



CCS projects and activities in Switzerland: a chronological overview

Mischa Werner and Marco Mazzotti, SCCER-SoE, ETHZ
Jahrestagung «Kraftwerk 2020», Ittigen, Sept. 1st 2014

Early developments

08.3064 – Interpellation
CO₂-Sequestrierung in der Schweiz

Eingereicht von



Girod Bastien

Einreichungsdatum 12.03.2008

Eingereicht im Nationalrat

Stand der Beratung Erledigt

Eingereichter Text

Der Bundesrat wird ersucht, folgende Fragen zu beantworten:

1. Welches Potenzial besteht in der Schweiz für eine CO₂-Sequestrierung?
2. Zu welchen Kosten könnten diese Potenziale ausgeschöpft werden?
3. Welche Risiken birgt die Ausschöpfung dieser CO₂-Sequestrierungs-Potenziale?
4. Welche Anstrengungen werden unternommen, um die Fragen 1 bis 3 genauer beantworten zu können?
5. Welche gesetzlichen Regulierungen bestehen für das Ausschöpfen von CO₂-Sequestrierungs-Potenzialen? Was plant der Bundesrat?

Reply from Fed. Council (June 08):

Antwort des Bundesrates vom 18.06.2008

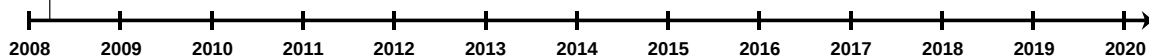
1. Das Potenzial in der Schweiz ist nach heutigem Wissen als gering einzustufen.

Der geologische Untergrund und die tektonische Struktur der Schweiz scheinen für eine CO₂-Sequestrierung im grosseren Ausmass kaum geeignet. Die zahlreichen Bohrungen nach fossilen Lagerstätten in den sedimentären Schichten des Mittellandes und die Suche nach einer geeigneten Erdgas-Lagerstätte für die Versorgungssicherheit verliefen ohne nennenswerten Erfolg. Beides kann als Indiz dafür gewertet werden, dass auch für eine CO₂-Sequestrierung geeignete Lagerstätten fehlen.

Zudem gibt es zurzeit in der Schweiz kaum emissionsintensive Punktquellen, bei denen sich die Separierung und das Auffangen grosser Mengen Kohlendioxids anböte. Etwa 75 Prozent der CO₂-Gesamtemissionen werden durch mobile beziehungsweise diffus verstreute Quellen verursacht (vor allem Verkehr und Gebäude). Hier stellt die CO₂-Sequestrierung keine realistische Option dar. Infrage kämen hingegen bestehende Zementwerke oder allfällige zukünftige fossil-thermische Kraftwerke.

2. Die Kosten einer CO₂-Sequestrierung umfassen Investitionen in die Infrastruktur (Anlagen zur Abscheidung, zum Transport und zur Speicherung von CO₂) und Kosten für den praktischen Betrieb der CO₂-Speicheranlagen. Die effektiven Kosten hängen massgeblich von den lokalen und nationalen Voraussetzungen ab, d. h. den energie- und klimapolitischen, rechtlichen und geologischen Rahmenbedingungen.

Interpellation Girod 08.3064
«CO₂-Sequestrierung in der Schweiz»



Early developments

Call for «BAFU study» by FOEN:

Carbon dioxide Capture and Storage – CCS Studie zum Entwicklungsstand von CCS in der Schweiz

Lasse Wallquist und Mischa Werner

November 2008

Im Auftrag des Bundesamtes für Umwelt, BAFU

Call for «BFE Study» by SFOE:



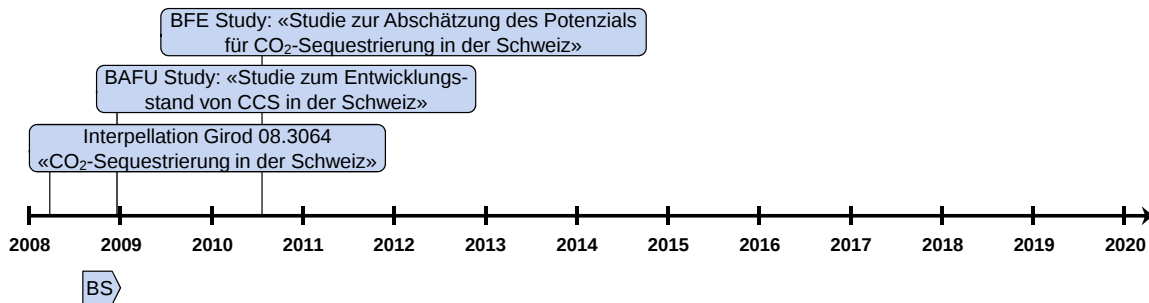
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

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

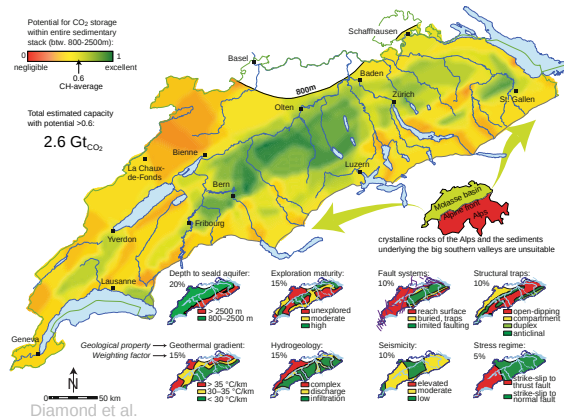
Schlussbericht 31. August 2010

Studie zur Abschätzung des Potenzials für CO₂-Sequestrierung in der Schweiz

Potential for geological sequestration of CO₂ in Switzerland



Early developments



Call for «BFE Study» by SFOE:



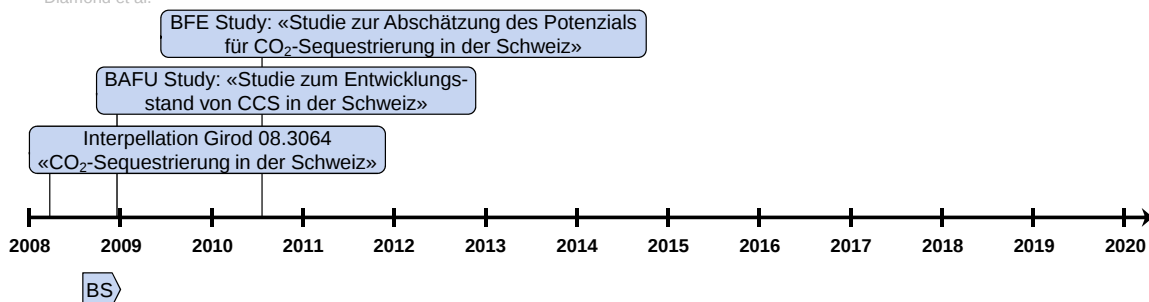
Schweizerische Eidgenossenschaft
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Umwelt, Verkehr, Energie und Kommunikation UVEK
Bundesamt für Energie BFE

