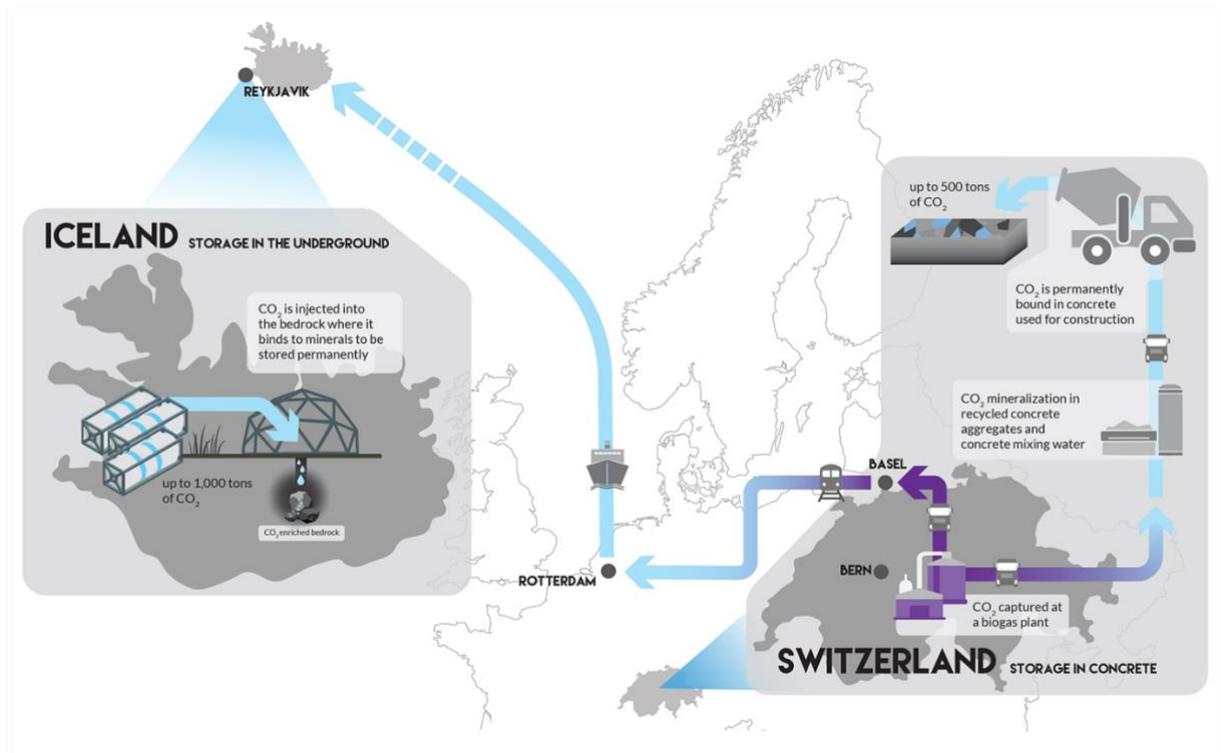




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DemoUpCARMA

WP1 - Project dissemination



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Subsidy recipients:

ETH Zürich
Rämistrasse 101
8092 Zürich

Empa
Überlandstrasse 129
8600 Dübendorf

PSI Paul Scherrer Institut
Forschungsstrasse 111
5232 Villigen PSI

Neustark
Luisenstrasse 14
3005 Bern

Kästli Bau AG
Altes Riedgässli 2
3113 Rubigen

Casale
Via Pocobelli 6
6900 Lugano

South Pole Carbon Asset Management AG
Technoparkstrasse 1
8005 Zürich

JURA Management AG
Zurlindeninsel 1
5000 Aarau

Entsorgung + Recycling Zürich
Hagenholzstrasse 110
8050 Zürich

**Authors:**

Viola Becattini, Separation Processes Laboratory, ETH Zurich, viola.becattini@ipe.mavt.ethz.ch

Katrina Klösel, Separation Processes Laboratory, ETH Zurich, kloeselk@ipe.mavt.ethz.ch

Marco Mazzotti, Separation Processes Laboratory, ETH Zurich, marco.mazzotti@ipe.mavt.ethz.ch

Stefanie, Zeller, Swiss Seismological Service (SED) at ETH Zurich, Stefanie.Zeller@sed.ethz.ch

Michèle, Marti, SED, Michele.Marti@sed.ethz.ch

SFOE project coordinators:

Men Wirz, men.wirz@bfe.admin.ch

Sophie Wenger, sophie.wenger@bafu.admin.ch

SFOE contract number: SI/502303-01

The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.



