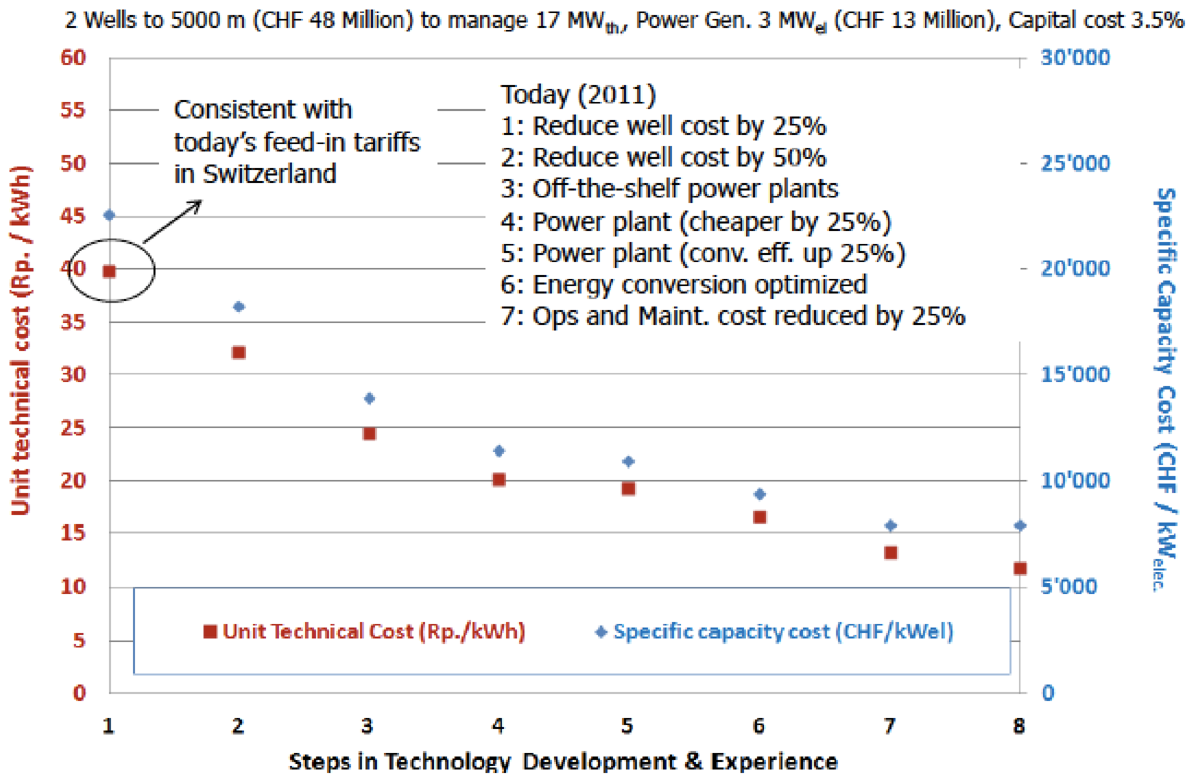
- ✓ Spain, 2011: the largest damaging quake in decades is associated with long-term ground-water extraction in Lorca
- ✓ Holland, 2012: Induced seismicity in Groningen, the largest on-shore gas field in Europe, is increasing and is forcing lower extraction rates, with significant impact on Dutch GDP and European supply
- ✓ Switzerland, 2006 and 2013: Induced seismicity released during a EGS stimulation (Basel) and hydrothermal injection (St.Gallen)
- ✓ UK, 2011: Felt seismicity stoppped hydro-fracking in Blackpool
- ✓ Italy, 2012: 14 Beuros damage and 24 casualties from a sequence of M5-6 earthquakes, possibly associated to hydrocarbon extraction
- ✓ Spain, 2013: the EU-sponsored Castor offshore gas storage field near Valencia is halted after producing earthquakes during the first fill
- ✓ Italy, 2014: seismicity is induced by waste-water injection in Val d'Agri

Challenge: cost

Today's costs are in the order of 40-50 cents/kWh (SFOE), we need to bring them down to 10 Rp./kWh or less, if we want DGE to be a competitive source of band-electricity.