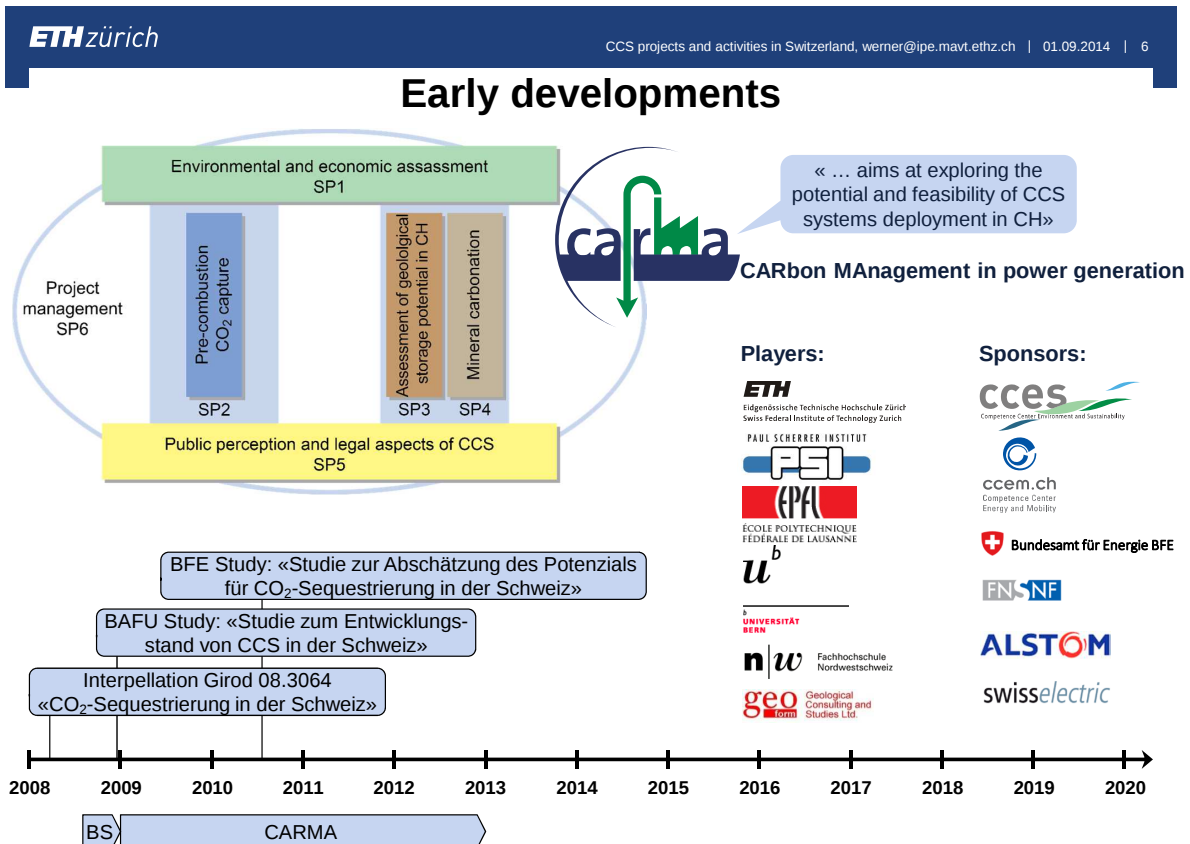
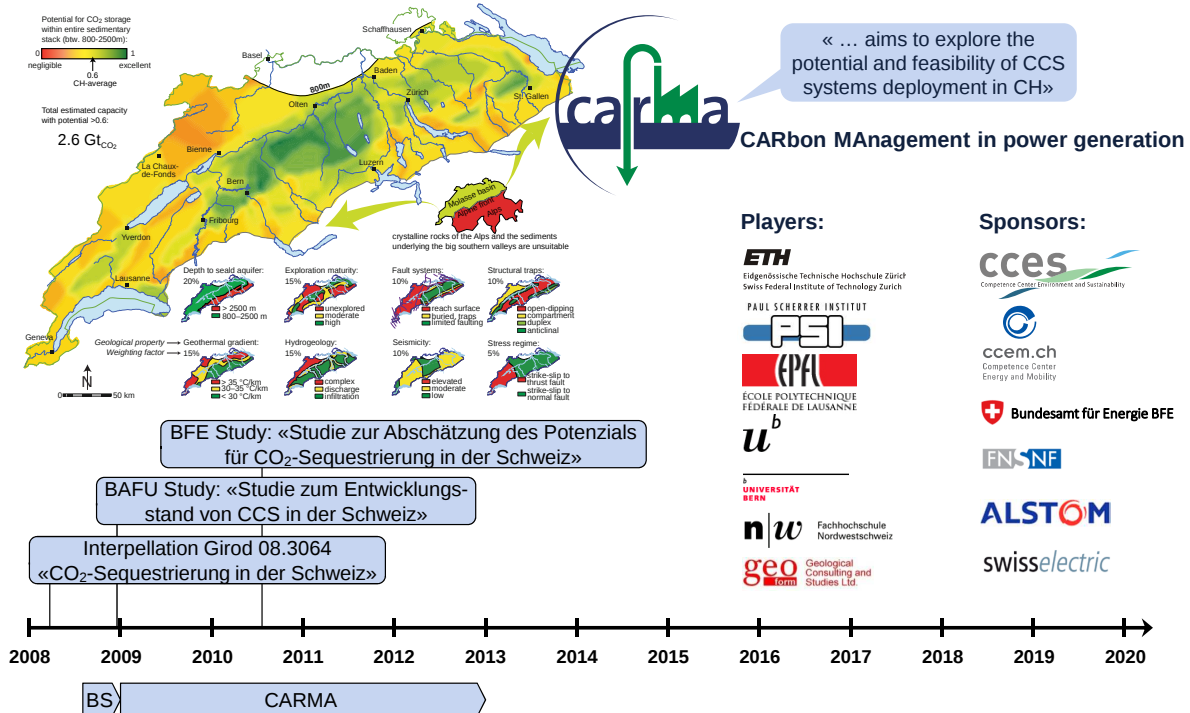
Schlussbericht 31. August 2010

Studie zur Abschätzung des Potenzials für CO₂-Sequestrierung in der Schweiz

Potential for geological sequestration of CO₂ in Switzerland



Early developments



CARMA follow-up: CCS pilot roadmap

Final Report 31 May 2013

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

«... to outline the future steps that may enable the application of GUD+CCS within the Swiss energy portfolio»

- WP1: Motivation and deliverables of a CCS pilot project in CH
- WP2: Project setup proposal
- WP3: Legal and regulatory aspects
- WP4: Roadmap to a CO₂ injection test in CH

Players:

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Ecosens
Environmental
Management
Consultants

u^b
UNIVERSITÄT
BERN

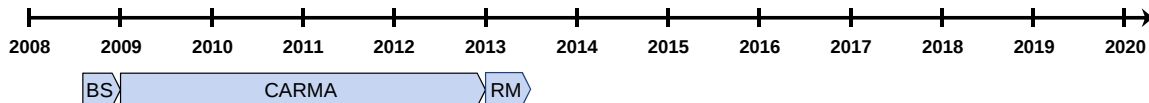
ALSTOM

geo Geological
Consulting and
Studies Ltd.

