CCS geological storage pilot

The opportunity of Elegancy

Alba Zappone (ETHZ)

with contributions of :
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Domenico Giardini
Marco Mazzotti
and the ELEGANCY Team

Birmensdorf, 15 Sept. 2017

SCCER SoE
SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

In cooperation with the CTI

Energy funding programme
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

Activity Overview of GeoEnergy

Target electricity production for 2050: 4400 GWh

Key goals:

- extract safely the deep geothermal heat and produce electricity at competitive cost
- geological capture of CO_2 to enable carbon free electricity from hydrocarbon resources

Roll-out
Prototyping
Validation
Concept
System

Petro-thermal plants
20MWe per year

Hydro-thermal plants
Heat and Storage

CCS-CCUS
Industry & air capture

EGS Pilot 1: Project Haute Sorne
EGS Pilot 2
EGS Pilot 3

Hydrothermal P&D 1: Geneva basin
Hydrothermal P&D 2
Hydrothermal P&D 3

CCS field-scale demonstrator 1
CCS Demo 2

Laboratory and Deep-Underground Laboratory testing

Phase 1-2

Innovation technologies
- Advanced cementious grouts
- Corrosion resistant heat exchanger
- Sensor for harsh environment
- Optimisation of geothermal energy conversionn
- Next generation numerical methods and simulation tools for DGE reservoir eng.
- Real time, data driven reservoir characterization and risk assessment

Integrated solutions
- Resource exploration and characterization
- Reservoir enhancement and engineering
- Limit induced seismicity while creating an efficient reservoir
- Hydrothermal and aquifer resource exploitation and storage
- Chemical processes in the reservoir

Phase 3
New innovation technologies and integrated approach

Risk, safety and societal acceptance– Technology assessment– Energy economic modeling

GeoData infrastructure and resource exploration on national scale

2014 – 2016 | 2017 – 2020 | 2021 – 2025 | 2026 – 2035

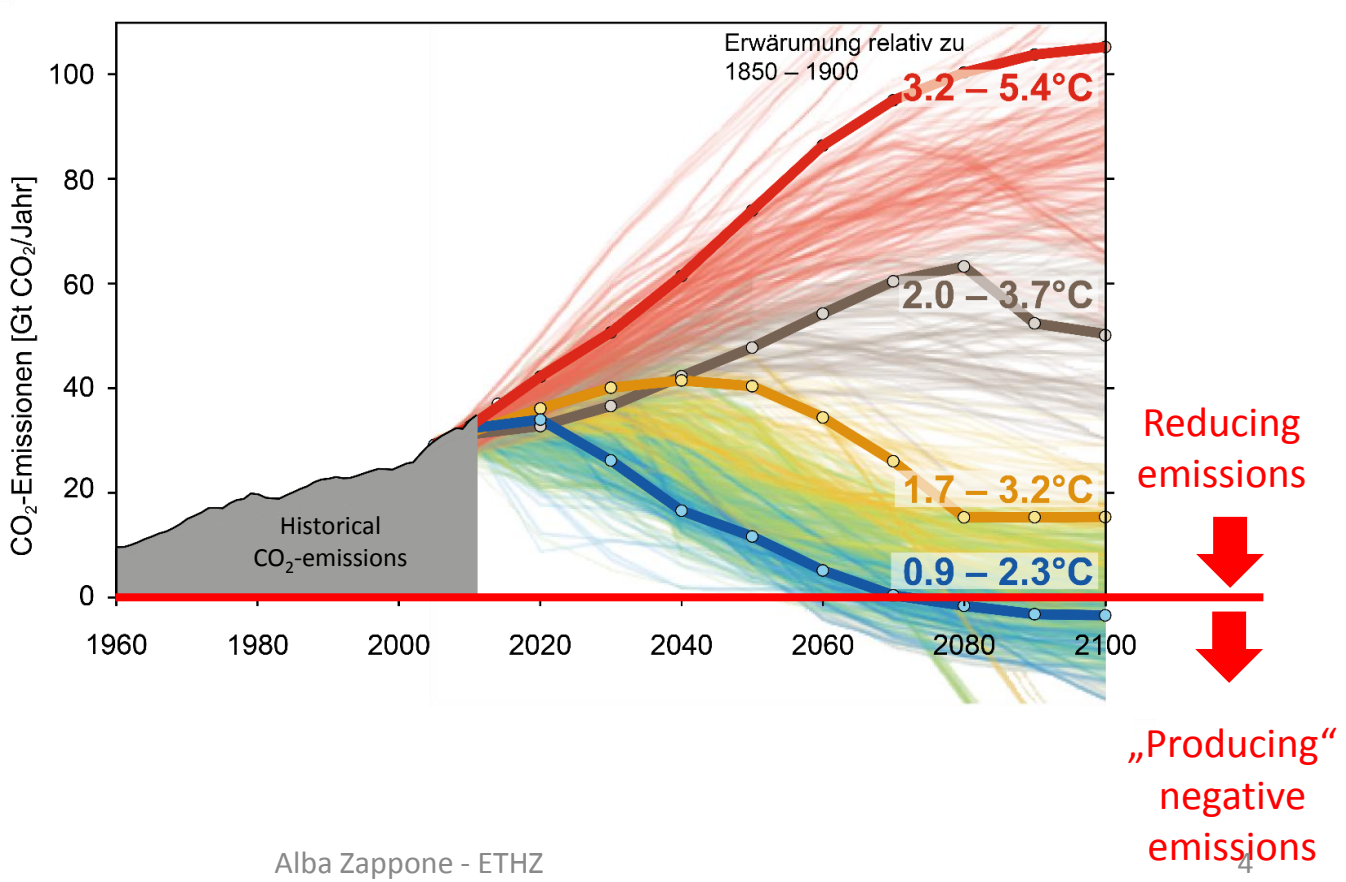
Major roadblocks for CCS from my layman‘s perspective

- No business or regulatory case for CCS. Little industry in CH-.
- Not the most favorable geology in CH, no hydrocarbon reservoirs.
- Large uncertainty.
- Opposition from supporters of renewable energy.
- No scientific CCS ‘hero’ (?).
- No funding avenue for a test site.
- Lack of public acceptance (?), NIMBY
- etc.

But: We probably need CCS, DACCS – and/or geo-engineering.
And changes may come more quickly than we think

Switzerland is aiming at:

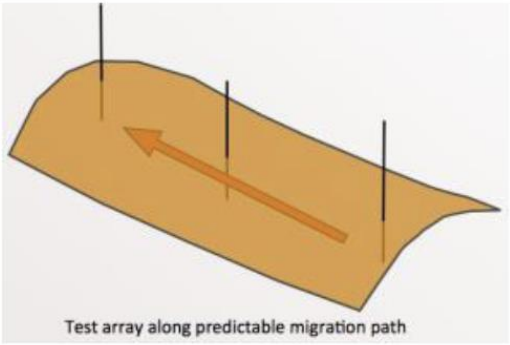
- 20% greenhouse gases emissions reduction by 2020.
- 50% emissions reduction by 2030.

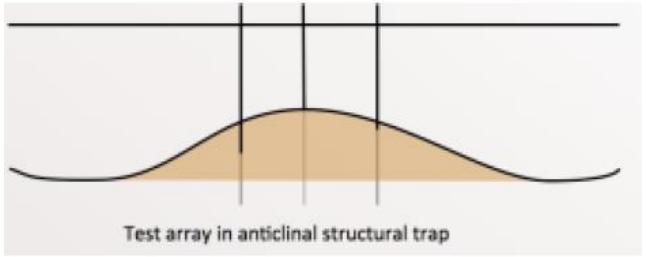


Phases of the storage roadmap

- We had a plan for the next step since CARMA:
  a test site
- But we cannot afford it. So:

carma 2010-2013
Carbon Management in Power Generation

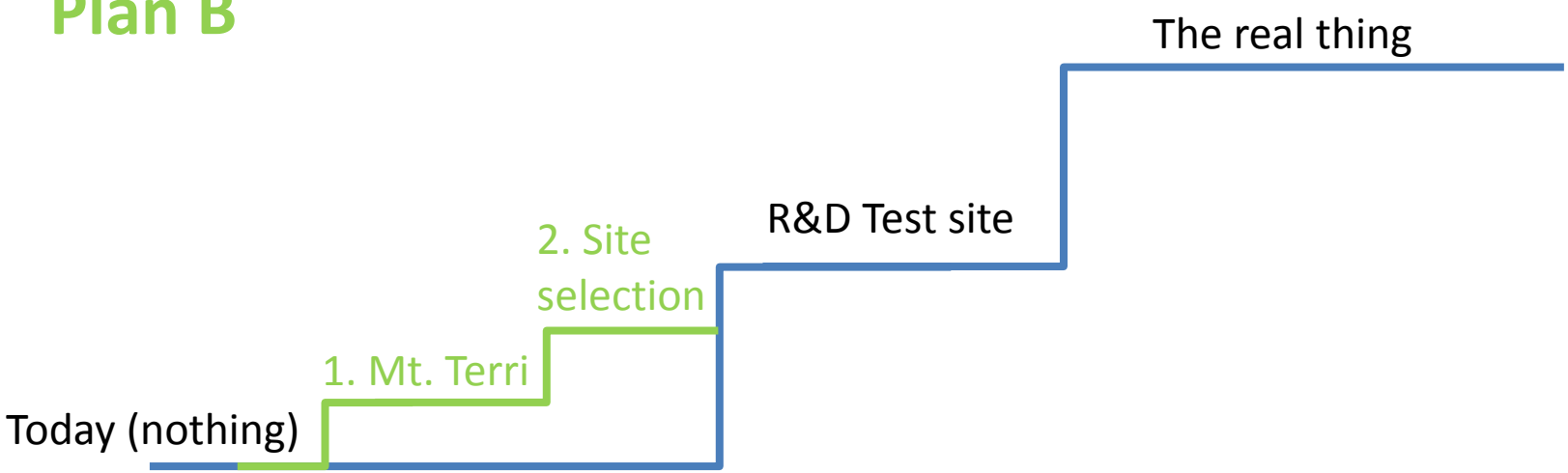




	Year 1	Year 2	Year 3	Year 4-5	Year 6-7	Year 7-post
	PHASE 1	**PHASE 2**	**PHASE 3**	**PHASE 4**	**PHASE 5**	**PHASE 6**
Co2 storage Explore and drill pilot well in Switzerland (CO2 Transported by Truk)	Test site design Risk Dialogue	Risk Dialogue Permitting	Seismic exploration	Site aquisition Drilling Permit	Drilling and Installation Operations	Injection & Monitoring

Fig.7: Draft CO_2 storage pilot master time plan.

