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Chair of Reservoir Engineering

# $CO_2$ Storage in Deep Geological Formations – Options from the Austrian Perspective

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# Abstract

**$CO_2$ Storage in deep geological formations – options from the Austrian perspective**

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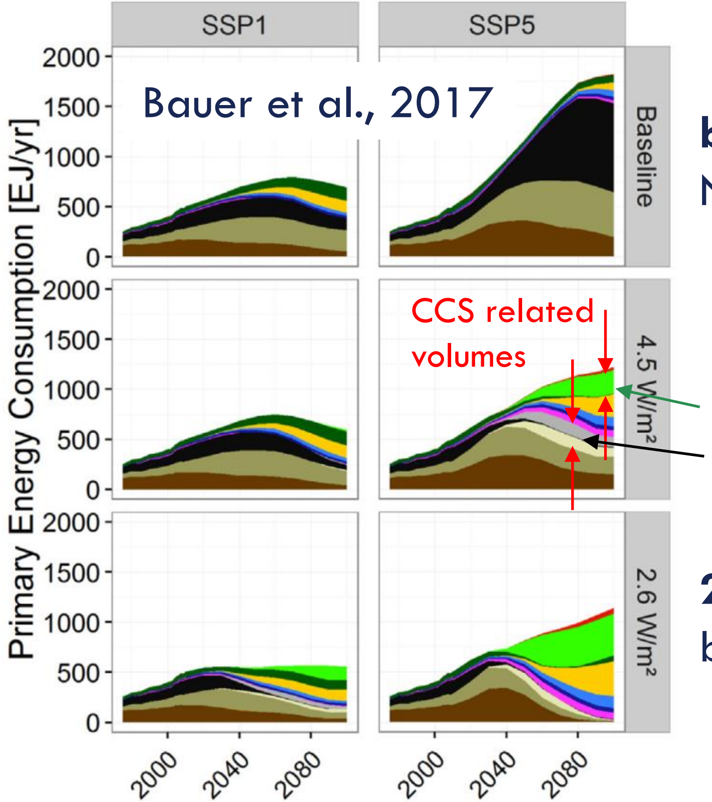
Geological $CO_2$ storage is a part of the Carbon Capture and Storage (CCS) technology chain. CCS allows for (a) the capture and long-term storage of $CO_2$ from industrial sources, thus preventing its release into the atmosphere, and (b) the direct capture from the air (from biomass or direct air capture) to achieve negative emissions. CCS is therefore considered a key enabler for decarbonizing $CO_2$-intensive industries and particularly for hard-to-abate emissions. The presentation gives a brief overview of the geological storage options and the underlying storage mechanisms. The resulting storage capacity and what makes us sure that geological $CO_2$ storage is safe are addressed in the presentation.

In Austria, there are several potential types of geological targets, including depleted oil and gas fields and deep saline aquifers. Furthermore, Austria has several large industrial $CO_2$ emitters located in close proximity to potential storage sites, making CCS a potentially viable option in the country. Although, CCS has worldwide been deployed on various scales, however, not to the required extent, in Austria a federal law prohibits the geological storage of $CO_2$ due to concerns on the grounds that technical and safety issues still had to be clarified and concerns regarding the environmental impacts and risks. The underlying evaluation report stated that further research is needed for permanent geological storage of $CO_2$, with a particular focus on national geological conditions and environmental impacts. Based on that the newly granted CaCTUS project will re-evaluate the potential for CCS in Austria according to state-of-the-art knowledge and methods in terms of storage mechanisms and safety as well as suitable geological conditions. Furthermore, potential capacities for CCS in Austria are gathered based on data material from Austrian rock formations and evaluated in a harmonized evaluation scheme.

# Why CCS? The Business Case

# SSPs – Global Primary Energy Mix

Sustainable | Energy Intensive




**baseline** scenarios
No mitigation

**2.6 →** goals can be reached

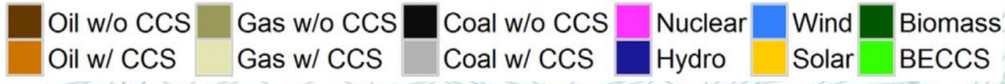
IIASA – International Institute for Applied Systems Analysis
Database: https://tntcat.iiasa.ac.at/SspDb/

Oil extraction in **baselines** exceeds current estimates of conventional and unconventional reserves!

**CCS** plays a role in all mitigation scenarios

Major role if **BECCS** in all climate friendly and **2.6 scenarios**

Fossil fuels reduced to ~0 in **SSP5/2.6** – extremely high carbon price exceeding 300 US$/t $CO_2$



# Business Cases: Sequestering Emissions from:

**Coal/HC combustion**

**Coal/HC supply** (~20-30% HC related emissions)
- ❑ Sour gas developments ($CO_2$ containing gases)
- ❑ Heavy oil upgrading – steam reforming etc.
- ❑ Refining …

License to operate for O&G operations → main reason so far for CCS technology development in the industry/academia

Other **$CO_2$ intensive industries** like cement- and steel industry etc.