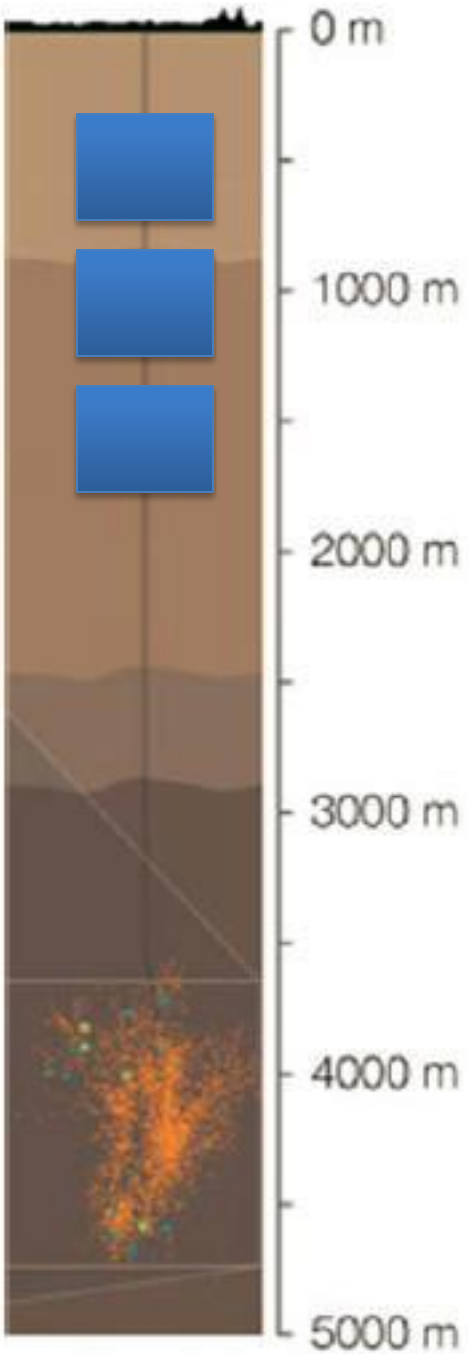


R&D is needed to reduce costs for successful DGE exploitation: innovative drilling technologies, energy techniques, improved heat exchange and efficiency, corrosion, cooling, M&O, reservoir engineering, exploration and imaging, life-cycle sustainability, risk mitigation, monitoring and abatement of induced seismicity (BFE).

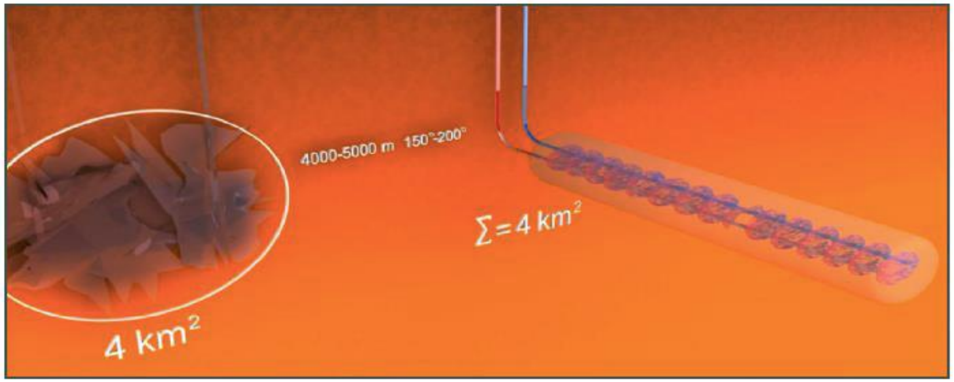
DGE Roadmap

- ✓ A national Geodata Infrastructure, with 3D mapping to 5km depth
- ✓ 10-yr R&D agenda: resource and reservoir exploration, assessment and characterization; fractures and reservoir creation; reservoir modeling and validation; induced seismicity; monitoring; well completion; chemical interactions and transformations.
- ✓ Three main classes of experimental facilities:
  - i. National, distributed rock deformation laboratory to handle 20-60cm size samples at conditions found in 4-6 km depth
  - ii. National Deep UnderGround Laboratory infrastructure, to conduct 10-100m scale injection experiments at depth of 500-2‘000 m
  - iii. The installation of up to 3 deep EGS reservoirs over the next 10 yeras, conducted as P&D projects, with a target of 4-20 MWel installed capacity each
- ✓ The identification of innovative technologies and their development to a high TRL, in collaboration with international developments