Plan B



Accelerating CCS Technologies

Enabling a Low-Carbon Economy via Hydrogen and CCS

ELEGANCY

1. Caprock/fault sealing integrity: in situ experiment

Testing of a fault subjected to CO_2 injection

Mont Terri

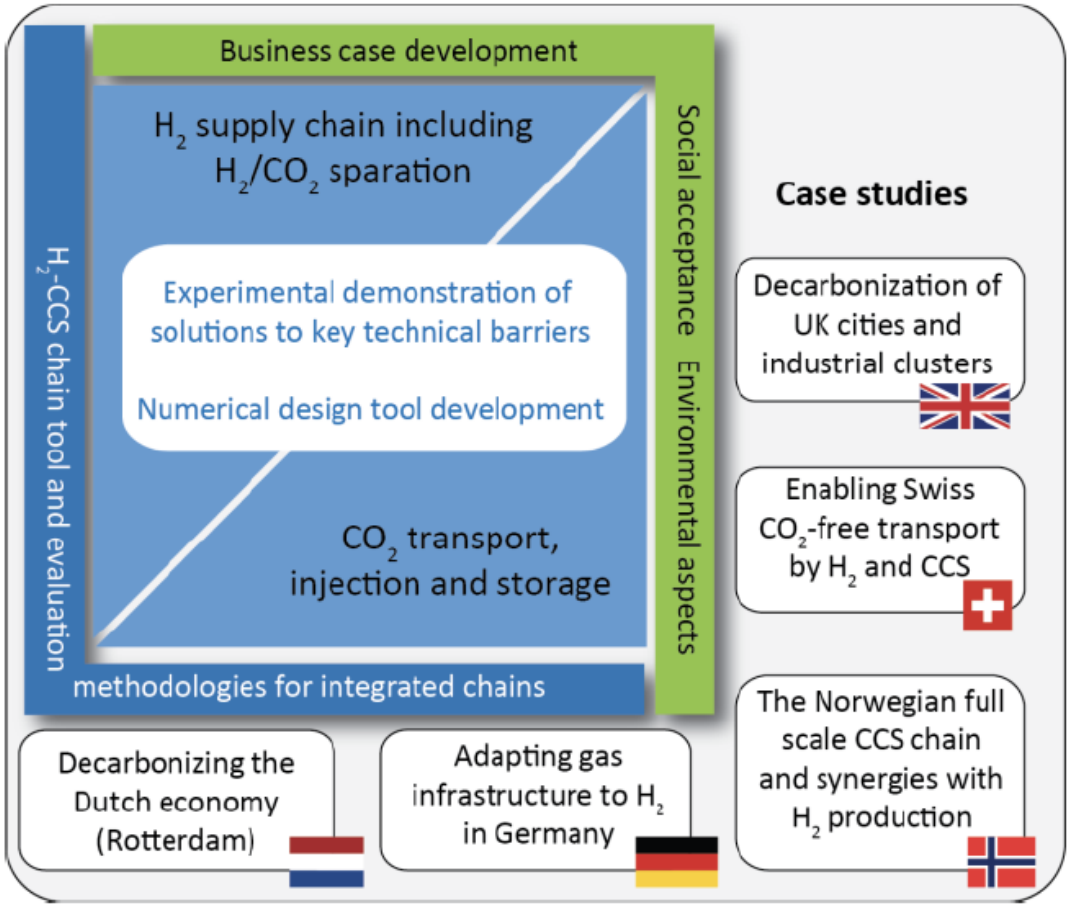
2. CO_2 storage site selection

ELEGANCY

Overview

Efficient generation of renewable H_2 from biomass, while harvesting geothermal heat and enabling negative CO_2 emissions

September 2017-August 2020



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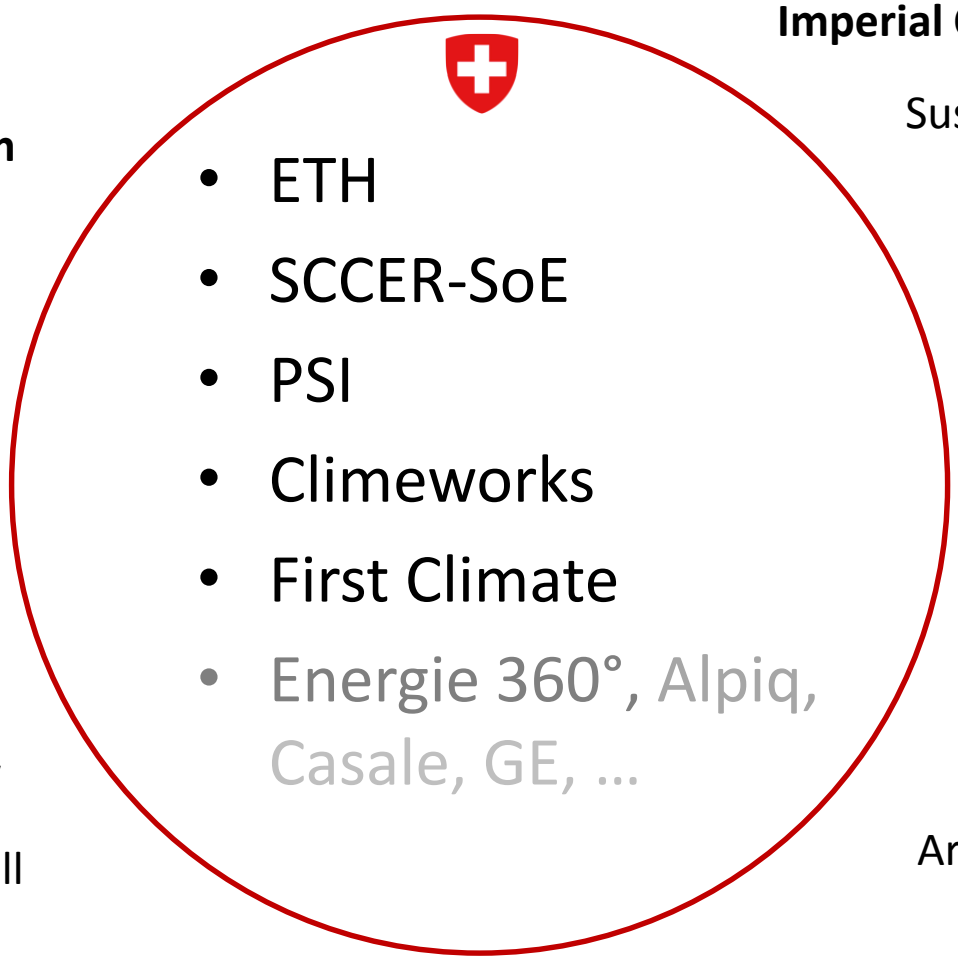
Actors



Imperial College

Sustainable Decisions Ltd.

