Sessionsanlass PG BFI – GP FRI

Donnerstag, 30.09.2021

«Proaktiver Klimaschutz in der Schweiz – Perspektiven aus der Forschung»

Dr. Christian Schaffner, Direktor Swiss Energy Science Center, ETH Zürich
Prof. Dr. Marco Mazzotti, Professor für Process Engineering, ETH Zürich

PG BFI BILDUNG FORSCHUNG INNOVATION
GP FRI FORMATION RECHERCHE INNOVATION
FORMAZIONE RICERCA INNOVAZIONE

SR Damian Müller
Präsident PG BFI

Ziele der PGBFI

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Das **Verständnis** für die Bedeutung von Bildung, Forschung und Innovation im Parlament steigern.

Relevante Sachfragen zu **diskussionsfähiger Reife** aufbauen.

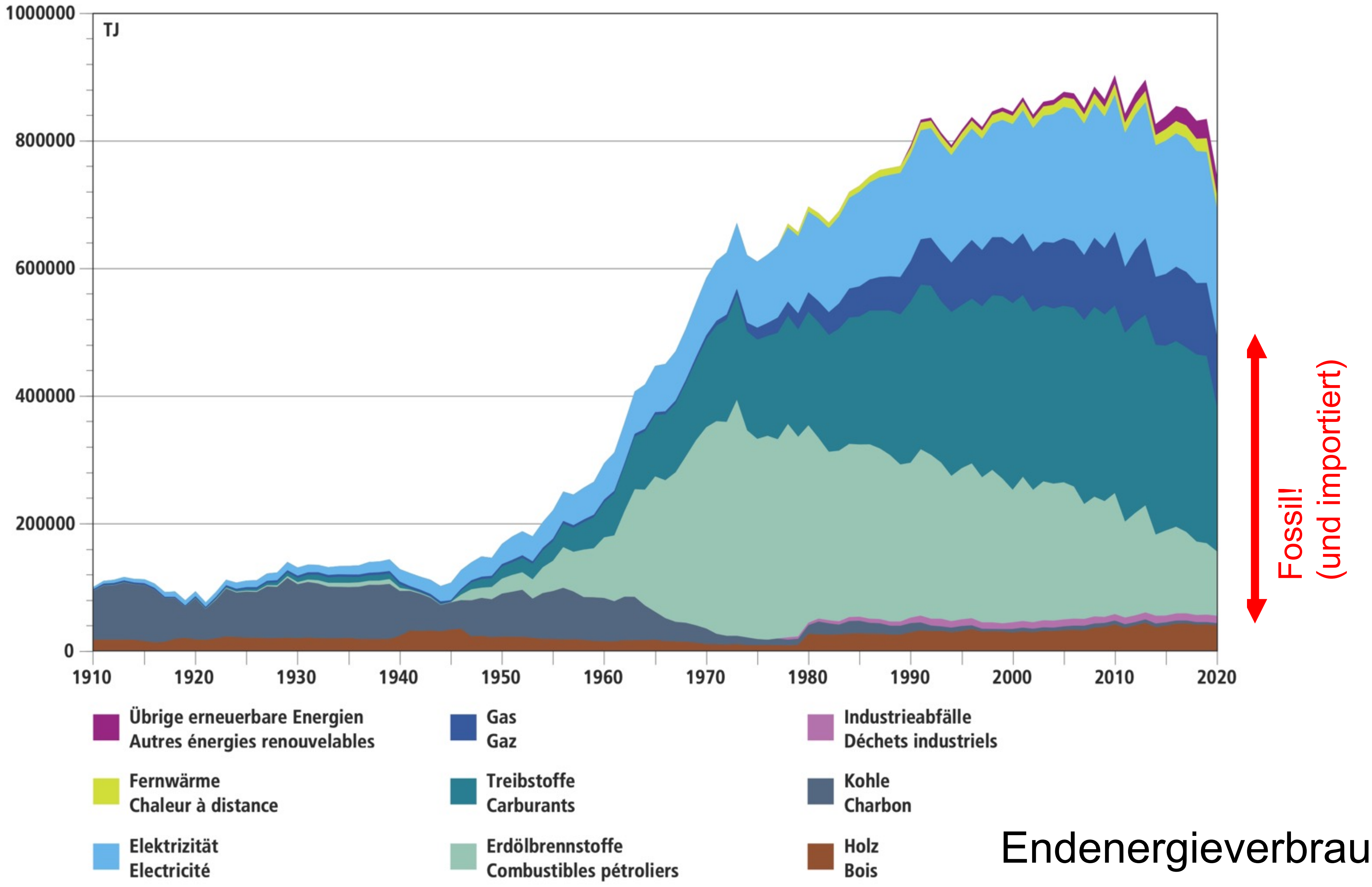
Den Anliegen des Wissens- und Innovationsstandortes Schweiz Nachdruck und Gewicht verleihen.

ETH zürich

Wie gelingt die Halbierung der Treibhausgase bis 2030?

Christian Schaffner, Viola Becattini, Marco Mazzotti

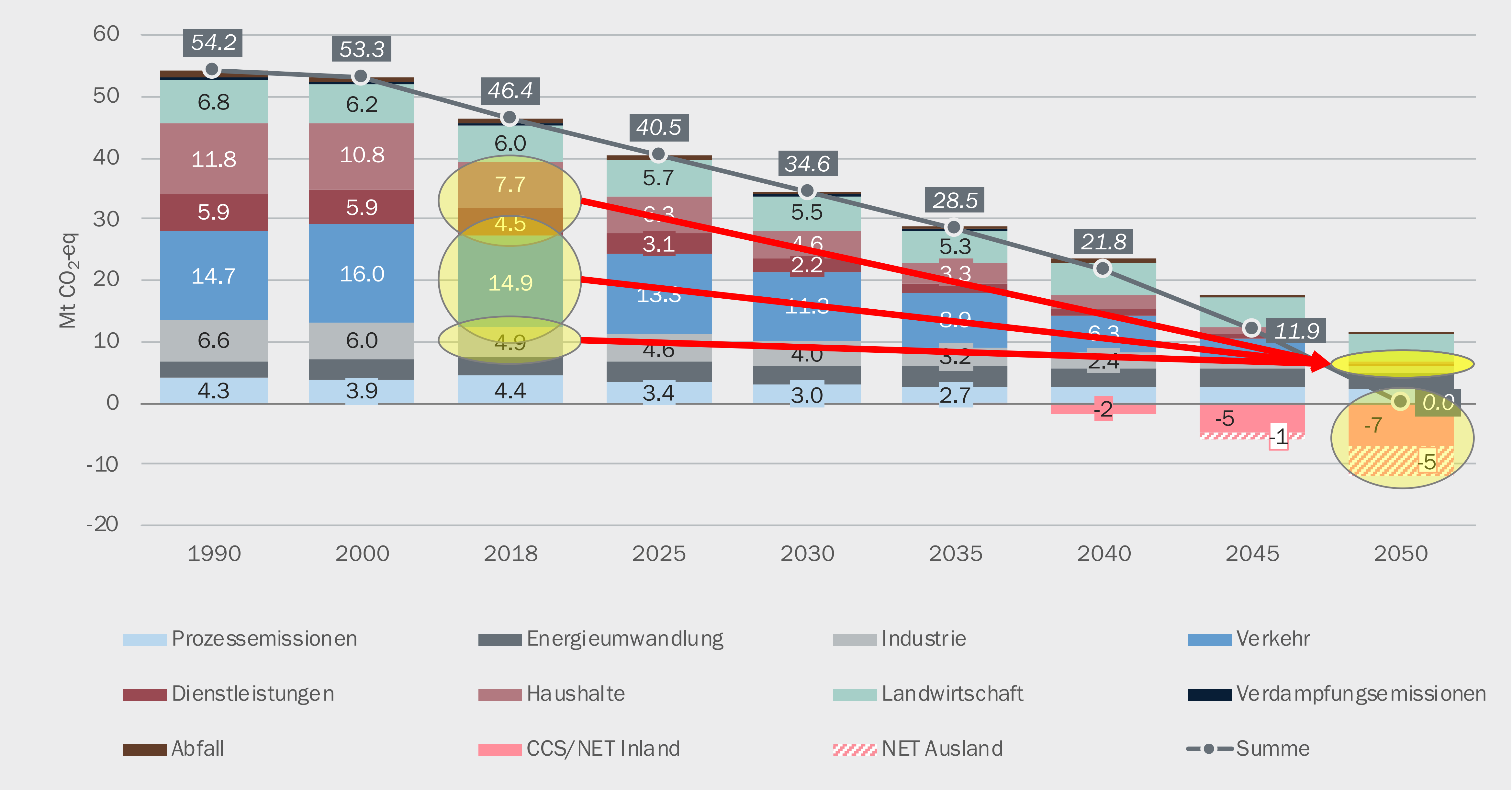
September 30th, 2021



Endenergieverbrauch CH

BFE, Schweizerische Gesamtenergiestatistik 2020 (Fig. 1)
OFEN, Statistique globale suisse de l'énergie 2020 (fig. 1)