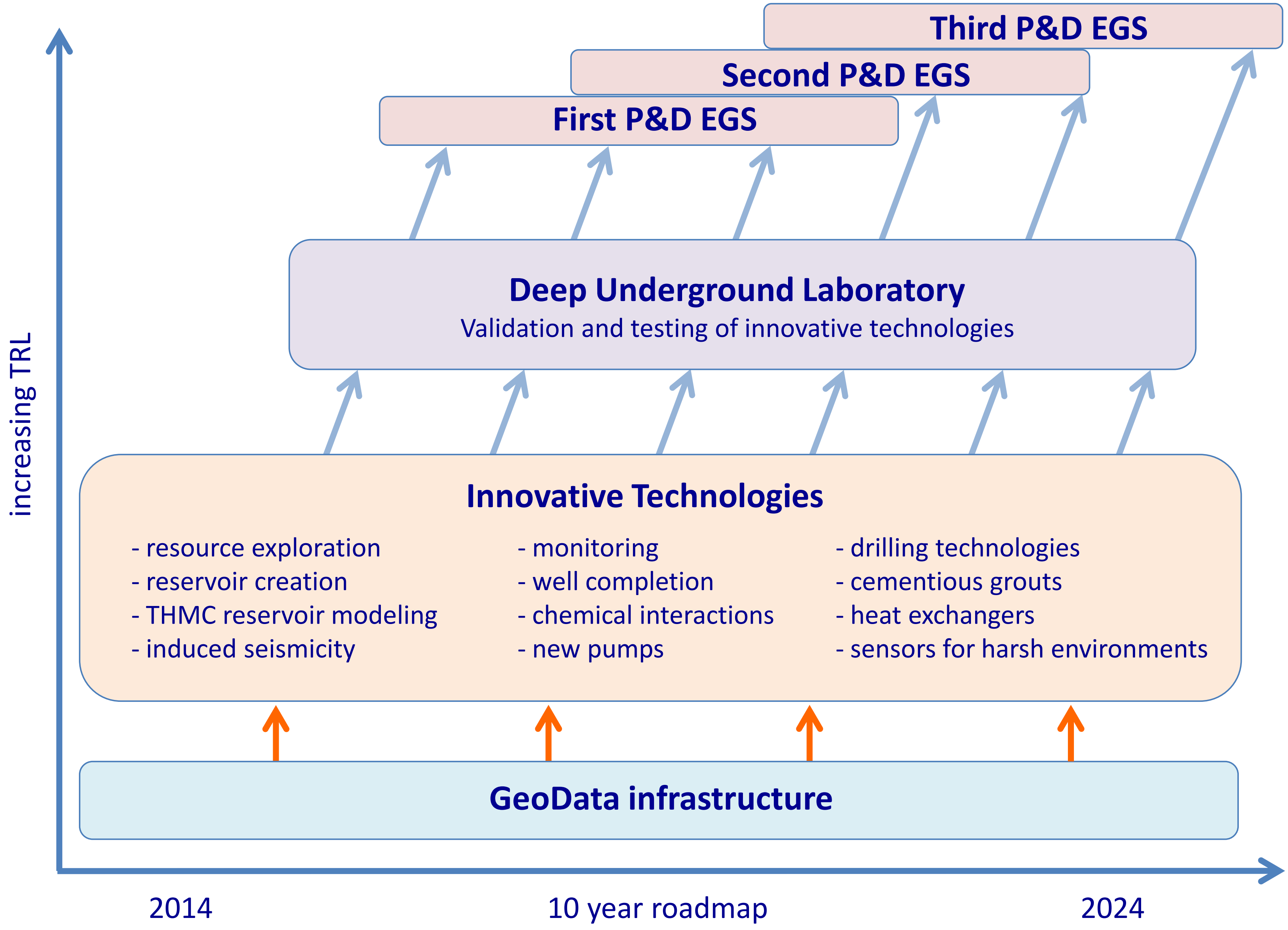
Why a DUG-Lab ?



- ✓ To perform stimulation experiments under a fully controlled environment at increasing depths and realistic conditions
- ✓ To validate protocols and procedures before deployment in deep EGS
- ✓ To provide a testing ground integrating experimental, modeling and monitoring technologies
- ✓ To develop and test innovative methodologies for reservoir engineering
- ✓ To increase public confidence in geo-energy technologies



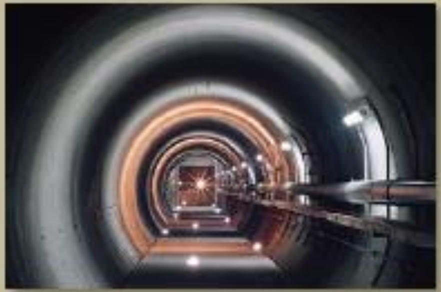
DGE Roadmap

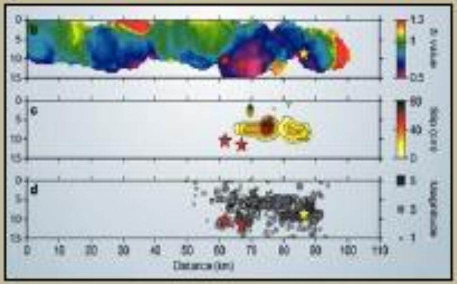


Third P&D EGS
Second P&D EGS
First P&D EGS
Deep Underground Laboratory
Validation and testing of innovative technologies
Innovative Technologies
- resource exploration
- reservoir creation
- THMC reservoir modeling
- induced seismicity
- monitoring
- well completion
- chemical interactions
- new pumps
- drilling technologies
- cementious grouts
- heat exchangers
- sensors for harsh environments
GeoData infrastructure
increasing TRL
2014
10 year roadmap
2024