Zusammenfassung

DemoUpCARMA (Demonstration and Upscaling of CARbon dioxide MANagement solutions for a net-zero Switzerland) ist ein von der ETH Zürich geleitetes Pilotprojekt. Es hatte zum Ziel, zwei Pfade umzusetzen, die zur dauerhaften Entnahme von CO₂ aus der Atmosphäre oder zur Vermeidung von CO₂-Emissionen führen:

- Nutzung und permanente Speicherung von CO₂ in Abbruchbeton in der Schweiz mittels eines neuen Verfahrens. Dieser Pfad wird als CCUS (Carbon dioxide Capture, Utilisation and Storage) bezeichnet. CCUS steht für die Abscheidung, den Gebrauch und die Speicherung von CO₂.
- Transport und permanente Speicherung von CO₂ in einem geologischen Reservoir im Ausland.

Dieser Pfad wird als CCTS (Carbon dioxide Capture, Transport and Storage) bezeichnet. Damit ist die Abscheidung, der Transport und die Speicherung von CO₂ gemeint.

DemoUpCARMA untersuchte unter Berücksichtigung technologischer, wirtschaftlicher, regulatorischer, politischer und gesellschaftlicher Aspekte, wie diese Pfade mittel- bis langfristig optimal gestaltet und skaliert werden können.

In diesem Bericht geben wir einen Überblick über alle Kommunikationsaktivitäten, die während der Projektlaufzeit durchgeführt wurden.

Résumé

DemoUpCARMA (Demonstration and Upscaling of CARbon dioxide MANagement solutions for a net-zero Switzerland) est un projet pilote conduit par l'EPF de Zurich. L'objectif était d'expérimenter deux approches conduisant à la capture continue de CO₂ de l'atmosphère ou à éviter des émissions de CO₂:

- L'utilisation et le stockage permanent de CO₂ dans du béton de démolition en Suisse au moyen d'un nouveau procédé. Cette solution est de type CCUS (Carbon dioxide Capture, Utilisation and Storage - captage, utilisation et stockage du CO₂).
- Le transport et le stockage permanent de CO₂ dans un réservoir géologique à l'étranger.

Cette solution fait partie des approches CCTS (Carbon dioxide Capture, Transport and Storage – Captage, transport et stockage du CO₂).

DemoUpCARMA a étudié, en tenant compte des aspects technologiques, économiques, réglementaires, politiques et sociaux, comment ces solutions pouvaient être conçues et mises en œuvre à grande échelle de manière optimale à moyen et long terme.

Dans ce rapport, nous fournissons un aperçu de toutes les activités de diffusion liées au projet qui ont été réalisées pendant son exécution.

Summary

DemoUpCARMA (Demonstration and Upscaling of CARbon dioxide MANagement solutions for a net-zero Switzerland) is a pilot project led by ETH Zurich. Its aim was to implement two pathways that lead to the permanent removal of CO₂ from the atmosphere or to the avoidance of CO₂ emissions:

- CO₂ utilisation and permanent storage in demolition concrete in Switzerland using a novel technology. This pathway is referred to as Carbon dioxide Capture, Utilisation and Storage (CCUS).



- CO₂ transport and permanent storage in a geological reservoir abroad. This pathway is referred to as Carbon dioxide Capture, Transport and Storage (CCTS).

DemoUpCARMA investigated the optimum design of these pathways and how to scale them in the medium to long term, taking into account technological, economic, regulatory, political and societal factors.

In this report, we provide an overview of all the dissemination activities relative to the project that have been carried out during its execution.