$CO_2$ **removal form the atmosphere**
- ❑ BECCS – Bioenergy + CCS
- ❑ Direct air capture + CCS

Light oils



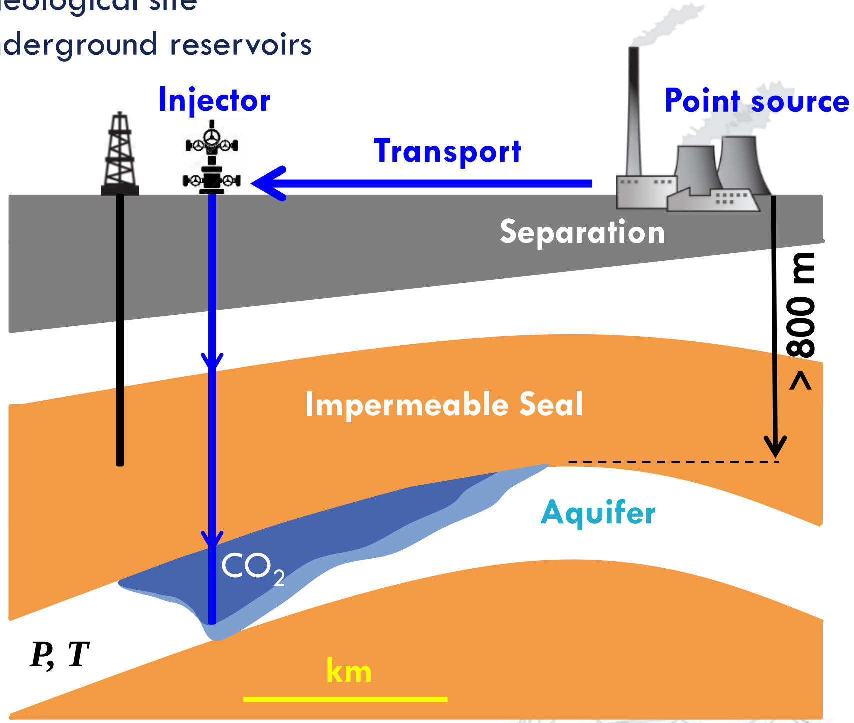
Energy return on investment:
Conventional HC: ~10 Joule/Joule
Unconventional HC: ~3 Joule/Joule

# What is CCS?

# Carbon Capture and Storage

**Technology chain**

1. Separation form large scale $CO_2$ emitters (point sources >0.1Mt $CO_2$/a)
2. Transport to a proper geological site
3. Injection into suitable underground reservoirs