Multiscale modeling approach

10 cm | 10 m | 100 m | 1 km | 10 km

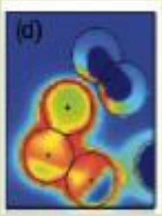




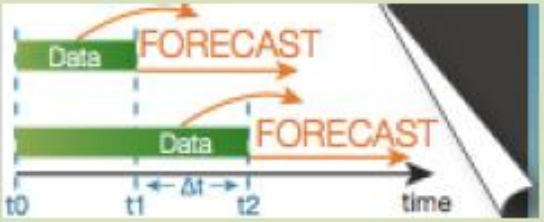
Laboratory Scale

Underground Lab Scale

Natural Systems

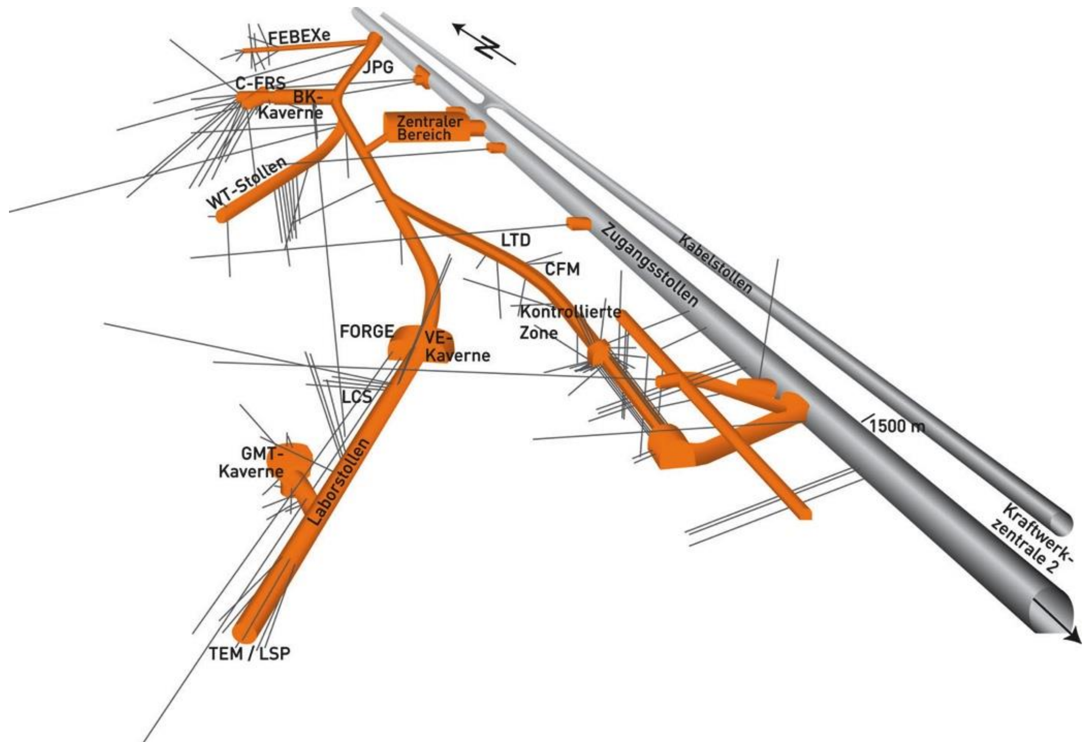


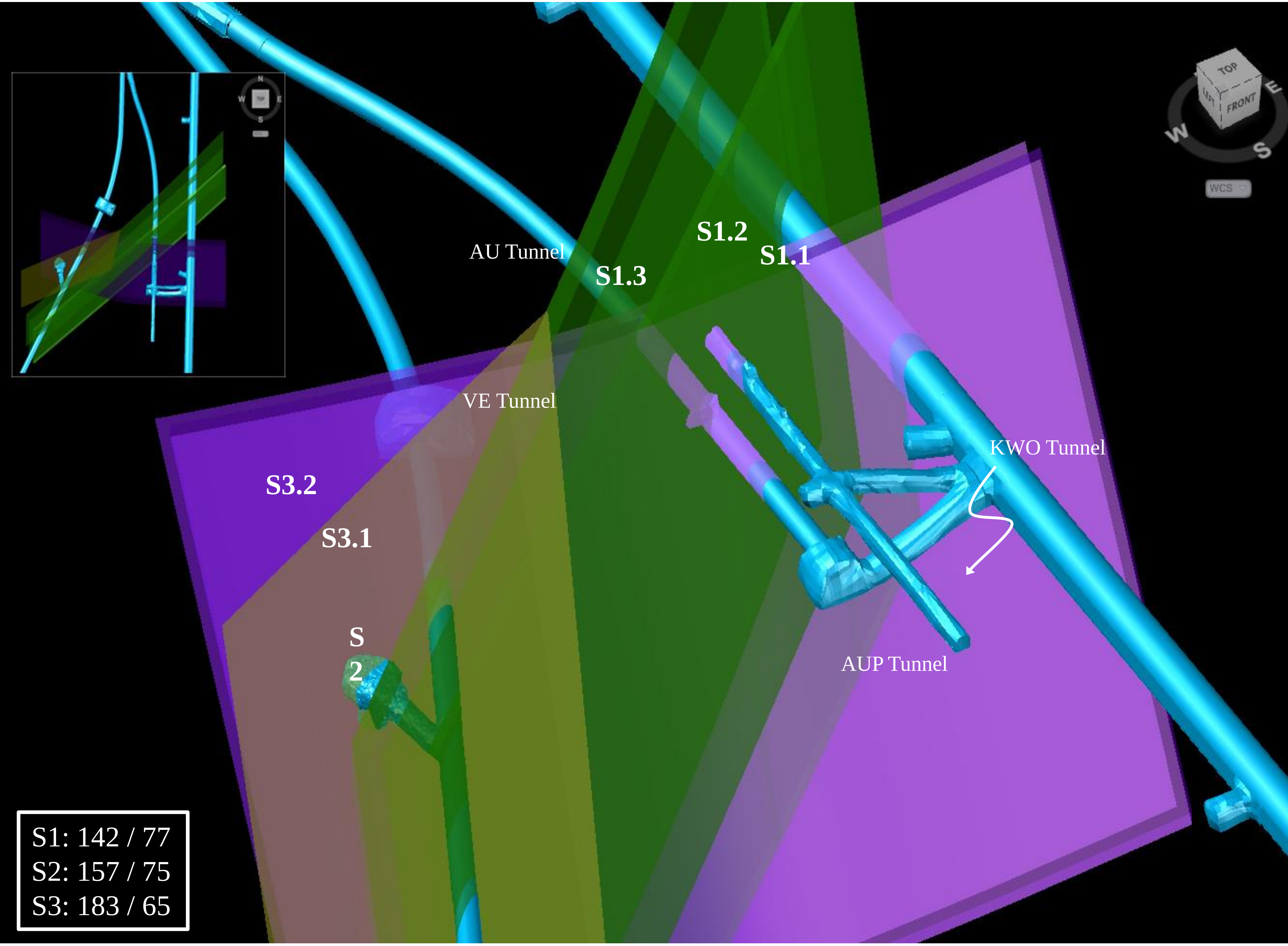
High Performance Computing, Modeling & Validation