Main findings of the project

CO₂ storage in demolition concrete in Switzerland

As part of DemoUpCARMA, the ETH spin-off Neustark, founded in 2019, has refined its process for the permanent storage of CO₂ in recycled concrete aggregate and concrete mixing water and tested it on an industrial scale.

The results show that the infrastructure required for CO₂ storage can be installed in an existing concrete recycling plant and operated on an industrial scale. For storage purposes, concrete aggregate produced during demolition (e.g. of buildings) is mixed with biogenic CO₂ provided by ARA Bern, a wastewater treatment and biomass recycling company. The CO₂ mineralises to form calcium carbonate, thus remaining permanently stored; only temperatures of over 600°C or very strong acids are able to release the CO₂ bound in this way. Mineralisation ensures that the CO₂ remains stored in the concrete aggregate even after it has been reused in road construction or added to fresh recycled concrete, used and then demolished again. Each tonne of recycled concrete aggregate can bind around 13kg of CO₂. Empa laboratory tests also show that concrete containing carbonated recycled concrete aggregate has higher compressive strength than primary concrete. This opens the door to reducing the cement content and the associated CO₂ emissions.

Concrete mixing water is a by-product that is produced when concrete mixing vehicles and concrete mixing plants are cleaned. It consists of water with a solids content (mainly cement and sand) of less than 10 percent. The concrete mixing water is collected in a basin and added to the ready-mixed concrete as a water substitute. It can absorb around 25kg of CO₂ per cubic metre. In the laboratory, the addition of carbonated concrete mixing water to primary concrete showed improved workability and also increased compressive strength compared to primary concrete to which non-carbonated concrete mixing water had been added.

Storing CO₂ in both recycled concrete aggregate and concrete mixing water has a positive effect on the climate. More emissions are avoided and, when using biogenic CO₂ as in DemoUpCARMA, more emissions are removed than generated. The efficiency levels (ratio of used energy to supplied energy) were over 90 percent. When it comes to costs, there are economies of scale to be had: with an integrated storage system, costs can be reduced in the long term starting from a quantity of 500 tonnes of stored CO₂ per year.

CO₂ storage in a geological reservoir in Iceland

The DemoUpCARMA project was the first to demonstrate a CO₂ supply chain from capture and transport to geological storage in Icelandic basalt. Biogenic CO₂ is captured and liquefied at ARA Bern. From



there, it is transported by lorry in special containers to Weil am Rhein, Germany, where it is then transported by rail to the port of Rotterdam in the Netherlands, and onwards by sea freight to Iceland. In Iceland, the container is transported from the port to the geological reservoir by lorry.

80 tonnes of CO₂ have been transported to Iceland. A life-cycle assessment has shown that the entire supply chain causes significantly fewer greenhouse gas emissions than are removed through geological storage. This means that although additional emissions are generated during transport, the climate effect is still positive in the end. If the CO₂ is biogenic, as in our pilot project, it can even lead to negative emissions. Each stored tonne of CO₂ generates around 200 to 250kg of CO₂ emissions, so it is possible to store 750 to 800kg net CO₂. Transport using fossil fuels causes the most emissions; in the future, this could be optimised by using renewables in rail transport or establishing a CO₂ pipeline network.

In Iceland, the Swiss CO₂ is mixed with seawater and injected into the basaltic subsoil through a specially constructed borehole at a depth of 300 to 400 metres. Previously, the partner company Carbfix had been dissolving the CO₂ in freshwater in order to mineralise it underground. Now an extensive monitoring network is being employed to investigate whether the procedure and the mineralisation processes also work with seawater and how exactly the mineralisation occurs. Due to delivery difficulties caused by the pandemic and the war in Ukraine, transport and material procurement were delayed. In addition, technical problems meant drilling progressed more slowly than originally hoped. In consequence, injections could not commence until the beginning of November 2023, meaning that only a few results are available so far. The DemoUpStorage partner project supported and monitored the injection and CO₂ mineralisation in the reservoir until the end of 2024.