Netto-Null-Emissionsszenario für die Schweiz

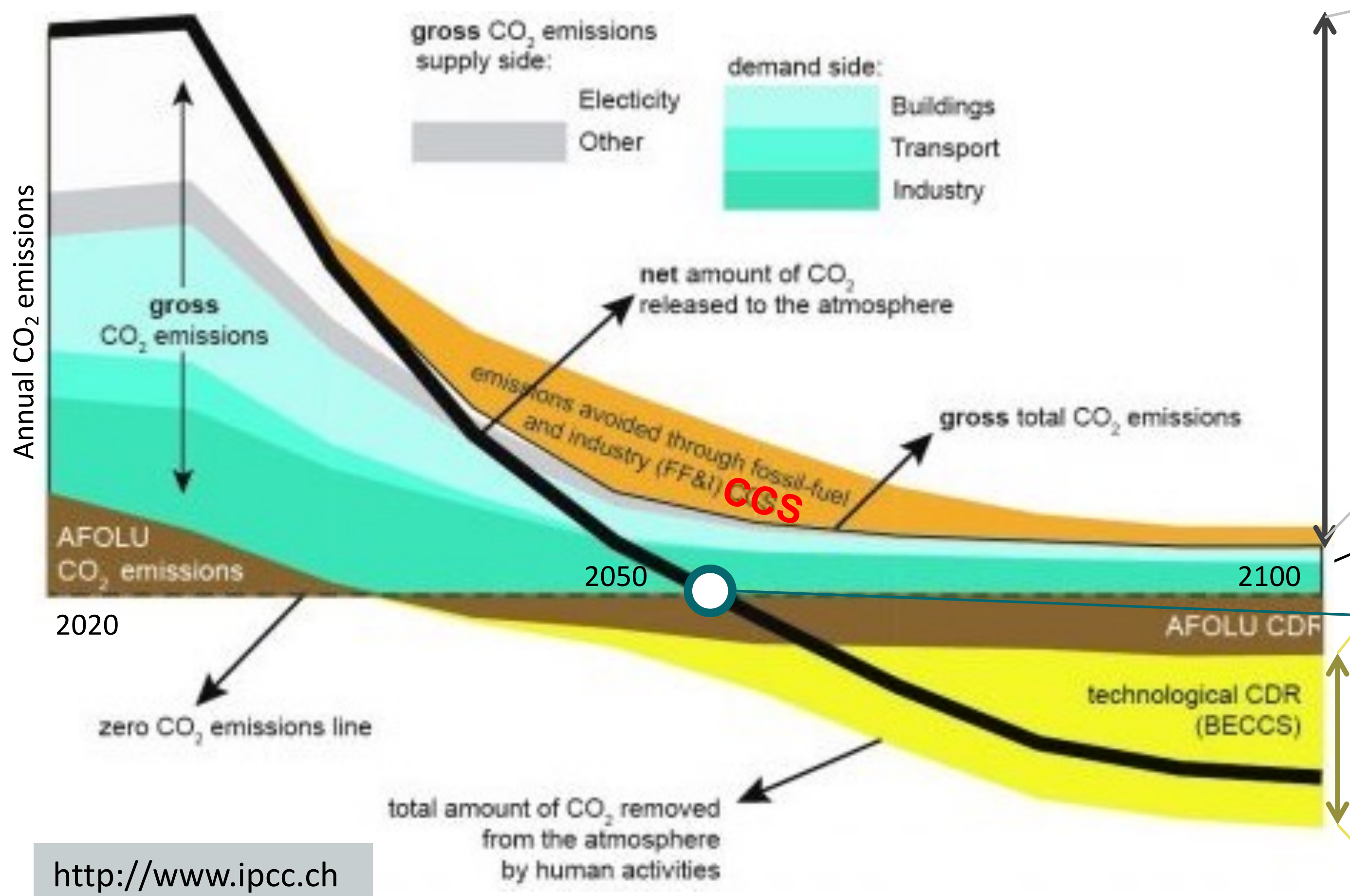


Quelle: Energieperspektiven 2050+ (BFE), Prognos AG / TEP Energy GmbH / INFRAS AG 2020

Take-Home Messages

1. Um dem Klimawandel entgegenzuwirken, müssen sowohl Emissionen reduziert als auch negative Emissionen generiert werden

1. Goal 1.5°C: net-zero-CO_2 emissions & NETs



http://www.ipcc.ch/report/sr15/Fig 2-5

<u>Decarbonization of:</u>
- Power generation;
- Mobility;
- Households;
- Industry (– 75-90%);
- Agriculture;
- Lifestyle.

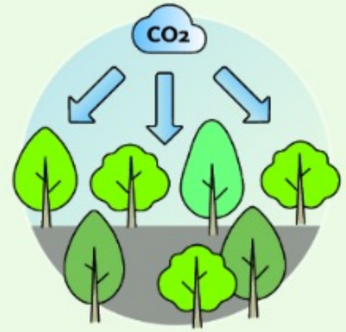
Unavoidable emissions, e.g. chemical industry, aviation

<u>Negative emission technologies, NETs (100-1000 $GtCO_2$):</u>
- Bio-Energy w/ CCS;
- Direct Air Capture (DAC) w/ CCS;
- (CCS = Carbon Capture & Storage.)

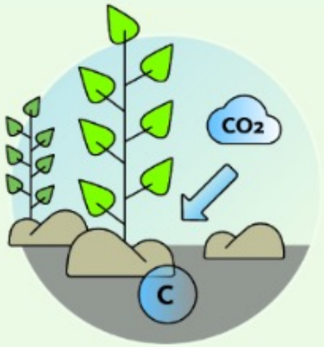
Net-zero-CO_2 emissions solutions, in all sectors and for everybody

1. Mögliche Ansätze für negative Emissionen

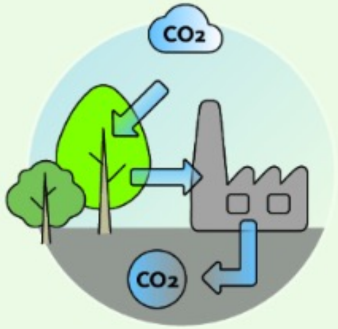
Aufforstung, Wiederaufforstung, Waldbewirtschaftung und Holznutzung
Baumwachstum entzieht der Luft CO_2. Dieses kann in Bäumen, Böden und Holzprodukten gespeichert werden.



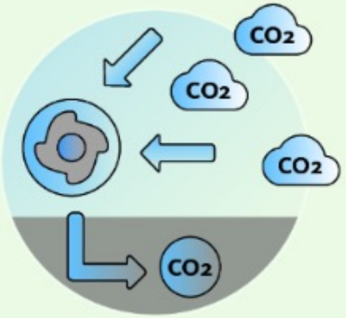
Bodenmanagement (inkl. Pflanzenkohle)
Einbringung von Kohlenstoff (C) in die Böden, z. B. mittels Ernterückständen oder Pflanzenkohle, kann C im Boden anreichern.



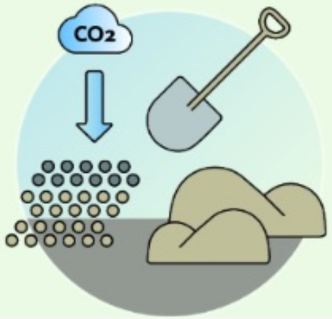
Bioenergienutzung mit CO_2-Abscheidung und Speicherung (BECCS)
Pflanzen wandeln CO_2 in Biomasse um, die Energie liefert. CO_2 wird aufgefangen und im Untergrund gespeichert.



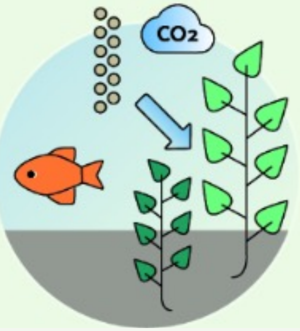
Maschinelle CO_2-Luftfiltrierung und Speicherung (DACCS)
CO_2 wird der Umgebungsluft durch chemische Prozesse entzogen und im Untergrund gespeichert.



Beschleunigte Verwitterung
Zerkleinerte Mineralien binden chemisch CO_2 und können anschliessend in Produkten, im Boden oder im Meer gelagert werden.



Ozeandüngung
Eisen oder andere Nährstoffe werden dem Ozean zugesetzt, um die CO_2-Aufnahme durch Algen zu erhöhen.



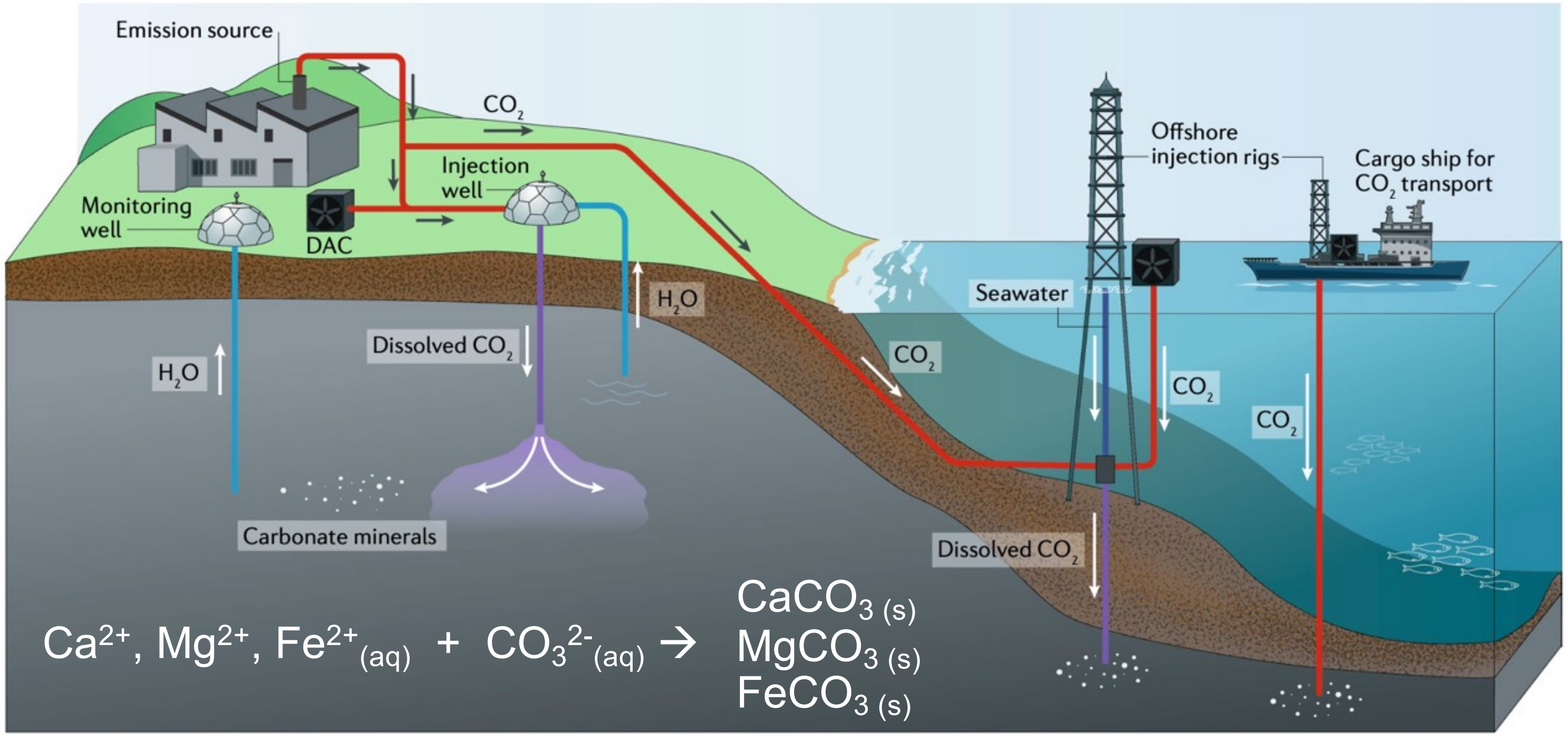
https://www.bafu.admin.ch/bafu/de/home/themen/klima/fachinformationen/emissionsverminderung/negativemissionstechnologien.html