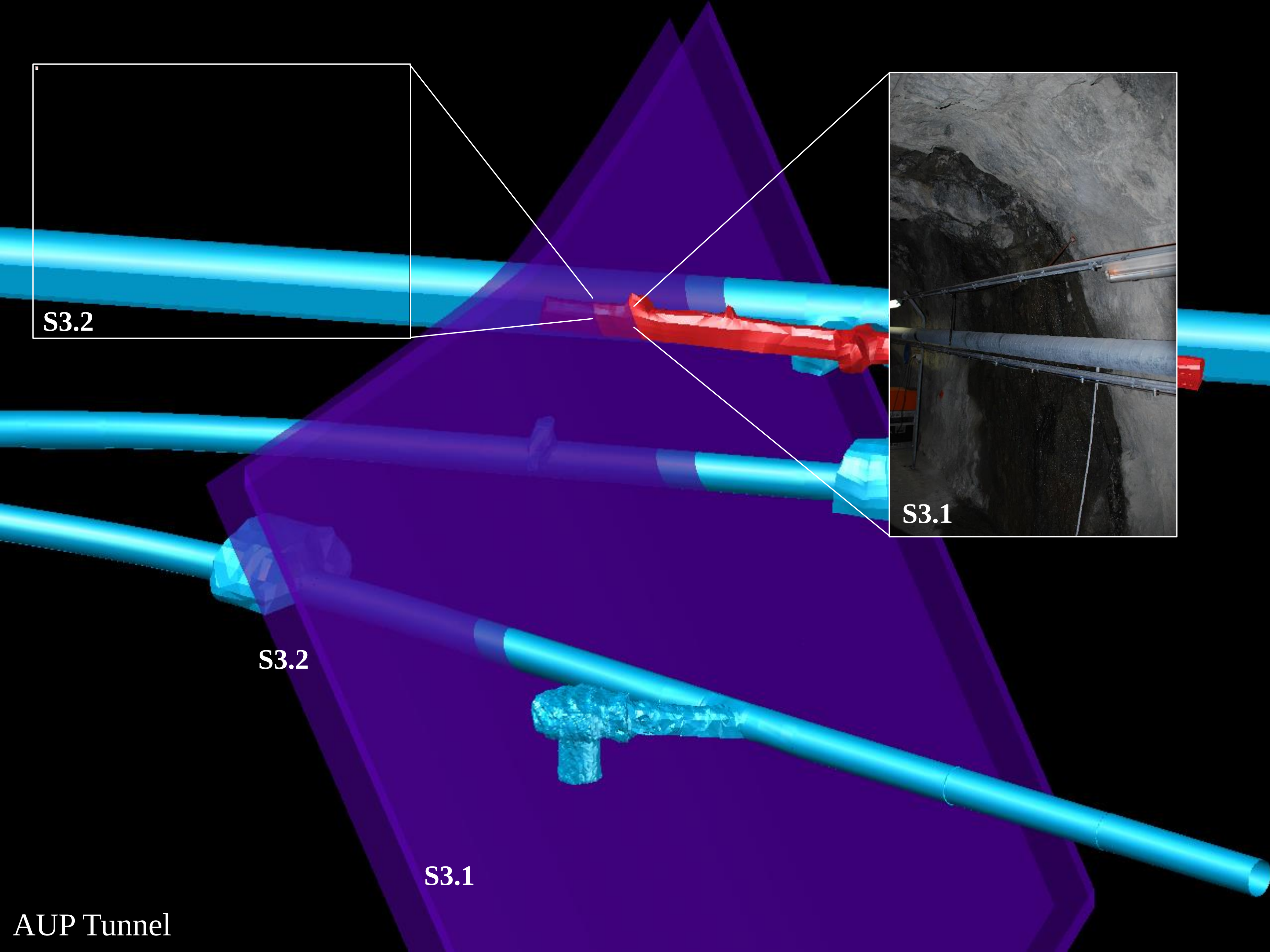


DUG-Lab progress

- ✓ First ETHZ-lead experiment initiated at Grimsel NAGRA laboratory
- ✓ Options for deeper experiments under investigation: deep Alpine tunnels, deep laboratories and deep mines in other countries (Swe, Fi)
- ✓ DUG-Lab included in the Swiss national roadmap of Research Infrastructures
- ✓ International partnership (IPGT, Australia, Germany, US/DOE/FORGE)
- ✓ Part of the Geo-Energy Testbeds initiative under EPOS

