# DemoUpCARMA & DemoUpStorage – FAQ (English version)

## 1. What is net-zero and why is it important to achieve it by 2050?

Switzerland has committed itself to meet the internationally agreed goal of limiting global climate warming well below 2° C, preferably to 1.5° C, compared to pre-industrial levels, as defined in the Paris Agreement. To reach this goal and, consequently, limit the effects of climate change is of high importance for Switzerland. Global warming is caused by the emission of greenhouse gases, with carbon dioxide ($CO_2$) accounting for the largest share. To achieve the global temperature goal, emissions need to reach net-zero by 2050. Net-zero means reducing greenhouse gas emissions as close to zero as possible and offsetting those $CO_2$ emissions which are hard to abate (s. Q 5).

## 2. What is the difference between fossil, biogenic and atmospheric $CO_2$?

Atmospheric $CO_2$ is the $CO_2$ that has been released into the atmosphere and therefore causes the increase in global temperature. Atmospheric $CO_2$ can be of different origin. In the context of net-zero, there is fossil and biogenic $CO_2$.

Fossil $CO_2$ is emitted from the combustion of fossil resources, such as coal, oil, or gas. The fossil $CO_2$ has been stored underground for millions of years. By burning fossil fuels, this large amount of stored $CO_2$ is released back into the atmosphere. Additionally, also other industrial and chemical plants such as the production of cement emit fossil $CO_2$.

Biogenic $CO_2$ is $CO_2$ released by combustion or decomposition of organic material (biomass such as compost, burned wood, or residual sludge) that took up the $CO_2$ from the atmosphere via photosynthesis.

## 3. What is the difference between CCS, CCUS, and CCTS?

**CCS** stands for **Carbon dioxide Capture and Storage**. CCS refers to the capture of $CO_2$ from point-emission sources, such as waste-to-energy, chemical, or cement plants, and permanent storage in underground geological formations or in building materials (e.g. concrete). The source of the $CO_2$ captured thereby can be of fossil or biogenic origin (s. Q 2).

In DemoUpCARMA, we focus on and distinguish two specific CCS approaches, which are referred to as **CCUS (Carbon dioxide Capture, Utilisation and Storage)** and **CCTS (Carbon dioxide Capture, Transport and Storage)**. In these two acronyms, the letters "U" and "T" are added to emphasize the "utilization" and "transport" components of these two approaches.

CCUS involves three steps: (i) $CO_2$ capture from point-emission sources, (ii) utilization of $CO_2$ as a feedstock to produce a range of products, such as concrete, methanol, ethanol, carbonates, plastics etc. DemoUpCARMA investigates a CCUS pathway that optimizes permanent $CO_2$ storage in building materials, i.e., recycling concrete. In DemoUpCARMA, a CCUS pilot is investigated and demonstrated, in which biogenic $CO_2$ captured at a biogas plant is utilised and stored in concrete that is then used as a building material.

Similarly, CCTS involves three steps: (i) $CO_2$ capture from point-emission sources, (ii) transportation of $CO_2$ by truck, train, ship/barge, or pipeline, and (iii) permanent $CO_2$ storage in a geological reservoir. In DemoUpCARMA, a CCTS pilot is investigated and demonstrated, in which biogenic $CO_2$ captured at a biogas plant is transported from Switzerland to Iceland, where it is dissolved in seawater and stored underground in a basalt formation.

If CCUS or CCTS approaches are based on fossil $CO_2$ (e.g., $CO_2$ captured from a chemical plant), they result in $CO_2$ emissions being avoided. On the contrary, if CCUS or CCTS approaches are based on biogenic $CO_2$ (e.g., $CO_2$ captured from a biogas plant), negative emissions are generated ($CO_2$ removal). In the latter case, the CCUS or CCTS application would be categorized as a negative emission technology (NET; for details, see Q4). This also applies to the two DemoUpCARMA pilots outlined above.

## 4. What are NETs?

**NETs** stand for **negative emission technologies**. NETs encompass all manmade solutions that permanently remove $CO_2$ from the atmosphere, including landscape management solutions such as soil carbon management and reforestation. This process is also called carbon dioxide removal (CDR). The solutions that are predominantly discussed, developed, and implemented are biochar, soil carbon sequestration, afforestation and reforestation, bioenergy with carbon capture, permanent $CO_2$ storage (BECCS), and direct air capture and permanent $CO_2$ storage (DACCS). When biogenic $CO_2$ is permanently removed from the atmosphere via NET, negative emissions are generated.