Take-Home Messages

1. Um dem Klimawandel entgegenzuwirken, müssen sowohl Emissionen reduziert als auch negative Emissionen generiert werden
2. Die punktuelle CO2-Abscheidung ist sektorübergreifend machbar, die sichere Speicherung wird europaweit verfügbar sein.

2. CCS at the CarbFix project, Iceland

- The CarbFix pilot project undertaken in 2012 near the Hellisheidi geothermal power plant
- 230 t of CO_2 in groundwater injected to a depth of ca. 500 m into basaltic rocks
- 95% of the injected gas mineralized within 2 years (permanently stored)



Schematic of current and prospect CarbFix operation.

- ➢ CarbFix2 project couples DAC and mineral carbonation achieving a negative emissions pathway
- ➢ Moving offshore: the CarbFix2 project will inject CO_2 dissolved in seawater into submarine basalts

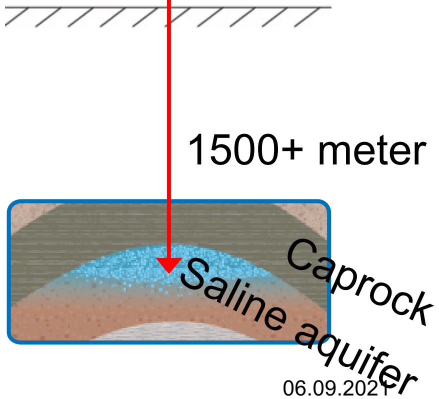
Snæbjörnsdóttir, S. Ó., et al. "Carbon dioxide storage through mineral carbonation." *Nature Reviews Earth & Environment* 1.2 (2020): 90-102.
Gunnarsson, I., et al. "The rapid and cost-effective capture and subsurface mineral storage of carbon and sulfur at the CarbFix2 site." *International Journal of Greenhouse Gas Control* 79 (2018): 117-126.

2. CCS

Direct Air Capture

- DAC of 1.5 kt CO_2/y in Hinwil, ZH
- Vacuum-Temperature Swing Adsorption
- Regeneration w/ or w/o steam at 100°C
- CO_2 fed to greenhouse nearby
- Operational since May 2017

- 120 MW net coal-fired power plant
- 1 Mt CO_2/y
- Storage in aquifer
- Operational since October 2014



Take-Home Messages

1. Um dem Klimawandel entgegenzuwirken, müssen sowohl Emissionen reduziert als auch negative Emissionen generiert werden
2. Die punktuelle CO2-Abscheidung ist sektorübergreifend machbar, die sichere Speicherung wird europaweit verfügbar sein.
3. Die CO2-Nutzung ist sehr energieintensiv (und erfordert daher eine erneuerbare Energieversorgung sowie eine Analyse auf Systemebene)
4. Die CO2-Abscheidung kann durch direkte Abscheidung aus der Luft oder durch Nutzung von Biomasse erreicht werden.

4. Carbon Dioxide Removal

Direct Air Capture

- DAC of 1.5 kt CO_2/y in Hinwil, ZH
- Vacuum-Temperature Swing Adsorption
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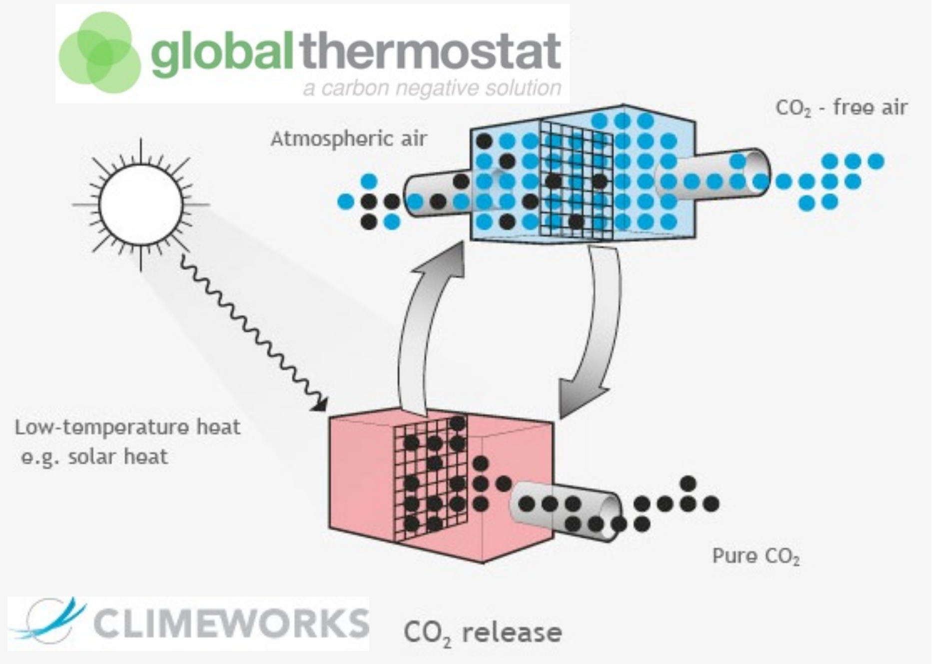
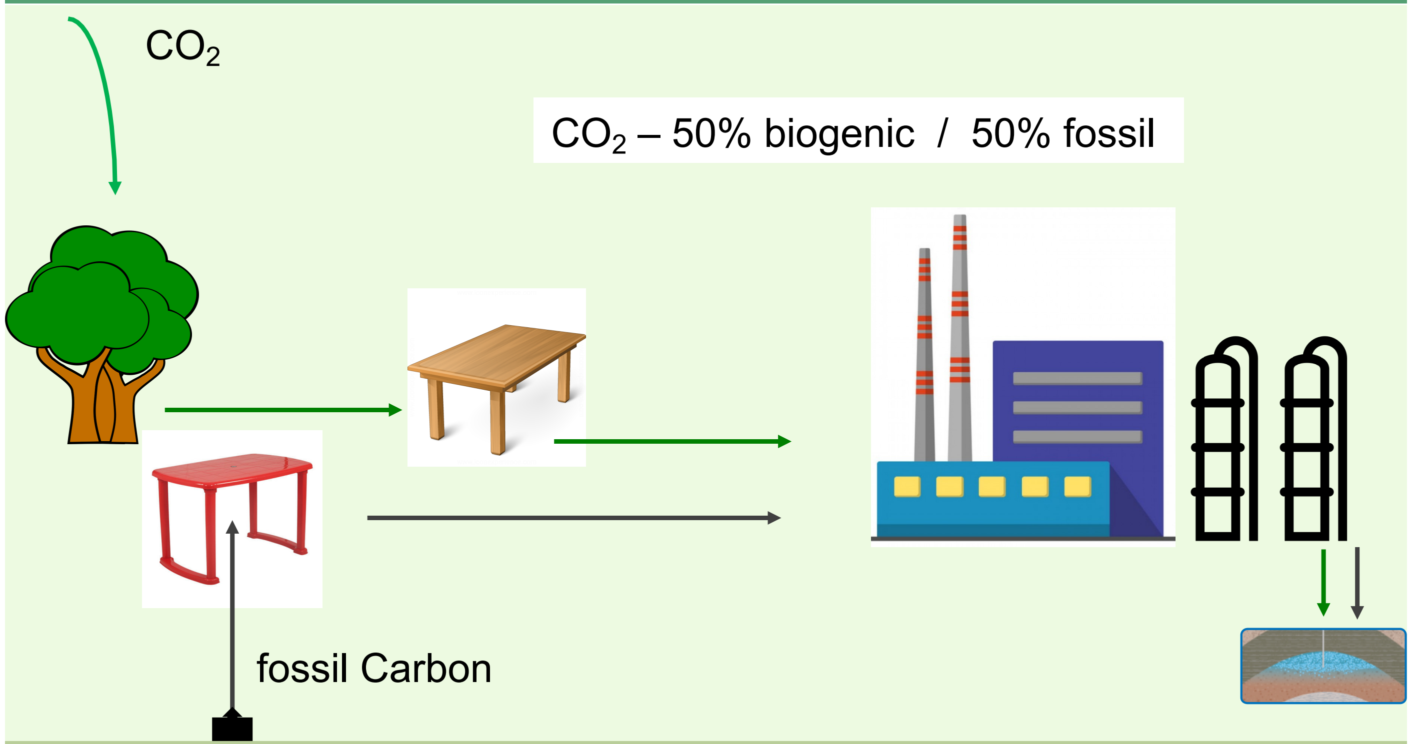
4. Carbon Dioxide Removal