Sponsors:

Bundesamt für Energie BFE

Bundesamt für Umwelt BAFU



CARMA follow-up: CCS pilot roadmap

Final Report 31 May 2013

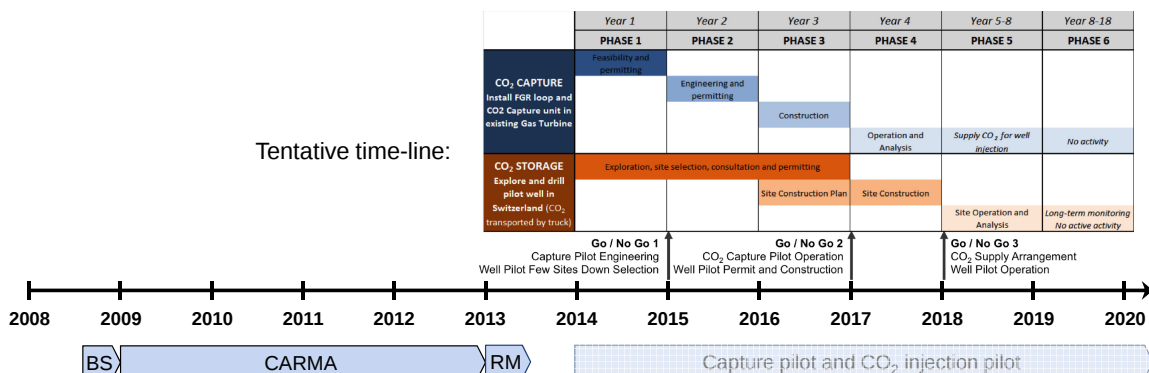
Roadmap for a Carbon Dioxide Capture and Storage pilot project in Switzerland

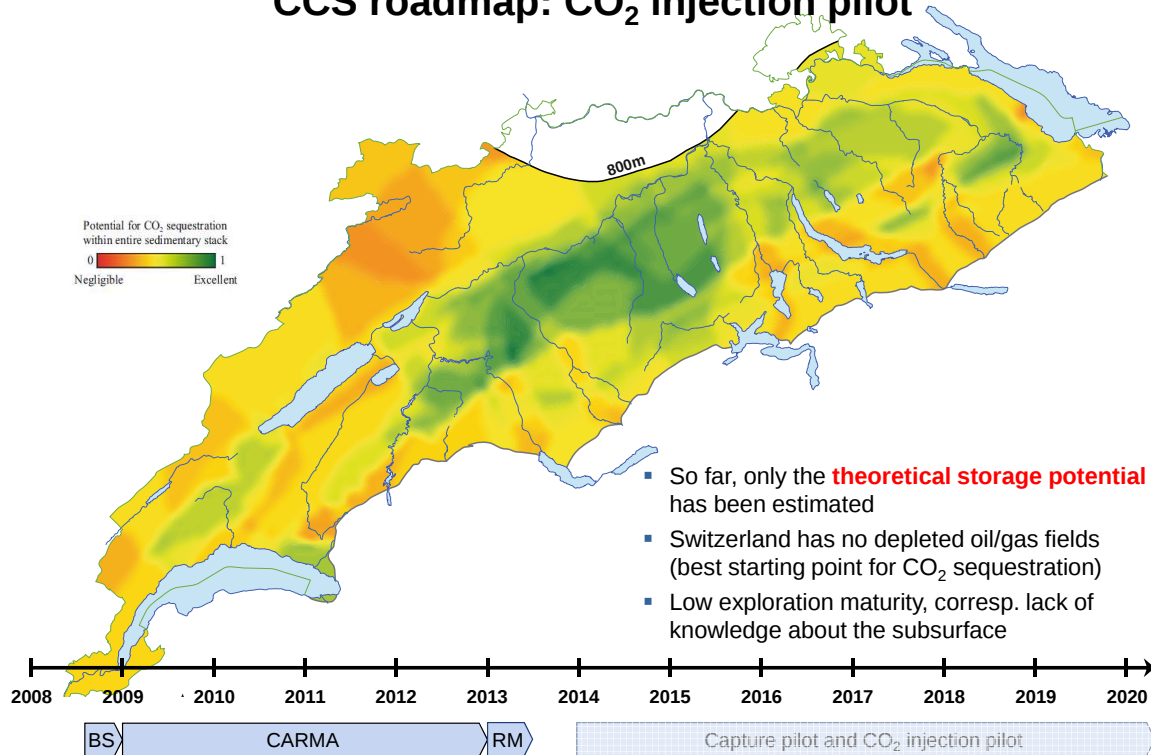
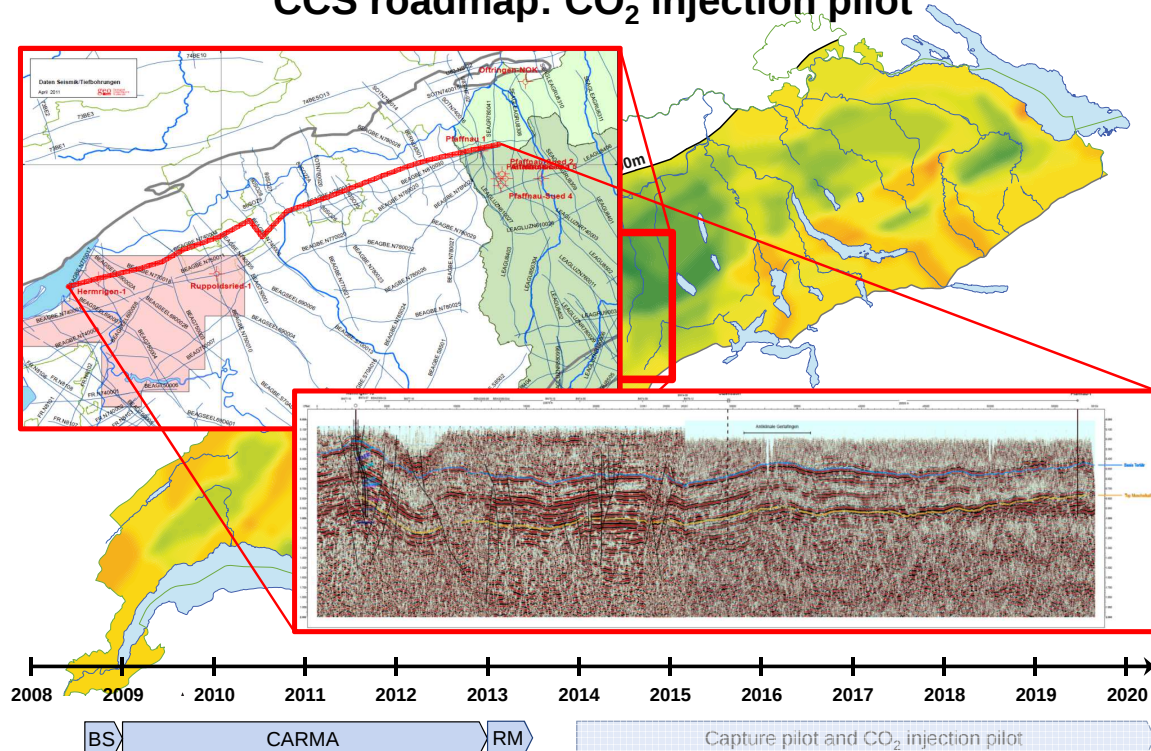
- WP1: Motivation and deliverables of a CCS pilot project in CH
- WP2: Project setup proposal
- WP3: Legal and regulatory aspects
- WP4: Roadmap to a CO₂ injection test in CH

→ A capture pilot is not critical for the deployment of CCS in CH ...