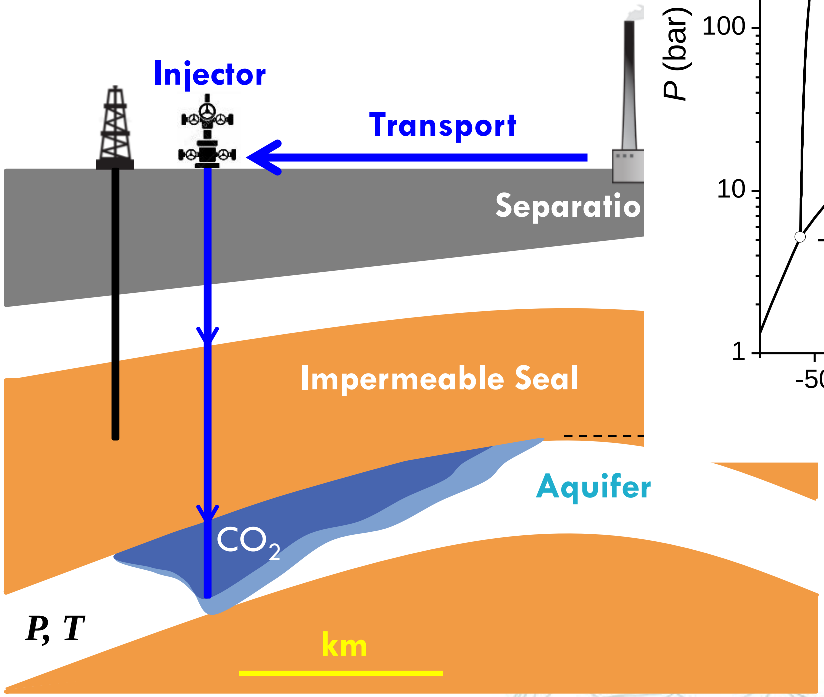

**Requirements** for being a suitable geological storage:

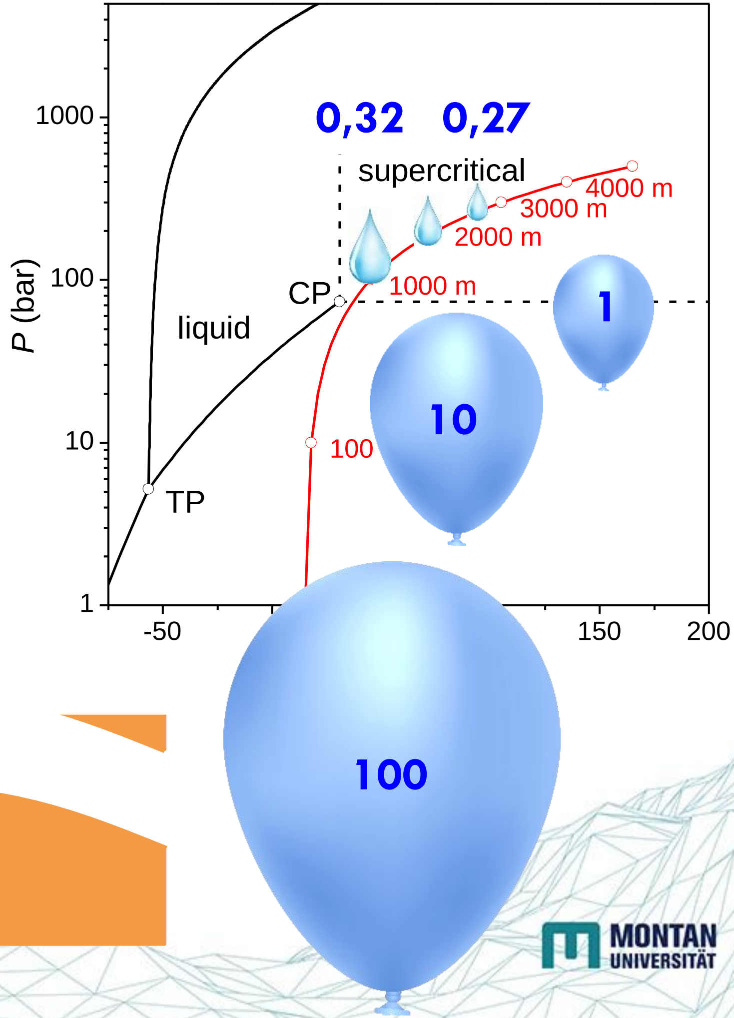
- impermeable **seal** that cannot be penetrated by $CO_2$
- Structural **trap** – under which $CO_2$ can accumulate
- A porous **reservoir** providing the storage space

# CCS: Thermodynamic Conditions

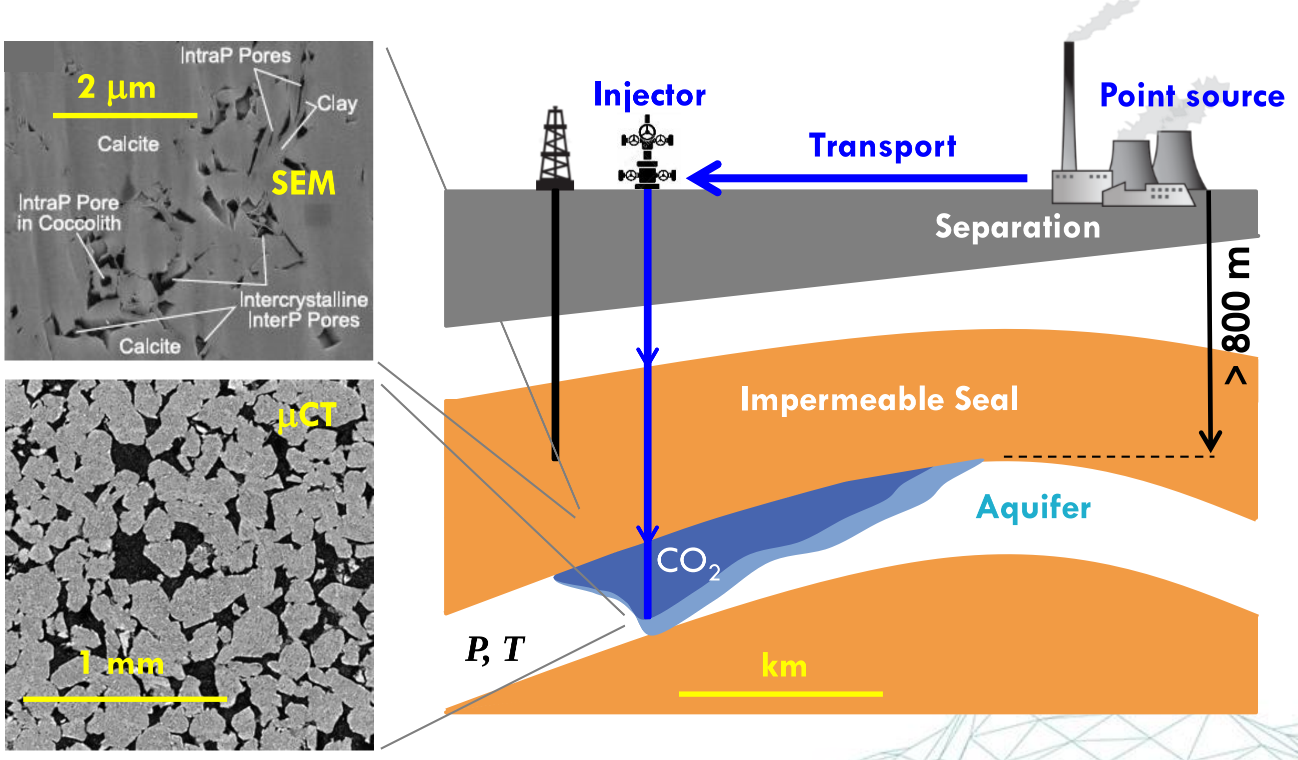
At the reservoir pressure and temperature conditions at **depth** larger than **800** – 1000 m, $CO_2$ enters a **supercritical** phase