Direct Air Capture



- DAC of 1.5 kt CO_2/y in Hinwil, ZH
- Vacuum-Temperature Swing Adsorption
- Regeneration w/ or w/o steam at 100°C
- CO_2 fed to greenhouse nearby
- Operational since May 2017

Waste-to-Energy Plants



- CO_2 emissions from European WtE plants are significant
- WtE plants enable sustainable cities: waste treatment, recycling, heat & power, CO_2 mitigation and CDR
- Biogas upgraders provide even more accessible biogenic CO_2

ORCA inauguration (Climeworks & CarbFix)

- Hellisheidi, Iceland – September 8th, 2021
- 4000 tons CO_2/year will be captured and stored underground

Take-Home Messages

1. Um dem Klimawandel entgegenzuwirken, müssen sowohl Emissionen reduziert als auch negative Emissionen generiert werden
2. Die punktuelle CO2-Abscheidung ist sektorübergreifend machbar, die sichere Speicherung wird europaweit verfügbar sein.
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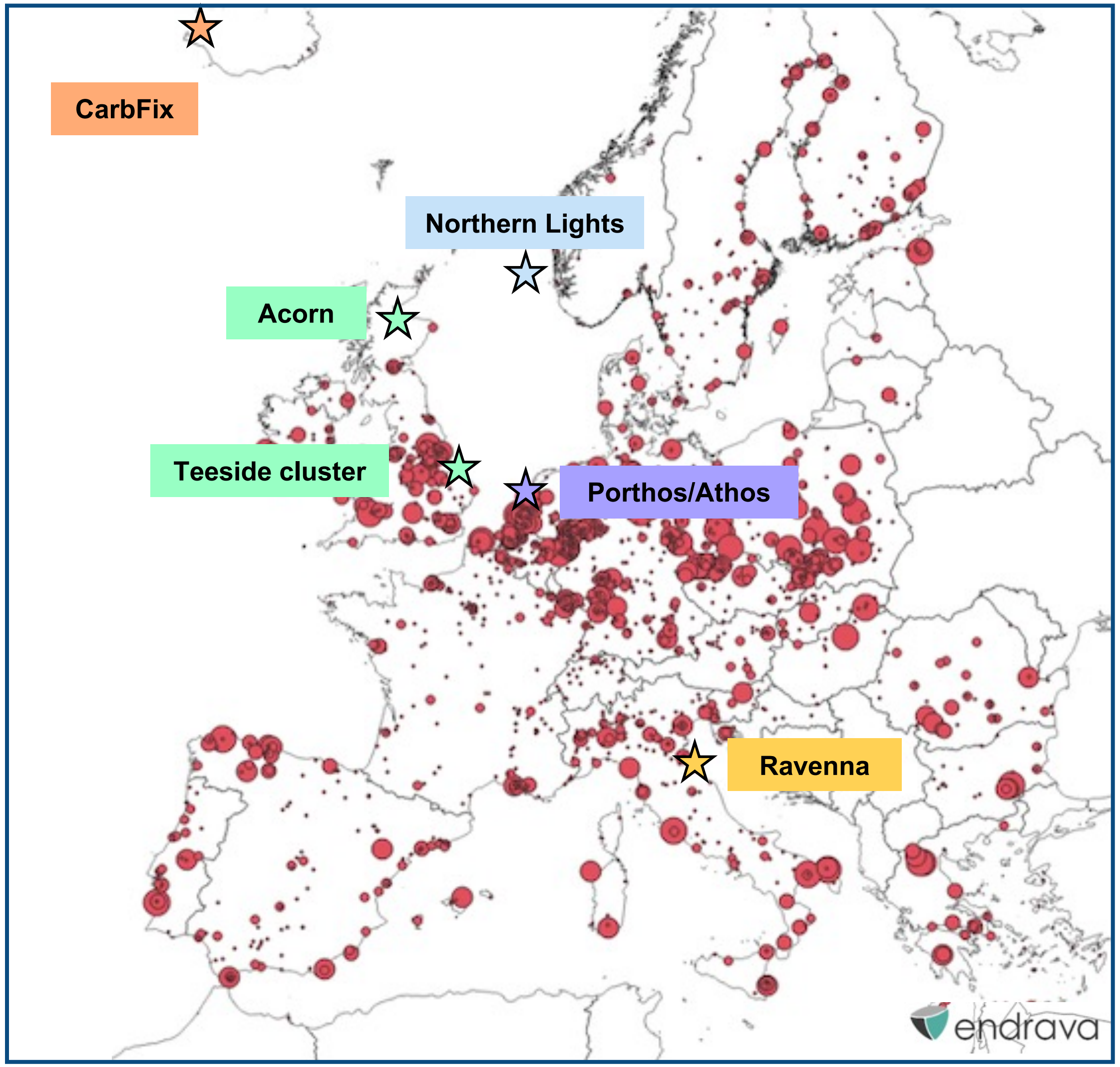
4. Die CO2-Abscheidung kann durch direkte Abscheidung aus der Luft oder durch Nutzung von Biomasse erreicht werden.
5. Es besteht ein dringender Bedarf an einem europaweiten CO2-Netz, das alle CO2-Quellen und CO2-Senken miteinander verbindet.

5. CO_2 sources and sinks across Europe



Sectors with the largest potential

- Waste incineration / WtE
- Cement
- Biomass and biofuel
- Refineries
- Steel
- Natural gas
  - Hydrogen
  - Electricity
- DAC

- Order of magnitude: hundreds of millions of tons CO_2 in 2050

Take-Home Messages

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5. Es besteht ein dringender Bedarf an einem europaweiten CO2-Netz, das alle CO2-Quellen und CO2-Senken miteinander verbindet.
6. Es gibt einen anspruchsvollen und dringenden, aber machbaren Weg für CCS-basierte Lösungen, um zu den Schweizer Klimazielen beizutragen.

Take-Home Messages (F)

1. Pour lutter contre le réchauffement climatique, il faut réduire les émissions et générer des émissions négatives.
2. Le captage du CO2 à la source est réalisable dans tous les secteurs, et un stockage sûr sera disponible dans toute l'Europe.
3. L'utilisation du CO2 est très intensive en énergie (et nécessite donc un approvisionnement en énergie renouvelable et une analyse au niveau du système).
4. Le captage du CO2 peut être réalisé par captage direct dans l'air ou en utilisant la biomasse.
5. Il est urgent de créer un réseau européen du carbone reliant toutes les sources et tous les puits de CO2.
6. Il existe une voie difficile et urgente, mais réalisable, pour que les solutions basées sur le CSC contribuent aux objectifs climatiques de la Suisse.

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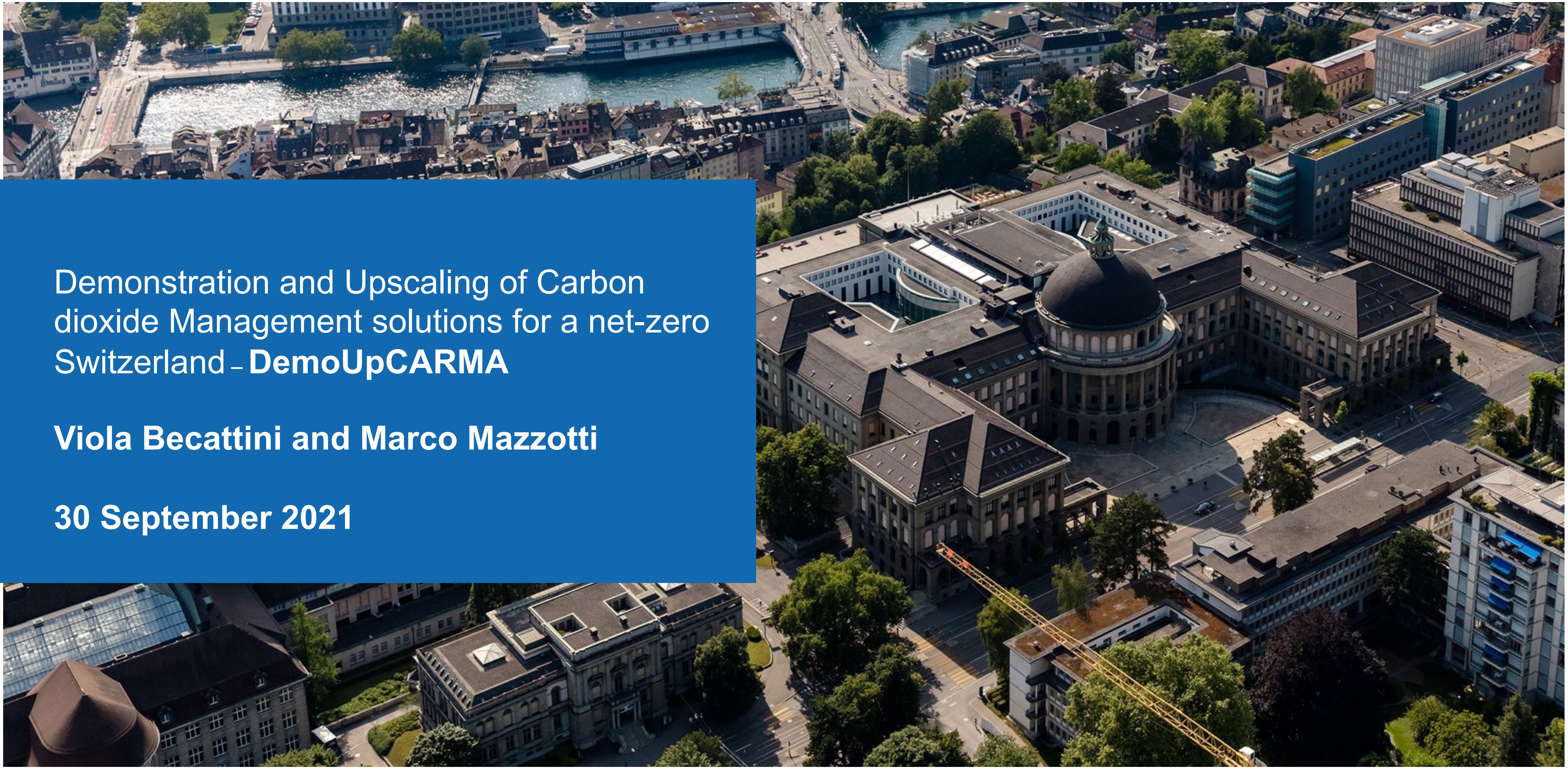
Separation Processes
Laboratory