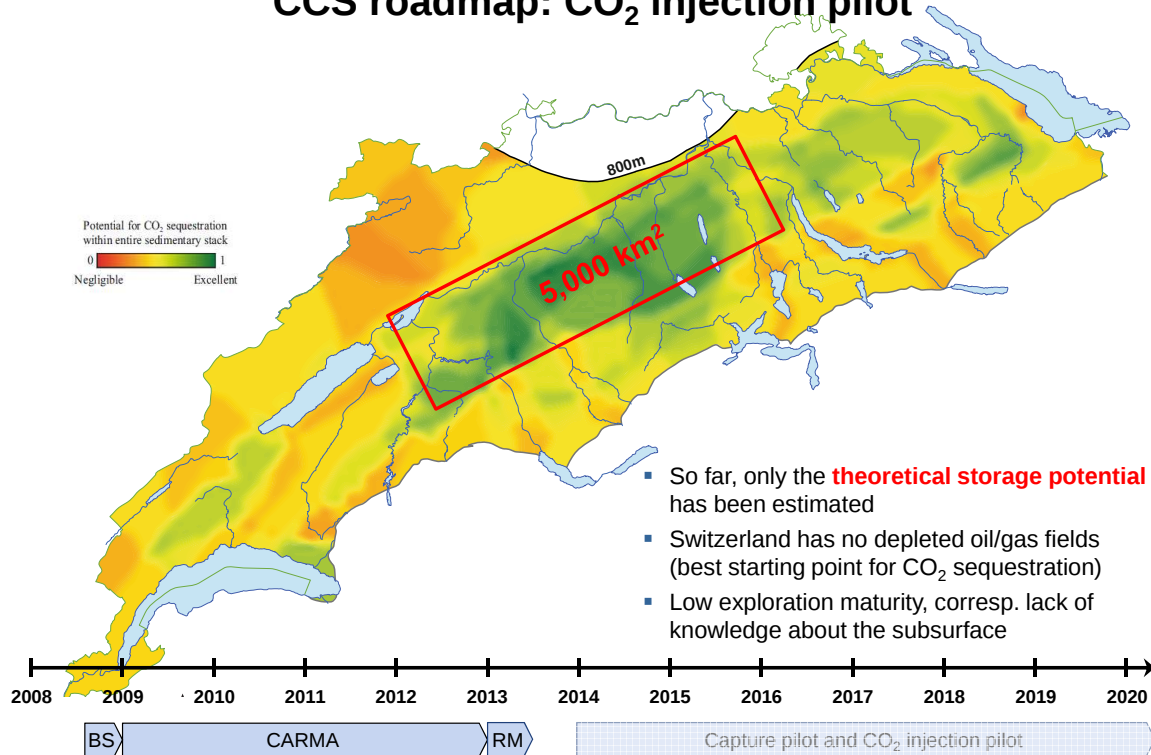
→ ... a storage pilot is!

Tentative time-line:



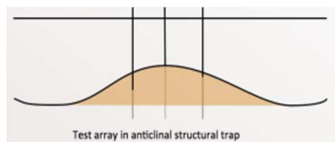
CCS roadmap: CO₂ injection pilotCCS roadmap: CO₂ injection pilot

CCS roadmap: CO₂ injection pilot



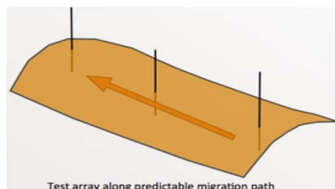
CCS roadmap: CO₂ injection pilot

Scenario "STORAGE":

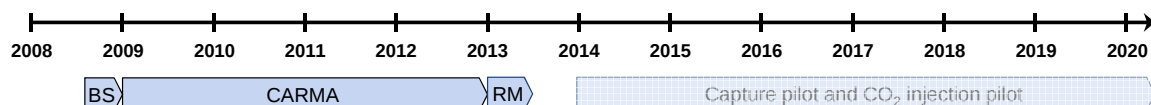


- + Could be final storage site (small)
- + Will demonstrate CCS feasibility in CH
- Long and costly exploration phase

Scenario "FIELD LAB":

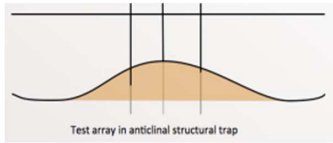


- + Results on migration process in short time
- No final storage site, up-scaling problems, public acceptance

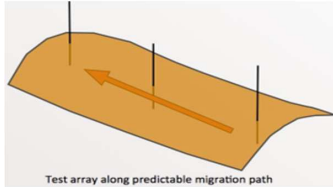


CCS roadmap: CO₂ injection pilot

Scenario "STORAGE":



Scenario "FIELD LAB":



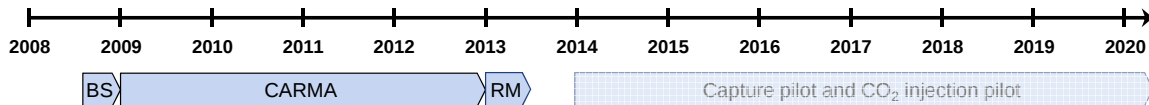
Site selection procedure: Tentative line of action

- 0 Project set-up (legal entity, project team and financing)
- 1 **Geology regional: Define area of interest**
- 2a Check license situation / Potential JV's and collaboration
- 2b **Environmental screening regional (restrictions/conflicts/proximity)**
- 3 **Geology local: Evaluate existing seismic/well data, define leads**
- 4 Decide on STORAGE or FIELD LAB project
- 5 **Environmental screening local / Information strategy**
- 6a **Start numerical modeling**
- 6b **Exploration seismic&wells if STORAGE**
- 7 **Well design (1 injection & ~2 monitoring wells)**
- 8 **Drill injection & monitoring wells**

Risk assessment

Schedule & cost estimate

Injection & monitoring phase



CCS roadmap: CO₂ injection pilot

Tentative schedule and cost estimate:

