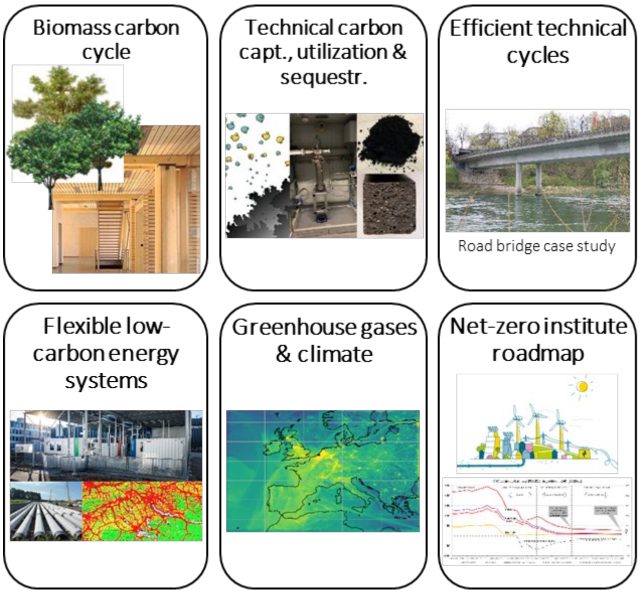
Swiss Center of Excellence on Net-Zero Emissions (SCENE)



The ETH Board is co-financing six Joint Initiatives (JI) in the strategic area "Energy, Climate and Environmental Sustainability" for a duration of three years. These Joint Initiatives are large, strategic projects in which at least two institutes of the ETH Domain must be involved.

The SCENE Joint Initiative has established a Center of Excellence that covers a wide range of research areas related to net-zero emissions and provides a platform for cross-institutional collaboration in the ETH Domain. More than 100 researchers in 30 laboratories from all four Research Institutes of the ETH Domain (PSI, Empa, WSL, Eawag) and the two Technical Universities ETHZ and EPFL are involved. The project is led by PSI and runs from 1.1.2023 - 31.12.2025 with a total budget of approx. 17 million CHF.

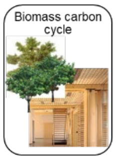
In order to support the achievement of the goal of net-zero emissions by 2050, described in the Federal Government's climate and energy strategy, SCENE performs holistic research in six Net-Zero Action Areas (Figure 1), covering the avoidance, removal, monitoring and analysis of greenhouse gas emissions.

In addition, an Expert Hub strengthens the network within the ETH Domain and pools a broad range of interdisciplinary expertise. It proactively publishes reports and white papers and responds to requests from stakeholders in order to achieve a strong, direct public impact.

In the long term, SCENE plans to create a platform that supports scientifically sound decisions, both at the national level and for stakeholders, so that the technologies, instruments and methods developed at the Center of Excellence can be put into practice in a timely manner.

Action Areas in SCENE

AA 1: Biomass carbon cycle

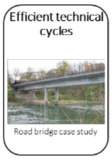


We demonstrate optimization pathways of forest and landscape management, the utilization of woody biomass, and substitution effects to mitigate climate change.

AA 2: Technical carbon capture, utilization, and sequestration

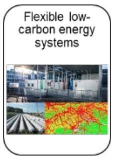
We establish a sustainable energy supply chain with negative CO_2 emissions, enabling global transport, large-scale seasonal storage, and carbon sequestration in Switzerland using existing infrastructure.

AA 3: Efficient technical cycles – Circular carbon-neutral infrastructure



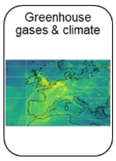
We support the decarbonization of the construction sector (30% of Swiss emissions) by providing decision-making tools and strategies, including design for disassembly and materials/component reuse, enabling carbon-neutral, circular infrastructure by 2050.

AA 4: Flexible low-carbon energy systems



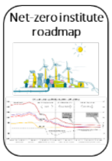
We unlock the flexibility potentials of the Swiss energy system to ensure supply security and social acceptance in a renewable-based future, supporting decision makers with energy investments.