Demonstration and Upscaling of Carbon dioxide Management solutions for a net-zero Switzerland – **DemoUpCARMA**

Viola Becattini and Marco Mazzotti

30 September 2021

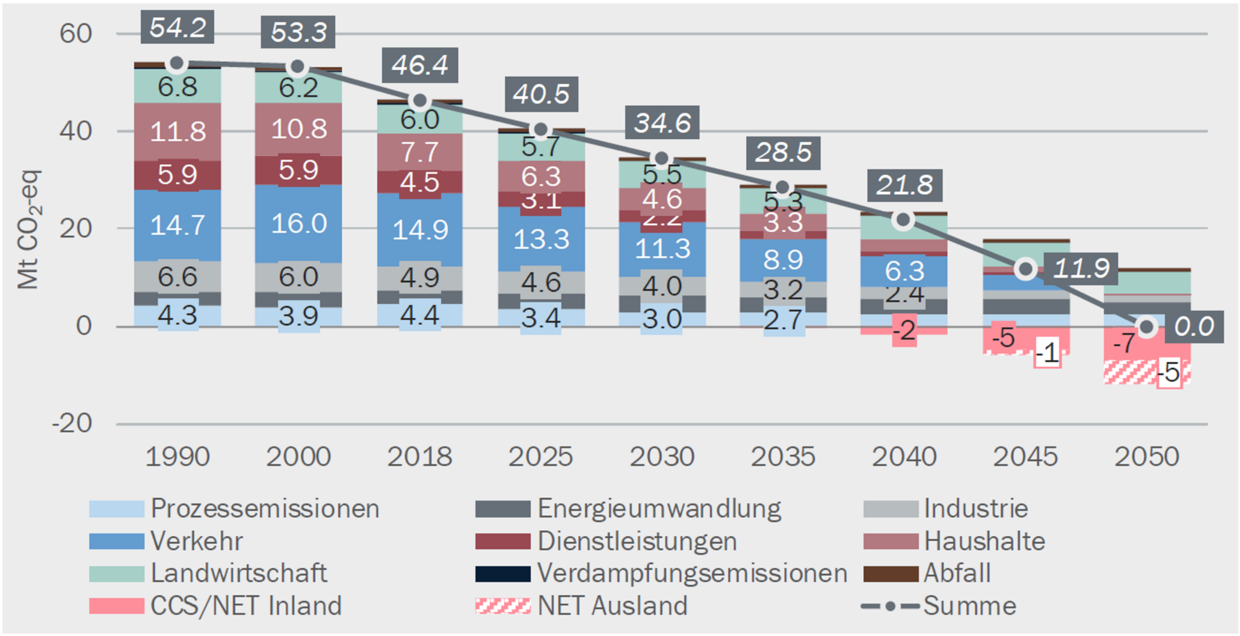
D MAVT

Context

The *Long-Term Climate Strategy for Switzerland* published by The Federal Council (27.01.2021) shows that CCS shall play a key role, i.e. 5 mton CO_2/y CCS (fossil/geogenic) & 2 mton CO_2/y NET domestic, to achieve the goal of carbon neutrality in Switzerland by 2050.

Abbildung 1: Treibhausgasemissionen

Entwicklung der Treibhausgasemissionen und des Einsatzes von Negativemissionstechnologien im Szenario ZERO Basis, in Mio. t CO_2-eq



Total emissions (fossil and biogenic) from Swiss CO_2 point sources[1,2]:

i.	Waste-to-Energy (30 plants)	4.5 Mt CO_2-eq/y
ii.	Cement industry (7 plants)	2.6 Mt CO_2/y
iii.	Chemical industry (9 plants)	1.1 Mt CO_2/y

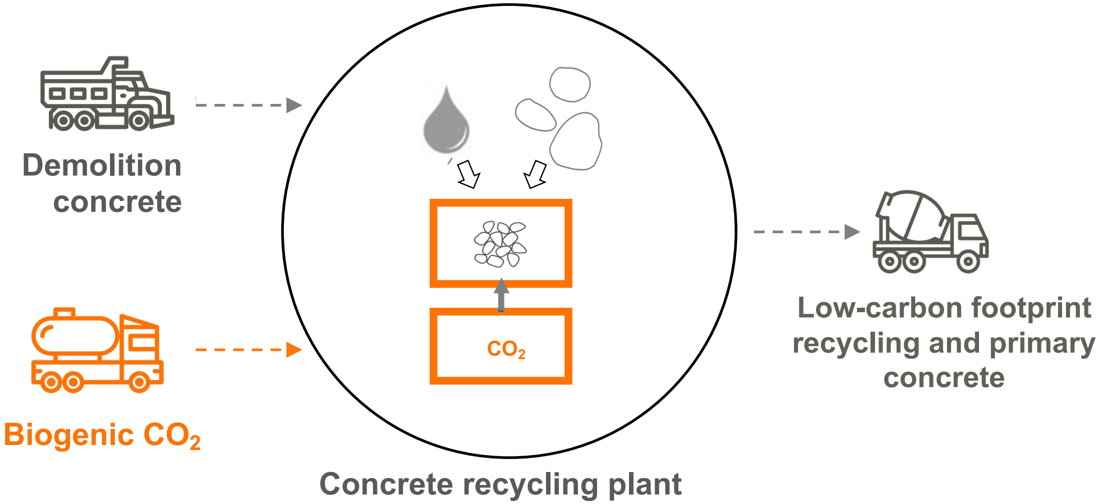
"Countries' net-zero emissions pledges must urgently be translated into strong near-term policies and action"
(United Nations Environmental Program – Emissions Gap Report 2020 – Dec. 2020)

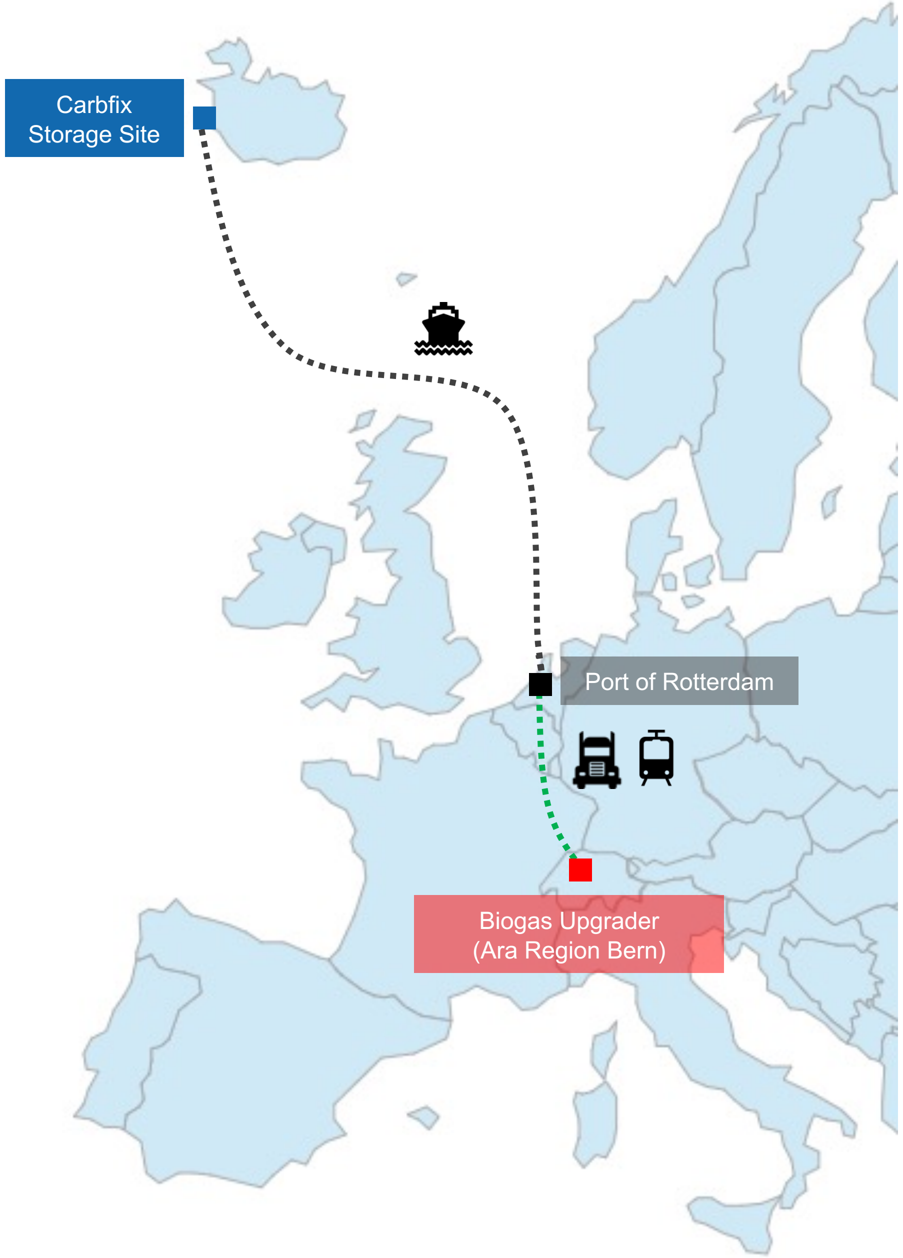
The significance of the different types of negative emissions solutions for Switzerland is discussed in the 02.09.2020 report of the Federal Council (in fulfilment of the postulate 18.4211 Thorens Goumaz of 12.12.2018), and titled "*Von welcher Bedeutung könnten negative CO_2-Emissionen für die künftigen klimapolitischen Massnahmen der Schweiz sein?*".