	Activity Name	Activity Cost (kFr.)	2013				2014				2015				2016				2017				2018				2019			
			1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1	Project setup...	30																												
5	Test site design (generic)	280																												
6	Test programme...	50																												
10	Injection well design...	70																												
15	Reservoir Monitoring...	60																												
19	Microseismic Monitoring...	40																												
24	Onsite facilities...	60																												
30	Risk dialogue with authorities and public	0																												
31	Area selection process	60																												
32	Evaluate existing data	50																												
33	Check joint venture options	10																												
34	Acquisition of exploration permit	70																												
35	Submission to cantonal regulator...	70																												
43	Permitting process	0																												
44	Seismic exploration	12'845																												
46	Define Work Programme...	45																												
49	Field Permitting	300																												
50	Field operations	12'000																												
51	Data processing / Interpretation	500																												
52	Site selection	0																												
53	Site acquisition & Drilling Permit	165																												
54	Test site design (site specific)...	70																												
59	Submission to cantonal regulator...	85																												
67	Permitting process	0																												

Lifetime: 15y

6y site selection

3y injection/monitoring

6y monitoring

FIELD LAB time saving: 2-3y

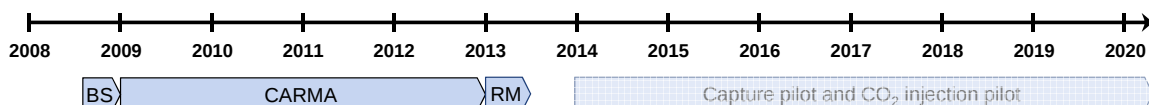
Estimated costs: ~40 Mio.CHF

seismic 13 Mio.CHF

site/drilling 15 Mio.CHF

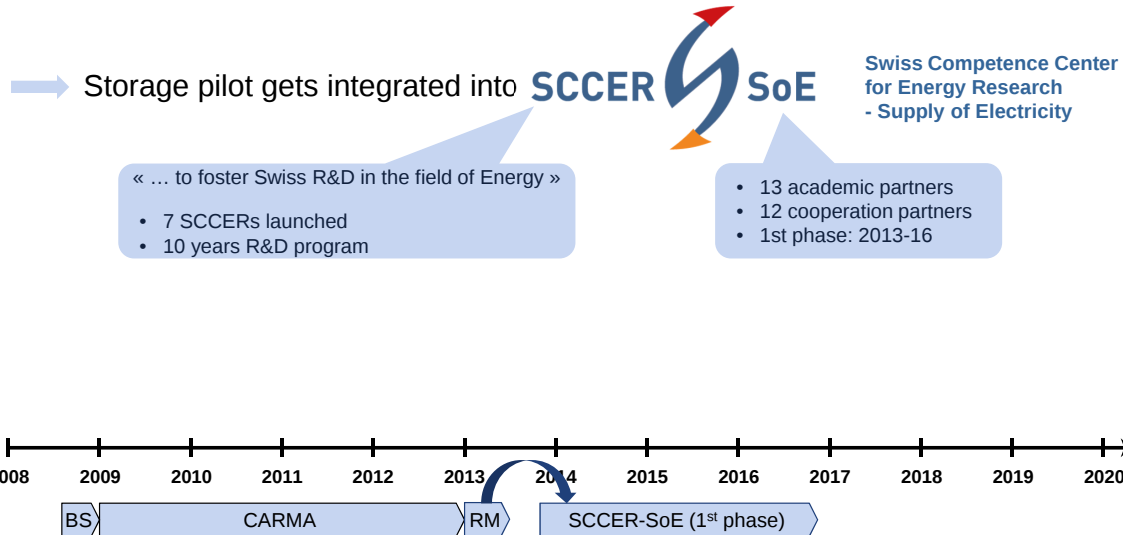
operating 12 Mio.CHF

F. LAB cost saving: ~10 Mio.CHF

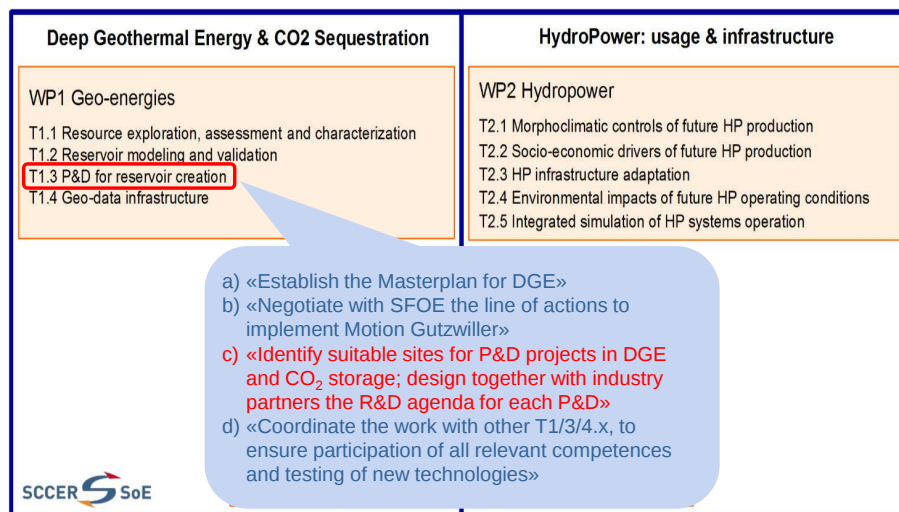


Post-roadmap

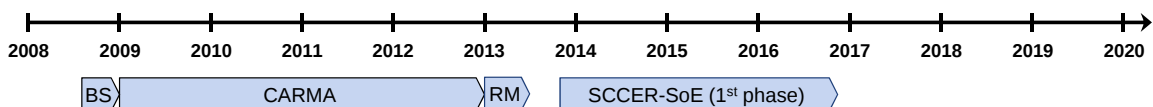
- Financial burden too high for academia to bear on their own
- Absence of partners and sponsors
- At the same time, the messages given in the roadmap retain their validity



Post-roadmap: SCCER-SoE

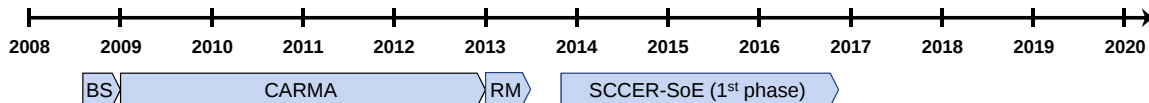


→ Thus, the community is given an official mandate to push on a Swiss field test!