At this conditions, $CO_2$ **weights a liquid** and **flows like a gas**
→ resulting in high storage and flow capacity



# CCS: Seal and Reservoir Rock




$CO_2$ is buoyant in reservoirs, therefore an impermeable seal is required

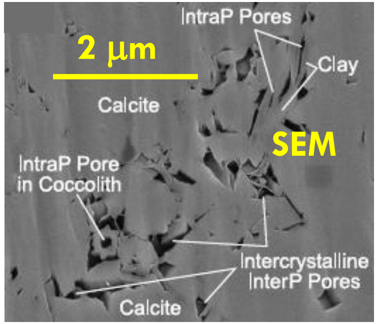
Seal rocks are, e.g., shales forming a capillary barrier for $CO_2$ migration → this refers to **seal capacity**

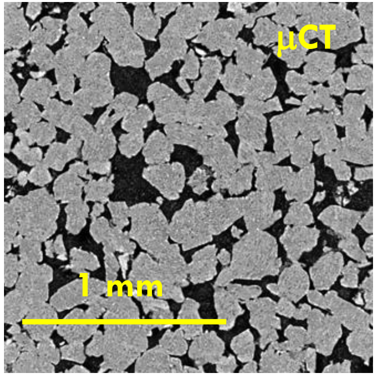
Next to the right thermodynamic conditions (fluid properties), a proper reservoir rock reservoir required

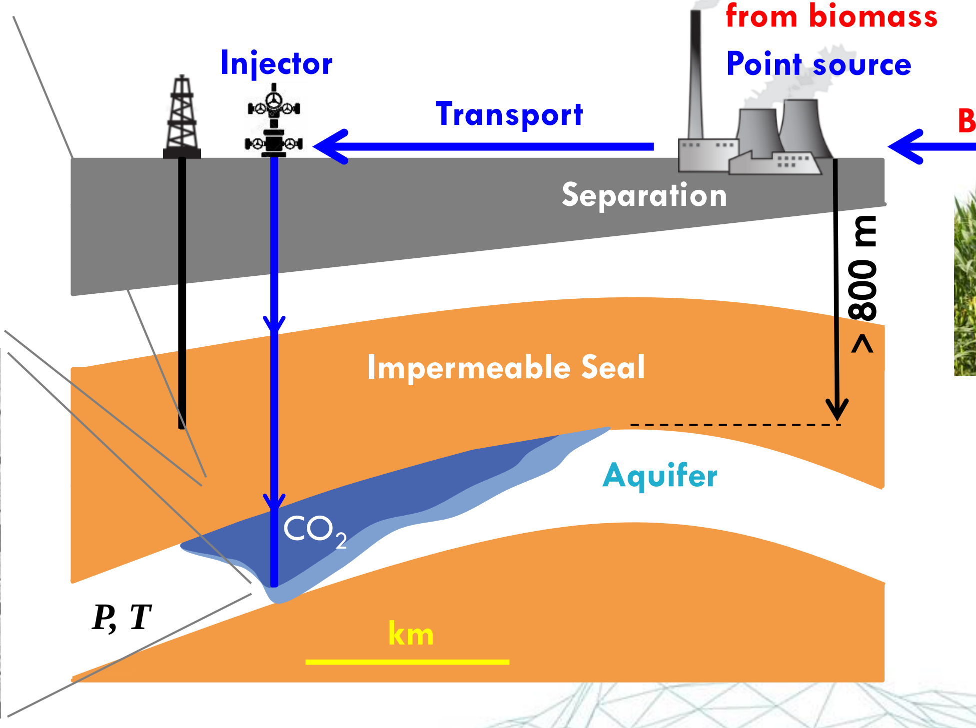
- ❑ High porosity referring to **storage capacity**
- ❑ High permeability referring to **flow capacity**

# BECCS

Combining CCS with bio energy and central combustion, e.g., in a powerplant, results in a direct path from the atmosphere to the geological carbon cycle → a negative $CO_2$ footprint can be achieved.



