Back to Earth – Using Natural Processes to Turn CO2 Permanently Into Rock

Context and rationale

Reducing man-made CO_2 emissions is one of the main challenges of this century. By capturing CO_2 from variable sources and injecting it into suitable rock formations, carbon can be permanently removed from the atmosphere through natural and environmentally benign processes.

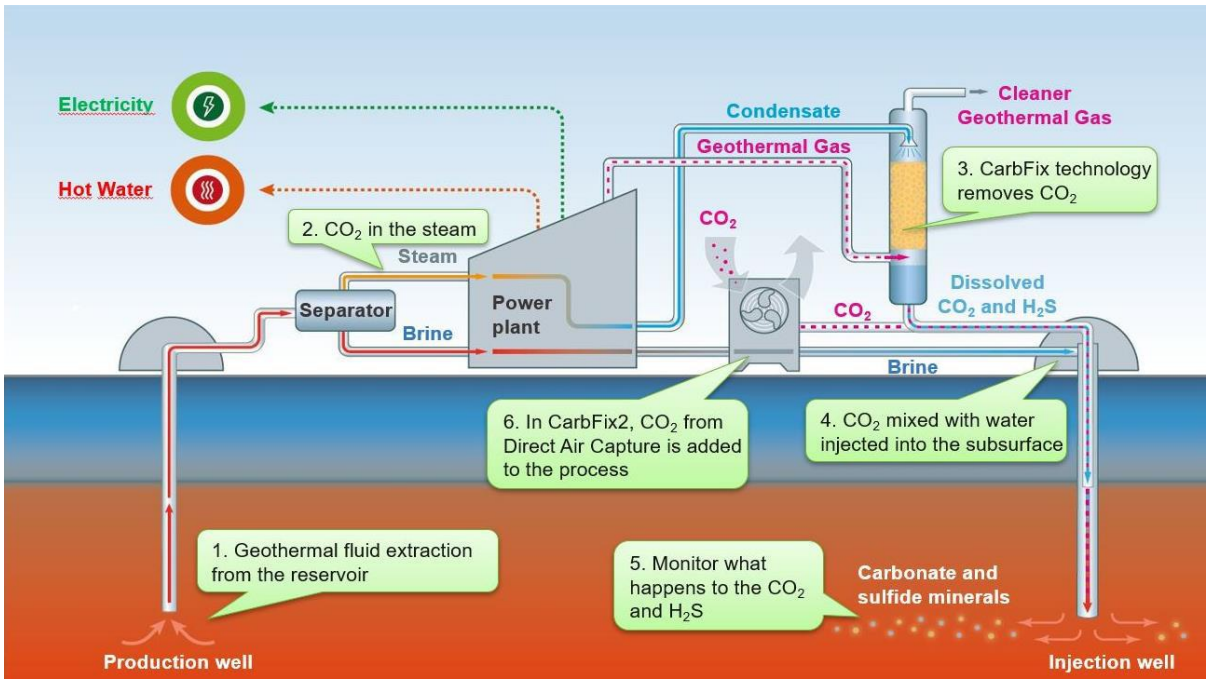
Awareness of the potential of this nature-based solution has mostly been confined to scientific circles but pilot testing and demonstration projects are starting to emerge. The rationale of this contribution is to accelerate the research and demonstration of this solution as well as its deployment at scale. This coalition will leverage the experience gained in Iceland through the CarbFix project and of other similar endeavors.

The CarbFix process is designed to optimize industrial methods for storing CO_2 in favorable rock formations through;

- capture of CO_2 from emission points or from the atmosphere,
- injection of CO_2 charged waters into geological formations that efficiently turn CO_2 into rock through natural processes,

A second goal of CarbFix is to generate the human capital and expertise to apply the advances made in this project in the future.

Global capacities for applying CarbFix and other CCS methods to mitigate climate change by capturing and injecting otherwise emitted CO_2 from e.g. power plants, heavy industry or ambient air, are large as storage capacities in favorable rock formations more than suffice to store all carbon available on Earth.



An overview of the contribution

The CarbFix collaborative research project, led by Reykjavik Energy, centers around one of the world's largest geothermal power plants in Hellisheidi, Iceland. Industrial scale application of the CarbFix process has been ongoing at the power plant since 2014 with 66,000 tons of sour gases captured and

injected at the end of 2018, 2/3rd of which were CO_2 and 1/3rd H_2S. This accounts for over 40% reduction in emissions from the geothermal power plant. The fact that the CarbFix CCS process allows for co-capturing and mineralizing other environmentally important gases like sulfur, provides significant added value to the method.

Over 95% of the CO_2 captured and injected has been demonstrated to be turned into rock in the subsurface in less than two years. This contrasts the previous common view that mineral storage in CCS projects takes hundreds to thousands of years and allows for increased safety and permanency of this storage method.

The cost of industrial scale application of the CarbFix method at Hellisheidi power plant is less than $25/ton. That is significantly lower than most other reported cost figures for CCS, and currently on par with the price of carbon quota on the ETS market. Furthermore, the process has been demonstrated to be a secure and environmentally benign method to reduce atmospheric CO_2 levels that can be applied world-wide.

The most recent advances within CarbFix result from Reykjavik Energy's partnering with the Swiss company Climeworks and involve combining for the first-time direct air capture (DAC) technology with permanent geological storage of CO_2.This type of conjugate application of carbon dioxide removal (CDR) and permanent storage has been recognized as a crucial component in efforts to achieve global climate goals. The resulting world's first negative emission plant, currently being operated at the CarbFix site at Hellisheidi, was awarded the National Energy Globe Award in 2019 for the world's first global negative emission plant.