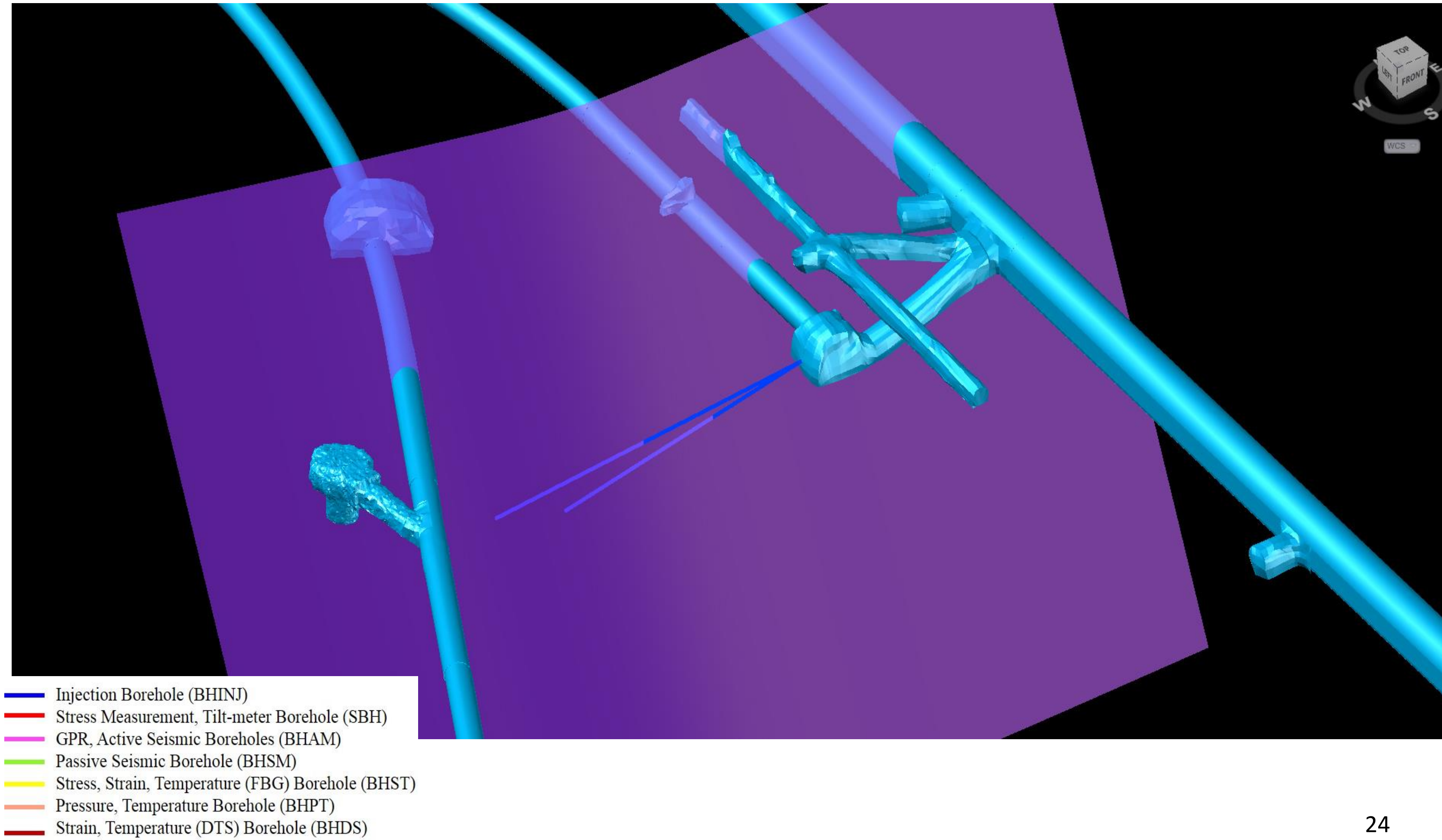


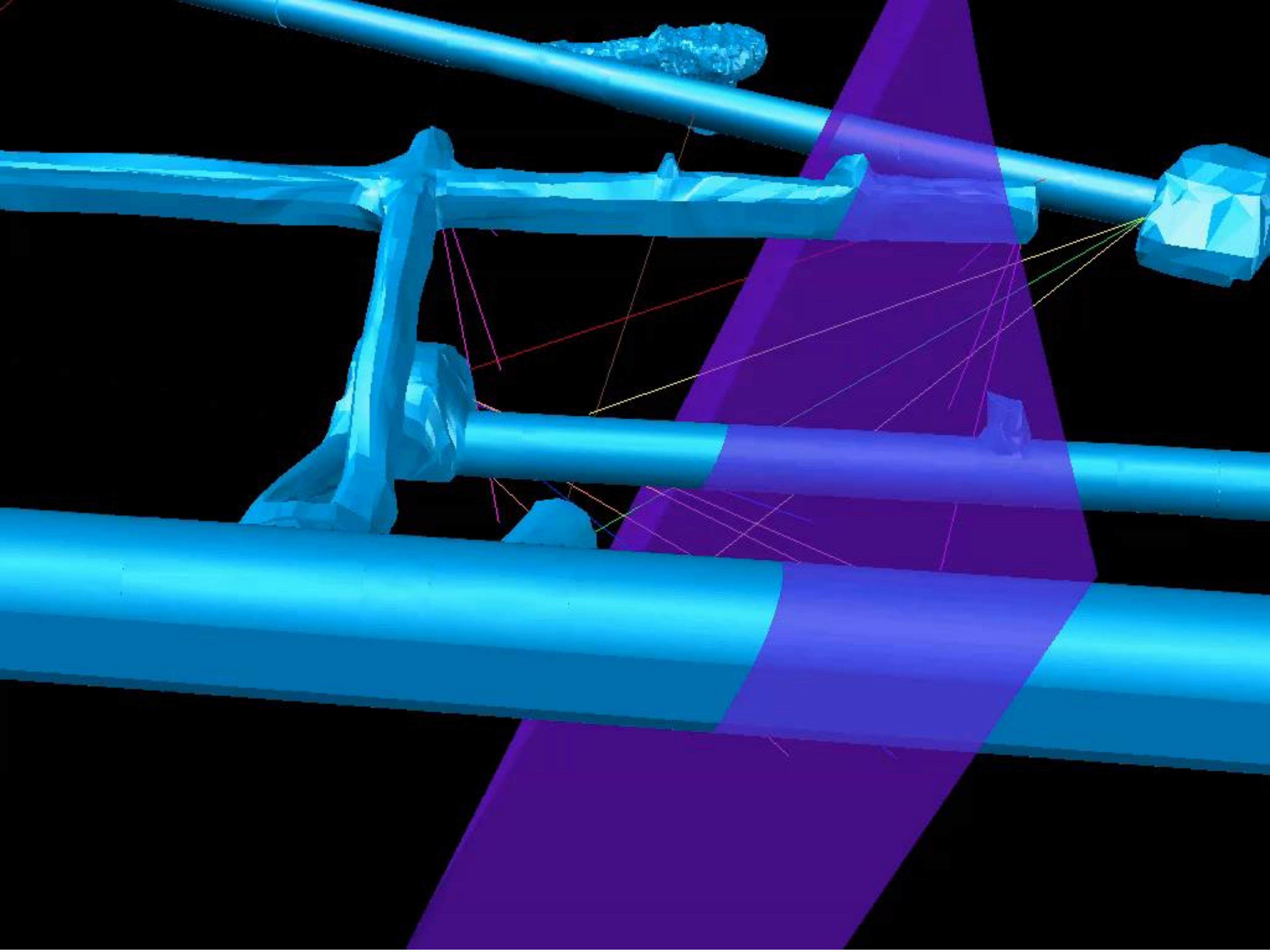

AU Tunnel
S1.2
S1.1
S1.3
VE Tunnel
KWO Tunnel
S3.2
S3.1
S
2
AUP Tunnel
S1: 142 / 77
S2: 157 / 75
S3: 183 / 65
TOP
FRONT
LEFT
W
E
S
N
WCS


S3.2
S3.1
S3.2
S3.1
AUP Tunnel

Boreholes Trajectory w.r.t. S3 Fault

[illegible]





Experimental setup

Surface seismic monitoring system installed

Modeling environment with real-time data assimilation in preparation

Stress measurements (3 months, started)