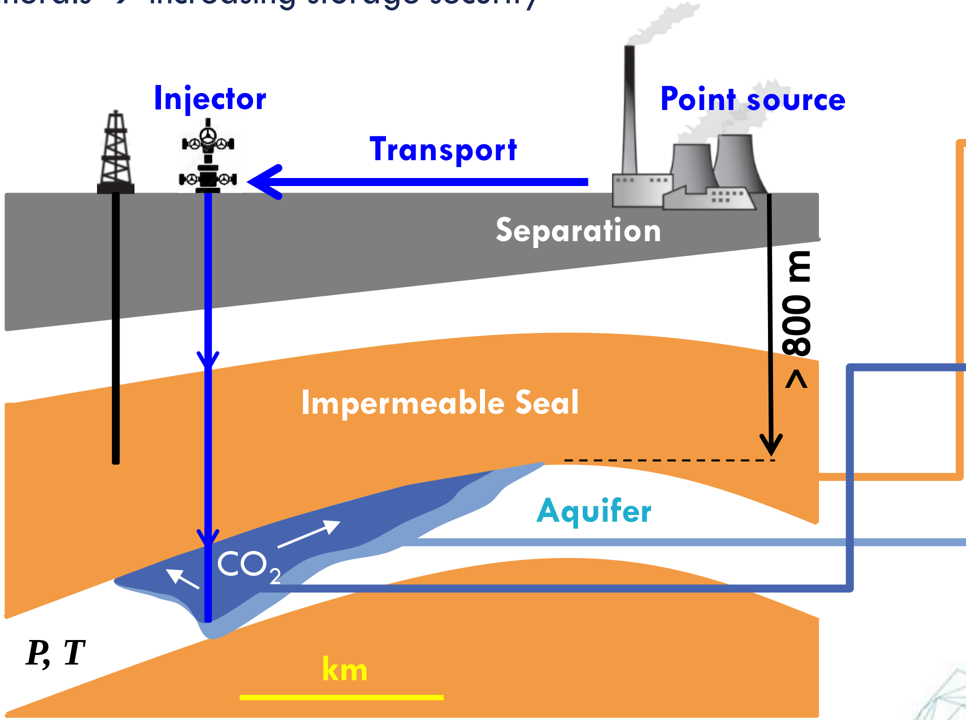



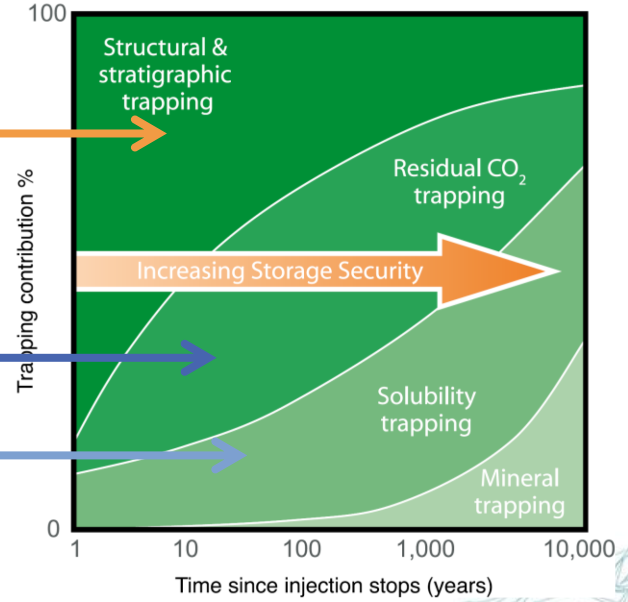

# Aspects of Storage Safety

# Trapping Mechanisms

Trapping (demobilizing) of $CO_2$ by barriers, capillary and gravitational forces and ultimately by forming carbonate minerals → increasing storage security