Ongoing activities

- Cost situation remains difficult, also under the SCCER-SoE umbrella
- Ongoing activities and new ideas aim at international cooperation and «low hanging fruit»:
 - ECCSEL
 - ERA-NET Cofund «CCS»
 - Mont Terri Rock Laboratory
 - (Horizon 2020 proposals)



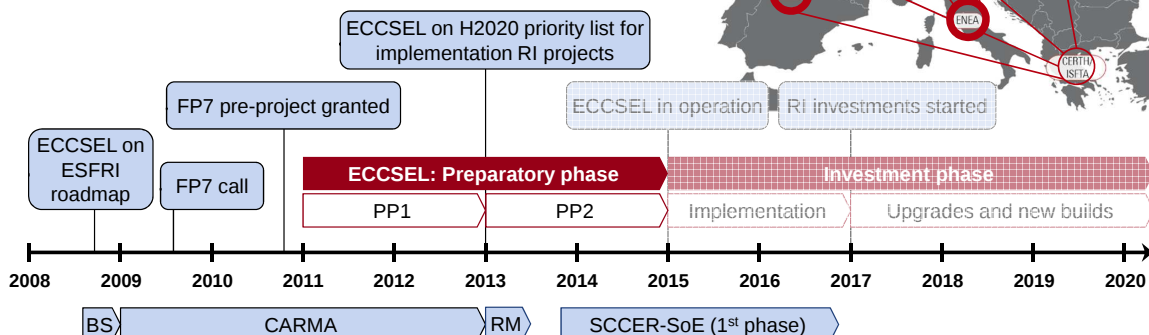
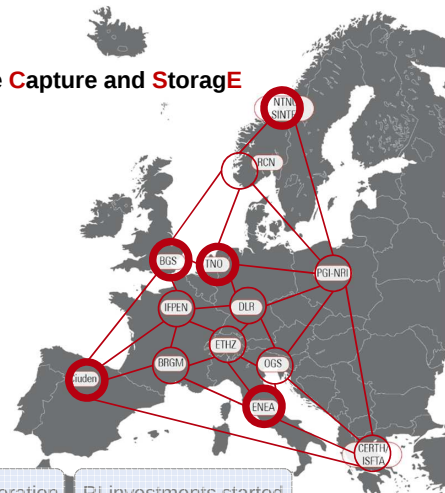
Ongoing activities: ECCSEL



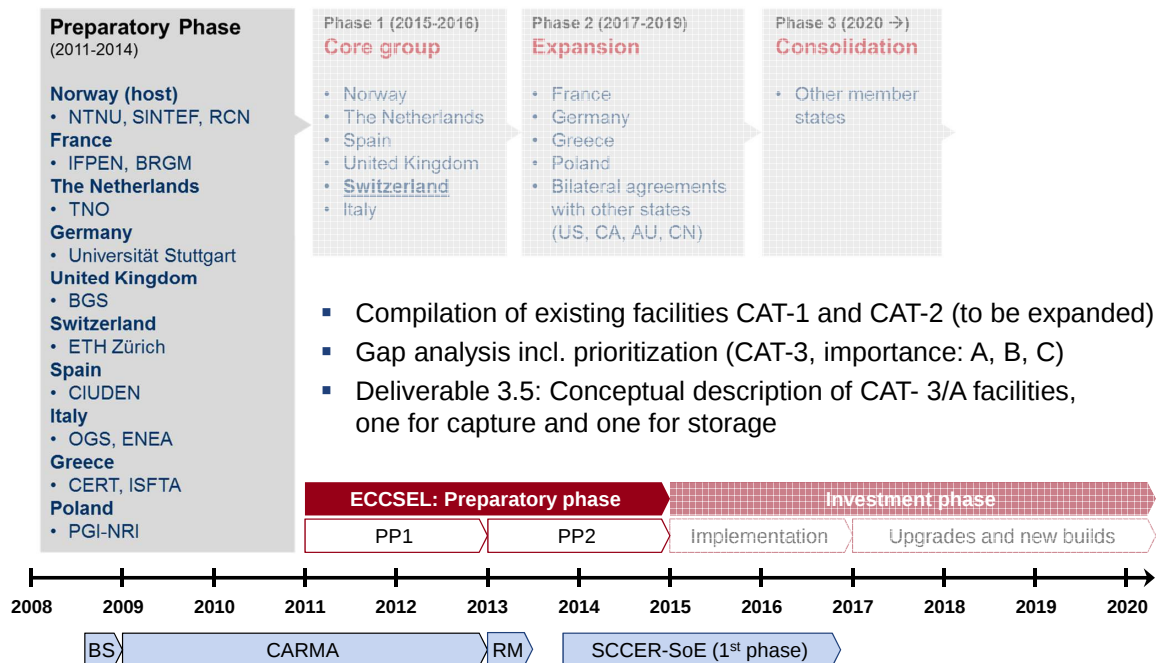
European Carbon Dioxide Capture and Storage
Laboratory Infrastructure

« ... to close the CCS knowledge gaps»

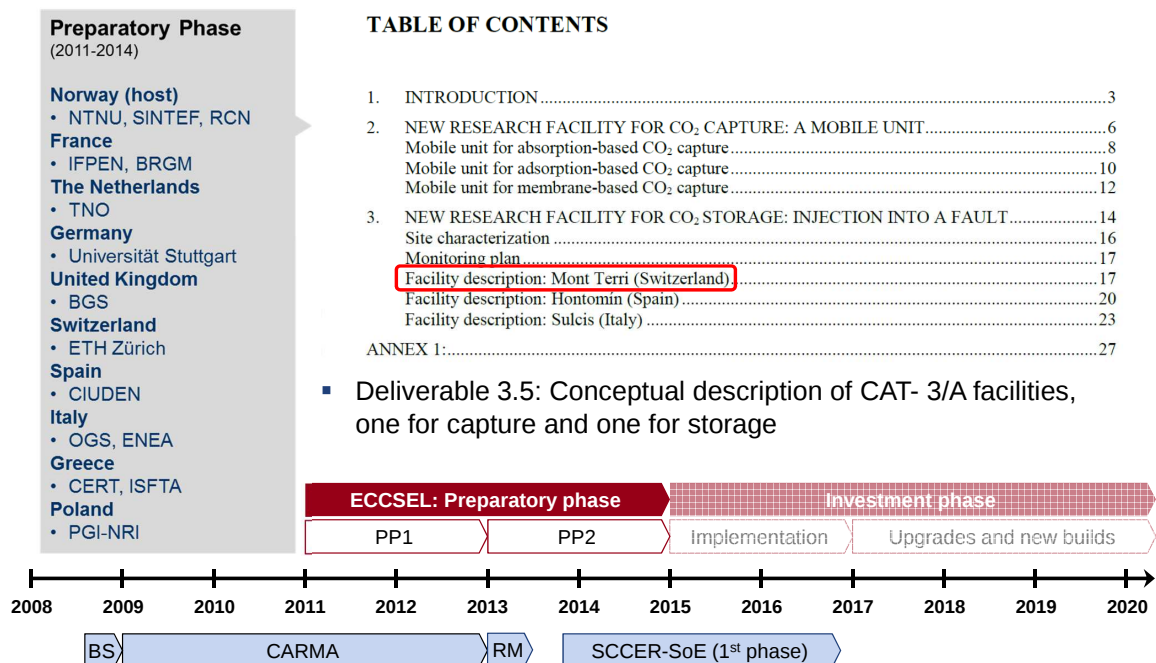
- Establish and operate a world class CCS distributed research laboratory infrastructure in Europe
- A network of complementary distributed laboratories
- A limited set of pilots and test sites