The costs calculated in the project amount to several hundred Swiss francs per tonne of stored CO₂. However, it must be noted that this cost calculation was done for a pilot project, where the associated challenges are likely to have increased costs. Costs could be brought down in the future by economies of scale, an established regulatory framework and more experience in transport management.

Transport and financing

Transport from the emission source to the storage location is a central element of **CCT(U)S**. As part of the project, the establishment of a real supply chain from the capture unit to the concrete recycling plant functioned smoothly. In contrast, the cross-border supply chain to Iceland brought with it a number of challenges that would hardly have become apparent through modelling alone. One such difficulty, for example, related to declaring the CO₂ for export and the associated regulations.

The challenges differ depending on the supply chain, as illustrated by the two case studies that DemoUpCARMA examined: different solutions for capture processes and systems were tested for the Hagenholz waste-to-energy plant in Zurich and the Jura cement plant in Wildegg. The studies showed that the choice of capture technology depends on which energy resources (e.g. heat or electricity) are already available at the site or can be put to effective use.

In terms of costs, the currently established multimodal transport chain (with lorry, rail and ship) is relatively expensive for CCTS and is expected to offer few economies of scale. A significant reduction in costs and emissions could probably only be achieved in the long term through the construction of a pipeline network. However, the construction of such CO₂ pipelines would require a legal basis at cantonal (if general legislations not already in place) and federal level. The high financing and interest costs of such a major project would be lowest if the public sector were able to bear them. However, the legal basis for this would first have to be created. Alternatively, warranties or guarantees from the federal



government would also be worth considering. The investment costs could possibly be reduced if a model were established under which various CO₂ emitters join together to form a network and exploit synergy effects in transport and storage.

The most expedient business model for managing and operating such a network appears to be a regulated business model with a central operating company. This would offer low financing costs, incentives for efficient operations and the flexibility to evolve with changes in the regulatory environment over time. There are currently no viable business models for CCT(U)S in Switzerland. Insufficient or unclear regulatory guidelines are currently hampering market development. This means climate finance mechanisms need to be developed for specific use cases. For operators of installations with high greenhouse gas emissions that participate in the Swiss emissions trading system, for example, the crediting of CCT(U)S measures would be an important factor in generating additional investment. This is provided for in the current revision of the CO₂ Act. The revised CO₂ Act and the Climate and Innovation Act (KIG) further provide for new funding from 1 January 2025 for climate protection projects including CCS and carbon removal.

With CCT(U)S, a positive climate footprint can already be achieved today, as the life-cycle assessments carried out show. Regardless of the methods chosen for transport and capture, the emissions produced are lower than the amount of CO₂ stored.

Acceptance

Future CCT(U)S projects must not only be financed and regulated, but also supported by politics and society. A representative survey conducted as part of DemoUpCARMA shows that the Swiss public currently knows little about CCT(U)S. This points to a great need for information, particularly with regard to the specifics of implementation. The perceived benefits and risks differ for the two CO₂ storage pathways examined, meaning they are highly context specific. People's level of acceptance is influenced by personal factors such as their general attitudes towards climate change or their political orientation. Initiatives that are driven by trustworthy actors attract greater support, with science in first place, followed by authorities and NGOs.

The results of a representative online experiment also indicate that people are more willing to bear the costs of CCT(U)S if long-term storage is guaranteed. Respondents consider it important for storage abroad to meet high safety standards and be accepted by the local population. In view of the upcoming challenges for the implementation of CCT(U)S initiatives, early involvement of various interest groups and a transparent information policy are important elements in establishing acceptance.

A stakeholder survey has further shown that critical voices might arise once CCT(U)S initiatives are actually implemented or when they are scaled up. This makes it important to involve various interest groups as early as possible. At the same time, the stakeholders directly involved have a high level of awareness of the problem and the need for action; this awareness was further heightened in the course of DemoUpCARMA.