[1] *Monitoring-Bericht zur CO_2-Branchenvereinbarung für das Jahr 2019*, Verband der Betreiber Schweizerischer Abfallverwertungsanlagen (VBSA).
[2] Swiss Emissions Trading Registry, 2018.

Project goals

1. Demonstrate the technical feasibility of using and storing CO_2 captured at a Swiss industrial site (biogas upgrading plant) and of generating negative emissions when CO_2 is biogenic by:
   (i) utilizing and storing it in primary and recycling concrete via a novel technology solution → domestic CCUS value chain (Neustark technology);
   (ii) Transporting and permanently storing it in a geological reservoir abroad (Carbfix, Iceland) using a novel injection technique → CCTS value chain.





CCUS: Carbon Capture, Utilization and Storage
CCTS: Carbon Capture, Transport and Storage

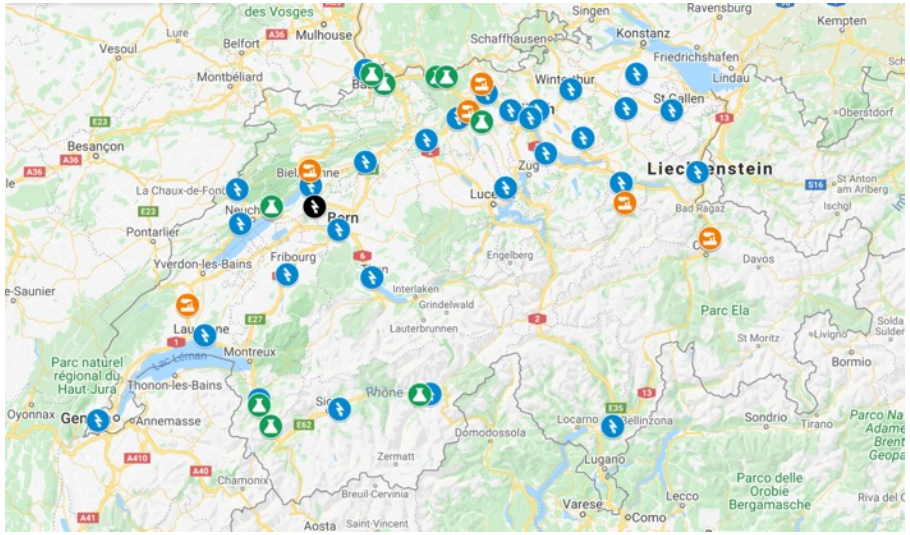
Project goals

1. Demonstrate the technical feasibility of using and storing CO_2 captured at a Swiss industrial site (biogas upgrading plant) and of generating negative emissions when CO_2 is biogenic by:
   (i) utilizing and storing it in primary and recycling concrete via a novel technology solution → domestic CCUS value chain (Neustark technology);
   (ii) Transporting and permanently storing it in a geological reservoir abroad (Carbfix, Iceland) using a novel injection technique → CCTS value chain.

2. Assess the upscaling potential of CCUS and CCTS chains as well as that of a Swiss CO_2 network in the near- and long-term, respectively, considering techno-economic, environmental, and reliability aspects.

3. Address policy, legal, and regulatory challenges to ensure economic viability, mobilization of financial investment, and acceptance of CCUS and CCTS value chains.

Swiss large CO_2 emitters[1,2]



- **Waste-to-Energy sector** (30 plants) 4.5 Mt CO_2-eq/y
- **Mineral industry** (7 plants) 2.6 Mt CO_2/y
- **Chemical industry** (9 plants) 1.1 Mt CO_2/y

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[2] Swiss Emissions Trading Registry, 2018.

DemoUpCARMA structure and work packages

WP1

Project coordination and dissemination
M. Mazzotti, V. Becattini

WP2. Demonstration of CO_2 utilization and storage in concrete (domestic solution, CCUS) – *V. Gutknecht*
Piloting a novel carbonation technology for primary and recycling concrete and minimizing the CO_2 footprint of construction materials

WP3. Demonstration of CO_2 transport and geological storage (abroad, CCTS) – *S. Wiemer*
Demonstrating the feasibility of the full supply chain comprising (biogenic) CO_2 liquefaction at a Swiss industrial emitter, trans-national transport, and geological storage in Iceland using a novel injection technique

WP4. Upscaling potential of CCUS and CCTS chains and CO_2 network – *M. Mazzotti*
Investigating the potential of upscaling CCUS and CCTS technologies and of creating a CO_2 network with optimal design with respect to techno-economic, environmental, and reliability aspects for the near- and long-term horizons

WP5. Addressing policy, regulatory, and acceptance challenges to enable CCUS & CCTS deployment – *P. Eckle*
Exploring effective policy designs, relevant legal frameworks, and public acceptance to fill existing gaps and to unlock the potential of CCUS and CCTS technologies

List of partners

Research institutions

- ETH Zürich – Institute of Energy and Process Engineering [All WPs]
  (Separation Processes Laboratory, Energy and Process Systems Engineering, Reliability and Risk Engineering)
- ETH Zürich – Sustainability in Business Lab [WP4, 5]
- ETH Zürich – Institute of Geophysics [WP1, 3]
- ETH Zürich – Institute of Science, Technology and Policy [WP5]
- ETH Zürich – Energy Science Center [WP1]
- École polytechnique fédérale de Lausanne (EPFL) [WP3, 4]
- University of Geneva [WP3]
- Swiss Federal Laboratories for Materials Science and Technology (EMPA) [WP2]
- Paul Scherrer Institute (PSI) [WP2, 4]
- Università della Svizzera Italiana [WP5]

National partners

- Ara Region Bern [WP2]
- Kästli [WP2]
- Casale [WP4]
- South Pole (and Perspectives) [WP5]
- SBB Cargo/Chemoil [WP3, 4]
- Verband der Betreiber Schweizerischer Abfallverwertungsanlagen (VBSA) [WP4, 5]
- Jura Cement [WP4, 5]
- Entsorgung + Recycling Zürich (ERZ) [WP4, 5]
- Stiftung Risiko-Dialog [WP5]
- Lonza [WP4, 5]
- Lonza Solutions [WP4, 5]
- scienceindustries [WP4, 5]
- Salzmann Transporte [WP3]
- Sulzer Chemtech [WP4]