AA 5: Greenhouse gases and climate



We create a publicly-accessible interactive platform with information about integrated greenhouse gas mitigation scenarios towards net-zero, overarching sustainability implications, and related air quality evolution.

AA 6: Net-zero institute roadmap



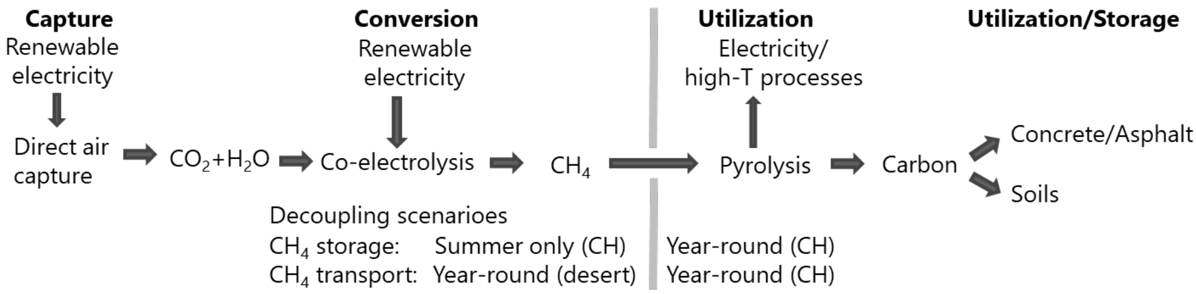
We define science-based, net-zero roadmaps for the four Research Institutes using gap analyses, energy scenarios with possible cost developments, and considerations about the necessary measures and their impacts to reach net-zero.

Action Area 2: Technical carbon capture, utilization, and sequestration

Motivation and Main Outcomes:

Reducing emissions of greenhouse gasses forms the cornerstone of any successful climate policy. Unfortunately, some emissions may not be possible to eliminate completely. Hence, the need for negative emissions technologies remains. Indeed, direct air capture, i.e. the removal of CO_2 from the atmosphere, will be a necessity to offset residual emissions and to remove historically emitted CO_2. At the same time, the rapid expansion of renewable energy leads to significant seasonal mismatch between electricity production and consumption, with projected excess production in summer and uncovered demands in winter.

Here, we investigate a carbon cycle that does the opposite of burning coal: we convert CO_2 from the atmosphere into solid carbon which can be stored long-term in construction materials or soils. At the same time, this carbon-negative cycle may help to ease the seasonal mismatch between production and demand. The cycle uses renewable electricity (e.g. from PV in Switzerland in summer, or from PV in deserts year-round) to capture CO_2 from the air and convert it into methane. This methane can then be transported (from the desert to Switzerland) or stored (in the summer for the following winter). When the energy demand is high, the methane is converted into H_2 for energetic use and solid carbon for long-term storage (or high added value applications).

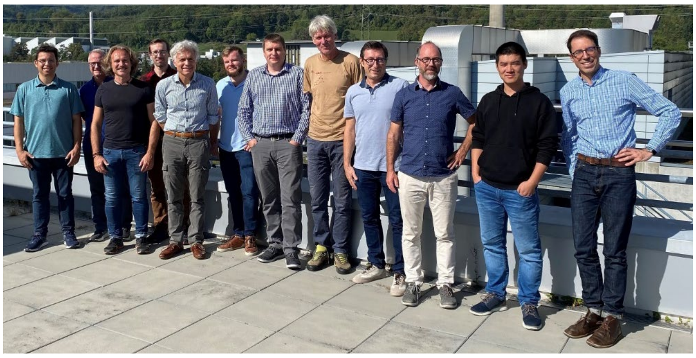


The main outcomes of this Action Area are on the one hand technical progress on all aspects of the project (carbon capture, electrolytic conversion of CO_2 into methane, pyrolytic conversion into carbon, catalytic conversion of methane into carbon nanotubes (CNT), storage of carbon in concrete and asphalt, storage of carbon in soils). On the other hand, we will evaluate the overall cycle in terms of energetic and cost efficiency, and investigate the societal acceptance of such a cycle with a comparative assessment of a Switzerland-only implementation (seasonal storage of methane) versus a desert-Swiss implementation (transport of methane).