BGS INEOS

Scottish Enterprise

RU Bochum

Open Grid Europe

UNIPER Energy Storage

GERG

Sintef

Gassco Aker

Arntzen de Besche

TNO/ECN

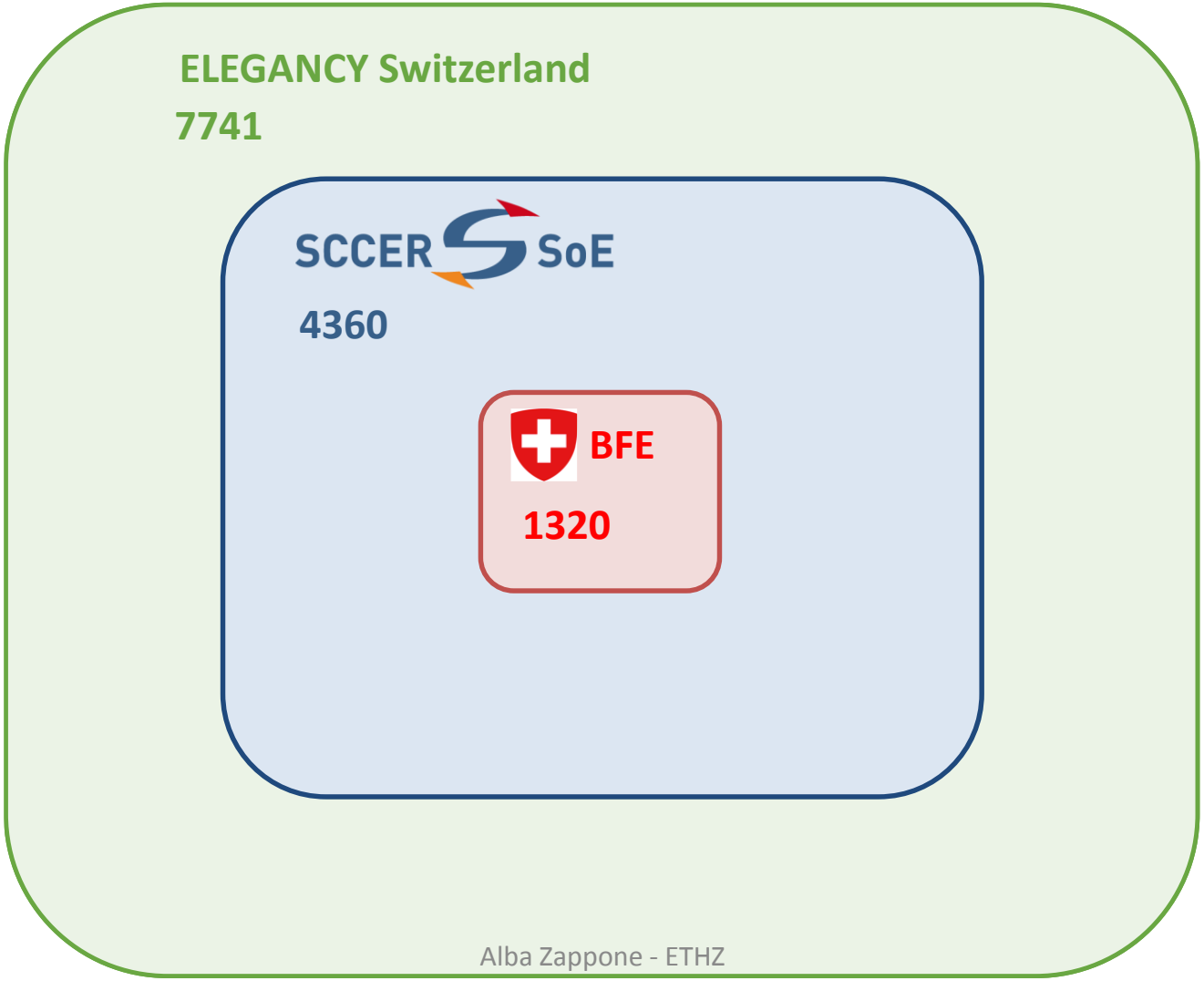
Utrecht University

Shell

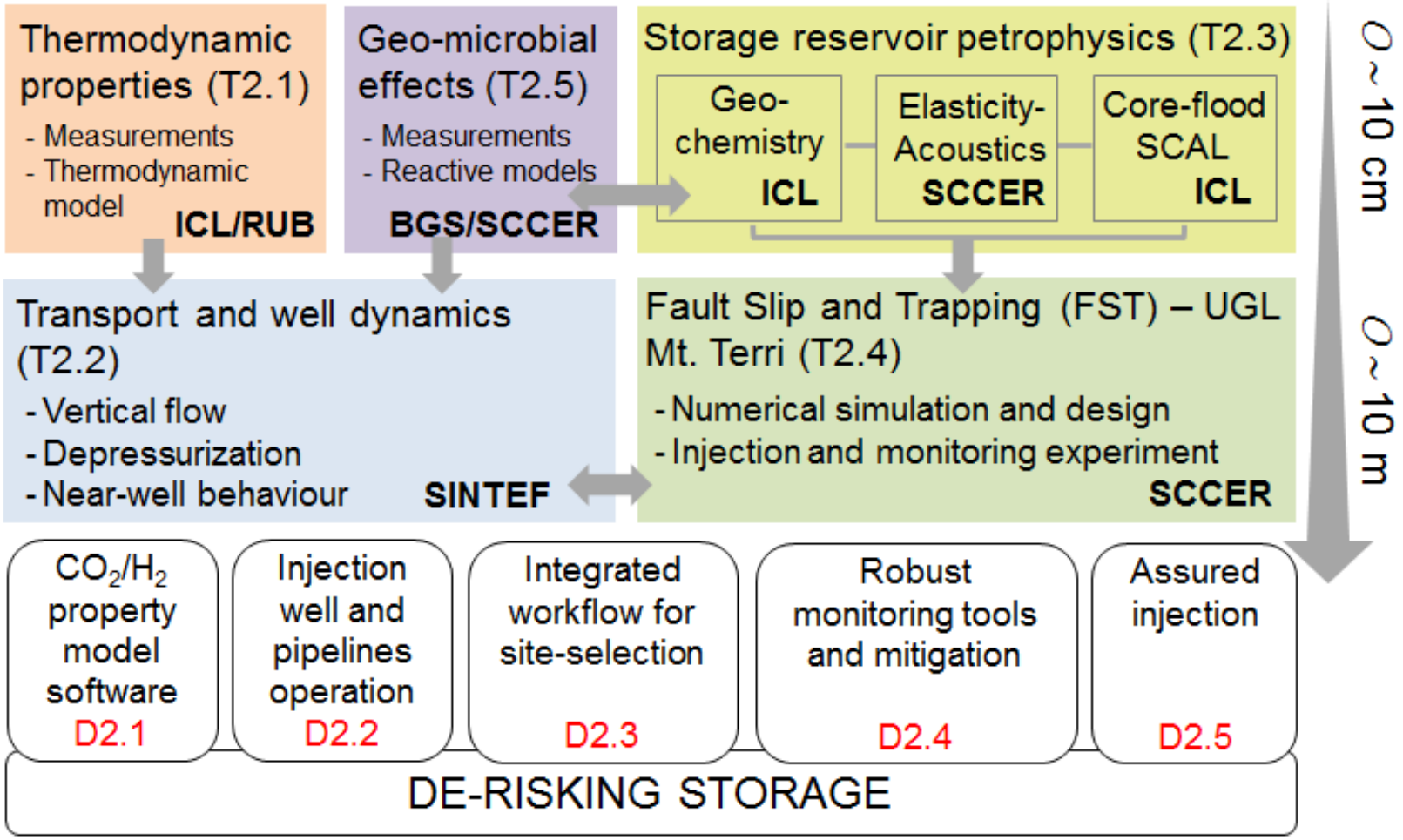
Swerea MEFOS

Budget (k€)

3 years



WP: CO_2 transport, injection and storage



ELEGANCY

Caprock/fault sealing integrity: in situ experiment

Testing of a fault subjected to CO_2 injection

Mont Terri

- Improve the understanding of the dynamic behavior of reservoirs over a range of spatial and temporal scales
- Advance the state-of-the-art by bridging the gap between the laboratory- and the reservoir-scale
- De-risking CO_2 injection operations
- Pilot project implementation or «pilotization».

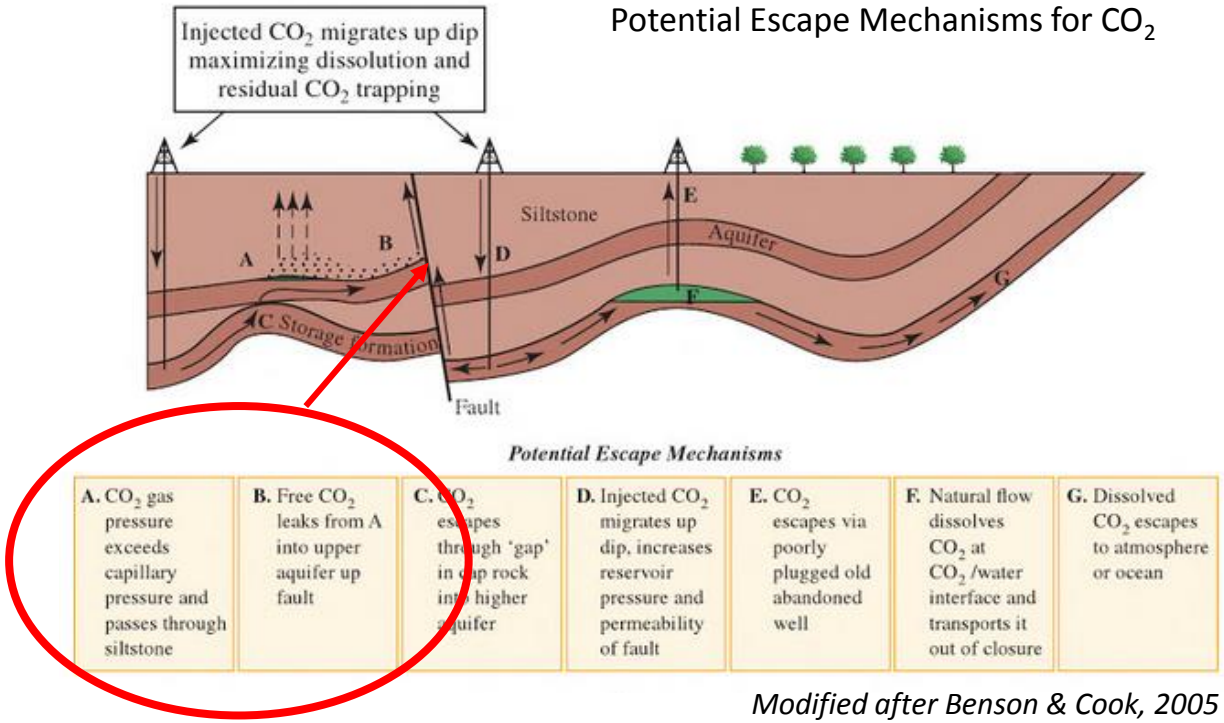
Scaling

ELEGANCY

Caprock/fault sealing integrity: Mont Terri experiment

Scientific objects

Potential Escape Mechanisms for CO_2



Modified after Benson & Cook, 2005

ELEGANCY

Caprock/fault sealing integrity: Mont Terri experiment

Scientific objects

- Understanding how exposure to CO_2-rich brine affects sealing integrity of caprock (hosting a fault system): permeability changes - induced seismicity
- Direct observations of fluid migration along a fault and of its interaction with the surrounding environment
- Validate instrumentation and methods for monitoring and imaging fluid transport
- Validate Thermo-Hydro-Mechanical-Chemical (THCM) simulations

ELEGANCY

Caprock/fault sealing integrity: Mont Terri experiment

Concept

- Inject CO_2 saturated brine (and tracers) in fault:
  - Continuous/long term (8-10 months)
  - Pulse/ pressure increase steps (at beginning and at end of the injection phase)

    Scale: 1-10 m^3 brine -> rock volume
- Monitor injection effects:
  - Strain = Extensometer(s)
  - Vp, (Vs), fiber optics and traditional methods
  - Microseismic…….
- Pre and post mechanical & geophysical characterization at lab scale
- Pre and post numerical simulations

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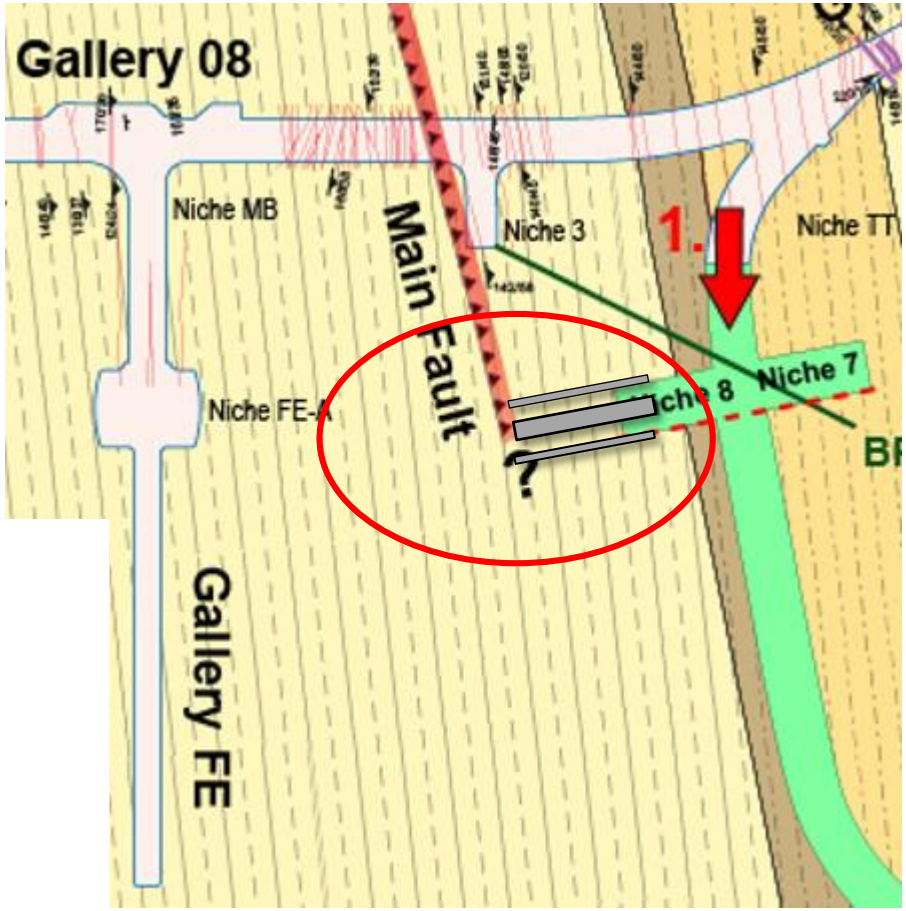
Caprock/fault sealing integrity: Mont Terri experiment

Technical layout

- Injection borehole
  - 40-50 m long
  - 120 mm diameter
  - 2 separated injection sections
- Parallel borehole for extensometer
- 3-5 Monitoring wells
- Sampling holes