Ongoing activities: ECCSEL



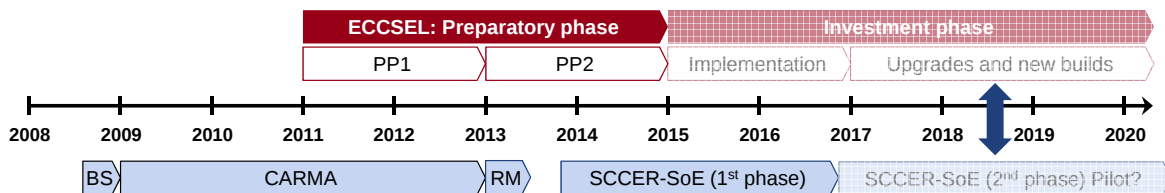
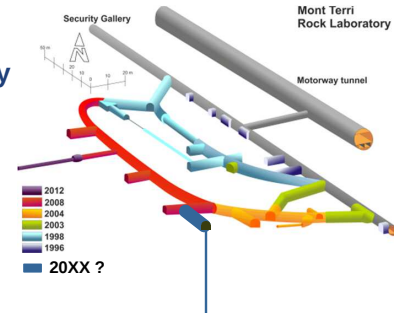
Ongoing activities: ECCSEL



Ongoing activities: ECCSEL D3.5

- New facility to test and study CO₂ migration and containment in fractured rock
- Conceptual description of such a facility on a purely generic basis not meaningful
- Approach: Extension of a suitable existing site
- For fractured reservoir rock: e.g. Hontomín, Spain
- **For fractured caprock: e.g. Mont Terri Rock Laboratory**

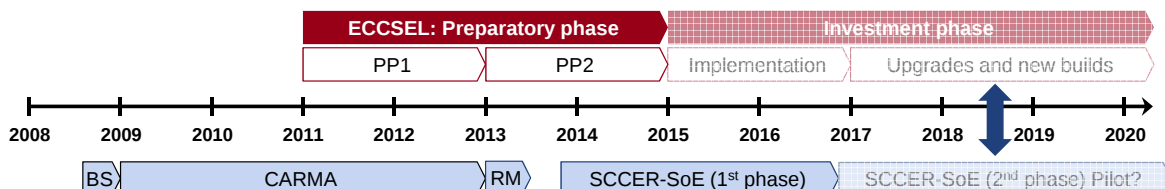
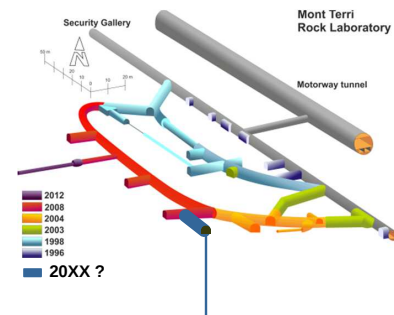
→ This could be a **short cut for an injection test in CH** in line with the RM and SCCER-SoE working document



Ongoing activities: UltimateCO₂

Ultimate
CO₂

UNDERSTANDING THE LONG-TERM FATE
OF GEOLOGICALLY STORED CO₂

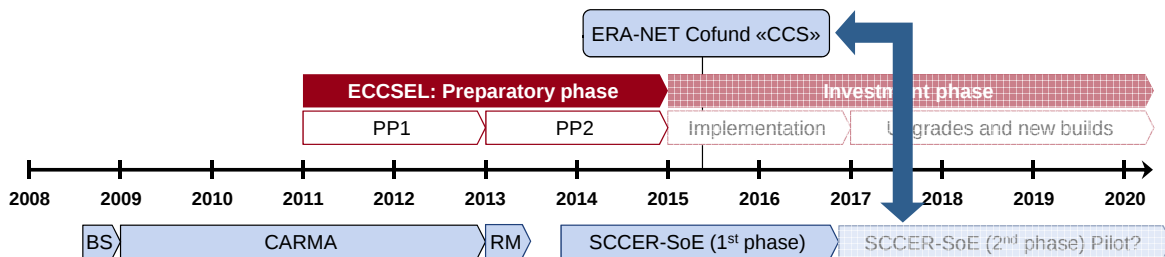


Ongoing activities: ERA-NET Cofund «CCS»

(Siddiqi, BFE, 08.04.2014)

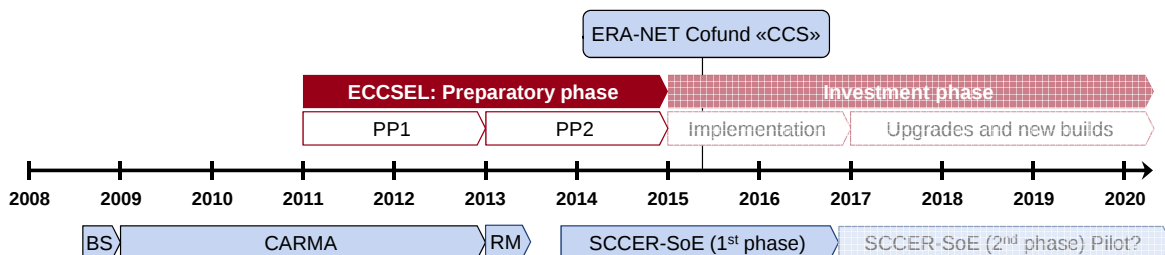
- ERA-NET Cofund under H2020 = top-up funding of single joint calls for transnational research in selected areas (public-public partnerships)
- Norway & Germany have taken the initiative to establish ERA-NET Cofund proposal on CCS by April 2015
- NOR, GER, Switzerland and Romania have shown their likely cash contribution (9 other countries have shown interest)
- Both capture and storage P&D activities will be included
- Limited number of pilots to avoid “dilution” of funds

➡ Again: This could be a **short cut for an injection test in CH**



Ongoing activities: ERA-NET Cofund «CCS»

- Based on the Roadmap and on the most recent literature about identification of the knowledge gaps reg. CCS in Europe (e.g. *Gap Analysis* developed within ECCSEL), the BFE asked ETHZ to compile a **list of research needs and possible projects** considered relevant for Switzerland
- The document has been **drafted**, sent out to the entire Swiss CCS community, **commented upon**, and **revised** accordingly



Ongoing activities: ERA-NET Cofund «CCS»

«Wishlist» outline:

CO₂ capture projects

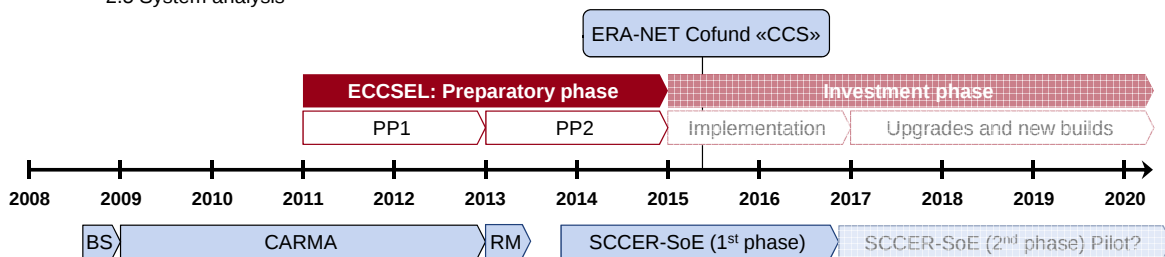
- 2.1 Post-combustion capture
 - 2.1.1 Absorption – liquid solvents
 - 2.1.2 Adsorption: solid sorbents/calcium looping/membranes
- 2.2 Pre-combustion capture
 - 2.2.1 Adsorption
 - 2.2.2 Membranes
 - 2.2.3 Gas turbine burner for H₂-rich gas and system design
 - 2.2.4 OFC-GT power plant with CO₂ capture
- 2.3 Oxy-combustion technologies
 - 2.3.1 Chemical looping combustion
- 2.4 Direct air capture
- 2.5 System analysis