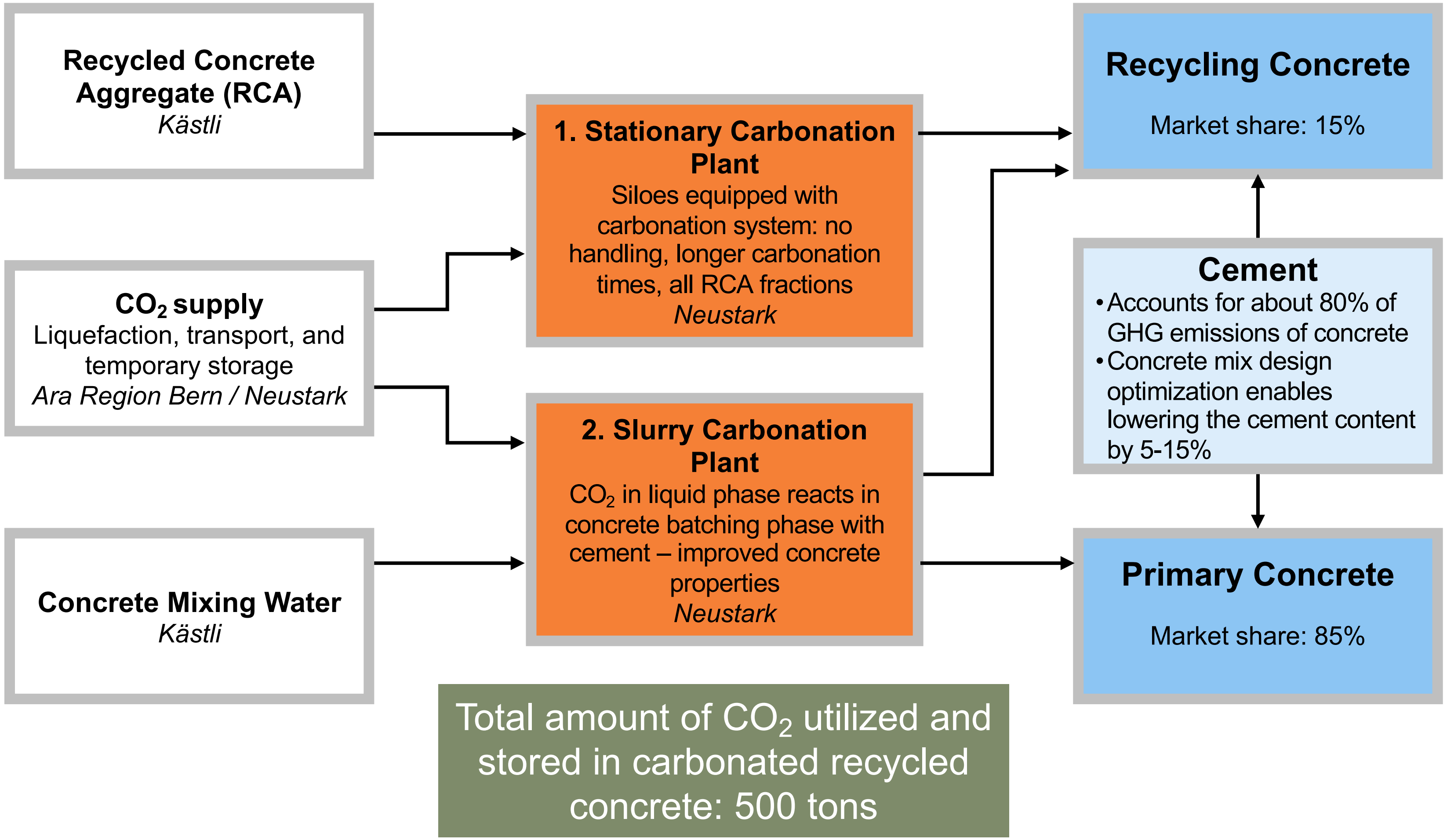
International partners

- Carbfix [WP3, 4]
- Northern Lights [WP4, 5]

ETH Spin-offs

- Neustark [WP2, 3, 4, 5]
- Climeworks [WP5]

WP2: Demonstration of CO_2 utilization and storage in concrete (domestic solution, CCUS)



Arabern: waste water treatment plant, with biogas upgrader - CO_2 supplier.

Kästli: concrete recycling plant.

Nuestark: carbonation of demolition concrete and concrete mixing water.

EMPA: material testing and development of low-carbon footprint concrete mix designs.

PSI: Cradle-to-grave LCA of the overall value chain.

Challenges: optimize on-site logistics and material flow, enhance energy efficiency and carbonation process, improve concrete quality and reduce its carbon fooprint, quantify environmental benefits of value chain.

Design and construction	Development of concrete mix designs	Demonstration	Cradle-to-grave LCA	Final Evaluation

Neustark, Ara Region Bern, Kästli, EMPA, PSI

WP3: Demonstration of CO_2 transport and geological storage (abroad, CCTS)

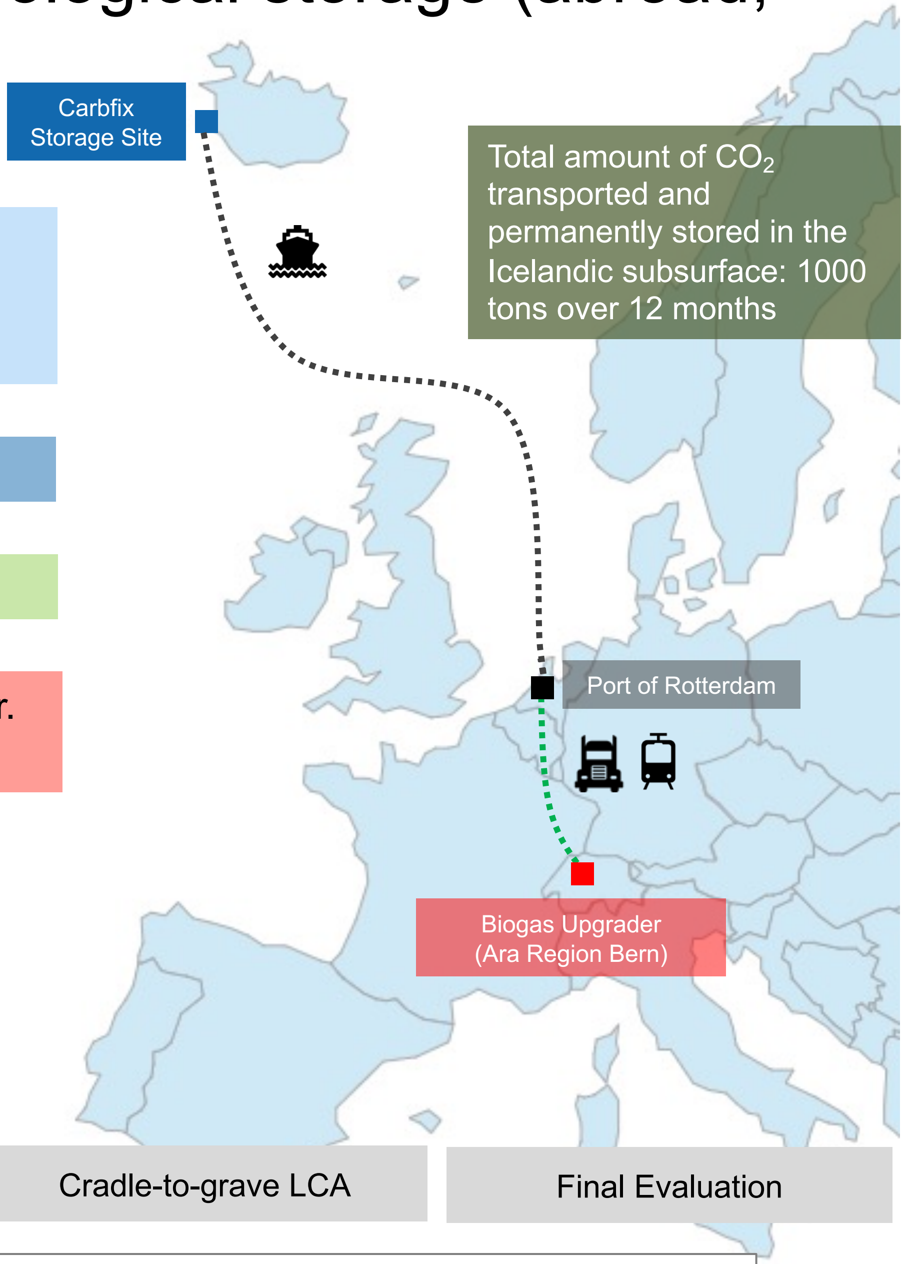
ETH, University of Geneva, EPFL
Cradle-to-grave LCA of overall CO_2 supply chain.
Comprehensive monitoring program before, during and after CO_2 injection.

Carbfix: CO_2 storage in basalt by mineralization (incl. CO_2 transport).

SBB Cargo: transport of chemicals, including CO_2, by road and rail.

Ara Region Bern: waste water treatment plant, with biogas upgrader - CO_2 supplier.
Neustark: liquefaction of CO_2 and loading of isotainers.

Challenges: scheduling CO_2 provision and coordinating its supply chain from Ara Region Bern to Icelandic storage site via Rotterdam, injecting CO_2 dissolved in seawater (first-of-a-kind demonstration), monitoring and assessing efficacy of permanent storage.



Design and planning	Monitoring	Demonstration	Cradle-to-grave LCA	Final Evaluation

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ETH-SED, ETH-SPL, ETH-EPSE, Carbfix, SBB Cargo/Chemoil, Neustark, University of Geneva, EPFL-LMS, Salzmann Transporte

WP4: Upscaling potential of CCUS and CCTS chains and CO_2 network

Upscaling of CCUS and CCTS value chains

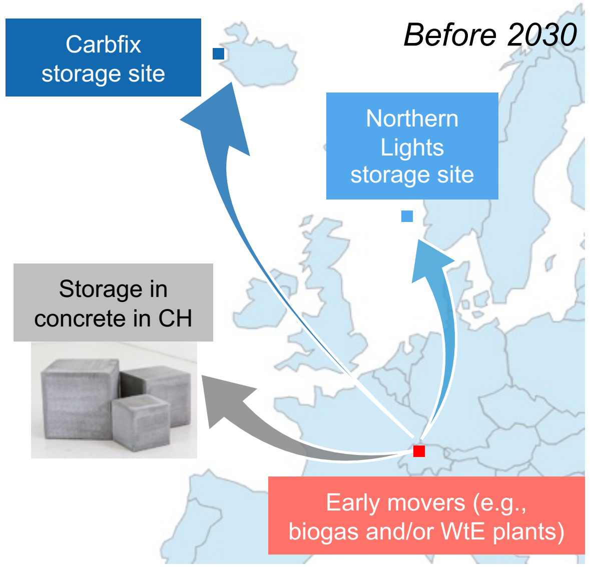
Analysis of CCUS and CCTS chains that may be deployed in the near-term (e.g., before 2030) by **early movers**, considering **techno-economic, environmental, and reliability** aspects of these chains from the capture and liquefaction sites, to transport and permanent storage.