More information can be found here: https://www.carbon-removal.ch/cdr-methods/ or here: https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/co2-capture-removal-storage.html .

## 5. Why are CCS and NETs needed for Switzerland?

According to Switzerland's long-term climate strategy, remaining, hard to abate greenhouse gas emissions from industry, waste management, and agriculture will amount to around 12 million tonnes of $CO_2$ equivalents. These can be offset by either CCS or NETs. Around 5 million tons of these $CO_2$ emissions shall by reduced from large point-emission industrial sources by CCS efforts. The remaining 7 million tons per year shall be offset via NETs such as bioenergy with $CO_2$ capture and permanent storage (BECCS) and direct air capture and permanent $CO_2$ storage (DACCS).

## 6. Where does the $CO_2$ captured in DemoUpCARMA come from?

For both pilots (see Q3), the biogenic $CO_2$ will be captured at the wastewater treatment plant ARA Bern, where biogas is generated and upgraded to bio-methane. The $CO_2$ is thereby separated and released in the atmosphere. By capturing and storing this $CO_2$ as in DemoUpCARMA, negative emissions are generated.


## 7. How safe is it to store captured $CO_2$ in concrete?

Carbon dioxide is mineralized in concrete. Thereby, the $CO_2$ binds with the concrete aggregate and is in consequence stored in solid form. This is regarded as a safe storage technique.

### 8. What happens with the $CO_2$ stored in concrete when a building is demolished?

The average lifetime of modern Swiss buildings is about 70 to 100 years depending on their usage. In general, carbonated concrete can be recycled and put into use again. In any case, once the $CO_2$ is mineralized in concrete, it remains there indefinitely also when the building is dismantled.

### 9. In which conditions is $CO_2$ captured and transported in DemoUpCARMA?

The biogas at the waste-water treatment plant ARA Bern consists of a gas mixture of methane (60%) and $CO_2$ (40 vol%), which must be separated to obtain high purity methane, so-called bio-methane. After being captured, $CO_2$ is conditioned to a liquid state. The liquid $CO_2$ is then loaded into dedicated ISO tank containers (or ISOtainers, see Q10) and transported to the storage site at conditions of -35°C and maximum 22 bar.

### 10. How is the $CO_2$ transported to Iceland in the CCTS pilot?

After capturing $CO_2$ at the waste-water treatment plant ARA Bern, the $CO_2$ is liquefied and loaded onto portable vacuum-insulated ISOtainers, which can keep the $CO_2$ in a liquid state until the delivery point (i.e., storage site). The ISOtainers are transported via truck from the capture site to the train station in Weil am Rhein (ca. 100 km). From there, the ISOtainers are transported first via rail to Rotterdam (ca. 800 km) and then via ship to Reykjavik (ca. 2200 km). Once delivered in Reykjavik, the ISOtainers are transferred to the injection site via truck.

An ISO tank container or ISOtainer is designed for transporting non-hazardous and hazardous liquids worldwide via truck, ship, or rail in a safe way. The abbreviation ISO stands for "International Organization for Standardization".


### 11. How is the $CO_2$ stored underground in the DemoUpCARMA/DemoUpStorage CCTS pilot?

For the DemoUpCARMA pilot, the captured $CO_2$ is dissolved in seawater and injected into basalts (a reactive rock formation) for permanent mineral storage. DemoUpStorage monitors both the response of the Icelandic underground to the injection of $CO_2$ dissolved in seawater, and the mineralization process.

This storage method has already been implemented using fresh water: once injected, the carbonated water reacts with the rock formation underground, releasing calcium, magnesium, and iron into the water stream. Over time, these elements combine with the dissolved $CO_2$ to form stable carbonates.

This differs from other methods of $CO_2$ storage that inject $CO_2$ into subsurface reservoirs, such as sedimentary basins, where $CO_2$ is physically trapped in porous rocks below an impermeable cap rock.

### 12. Why is the $CO_2$ stored in Iceland instead of Switzerland for the CCTS pilot?

The potential for storing $CO_2$ in geological storage formations has been investigated within the SCCER-SoE project (Swiss Competence Center for Energy Research – Supply of Electricity) as well as the international research project ELEGANCY. The research in these projects showed that the first estimates of the geological storage potential in Switzerland is limited. In addition, developing storage project in Switzerland will take several years. Consequently, exploring alternative storage options abroad are important.