Further developments underway in CarbFix include preparing for offshore carbon mineralization and mineralization of CO_2 in various reactive rock-formations.

Complementing living natural systems to avert climate change?

While this contribution does not leverage living natural systems, it complements them beautifully as it uses natural processes integral to the carbon cycle. The contribution demonstrates that CO_2 can be economically removed from the atmosphere and stored in favorable rock formations, making use of geology, chemistry and hydrology. Such formations are found in abundance on Earth both on land and within the ocean floor with a combined storage capacity orders of magnitudes larger than needed to store all CO_2 that would be emitted if all fossil fuel on Earth would be burnt.

Contribution's support to positive outcomes in coming years

CarbFix demonstrates how interdisciplinary collaboration between the green energy industry, academia, engineers and technicians allows for a fast and efficient development of the idea of battling climate change by permanently mineralizing otherwise emitted CO_2 in subsurface rock formation into an economic industrial scale process useful to the global economy. This promising idea to mitigate climate change was developed into an efficient, automatic process implemented at industrial scale in less than 10 years.

Cost of the overall CCS chain being carried out at Hellisheidi power plant has been demonstrated to be between one-half to one-quarter compared to conventional CCS methods. This, along with the fact that captured and injected CO_2 is being permanently mineralized and removed from the atmosphere, could make CarbFix important to the global economy. The degree to which this technology is embraced, however, will depend on the passing of national legislations providing enough incentive or obligations for such a solution to be applied at a large or even global scale.

Potential partners

The CarbFix Project was initiated in 2006 and formalized by four founding partners in 2007, namely Reykjavík Energy, the University of Iceland, CNRS in Toulouse, France, and the Earth Institute at Columbia University, New York, USA. Since then, several universities and research institutes have participated in the project under the scope of EU funded sub-projects, including Amphos 21 from Barcelona, Spain, the Swiss company Climeworks and the University of Copenhagen, Denmark.

As this effort moves to demonstration and deployment states, potential partner countries include other Nordic Countries, in particular Norway, as well as Switzerland.

This prove-of-concept effort started in to context of a point source of concentrated CO_2 from a geothermal power plant. The approach is equally suited to storage of CO_2 from other emission sources such as aluminum production. Initial feasibility studies are under consideration and interested industrial corporations would be encouraged to join the coalition.

Stakeholders involvement

The CarbFix team has strived to maintain active and positive communications with stakeholders and the general public from the very beginning. As a result, public acceptance of the project and its activities has been high throughout its lifetime.

Where can the contribution be put into action?

The contribution can be put into action on a global scale where favorable rock formations are found in vicinity of a source of water (including sea-water and waste water). Capture of CO_2 can either be from point sources such as power plants or heavy industry or directly from ambient air through Direct Air Capture (DAC) technologies.

Transformational impact

The Government of Iceland is stepping forward to facilitate cooperative action to accelerate the deployment of this nature-based solution. High-level political support was needed at the inception of the project. The same will be needed to bring world-wide deployment to scale.

This will take partnership between Governments, corporations, finance, academia and civil society organizations in the spirit of similar initiatives such as Mission Innovation announced at the Paris Conference in 2015.

The transformative impact relates to the fact that this solution can be deployed at rather small scale, is economical and has huge technical potential. It is also likely to enjoy more favorable reception from environmental NGOs that traditional CCS approaches associated with the fossil fuel economy.

Contribution to other workstreams

This contribution cuts across five workstreams namely nature-based solutions, industry transition, energy transition, carbon pricing, and mitigation strategy. It uses natural processes to reduce the carbon footprint of energy supply and industrial processes. Its economic feasibility is dependent on appropriate price on carbon and can be an important enabling technology as a part of a portfolio of mitigation strategies.

Building on experience and ongoing initiatives

Over the course of less than 10 years, CarbFix transformed from being an idea to being further designed and implemented in laboratories and numerical models to being tested in pilot scale at a favorable field site. Through an innovative monitoring program, the CarbFix team proved that the method successfully turns injected CO_2 into rock minerals in less than two years. As the minerals that form are stable over geological time scales the method provides an excellent way to permanently remove CO_2 from the atmosphere.

Notably, the reactions that mineralize injected CO_2 are already occurring in nature, the CarbFix process simply allows for a way to imitate and accelerate these already ongoing natural processes.

Following successful pilot scale operations and demonstrations, the method was further transformed to be applied at an industrial scale at Hellisheidi power plant in SW-Iceland. Via a step-wise scale-up of activities, the CarbFix CCS process currently captures and mineralizes about 1/3rd of the emissions of the power plant. Plans call for further reductions of emissions.

Funding

Reykjavik Energy has been the biggest contributor to funding CarbFix, particularly with respect to building up capture and injection infrastructure at site. Grants from competitive funds such as the EU's FP7 and H2020 research programmes have funded a large part of the R&D activities within the consortium, allowing for a successful and continuous active collaboration between academia and industry.

CarbFix has maintained an open communication strategy from its inception. All methods, strategies, technologies, results achieved etc. have been published in peer-reviewed journals. Media visits are common at the CarbFix site and the team strives to educate the young generation, the general public, the power sector and industries as well as politicians about the relevancy of the method in the fight against climate change.