Depends on injection design/strategy



# Carbon Cycle – a (too) Simple Picture

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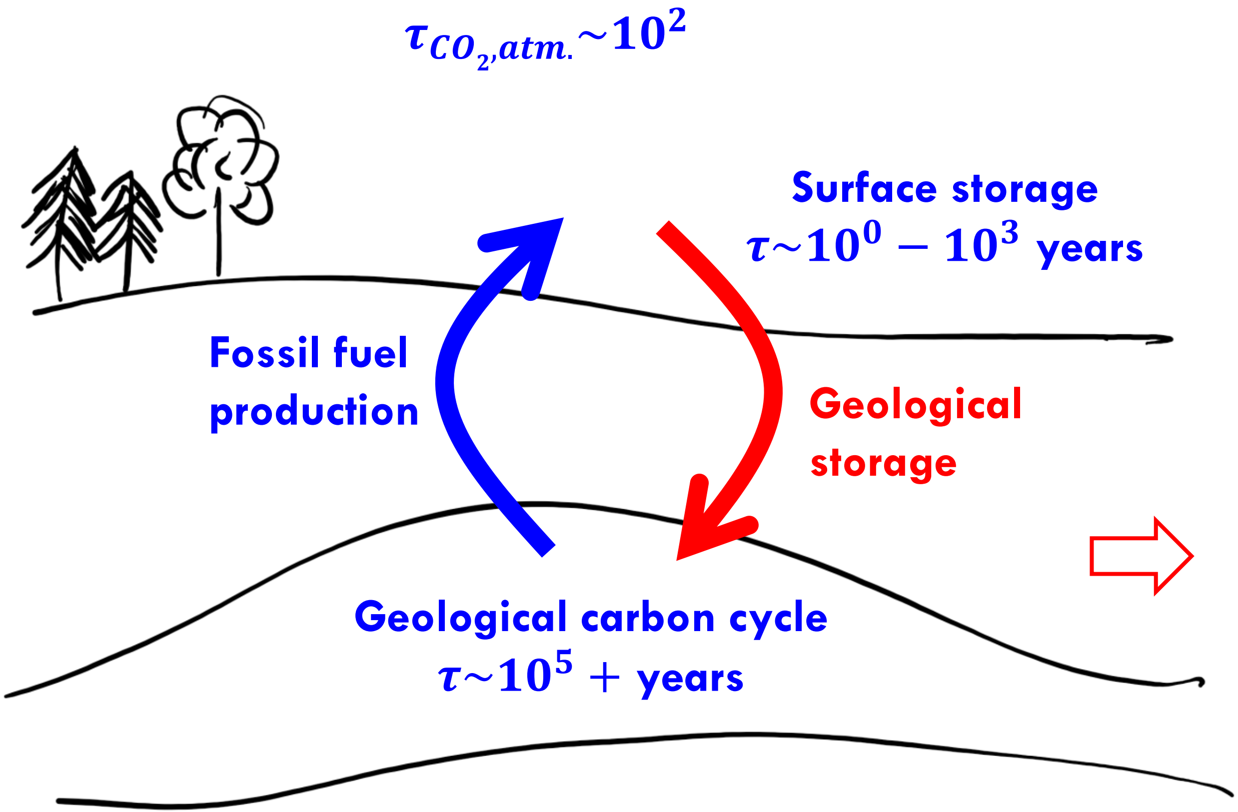


Arguing with time scales of storage

$C(O_2)$ storage time
>>
$CO_2$ residence time in the atmosphere

⇨ Geological storage Provides large enough storage time

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# Is Save Storage Possible?

- **Extensive research** on CCS since the 30 years +
  - Containment: sort-term requirement (time scale of operation): Seal Integrity, Integrity of the wells, both mechanical and chemical
  - Trapping mechanisms: long term requirements

- **"Short-term" experience** (time scale of operations)
  - $CO_2$ EOR (since the early 1970s)
  - Natural gas storage (common practice)
  - $CO_2$ storage (since the 1990s)

- **Also nature does it** – natural analogues
  - Natural HC sources
  - Natural $CO_2$ storage → extensively studied

Geological $CO_2$ storage is
- Well understood
- Mature → High "technology readiness levels"
- Worldwide in operation
- Requires extensive side specific evaluations

# Ongoing and Planned Projects

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Summary (IEA)