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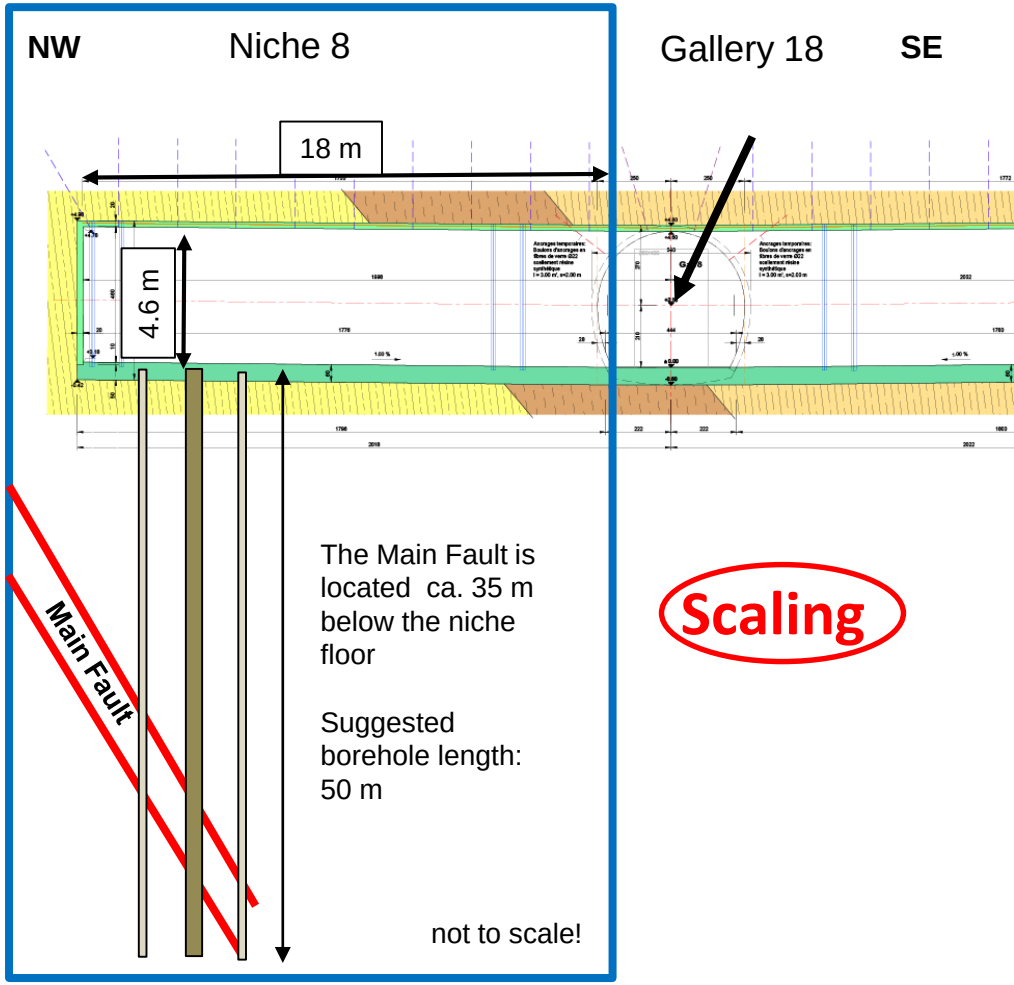
Caprock/fault sealing integrity: Mont Terri experiment

Technical layout

- 1 central injection borehole with two intervals in the Main Fault (scaly clay fabric and fractured zone). Injection of a CO_2-rich brine.
- Ca. 7-8 months of continuous injection, with pulse tests before and during injection.
- 3 to 5 monitoring boreholes for geophysical characterisation (active/passive seismic, etc.).
- Post-experiment: 2-3 sampling boreholes for geochemical characterization.



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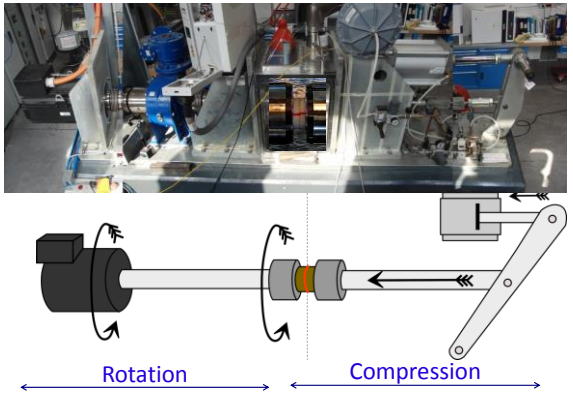
Caprock/fault sealing integrity: Mont Terri experiment

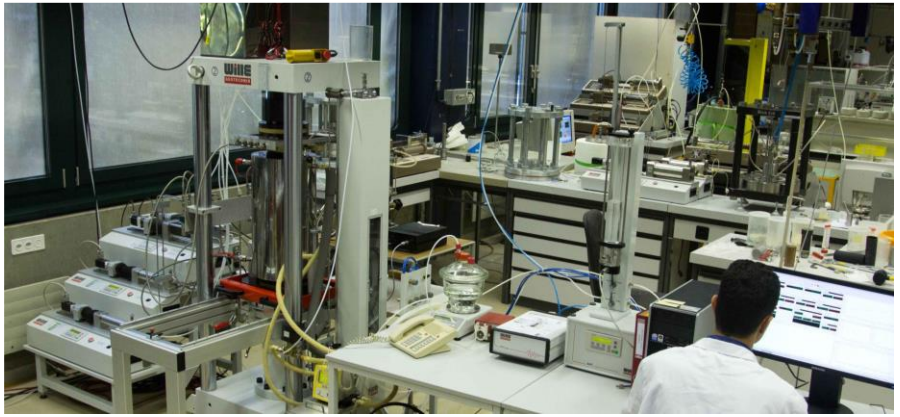
Laboratories

Rock Deformation Lab
(Dr. C. Madonna)

Lab of
Experimental Rock Mechanics
(Dr. Marie Violay)



Lab of Soil Mechanics
(D. Alessio Ferrari)



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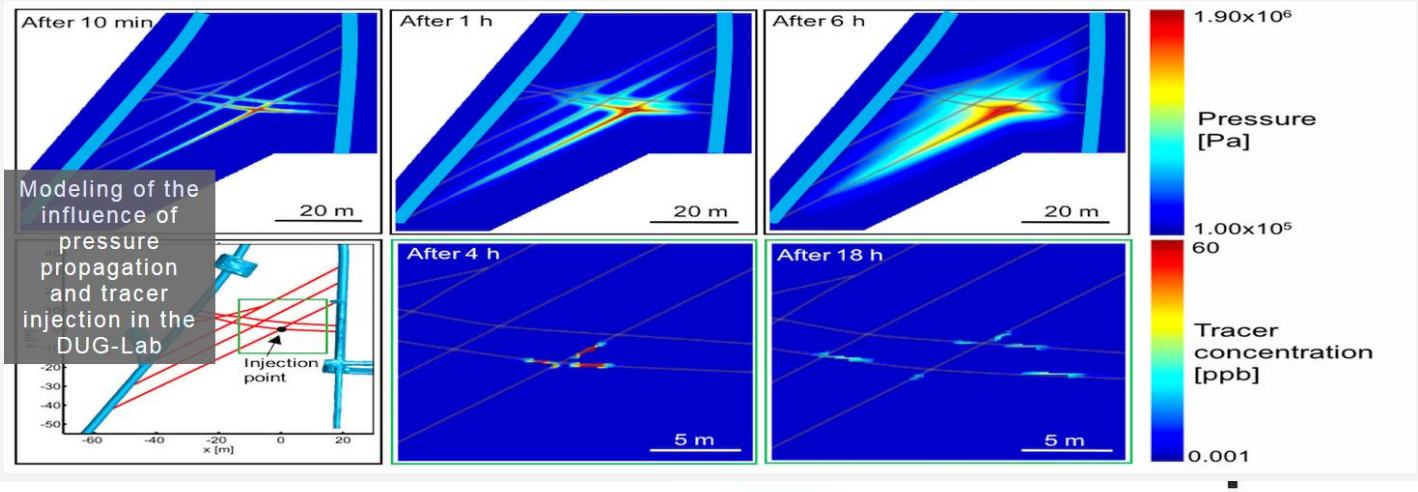
Caprock/fault sealing integrity: Mont Terri experiment

Modelling

Geothermal energy and geofluids
(Prof. Martin Saar)



Reaktoro
A unified framework for modeling chemically reactive systems

ELEGANCY

SCCER SoE

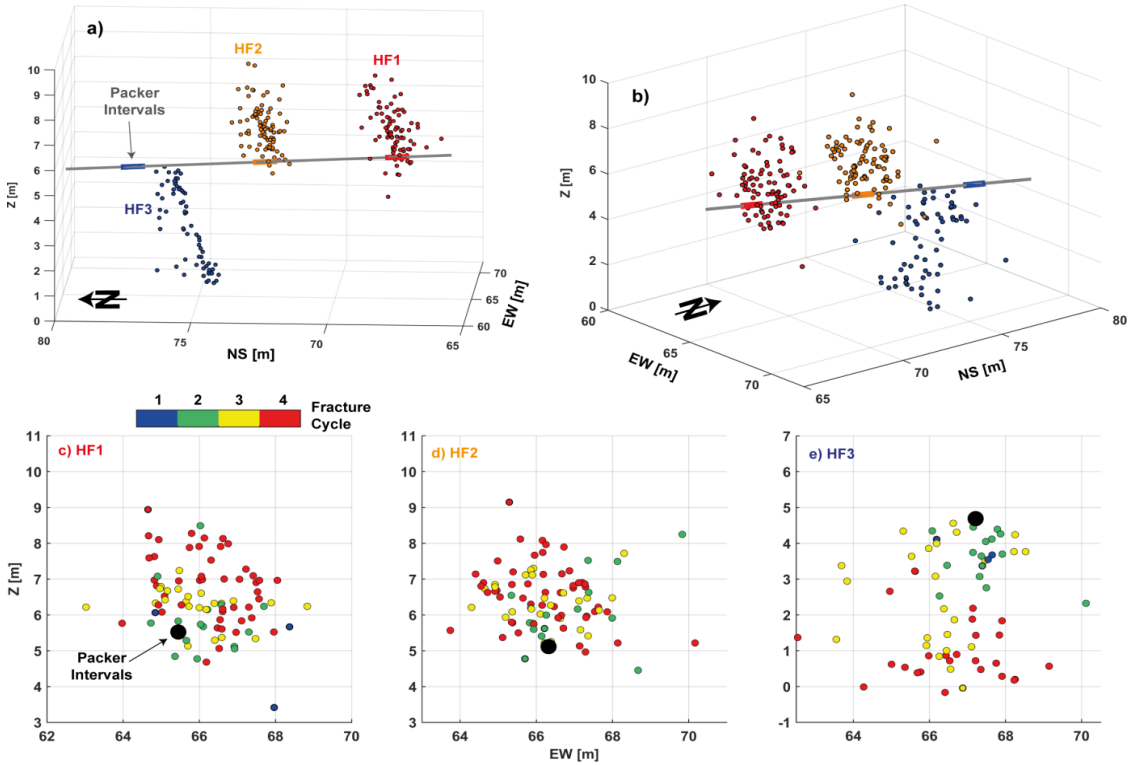
Caprock/fault sealing integrity: Mont Terri experiment

Monitoring

Exploration and Environmental Geophysics
(Prof. Hansruedi Maurer)

Swiss seismological survey
(Prof. Dr. Stefan Wiemer)

Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service



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Caprock/fault sealing integrity: Mont Terri experiment