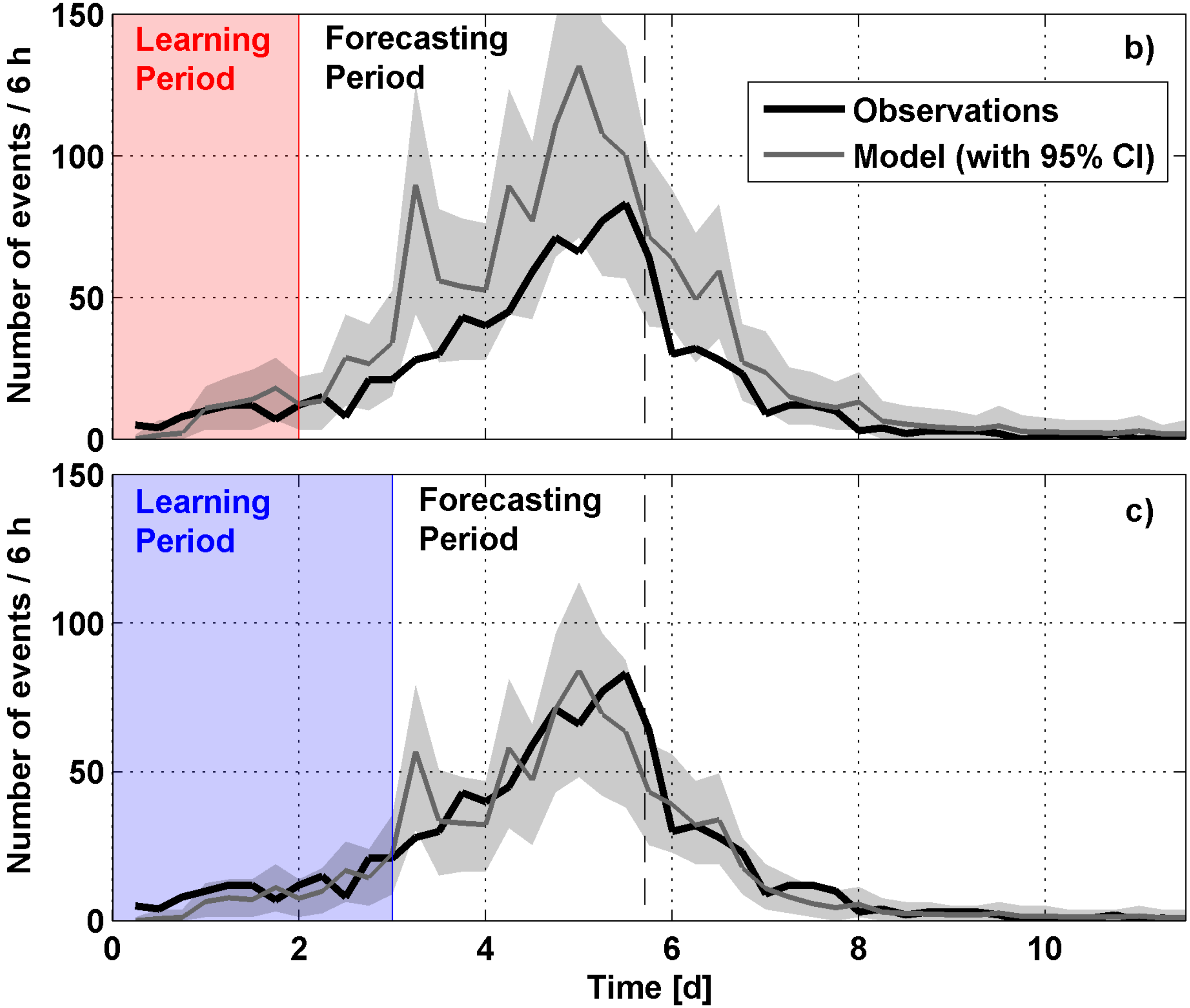
Phase I – Hydraulic Fracturing (start Sept 2015)

- *Injection pressure > fracture pressure*
- *Try different hydraulic fracturing methods*
- *Define the proper multi-stage HF spacing*
- *Try different HF injection hydraulic parameters*
- *Monitor the fluid propagation and microseimic emission*

Phase II – Hydraulic Shearing

- *Injection pressure < fracture pressure*
- *Stimulate the existing natural fractures*
- *Monitor the fluid propagation and microseimic emission*

Validation



150
100
50
0
Number of events / 6 h
Learning
Period
Forecasting
Period
b)
Observations
Model (with 95% CI)
150
100
50
0
Number of events / 6 h
Learning
Period
Forecasting
Period
c)
0
2
4
6
8
10
Time [d]

DGE outlook - I

- ✓ If we want to reach the ES2050 target of 7% electricity supply from DGE (500 MWel installed), we need to create the conditions to install one 20 MWel petrothermal plant per year between 2025 and 2050.
- ✓ In Europe, over 1‘000 20 MWel plants will be needed to meet the 5% EU28 target of electricity supply (20 GWel installed capacity).
- ✓ In Switzerland, until 2025 we need to successfully complete three EGS reservoirs, to demonstrate the DGE feasibility, with an expected investment in the order of 500 mFr.
- ✓ With a target cost of 10 MFr per installed MWel, a total investement of 5-7 BFr will be required in the 2025-2050 period to reach the 7% target.
- ✓ A cost target of 10 cents/kWh for DGE electricity will only be achieved by coordinated developments in the US and Europe and with the installation of a large number of DGE plants in Europe.

DGE outlook - II

We need

- ✓ A coordinated European strategy and roadmap
- ✓ Long-term (20+ yr) R&D support to DGE development
- ✓ Access to high-quality data
- ✓ Integrated approaches to image, model and forecast structures, resources and processes in the underground
- ✓ A network of european-class research Infrastructures and geo-energy testbeds
- ✓ Improved assessment and validation of protocols and procedures to control risks associated to geo-energies, to increase public acceptance
- ✓ Regional-scale demonstrators for energy system integration