- ❑ Mature technology
- ❑ High TRLs

www.globalccsinstitute.com

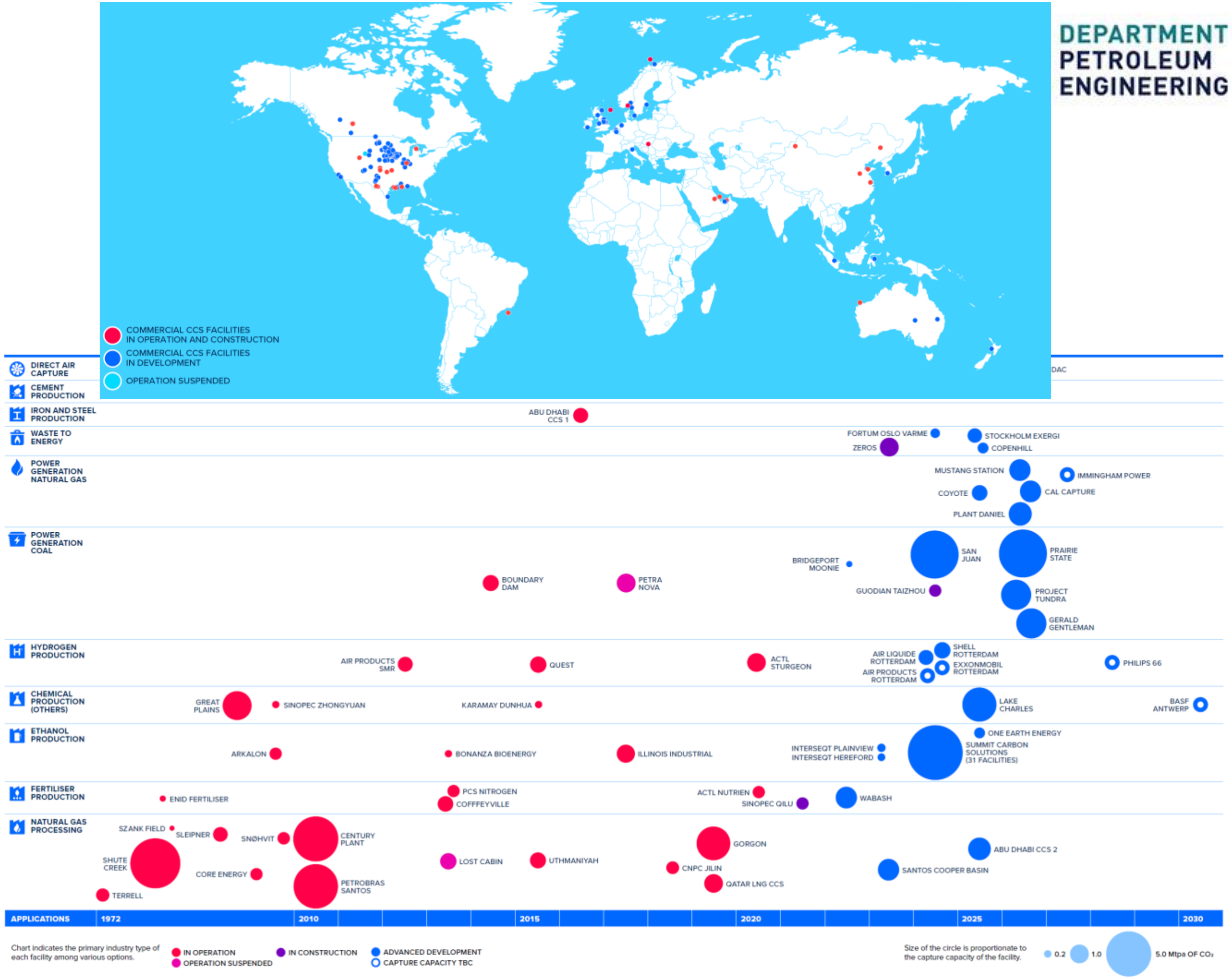
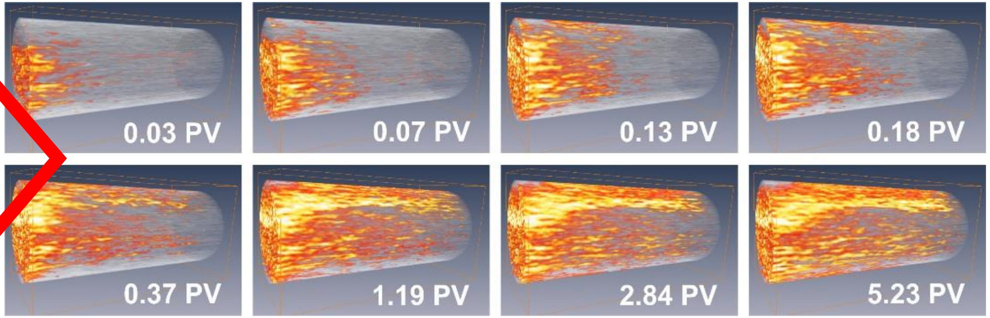



FIGURE 9 CCS PROJECTS BY SECTOR AND SCALE (BY $CO_2$ CAPTURE CAPACITY) OVER TIME

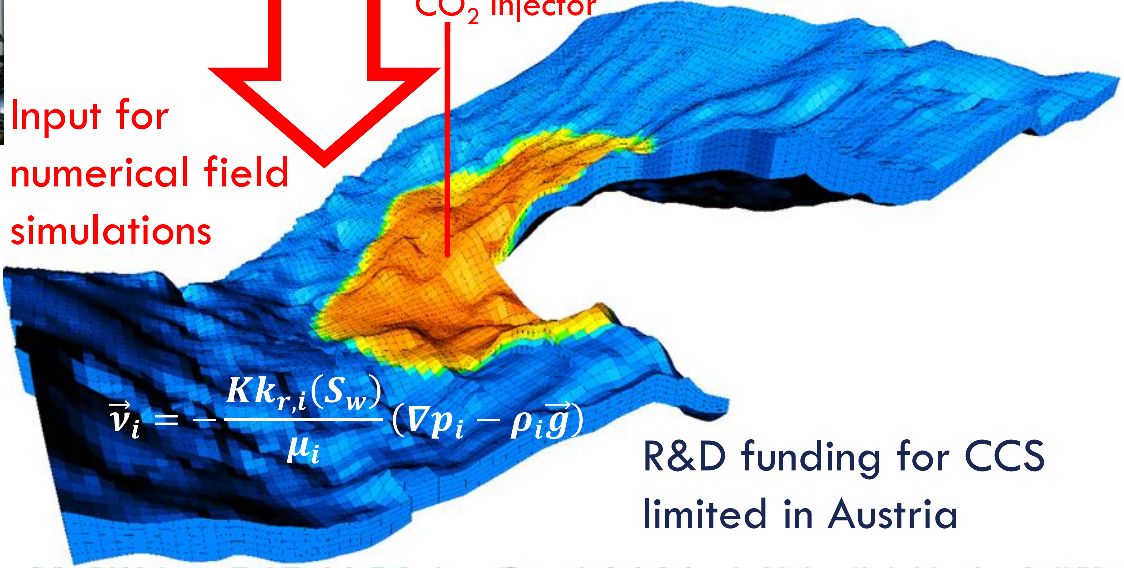
# Research Activities

# $CO_2$ Migration and Trapping Models






Input for numerical field simulations




$$\vec{v}_i = -\frac{K k_{r,i}(S_w)}{\mu_i}(\nabla p_i - \rho_i \vec{g})$$

Fluid displacement and reactive transport models from experimental and numerical research