Timeline

Target: Injection starts in Summer 2018

ELEGANCY: 1.9.2017- 31.8.2020

Mont Terri Phase 24-25

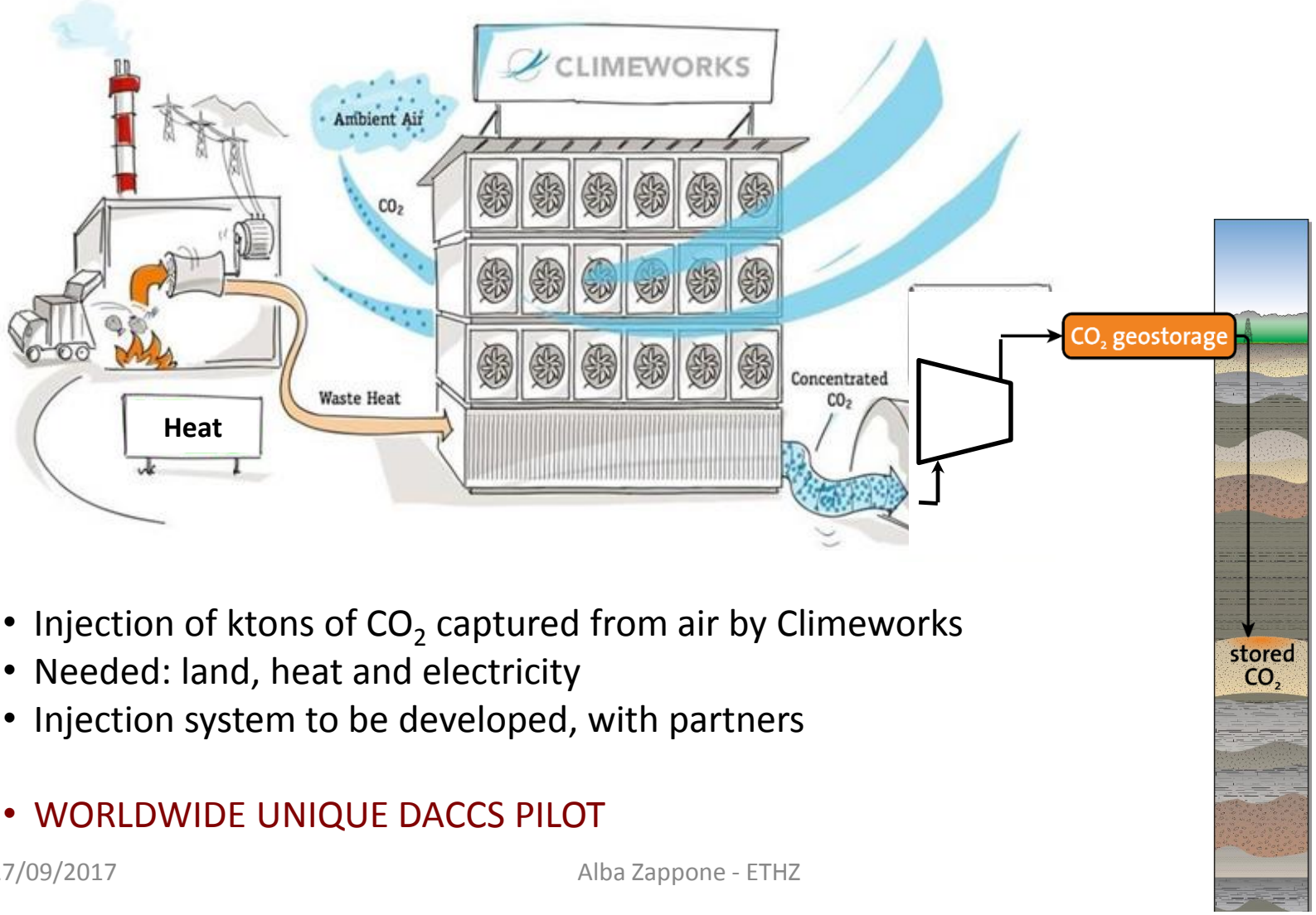
MT steering committee Nov 2017→ decision end March 2018

MT excavation of new tunnel & niche: Spring 2018

#	Task	Assigned To	Start	End	Dur
	Project Fault sealing integrity		1/9/17	30/7/20	759
1	Experimental design and feasibility study		1/9/17	31/5/18	194
2	Experimental installation		1/5/18	31/10/18	131
3	Injection and monitoring		1/11/18	30/6/19	172
4	Post experiment volume characterization		1/9/19	30/7/20	238

ELEGANCY

Long term vision? DACCS pilot in Switzerland: Demo 4?

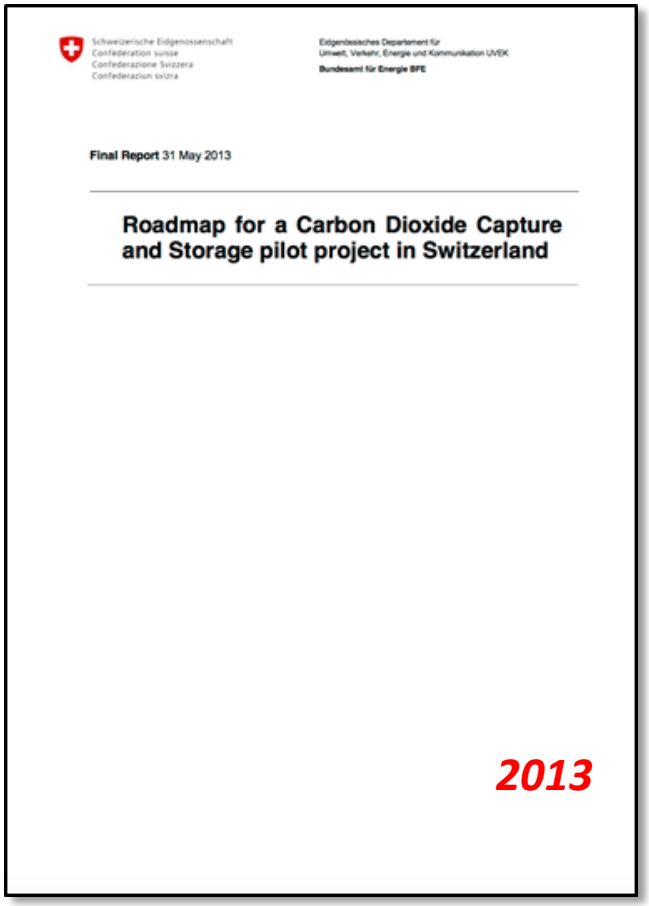


- Injection of ktons of CO_2 captured from air by Climeworks
- Needed: land, heat and electricity
- Injection system to be developed, with partners

- WORLDWIDE UNIQUE DACCS PILOT

ELEGANCY

CO_2 storage site selection



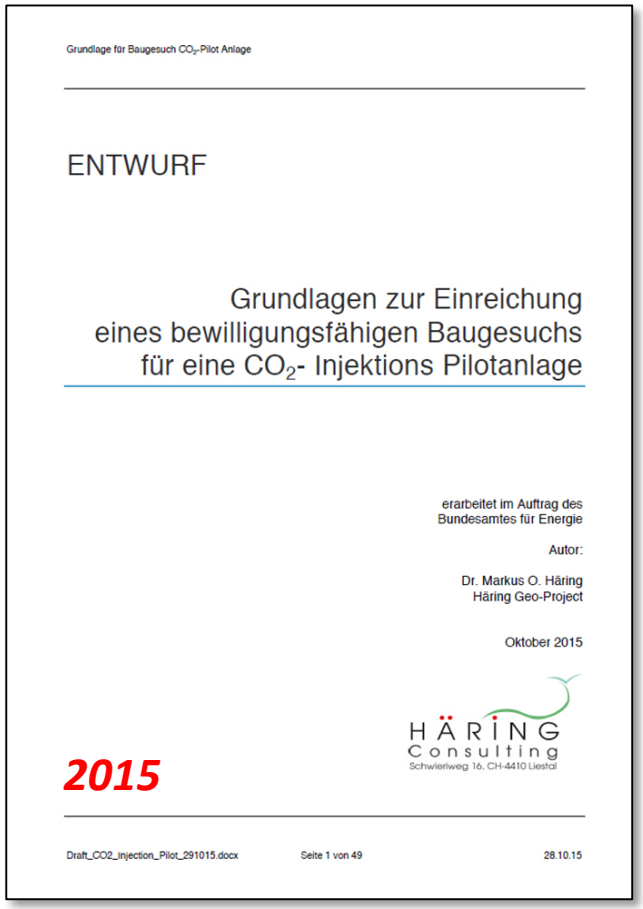
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK
Bundesamt für Energie BFE

Final Report 31 May 2013

Roadmap for a Carbon Dioxide Capture and Storage pilot project in Switzerland

2013



Grundlage für Baugesuch CO_2-Pilot Anlage

ENTWURF

Grundlagen zur Einreichung
eines bewilligungsfähigen Baugesuchs
für eine CO_2- Injektions Pilotanlage

erarbeitet im Auftrag des
Bundesamtes für Energie

Autor:

Dr. Markus O. Häring
Häring Geo-Project

Oktober 2015

HÄRING
Consulting
Schwierlweg 16, CH-4410 Liestal

2015

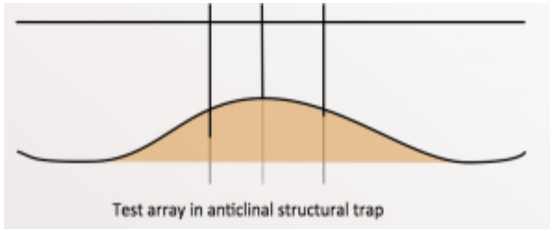
Draft_CO2_Injection_Pilot_291015.docx Seite 1 von 49 28.10.15

ELEGANCY

CO_2 storage site selection

Feasible Scenarios for Injection Test

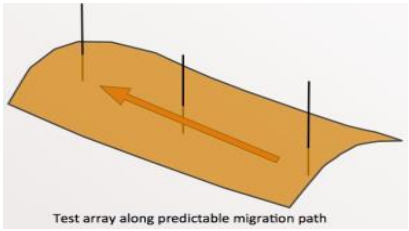
STORAGE



+ Could be final storage site (small)
+ Will demonstrate CCS feasibility in CH

- Long and costly exploration phase

FIELD LAB



+ Results on migration process in short time

- No final storage site, up-scaling problems, public acceptance

ELEGANCY

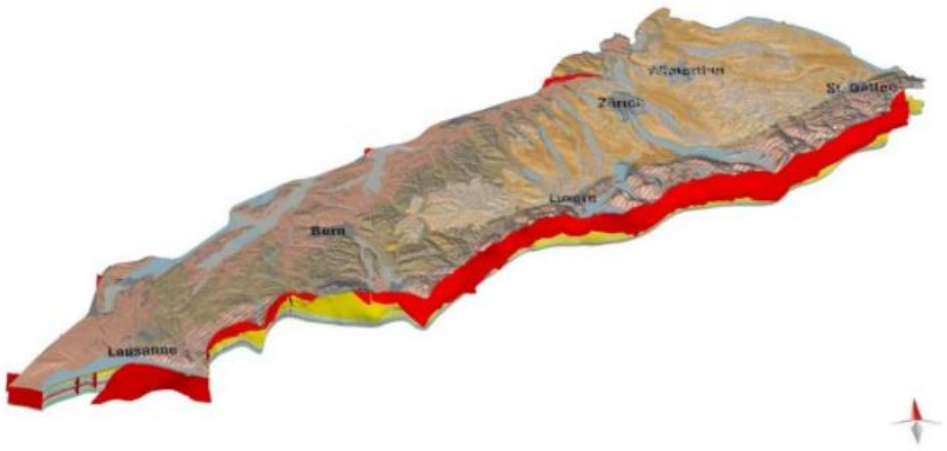
CO_2 storage site selection

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

Reservoir Geology and Sedimentary Basin Analysis
(Prof Andrea Moscariello)

GeoMol – Geologisches 3D Modell des Schweizerischen Mittellandes

Wie sieht es im Innern des Hügelzugs aus, auf dem Schloss Aarburg steht? Wo in der Schweiz gibt es Gräben, welche bis 3000 m unter die Erdoberfläche reichen? Wir können es Euch zeigen! Mit dem brandneuen geologischen 3D-Modell der Schweiz sind solche Einblicke in den Untergrund ab sofort möglich.