Conclusions

DemoUpCARMA has shown that two pathways to permanent CO₂ storage are technically feasible and have a positive climate footprint. Compared to modelling alone, the pilot character of the project had the advantage of highlighting unexpected challenges as well as practicable solutions. In addition, DemoUpCARMA helped to create and communicate new knowledge about CCT(U)S and bring together relevant stakeholders, who are now jointly initiating follow-up projects. By focusing on scaling CCT(U)S initiatives, DemoUpCARMA was also able to identify a number of challenges:



- A framework has yet to be established for the sustainable and financially viable implementation of large-scale CCT(U)S initiatives.
- There is currently no reliable business model for CCT(U)S for Swiss CO₂ emitters.
- It is unclear whether and under what conditions the Swiss general public supports or rejects specific CCT(U)S initiatives.

Based on the project findings, the project team sees a particular need for action in the following areas:

- Improving planning certainty, particularly with regard to the regulatory framework.
- Creating financial incentive systems or funding measures to establish CCT(U)S initiatives.
- Appointing an entity to develop a pipeline system to pursue this option for transporting large quantities of CO₂.
- Conducting pilot studies with mobile capture units for the practical testing of various processes.
- Planning and building large-scale CO₂ capture units for major emission sources.
- Ongoing research and regular updating of life-cycle assessments and techno-economic analyses.
- Actively involving various interest groups and the general public in the assessment, planning and implementation of CCT(U)S initiatives.



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1 Overview and objectives of dissemination activities

We established and used various communication channels to effectively communicate the project's outputs to key target audiences, namely the Swiss public, administration, academia and industry. The most important communication channel was the project website. Furthermore, social media channels were used to distribute information about the project. We also focused on ensuring internal communication among project partners.

A communication concept (s. Appendix A) was developed to lay out target groups and communication goals. Key dissemination activities included public lectures, a continuously updated website, scientific publications, media engagement, and a closing event showcasing the project's results to a broad audience.

Given the sensitive nature of the project's subject matter, i.e., climate change, the communication strategy prioritized transparency. Updates and information were shared regularly to keep stakeholders informed. One key pillar of the communication strategy was to communicate facts and results and avoid rash communications of premature findings.

2 Communication channels

2.1 Internal communication

The information flow within the consortium was maintained via different measures. Firstly, most important information that had to be delivered timely were sent out by the project manager and coordinator via email. Secondly, summarizing updates of the different working groups were compiled in an internal newsletter. The newsletter was distributed three times throughout the course of the project. Lastly, three consortium meetings fostered knowledge exchange and encouraged scientific discussions within the consortium.

2.2 External communication - project website

As main communication channel, a project website (<https://demoupcarma.ethz.ch>) was created and it followed the guidelines of the corporate design developed for the project. The homepage features a short description of the project and the work package supplemented by an infographic depicting the two pathways the project explored. The website also became host of the partner project DemoUpStorage.

The target audiences of the project website were the general public, stakeholders from industry and academia. Besides general information about the project, news articles about milestones, e.g. the first shipping of the CO₂ to Iceland, results, and other insights were published. Additionally, a series of blog posts were published providing a deep dive into different areas and outcomes of the project.

The following statistics (Figure 1) show how many people visited the website. In 2022 an average of 300 unique visitors were recorded per month, in 2023 the number of unique visitors rose to 1'500 and in 2024 then declined to 650 (counted until August 2024). The number of unique visitors correlates well with the outreach activities of the project.