CO₂ storage projects

- 3.1 Storage site characterization and capacity assessment
 - 3.1.1 Fault permeability estimation
 - 3.1.2 Understanding of pressure response and pressure management
- 3.2 Monitoring and verification
 - 3.2.1 Leakage detection and measurement
- 3.3 Impacts characterization and management
 - 3.3.1 Impact of induced seismicity

CO₂ utilization

- 4.1 Replacing the carbon based feedstock for the chemical industry
- 4.2 Energy storage using CO₂
- 4.3 Combining geological CO₂ storage with geothermal energy extraction



Weblinks

- www.ied.ethz.ch/pub/pdf/IED_WP04_Wallquist_Werner.pdf (BAFU study stage of develop.)
- www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_175156744.pdf (BFE study storage potential)
- www.carma.ethz.ch
- <http://www.bfe.admin.ch/php/modules/enet/streamfile.php?file=000000011169.pdf&name=000000290929> (Roadmap)
- <http://www.sccer-soe.ch/opencms/opencms/>
- <http://www.eccsel.org/>
- <http://www.mont-terri.ch/>
- <http://www.ultimateco2.eu/>
- http://ec.europa.eu/research/era/era-net-in-horizon-2020_en.htm (ERA-NET Cofund)

CCS roadmap: CO₂ injection test

- Objectives:

Assess if the Swiss subsurface has adequate geological formations with the necessary injection and storage potential for CCS site

Further:

- o Safety / Risk dialogue
- o Provide data for modelling and upscaling
- o Geomechanical response of subsurface

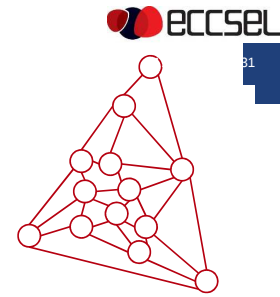
Back up: ECCSEL

6.1 CAT-1: Use of existing facilities

CAPTURE – TRANSPORT – STORAGE



Country	Capture CAT-1	Transport CAT-1	Storage CAT-1
France	11	0	4
Germany	4	0	1
Italy	0	0	3
The Netherlands	2	0	1
Norway	22	0	3
Spain	1	1	1
Switzerland	3	0	1
United Kingdom	12	0	5



Optimized utilization of existing resources

Complementary facilities

- Knowhow
- Infrastructure
- Estimated value of existing facilities that *could* form initial ECCSEL Phase
 - Replacement costs: 144.4M Euro
 - Operational costs: 14.5M Euro

6.3 CAT-3: Proposed new facilities

CAPTURE

TRANSPORT

STORAGE

(A) Facility for testing of H₂-rich fuels

(A) Experimental facility for testing of CO₂ properties

(A) Pilot injection site - **Understand migration and attenuation**

(A) Mobile unit for testing of CO₂ capture from flue gases

(A) **Aerosol counter measure** development facility (industrial)

(A) Simulate leakage for offshore storage

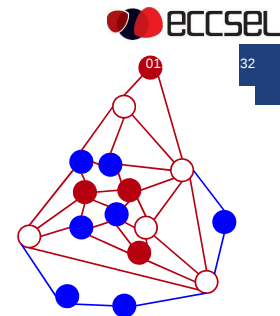
(A) Testing of **inorganic membranes** for oxy-combustion

(C) Test **dynamic performance of piping** using CO₂ mixtures.

(B) Well test facility for **well integrity** evaluation & **well monitoring**

(A) CO₂ purification of gas mixture from oxy-combustion processes

(B) Synthetic reservoir facility for assessing **pressure responses**



Common priorities

Mutual strategy
Coordinated effort
To benefit different CCS configurations in Europe and worldwide

Priorities: A: High B: Medium C: Low

7.4 High priority (A) facilities – summarized

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CO ₂ capture	Topic	Investment	Category	Location
Experimental facility	Testing of H2-rich fuels in gas turbine burners and combustor systems.	5-8 M€	Cat-3/2	
Mobile unit (container size)	Testing of CO ₂ capture from flue gases by absorption/desorption (≈1000 m ³ /h)	2-3 M€	Cat-3	
Test facility (pilot scale, 1-10 m ²)	Testing of inorganic membranes and modules for oxy-combustion applications		Cat-3	
Experimental facility	CO₂ purification of gas mixtures originating from oxy-combustion processes	...	Cat-3	
Boiler system (pilot scale)	Oxy-combustion boiler system enabled for various solids fuels		Cat-1/2	
CO₂ transport and general issues				
Experimental facility	Test various properties of CO₂ and mixtures with CO ₂ . Phase behavior, hydrate formation, physical and thermal properties.		Cat-3	
Development facility	Aerosol counter measure development facility at an industrial site	3-5 M€	Cat-3	
CO₂ storage				
Storage pilots (main priority)	Investigate a range of injection strategies to meet likely CO ₂ supplies in a range of storage types.		Cat-2	
Pilot scale injection site (not a storage site)	Injection into a fracture to understand migration and attenuation processes during migration through the overburden.	3-5 M€	Cat-3	
Natural laboratory (small field scale)	Assess fracture controlled migration and reservoir and caprock geomechanical responses		Cat-2	
Facility (not a storage site)	Simulate leakage for developing models and integrated monitoring technologies for offshore storage.		Cat-3	

E

ECCSEL

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7. ECCSEL Operations Centre

- **Location:**
NTNU, Trondheim, Norway
- **Lean organization:**
 - 4-6 employees
 - Hired personnel
 - Annual budget ≈ 1 MEUR
- **Key activities**
 - Administration
 - Operations
 - Coordinate the development and implementation of strategies and plans
 - External activities and communication



8. ECCSEL user groups and access policy

User groups

- Universities
- Research institutes
- Industry

Project types

- Basic research
- Contract research
- Collaborative research

Project selection criteria

- Alignment with ECCSEL objectives
- Significance, innovation, potential results
- Capabilities, track record of applicant

Open access policy

- ECCSEL infrastructure and facilities open for all research communities
 - 30 % reserved to non-ECCSEL members
- Non-commercial project will have priority over commercial projects
 - 20-40 % projects expected to be commercial
- Application-based access – fair and transparent procedures
- Procedures to deal with IPR, confidentiality and conflict of interest issues

Project selection procedure



8. Functional organization of ECCSEL