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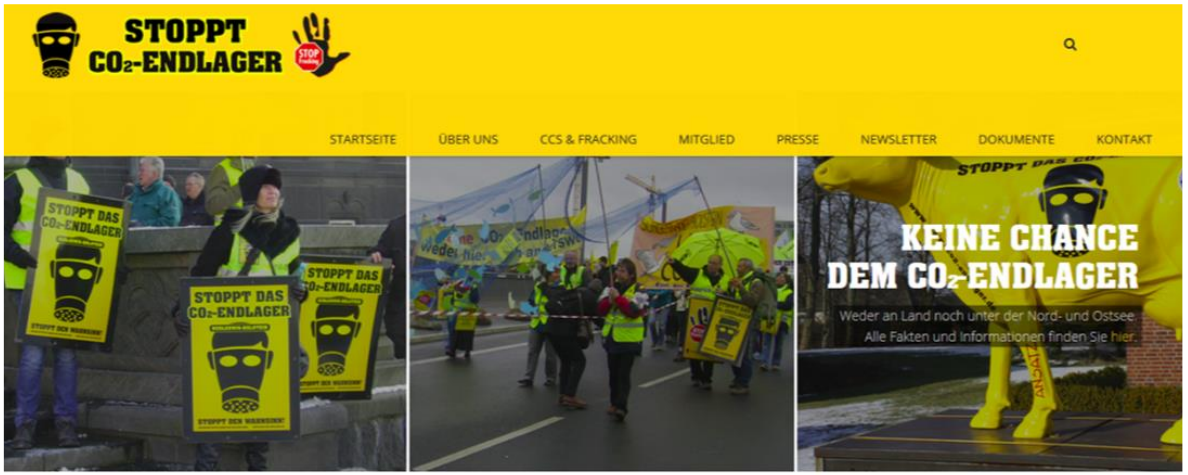
CO_2 storage site selection



USYS TdLab
Department of Environmental Systems Science
Transdisciplinarity Lab · Science-Society Interface

(Prof Michael Stauffacher)

Source: http://keinco2endlager.de/

CCS geological storage pilot

The opportunity of Elegancy

Thank you for your attention

Neue Zürcher Zeitung

Das neue Immobilienportal für Anspruchsvolle

Kohlendioxid-Rückgewinnung

Zürcher Startup-Unternehmen mit Weltpremiere: CO_2 wird aus der Luft gefiltert

von Christian Speicher / 31.5.2017, 12:00 Uhr

In Hinwil ist die weltweit erste Anlage in Betrieb genommen worden, die das Treibhausgas CO_2 aus der Luft filtert. Die Technologie könnte zukünftig dazu beitragen, unsere «Klimaschulden» zu begleichen.

Auf dem Dach der Kehrichtverbrennungsanlage in Hinwil steht der CO_2-Filter, der die Gärtnerei mit dem wachstumsfördernden Treibhausgas versorgt. (Bild: Climeworks / Julia Dunlop)

CLIMEWORKS

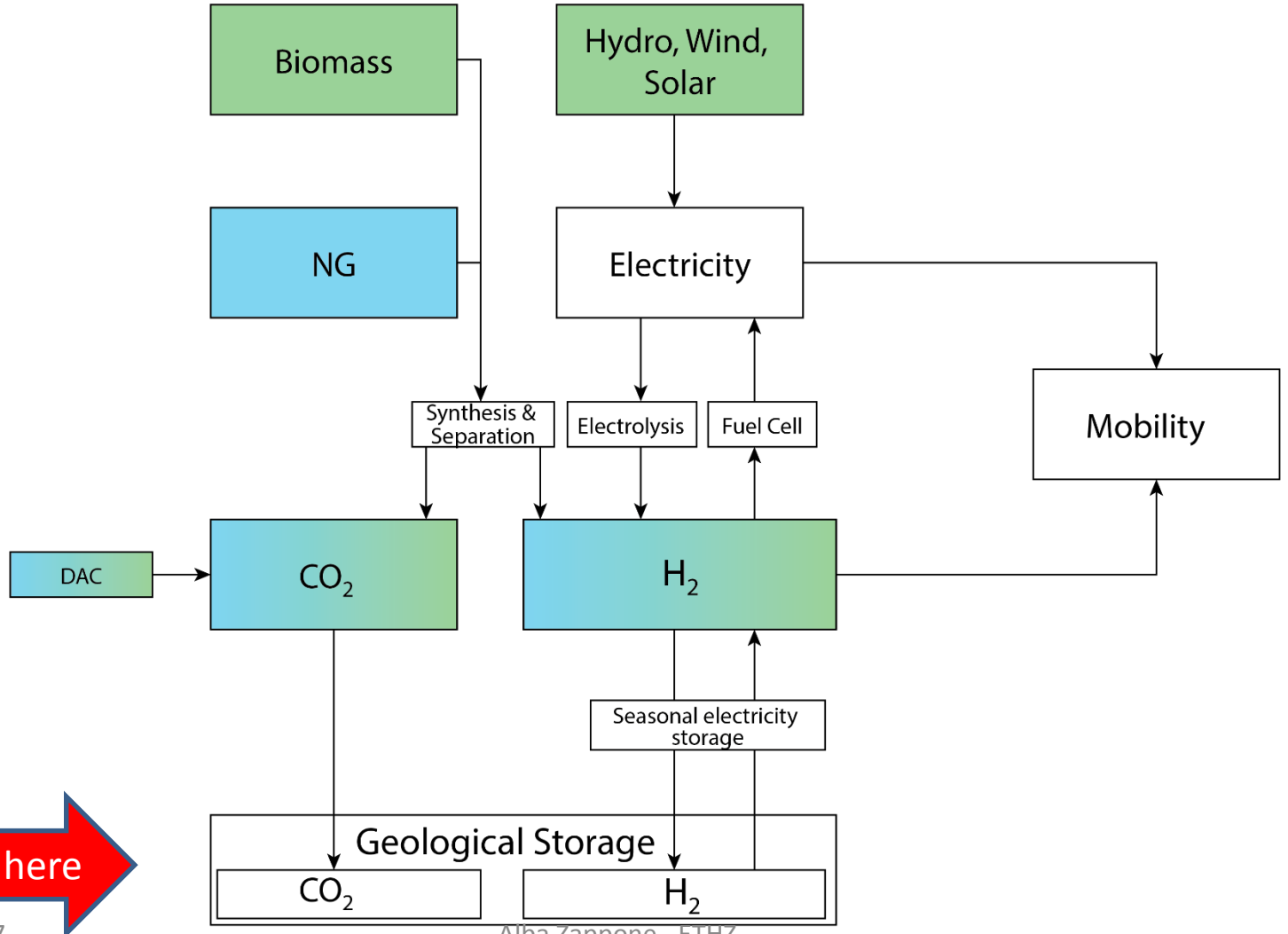
Capturing CO_2 from air

Climeworks makes history with world-first commercial CO2 capture plant

Today Climeworks is unveiling its proudest achievment to date: the world's first commercially operational plant capturing CO2 from the atmosphere.

We'll be bringing live updates from the launch event near Zürich, Switzerland. So check out our Twitter and Facebook feeds and sign up to our newsletter to get the latest updates from our ongoing mission to capture one per cent of global carbon emissions by 2025.

Elegancy - Vision



Proposal full title:

Enabling a Low-Carbon Economy via Hydrogen and CCS

Proposal acronym:

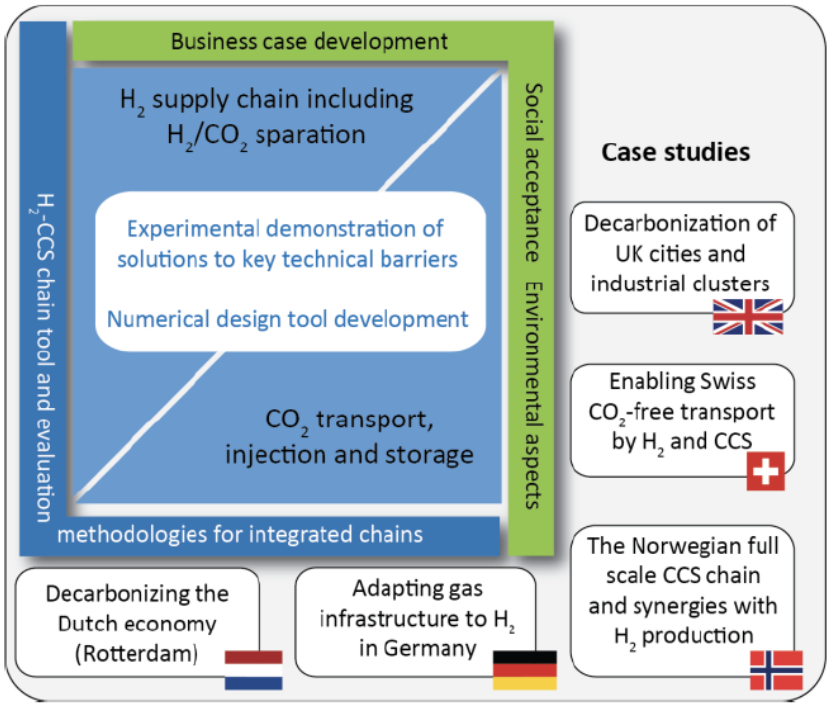
ELEGANCY

Call: ERA-NET Cofund ACT stage 2, full proposal, deadline 2017-01-16

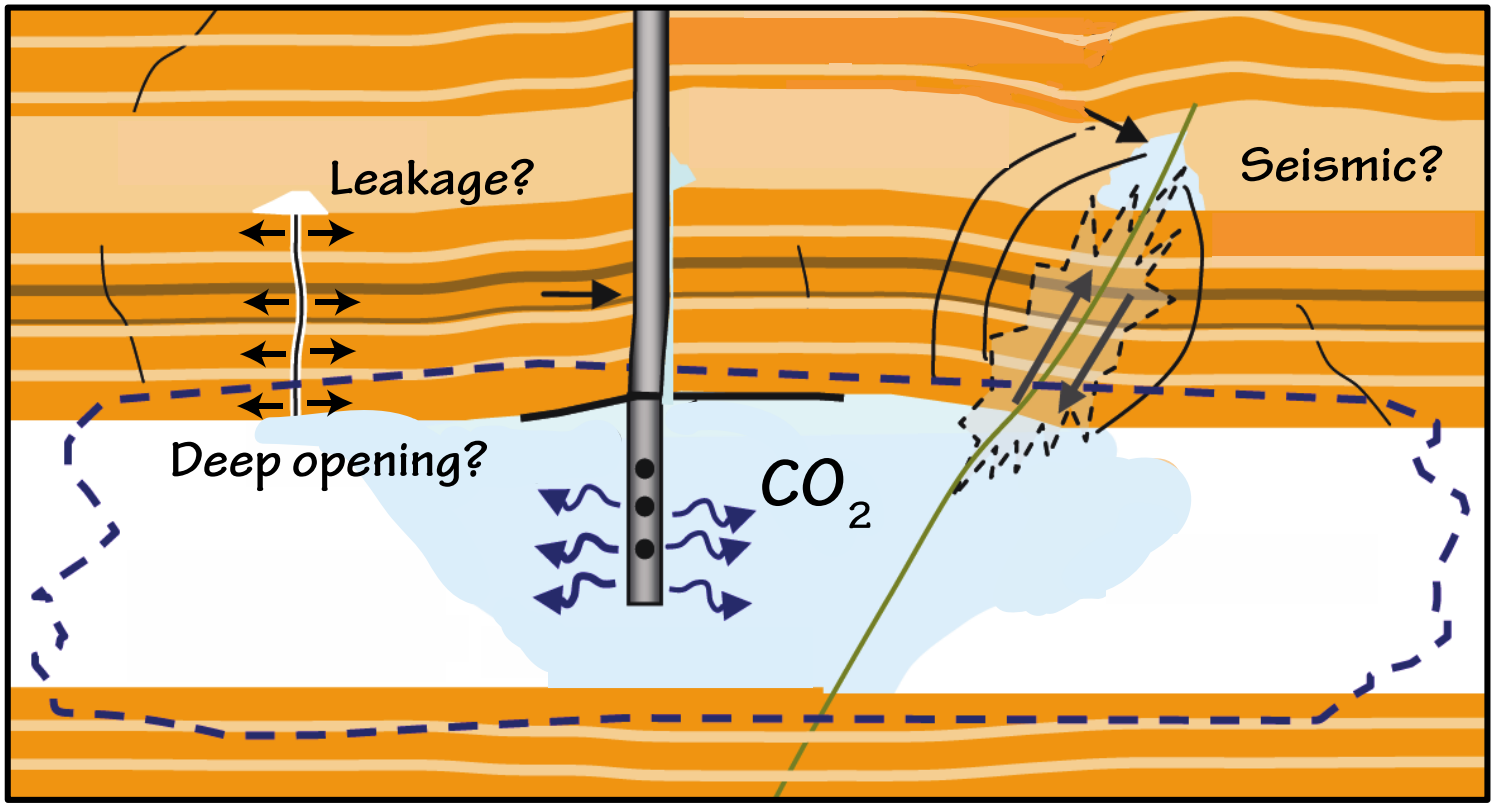
Project coordinator: Dr Svend Tollak Munkejord, Chief Scientist, SINTEF Energy Research
E-mail: svend.t.munkejord@sintef.no, Mobile phone: +47 47378042