Who we are:

Our team builds on the competences of 4 Empa laboratories, 3 PSI laboratories and 1 WSL laboratory. Together, we cover a wide range of expertise, including carbon capture materials and processes (Empa and PSI), conversion of CO_2 into methane (PSI and Empa), pyrolytic and catalytic conversion of methane (Empa and PSI), sequestration of carbons into concrete and asphalt (Empa) and soils (WSL), and life cycle and societal impact assessments (PSI and Empa). The project team comprises 5 postdocs and a senior scientist hired specifically for the SCENE project (and sometimes shared between institutes and labs), and over 10 senior scientists with long-term experience in the topic.

The following institutes are contributing with their expertise:



Participating Laboratories

Empa Building Energy Materials and Components

PSI Catalysis and Sustainable Chemistry

Empa Computational Engineering

PSI Electrochemistry

Empa Chemical Energy Carriers & Vehicle Systems

WSL Soils and Cycles

Empa Concrete & Asphalt

PSI Energy Systems Analysis

Contact: Wim Malfait, wim.malfait@empa.ch

Activities:

Carbon capture: selective sorbents during CO_2-H_2O co-sorption

For direct air-capture, the concentration of water is almost always orders of magnitude higher than that of CO_2. Hence, sorbents that are highly selective for CO_2 over H_2O are required to avoid excessive energy consumption to remove co-adsorbed water during the sorbent regeneration. Here, we develop new analytics for competitive CO_2-H_2O co-sorption, screen existing sorbents and develop new sorbents with higher selectivity for CO_2, based on silica gels and MOFS.

Conversion of CO_2 into methane: Electrolysis with Cu-based catalysts

Electrolytic conversion of CO_2 into methane is not straightforward. Here, we pursue electrolytic methane production using Cu-based catalysts. Activities include catalyst synthesis, optimization of the electrolysis conditions to increase selectivity for methane, and the fabrication of a proof-of-concept set-up.

Plasma-based conversion of methane into solid carbon

The project activities center on a prototype equipment that converts methane into solid-carbon and hydrogen using microwave irradiation. Activities include spectroscopic investigations for in-situ observation of plasma conditions and produced gasses, increasing selectivity of H_2 production, analysis of the quality of the produced carbons (poly-aromatic hydrocarbons PAH in particular), development of strategies to reduce PAH and the optimization of the solid carbon yield.

Catalytic conversion of methane into carbon nanotubes

Whereas the plasma-based conversion targets high volume applications for energy production and carbon storage, this activity focuses on the production of high added-value carbon nanotubes. New transition metal catalysts are developed and reaction conditions are optimized to increase the yield and quality of the multi-walled CNT. In-operando measurements provide mechanistic insight into the synthesis process.

Storage of carbon in construction materials

Because of their application volume and long-term stability, construction materials are the only man-made materials to bind climate-relevant amounts of solid carbon. Here, the incorporation of methane-derived carbon (and biochar as a readily available model system) in concrete and asphalt will be evaluated. Carbon can be added as-is to the binder phase, or alternatively, pelletized to substitute filler particles. The mechanical properties, carbon balance, and application potential are evaluated.

Storage of carbon in soils

In the right circumstances, solid carbon can improve soil quality and have climatically relevant residence times (10^2-10^4 years). Here, we compare the potential and barriers of carbon sequestration in (Swiss) soils for biochar and methane-derived carbon in terms of soil quality, storage time, and the regulatory framework.

Assessment of the overall cycle: energy, cost and acceptance

Here we assess the energetic and financial efficiency of the proposed cycle. Thermodynamically, the cycle consumes energy as it is in essence the opposite of the combustion of coal. In reality, the energy consumption is higher due to inefficiencies in all steps of the cycle. The overall cycle will be evaluated in terms of energy, climate impact and cost using state-of-the-art efficiencies for each process step. In addition, the social and political implication of two different implementations will be evaluated: a Swiss-only cycle versus a desert-Switzerland cycle.