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From offshore to onshore: Europe expands carbon storage with nature-inspired tech

Drawing on nature, researchers have developed a method to pump CO2 captured from industrial processes into volcanic rocks for safe and permanent underground storage.

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For the first time, Europe will bury its carbon not beneath the sea, but under its own soil, heralding a new chapter in the continent's fight against climate change.

On 30 April 2025, the EU issued its first permit for onshore geological storage of CO2. Until now, all EU permits under the 2009 Directive for geological CO2 storage were offshore.

The permit was awarded to Carbfix, an Icelandic company based in Reykjavík, for its injection site at the Hellisheiði geothermal power plant.

The company has grown alongside an EU-funded research initiative of the same name, which received worldwide recognition for developing a novel, safe and efficient carbon storage method. The process turns injected CO2 into stable carbonate rock within just two years.

From carbonated water to carbonated rock

While most carbon projects focus on offshore storage, CarbFix2's terrestrial approach marks a vital shift: it speeds up natural mineralisation processes within basalt, a volcanic rock formed from cooling lava.

At Hellisheiði, CO2 is captured from the geothermal plant and two direct air capture units. The CO2 gas is dissolved in water – much like making a fizzy drink – and pumped deep into porous layers of basalt, where minerals in the rock react with the CO2 and turn it into solid carbonate rock.

"This is a major milestone and an important step toward having a real, positive impact on climate change," said Carbfix CEO Edda Sif Pind Aradóttir, who coordinated CarbFix2 – the second leg of the EU-funded research.

Aradóttir said the new permit puts the Hellisheiði plant, run by Carbfix's sister company ON Power, "at the forefront of the global geothermal sector" and gives Iceland a leading role in building an industry that supports both EU and global climate goals.

To date, Carbfix has stored over 100 000 tonnes of CO2. Thanks to the new permit, it can now store the same volume annually, with a long-term goal of locking away up to 3.2 million tonnes over 30 years – fully offsetting the plant's emissions and capturing carbon from other projects operating at the site.

From research to reality

CarbFix began in 2007 as a partnership between industry and academia, focused on CO2 mineralisation. It became an EU-funded research initiative from 2011 to 2014. Field trials began at Hellisheiði in 2012, and by 2014, researchers had confirmed that CO2 was being successfully mineralised and had started storing the plant's emissions.

A second phase of the research, CarbFix2 (2017 to 2021), further advanced the technology with the help of research partners in France, Spain and Switzerland.

Bergur Sigfússon, CarbFix's chief of systems and a founding team member, outlined the three main research objectives: optimise the technology for capturing CO2 from industrial processes, integrate this with a means of storage, and explore the use of seawater in the storage process.

"Our overall concept is to use the same method nature uses to regulate long-term CO2 concentrations in the atmosphere," he said.

Mimicking nature

In the natural cycle, atmospheric CO2 dissolves in rainwater, which then seeps into the ground. The CO2 makes the water acidic, allowing it to dissolve rocks. In basalt formations, this releases minerals that react with the CO2 to form calcium carbonate – locking the carbon away.

Carbfix mimics this process by injecting CO2-enriched water into basalt layers located around 300 to 1 000 metres below ground.

"We speed the process up," said Sigfússon. "By loading more CO2 into the water, we make it more acidic so it dissolves the rocks faster." The water can contain several times more CO2 than a standard soft drink.

Secure and scalable solution

Unlike conventional methods that involve pumping CO2 gas into deep rock formations, like depleted oil wells, Carbfix's approach dissolves the CO2 first, reducing the risk of leaks and locking it into solid rock permanently.

Although underground storage may be more common, Carbfix offers an important alternative. Geological conditions vary worldwide, points out Sigfússon, so multiple storage options are needed to meet global climate goals.

Reducing emissions is clearly the priority, but Sigfússon is pragmatic.

"There are some emissions from heavy industries that we cannot reduce," he acknowledged.

That is why Carbfix has expanded its reach beyond geothermal plants to include hard-to-abate industries like cement manufacturing, steel production and chemical plants.

It currently operates five injection sites around the world and also collaborates with the Swiss company Climeworks, a world leader in direct air capture. Together, they became the first team to store CO2 from direct air capture underground.

Big potential

According to Sigfússon, who describes himself as a geologist by training, basalt is abundant, covering nearly all of the ocean floor and about up to 5% of land areas.

“It’s not everywhere,” he said, “but it’s widespread enough for our technology to have a global impact.”

Iceland alone could, in theory, store all of the world’s annual CO2 emissions, while Japan’s extensive volcanic rock formations could absorb 40 to 400 gigatonnes – enough to cover decades of its own output. Of course, practical and economic constraints mean that only a fraction of this capacity could ever be used.

In 2022, Japan’s Minister of Economy, Trade and Industry, Yasutoshi Nishimura, visited Carbfix’s facilities in Iceland, and while no joint projects have yet been announced, both sides recognise the huge potential.

Carbfix will feature at the World Expo in Osaka, Japan, in September, where its technology takes centre stage at the Nordic Pavilion, highlighting Iceland’s leading role in climate action.

Seawater injections

Currently, Carbfix stores around 90 000 tonnes of CO2 underground every year, but they are working on scaling up and exploiting some of Iceland’s vast capacity.

Their next major project is the development of a hub in southwest Iceland known as the Coda Terminal, which will store CO2 captured and shipped from industrial sites in Northern Europe. Starting in 2029, the terminal aims to store 700 000 tonnes of CO2 per year, ramping up to 3 million tonnes annually by 2032.

The Carbfix team’s latest research is focused on using seawater – instead of freshwater – to inject CO2 into rocks below the seabed, a technique first tested during CarbFix2.

“There’s an obvious appeal,” said Sigfússon. “There’s a ridiculous amount of seawater near all this basalt.” But the salts and minerals in seawater pose technical challenges that still need solving.

As this Icelandic experiment gains momentum, it could offer a global blueprint – turning CO2 into stone beneath our feet – and helping the world tackle climate change on a truly global scale.

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Showcasing EU research at the World Expo

Osaka, Japan

13 April – 13 October

This summer, millions of people from around the world will head to Osaka, Japan, for **Expo 2025**. At this global gathering, countries and regions will share how they’re tackling some of today’s biggest challenges, from sustainability and digital connectivity to inclusivity and security.

The central theme of this year's event is **Designing Future Society for Our Lives**. Visitors will get a chance to see how **EU-funded research** is helping shape that future. The EU's **Nurturing Tomorrow** pavilion reflects Europe's commitment to building a greener, more connected and inclusive world.

The EU pavilion is hosting exhibitions, talks and interactive experiences that spotlight **cutting-edge EU research and innovation projects** – all aimed at solving real-world problems and building international cooperation. Whether you're curious about the future of clean energy, digital tech, or inclusive design, there's something for everyone.

Carbfix will feature in the Nordic Pavilion's event **From Iceland to the World** on 15 September, with live demonstrations and interactive panels showcasing the project's innovative mineralisation technology.

Virtual visit

Can't go to Osaka? Explore the Expo online at: https://www.expo2025.or.jp/en/future-index/virtual/virtual-site/

More info

- CarbFix2
- CarbFix2 project website
- Carbon removals and carbon farming
- Climate change mitigation
- Carbon Removals and Carbon Farming (CRCF) Regulation
- Research and Innovation for Climate Neutrality by 2050: Challenges, opportunities and the path forward