List of applicants

Note	Organization name	Acronym	Country	Organization type
Main applicant	SINTEF Energy Research	SINTEF	Norway	Research institute
	Arntzen de Besche	AdeB	Norway	Law firm
	Aker Solutions	AKSO	Norway	Technology provider
	Gassco AS	Gassco	Norway	Natural gas network operator
National consortium leader, UK	Imperial College London	ICL	UK	University
	British Geological Survey	BGS	UK	Research institute
	Scottish Enterprise	SE	UK	Development agency
	Sustainable Decisions Ltd	SDL	UK	Consultancy firm
	INEOS Chemicals Grangemouth Limited	INEOS	UK	Petrochemical company
National consortium leader, CH	ETH Zürich	ETH	CH	University
	Swiss Competence Center for Energy Research – Supply of Electricity	SCCER	CH	University/Research institute
	Paul Scherrer Institute	PSI	CH	Research institute
	Climeworks AG	CW	CH	Technology provider
	Energie 360°	E360	CH	Natural gas grid operator
	First Climate AG	FC	CH	Consultancy firm
National consortium leader, DE	Ruhr-University Bochum	RUB	DE	University
	Open Grid Europe	OGE	DE	Natural gas grid operator
	Uniper Energy Storage	UES	DE	Technology provider
National consortium leader, NL	Energy Research Centre of the Netherlands	ECN	NL	Research institute
	Netherlands Organisation for Applied Scientific Research	TNO	NL	Research institute
	Utrecht University	UU	NL	University
	Shell	Shell	NL	Energy company
Cooperation partner	Swerea MEFOS	MEFOS	SE	Research institute
Cooperation partner	Groupe Européen de Recherches Gazières	GERG	BE	Industry association

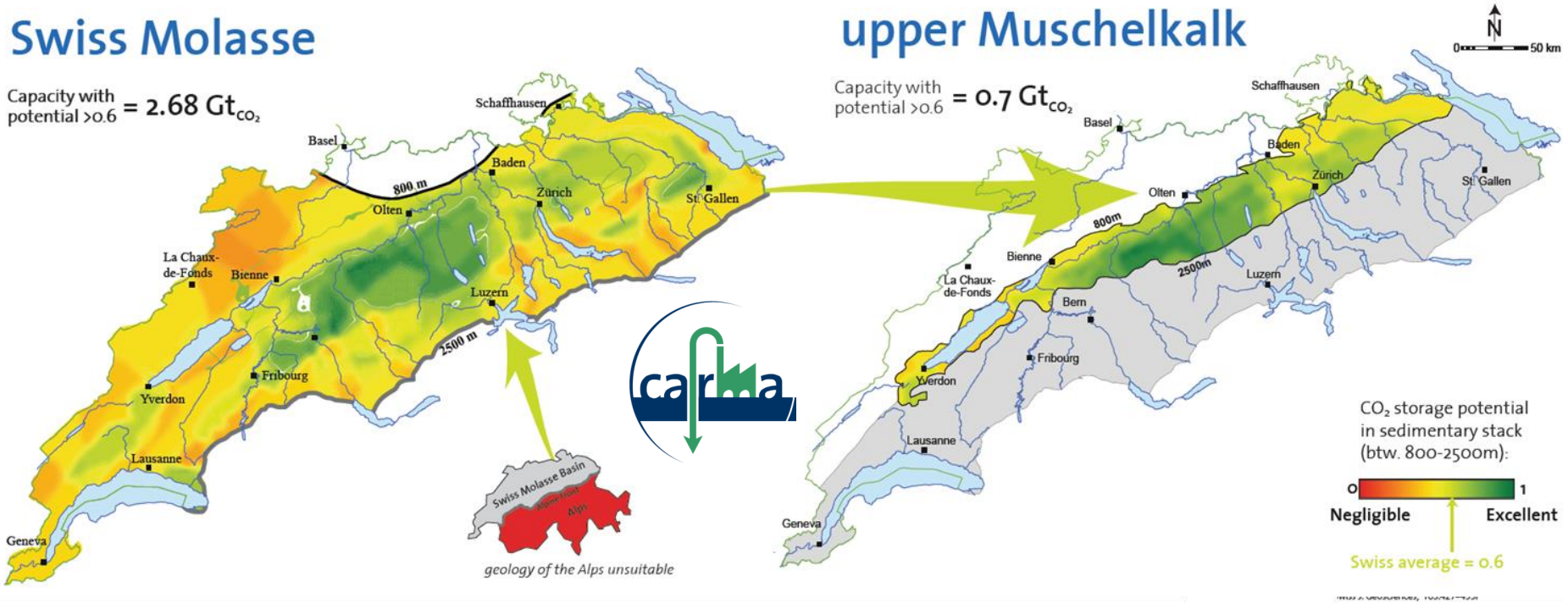


Roles of geophysics?