Website: Unique visitors

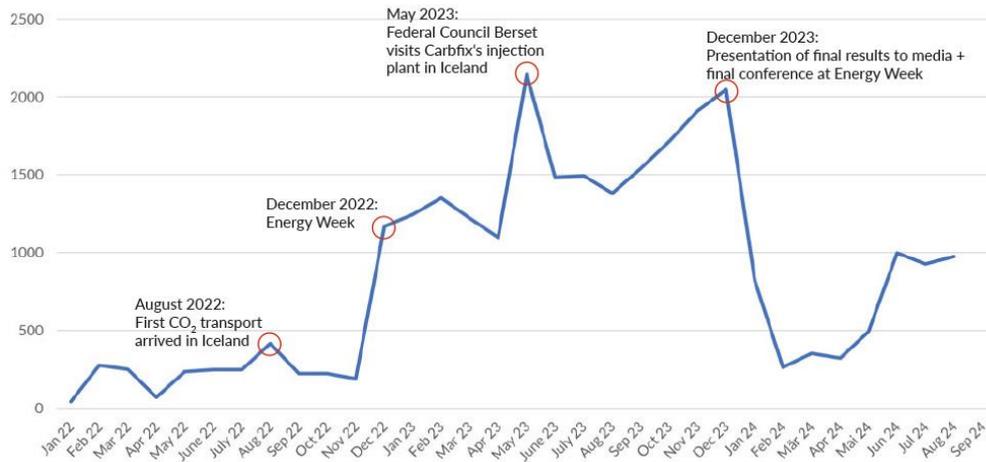


Figure 1: Statistics of website visitors (unique visitors)

2.3 External communication - social media

To reach a broader audience, two social media channels were established. An X account was started in March 2022. Since then, 88 posts were posted, and 91 Followers gained. X is a social media platform that is widely used by scientists and journalists to foster exchange. This was seen as an opportunity to make the project more visible among other scientists and journalists.

In September 2023, a LinkedIn account was created aiming at engaging more with professional stakeholders in the field of carbon removal. Since then, the account gained 487 followers.

2.4 External communication - closing event

On 6 December 2023, a closing event was held at ETH Zurich. The event was part of ETH's Energy Week, a week-long event series focusing on energy topics. The audience of the Energy Week is a mixture of industry representatives, scientists and students. Because of the mixed audience and the overlapping of Energy Week's target groups with the ones of DemoUpCARMA, this was a good opportunity to present the project and its findings to key internal (e.g. ETH students and scientists) and external stakeholders (e.g. industry representatives).

The DemoUpCARMA closing event constituted one of Energy Week's half-day events at ETH's Audi Max. The presentations at the event were structured in four sessions: pilot and demonstration activities, zoom-in: the science and technology, systemic aspects, and a panel discussion that concluded the event. Each session included a 10-minute question-and-answer session through which the audience had the possibility to pose questions using an online tool. The same concept was applied during the panel discussion. This helped to engage with the audience and to give the possibility to further explain or discuss certain aspects of the project. In total, 241 persons registered for the event from which around one third were people from ETH (students or staff).



3 Media reports

The work of media relations focused on the last part of the project as there were already more results coming from the different work packages. Interview and filming requests were assigned to and realized with the appropriate experts. Media interest increased with the Federal Council Berset's visit in Iceland in May 2023. The final media relations milestone was a media event held on 6 December 2023, on the same day of the closing event. It was attended by ten journalists representing the main media outlets of Switzerland.

This event resulted in the following number of reports published or aired in December:

- 16 articles (print, online)
- 1 radio report

In general, throughout the course of the project the following amount of media reports (s. Appendix B) were published or aired:

- 142 online articles
- 2 radio reports
- 2 TV reports

The recent bigger reportage was aired in SRF1 and RTS at the beginning of September 2024 focussing on the CO₂ transport from Switzerland to Iceland and the concept of CO₂ storage underground.

4 Conclusions

With the consortium consisting of industry and research representatives, communication faced the challenge of balancing different expectations: With the consortium consisting of industry and research representatives, communication faced the challenge of balancing different expectations: Industry representatives were eager to communicate publicly about the project and promote their initiative. However from a science communication point of view, communication activities were linked to the need to report on results and decisive steps in the project, a premise we followed. DemoUpCARMA was a pioneering activity in the field of international CO₂-transport for underground storage generating a high interest in the project and its outcomes. Transparent communication that objectively described the various results was central to the project. We are satisfied with the number and the tone of media reports featuring the project demonstrating the efficiency of the chosen communication strategy. We aimed for a constructive, fact-based discussion of the project and its achievements. The media reported accurately about the project and reflected the results in a balanced manner and therewith set the tone we aimed for. Further, internal communication efforts successfully supported the collaboration among project partners.



5 Appendix

Appendix A: Communication concept / Kommunikationskonzept (in German)

Appendix B: List of media reports; taken from Argus Data Insights