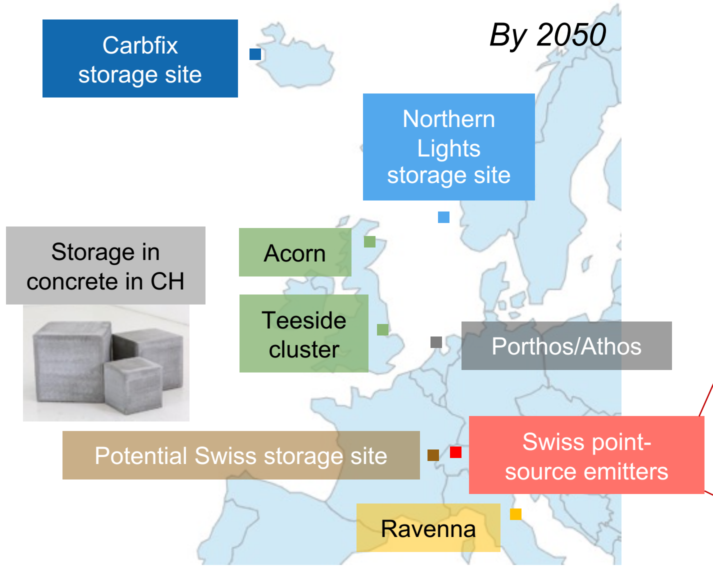
Swiss CO_2 network and shared infrastructure

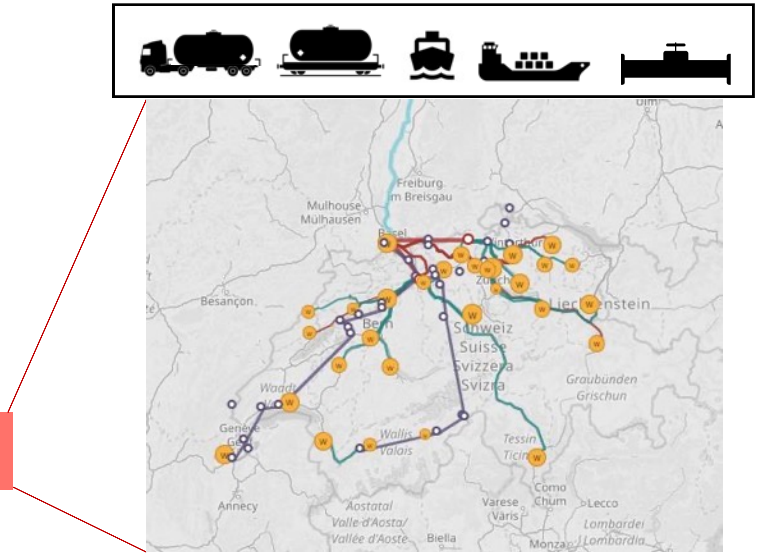
Develop scenario-based optimal designs of a Swiss **CO_2 network** connecting emission sources (from the WtE, cement, chemical and biogas sectors) to sinks domestically or abroad in the long-term and exploiting a potential shared CO_2 infrastructure established at the European level.

Integration of post-combustion CO_2 capture with WtE and cement plants

Identify **optimal integration** options for post-combustion CO_2 **capture technology** in (WtE) and cement plants with reference to specific plants (Hagenholz and Wildegg plants) and generalization to other plants.







ETH-SPL, ETH-RRE, ETH-EPSE, ETH-sus.lab, Neustark, SBB Cargo/Chemoil, VBSA, Casale, Jura Cement, ERZ, Lonza, Lonza Solutions, scienceindustries, Sulzer Chemtech, Carbfix, Northern Lights

WP5: Addressing policy, regulatory, and acceptance challenges to enable CCUS & CCTS deployment

Scope	Focus
1 **Emissions accounting and reporting tools, and crediting mechanisms for national and trans-national CCUS and CCTS solutions**	• Stocktaking and assessment of the climate finance landscape with applicability to prospective CCUS and CCTS activities • Methodology and toolsets for climate finance transactions • Blueprints for climate finance transactions
2 **Analysis of effective policy designs to overcome acceptance and financing challenges**	• Investment and financing needs along the CCUS and CCTS supply chains • Effective support policy designs for mobilization of finance • Public acceptance of support policies • Stakeholders map & knowledge and perception of the Swiss public towards CCUS and CCTS
3 **Technical and organizational questions for transport scale-up**	• Other regulatory gaps emerging from WP2 and WP3 • Technical regulatory gaps for CO_2 pipeline network • Organizational models for future CO_2 infrastructure

ETH-sus.lab, ETH-SPL, ETH-SED, ETH-ISTP, South Pole, Climeworks, Neustark, VBSA, Jura Cement, ERZ, Stiftung Risiko-Dialog, Lonza, Lonza Solutions, scienceindustries, USI, Carbfix, Northern Lights

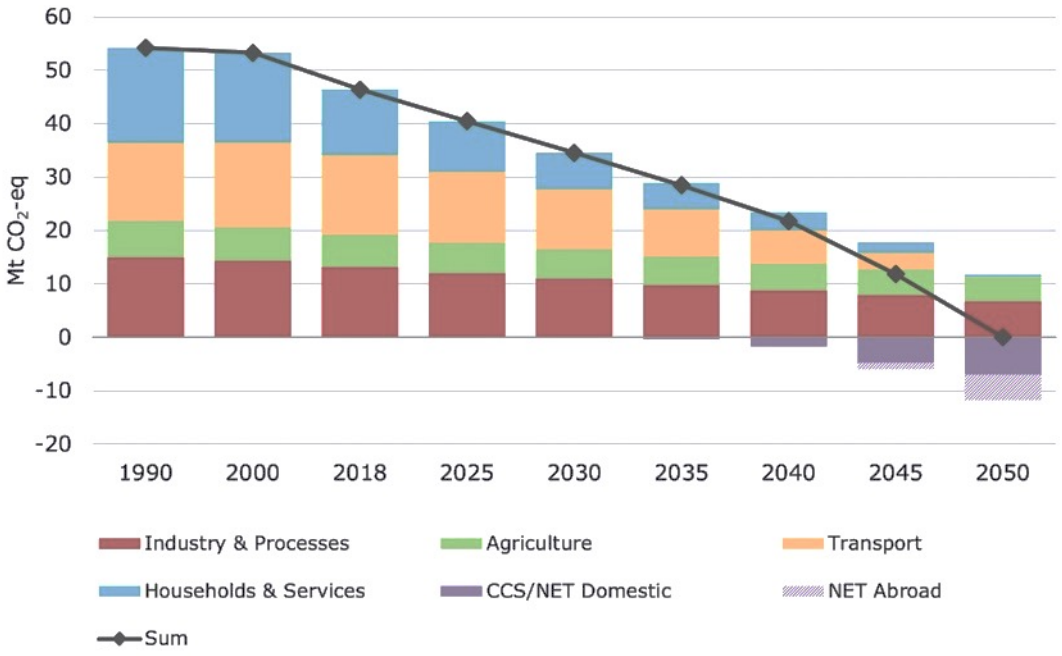
PATHFNDR project

Partnership Council Energy
29th September 2021
Lea A. Ruefenacht

In line with the national vision of net-zero GHG emissions we imagine …

an efficient, flexible, resilient, cost-effective, and sustainable Swiss energy system by 2050.

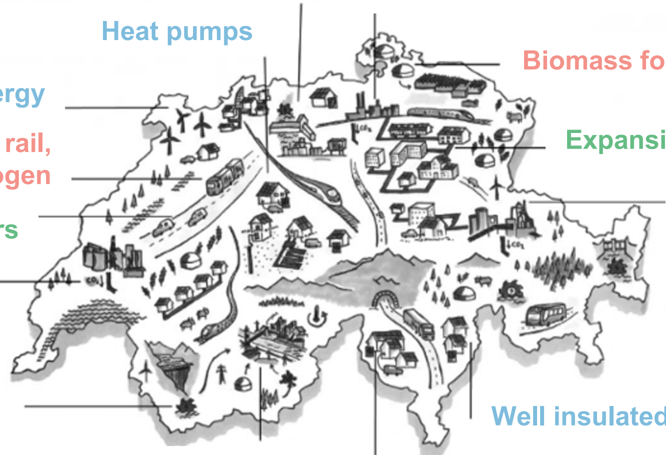
Climate-related emissions in Switzerland: net-zero scenario until 2050



Source: Energy Perspectives 2050+ (SFOE), Prognos AG / TEP Energy GmbH / INFRAS AG (2020)

Within this future, our main goal is to …

develop and analyze transition pathways for renewable energy integration in Switzerland.



Source: based on Prognos AG, https://www.bfe.admin.ch/bfe/en/home/policy/energy-perspectives-2050-plus.html

25 cooperation partners from the public and private sector

ABB aliunid AMSTEIN+WALTHERT axpo BKW EBP ecoqube energie360°

ewb ezs groupe e MAN primeo energie SVGW SSIGE SIEMENS swiss economics The Singularity group

sympheny VSE AES WWZ epexspot HELMHOLTZ GEMEINSCHAFT Imperial College London KOPERNIKUS P2X PROJEKTE Die Zukunft unserer Energie SENTINEL SUSTAINABLE ENERGY TRANSITIONS

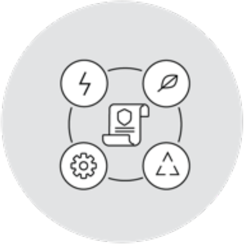
The expected outcomes are:

1. **Feasible pathways** for the energy transition that enhance flexibility and sector coupling

2. **Planning and operation tools** for assessing flexibility options across sectors and along different spatiotemporal scales

3. **Pilot and demonstration projects** for testing flexibility market designs and technologies

4. Identifying new **business opportunities and innovation strategies** for exploiting flexibility and sector coupling options



5. Analysis of **potential policies** for the energy transition and decarbonization

Fragen und Diskussion

PG BFI BILDUNG FORSCHUNG INNOVATION
GP FRI FORMATION RECHERCHE INNOVATION
FORMAZIONE RICERCA INNOVAZIONE

Moderation:

SR Damian Müller
Präsident PG BFI

Nächster Anlass PG BFI – GP FRI

PG BFI GP FRI BILDUNG FORSCHUNG INNOVATION FORMATION RECHERCHE INNOVATION FORMAZIONE RICERCA INNOVAZIONE

Frühjahrssession 2022:

Donnerstag, 17. März 2022 über Mittag

Anmeldung: info@pgbfi.ch