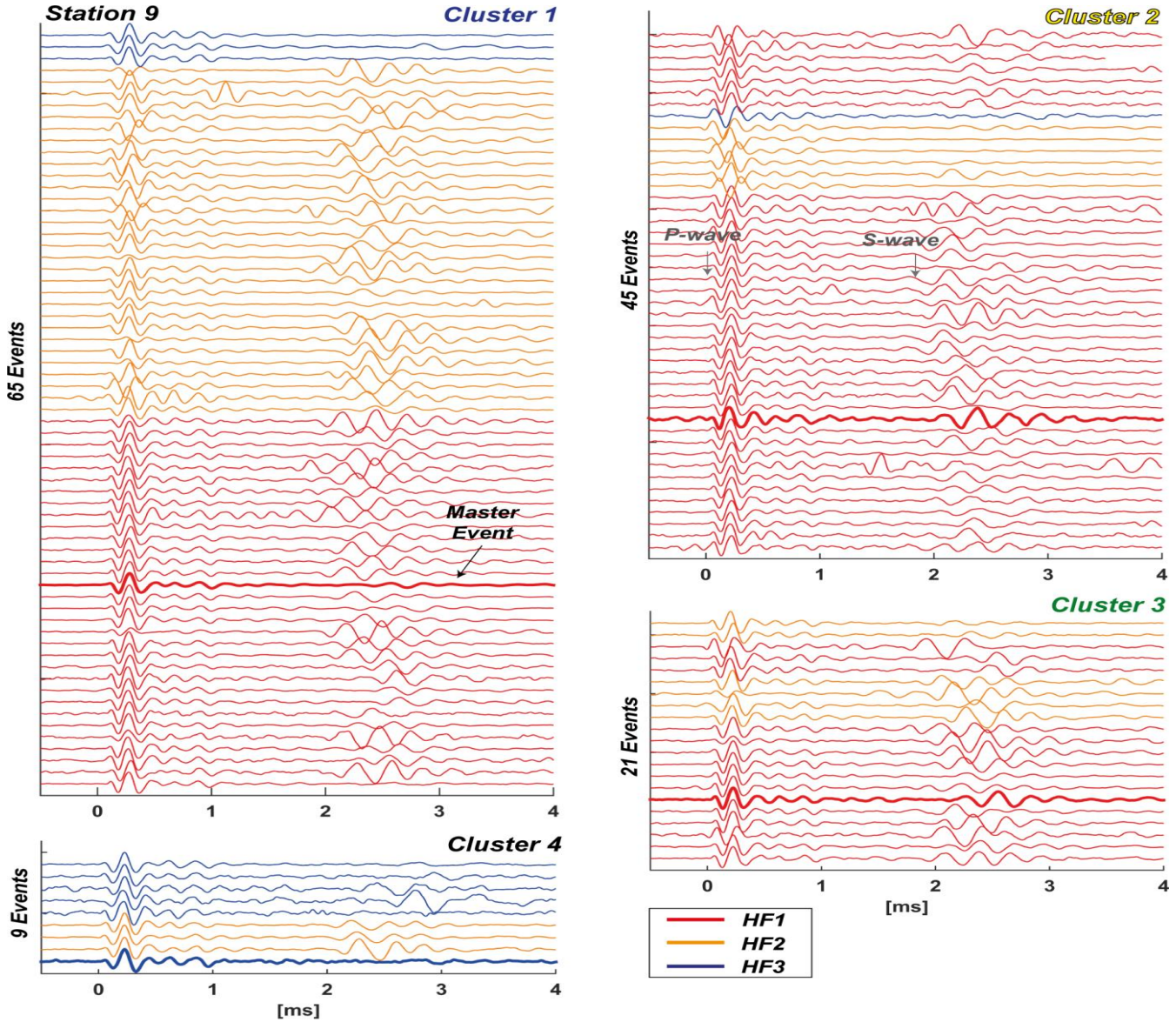
ELEGANCY

CO_2 storage site selection

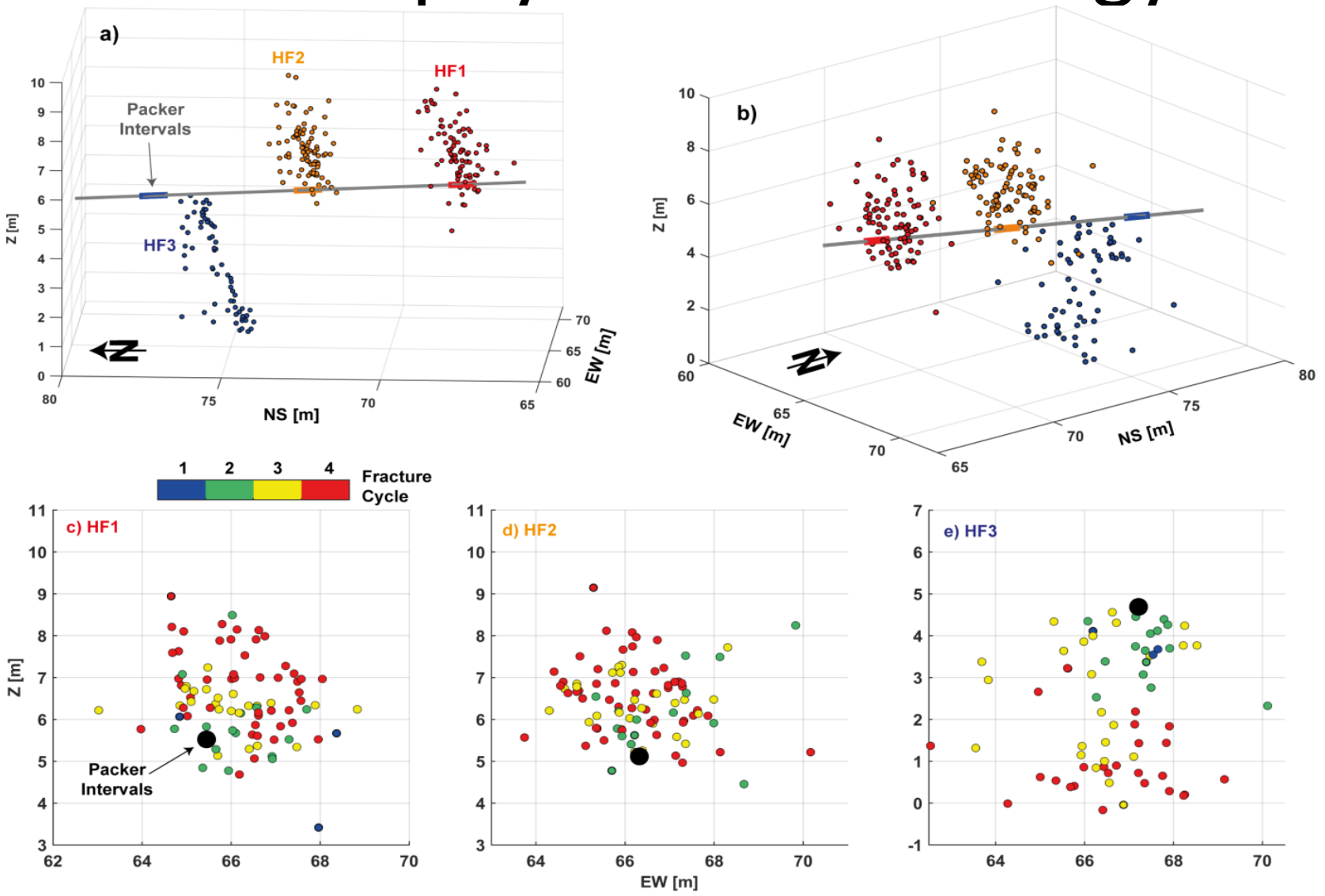


Chevalier G., Diamond L.W., Leu W. (2010) Potential for deep geological sequestration of CO_2 in Switzerland: a first appraisal, Swiss J. Geosciences, 103:427–455

Geophysics - Seismology



Geophysics - Seismology

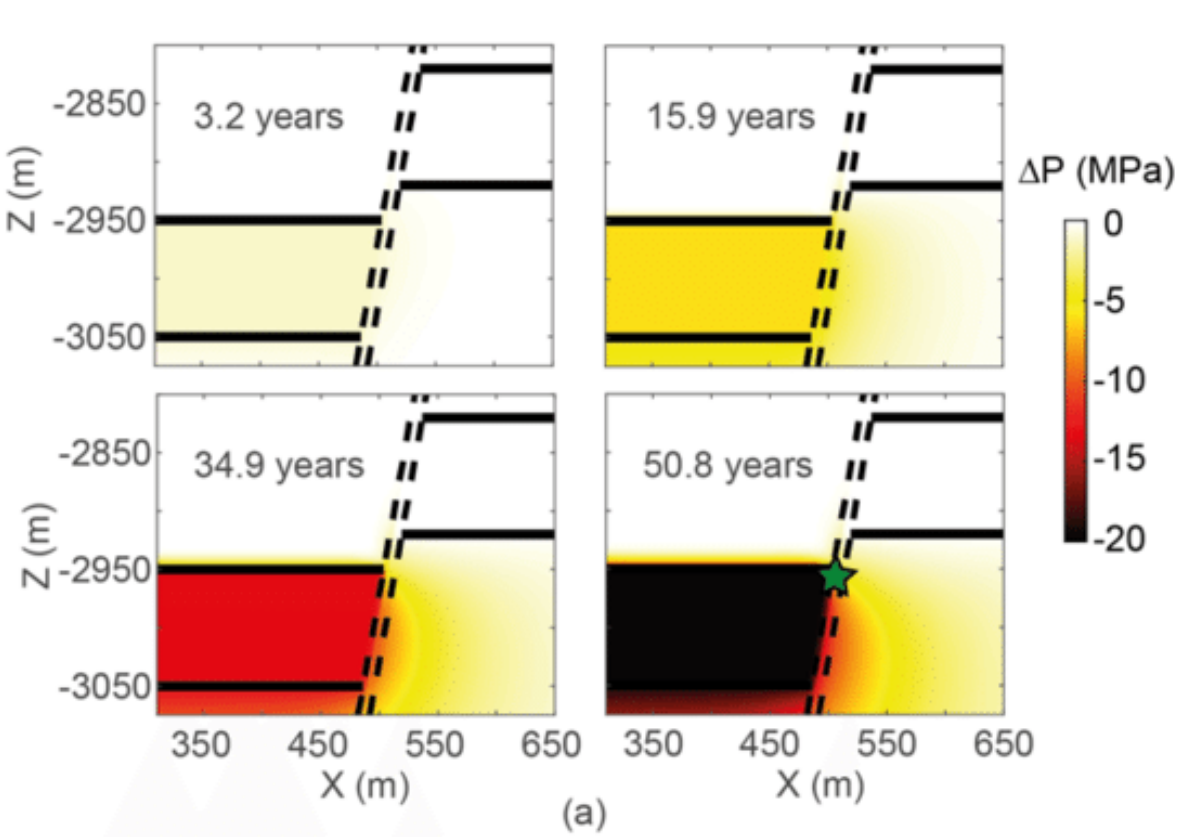


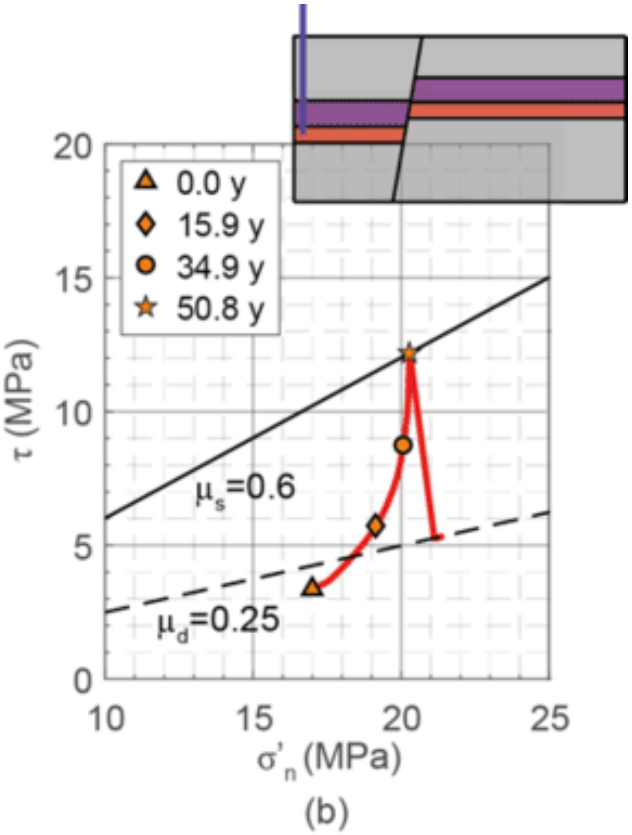
Seismology with no EQs?

- Really?
- What are the conditions under which micro-seismicity or creep dominate? (→ LabQuake, HighStep)
- Is creep only micro-seismicity with very high b and below the detection threshold?
- Can we optimism out detection algorithms to see smaller events (cross-correlation ...)
- Can we track fluid propagation using ambient noise (or coda wave) interferometry?
- Model validation (→ Antonio)

Risk Governance: Monitoring and Mitigation Strategies

Modelling of fault reactiviation potential





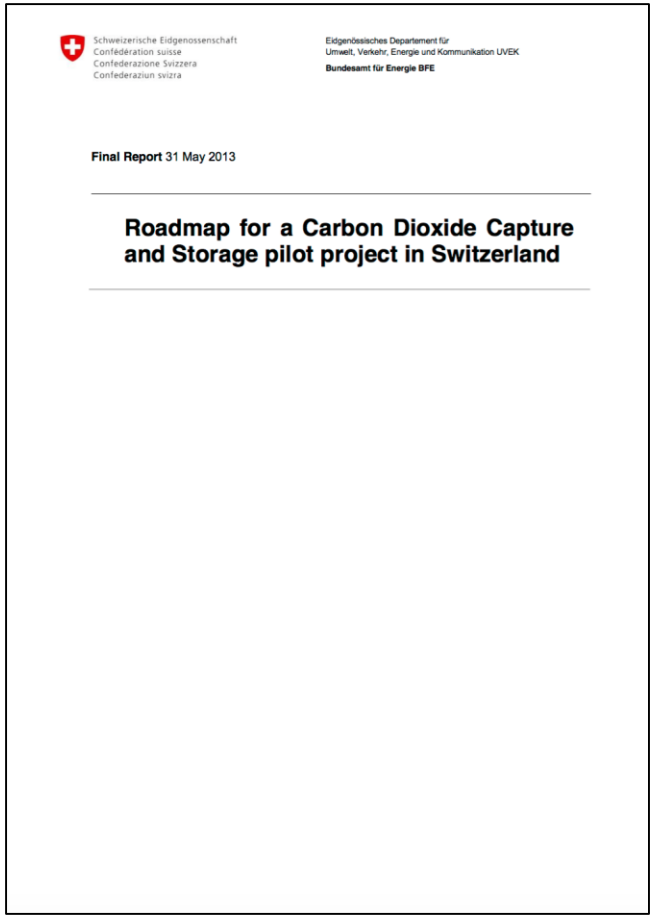
Doing what?

Based on literature study, modeling and expert elicitation continue to define for the Swiss context (‘what would it need’):

- Site characterization
- Risk assessment strategies
- Monitoring strategies
- Mitigation strategies
- etc.

CCS: why are we here?

- Rising CO_2 levels and resulting climate change is deeply worrisome.
- Science in Switzerland, should try to make a difference.
- ELEGANCY: An opportunity to do something, may be not perfect at all, but better than nothing.
- And, hopefully, networking opportunity and a stepping stone.


Schweizerische Eidgenossenschaft
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Umwelt, Verkehr, Energie und Kommunikation UVEK
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Final Report 31 May 2013

Roadmap for a Carbon Dioxide Capture and Storage pilot project in Switzerland

ELEGANCY

Swiss case study