Iceland has both, favourable geological characteristics (basalt formations) as well as the know-how and experience to store $CO_2$ underground. In DemoUpCARMA, Carbfix will implement and operate the $CO_2$ injection system. The Icelandic company has been pioneering $CO_2$ storage in basalts since 2012 and has demonstrated that $CO_2$ can mineralize within a few years after injection by turning into stone. DemoUpCARMA together with its partner projects DemoUpStorage and CO2SeaStone aim at demonstrating the feasibility of injecting $CO_2$ dissolved in seawater for permanent mineral storage. Using seawater instead of fresh water is expected to decrease the environmental impact of the storage technology, specifically its water footprint, and to allow its implementation offshore, thus unlocking a larger storage capacity worldwide.

DemoUpCARMA also assesses the ecological footprint of this option, see Q16.

### 13. Is it safe to store $CO_2$ underground?

The risks related to underground storage of $CO_2$ depend on the selected geological formation and the chosen procedure. So far, commercial scale $CO_2$ storage has targeted deep saline aquifers or depleted oil and gas reservoirs. Currently, there are about 30 operation projects worldwide that store $CO_2$ in such formations, with about 100 additional projects being planned. These successful projects demonstrate that a properly designed and operated underground $CO_2$ storage is safe, but every project must be accompanied by a detailed and project-specific risk assessment. Two of the risks that need to be carefully evaluated in aquifer storage projects are the risk of leakage through geological formation or existing boreholes, and the risk of induced seismicity (see Q14) and/or surface deformation.

In DemoUpCARMA and in its partner projects DemoUpStorage and CO2SeaStone, a host formation of basaltic rocks at depth of 300 – 500 m is used for storage. This technology promoted by Carbfix differs from the above described approaches and potentially offers several advantages with respect to safety.

- The $CO_2$ is dissolved in seawater and injected at low pressures into highly permeable and already fluid saturated formations. Because of the shallow depth, and because the injection does not require substantial overpressures, the risk of induced seismicity is low.
- The risk of leakage is also lower compared to the injection as a supercritical fluid (the current practice in running projects), because the $CO_2$ is dissolved in water.
- Finally, mineralisation processes of $CO_2$ dissolved in water and injected into basalts have been shown in laboratory experiments to be much faster when compared to injection into deep saline aquifers in sedimentary layers. In basalts, $CO_2$ will mineralize into carbonates and hence be permanently immobilized within a few years, a process that takes hundreds to thousands of years in other storage options.

One of the key objectives of DemoUpStorage is to observe in-situ the fluid propagation and mineralisation processes with geophysical and geochemical monitoring techniques. This will provide important and independent input for risk and safety assessments, monitoring strategies, and up-scaling of future sequestration projects.

### 14. What is the seismic risk of the underground reservoir in Iceland?

Induced seismicity has been observed as a consequence of oil and gas production, geothermal projects, mining related activities, or hydro-dams. Induced seismicity related to CO2 storage poses a risk in itself (the actual shaking), but an earthquake can potentially also create leakage pathways and also can negatively influence public acceptance of CCS projects, especially onshore ones.

There are only few reported cases of minor induced seismicity related to $CO_2$ storage in saline aquifers or depleted reservoirs so far, and none related to storage in basalts. In Iceland, the risk of induced earthquakes when injecting $CO_2$ dissolved in seawater is very low, because of the shallow depth of injection and because the overpressures are low. Nevertheless, the SED is installing a network of seismic sensors near the injection site capable of observing micro-earthquakes down to about magnitude 0.5.

### 15. Who is monitoring the injection of the CCTS pilot's $CO_2$ in Iceland?

As responsible for the injection site, Carbfix and DemoUpStorage partner EAWAG will perform in chemical and $CO_2$ flux monitoring using dedicated wells to determine the post-injection $CO_2$ mineralisation efficiency. In addition, in the framework of DemoUpStorage, the Swiss Seismological Service at ETH Zurich will install a seismic monitoring network (see question 14) to monitor seismicity. DemoUpStorage will also conduct geophysical measurements between the boreholes, with the objective to track the migration and potentially the mineralisation of the $CO_2$ injected.

### 16. What is the total carbon footprint of the two pilots?

To assess the environmental impacts as well as the actual and final carbon footprint of both pilots, a Life Cycle Assessment will be conducted. Thus, the entire chain will be assessed from capturing, transporting, and using or storing the $CO_2$. This for example includes the energy needed to transport and store the $CO_2$ underground.