R&D funding for CCS limited in Austria

H. Ott, S. Berg et al. , *IJGGC* (2013, 2015)
Kata Kurgyis, MSc Thesis, Leoben 2015

# The Situation in Austria

**Not permitted by law**

→ lack of research funds/lack of knowledge/experience building

Reevaluation of the legal situation in 2023

**Suitable geological deposits**

- ❑ Depleted oil and gas fields
  - ➢ Pros: known volume, very well known, models available → shorter development time
  - ➢ Cons: alternative commercial usage models, well bore materials maybe not $CO_2$ compatible
- ❑ Deep saline aquifers
  - ➢ Pros: probably higher total storage capacity
  - ➢ Cons: require larger field development times

} Evaluation of the CCUS potential in Austria:

# CaCTUS

**Project goals**

- ❑ Identification/**quantification of the technical potential of CCU/CCS** according to the Austrian "Nationaler Energie- und Klimaplan "
- ❑ **Identification** of source-specific **climate effects** and sink-related net **mitigation Potentials**
- ❑ **Techno-economic evaluation** of CCU/CCS and their contribution to climate neutrality
- ❑ Evaluation of **barriers and the regulatory situation** that prevent early implementation
- ❑ **Recommendations** for supporting climate-friendly CCUS activities in Austria.

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**Strong interdisciplinary consortium:**

ENERGIE INSTITUT an der Johannes Kepler Universität Linz

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denkstatt

CCCA Climate Change Centre AUSTRIA

# $CO_2$ Sources and Sinks in Austria

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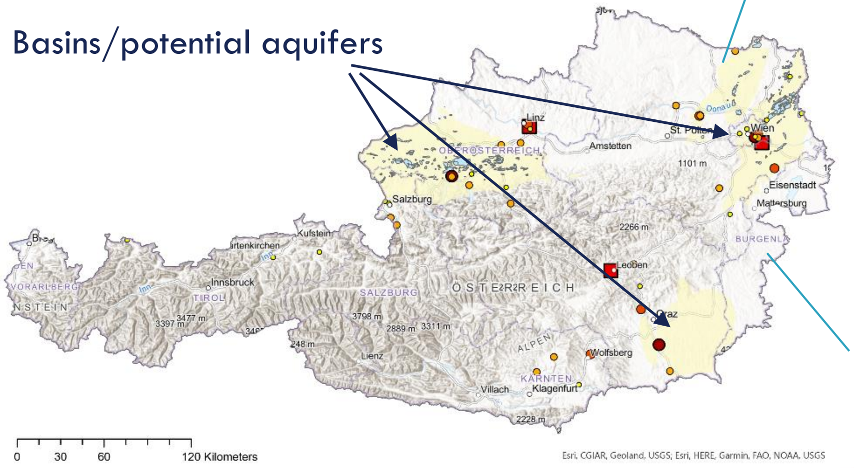
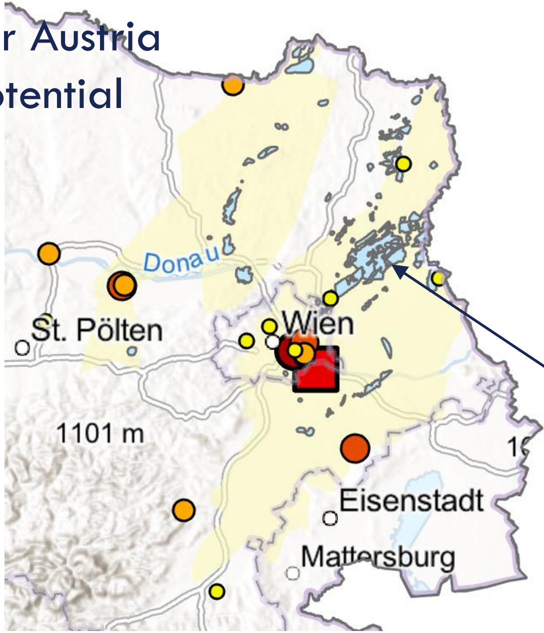
Tasks MUL Reservoir Engineering

- ❑ Sighting of existing geological data
- ❑ Development of an evaluation scheme for Austria
- ❑ Evaluation of $CO_2$ geological storage potential
- ❑ Sink-to-source matching.

**Potential for BECCS in Austria?**

Basins/potential aquifers




$CO_2$ sources [kg/a]

- <250.000.000
- <500.000.000
- <1.000.000.000
- < 2.500.000.000
- < 7.750.000.000

HC fields

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# Questions?

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