

Research and development projects on climate and environmental issues

Reykjavik Energy (OR) has been at the forefront of innovation and development on climate and environmental issues over the past decade.

Examples of projects developed in cooperation with the academia and business sector 2022:

- **Near-zero geothermal utilisation.** In 2018, OR and its partners received more than ISK 2 billion in funding from the Horizon 2020 EU Research and Innovation Program. The grant is for the GECO (Geothermal Energy and Climate Outlook) project, which is largely based on the Carbfix re-injection method. With the GECO project, the Carbfix method will be further developed into four types of bedrock to test whether it works as well there as has been shown in Icelandic basalt. The project includes preparations for the experimental capture and disposal of carbon dioxide and hydrogen sulphide at the Nesjavellir geothermal power plant scheduled in spring 2023. Furthermore, the experimental operation of the 2nd step of carbon dioxide purification at the Hellisheidi geothermal power plant is in preparation to support its utilization in ON Power's geothermal garden. See more below.
- **95% clean Hellisheidi geothermal power plant.** OR aims for carbon neutrality by 2030. If this is to become a reality, almost all carbon dioxide in the production cycle of ON Power plants will have to be removed. The main purpose of the first phases of the capture and storage plant at the Hellisheidi power plant was to reduce the emission of hydrogen sulphide, but at the same time it was possible to reduce the emission of carbon dioxide from the power plant. The results of analyses, which are based on the operation of the capture and storage plant from 2014, show that the same technology can be used to further reduce carbon dioxide emissions from the power plant or up to 95%, store it permanently in rock and / or utilize it in value creation. Furthermore, it will be possible to remove almost all hydrogen sulphide and store it permanently in rock. In 2021, a grant of ISK 600 million was received for the Silferstone project (i.e., to build an air purification plant), from the Innovation Fund, a development fund under the auspices of the European Union. Subsequently, design of a pilot plant has started at the Nesjavellir geothermal power plant, which also assumes a 95% injection of carbon dioxide.
- **Direct air capture plant at Hellisheidi.** Carbfix and ON Power have partnered with the Swiss company Climeworks, which specializes in capturing carbon dioxide from the atmosphere. This is a large-scale project based on experience from a pilot project on the integration of carbon dioxide capture from the atmosphere and its binding in rock that has been going on at the Hellisheidi Geothermal Power Plant since 2017. That project was part of the Carbfix2 project funded by the H2020 research and the European Union's Innovation Program. In 2021, the first direct air capture plant of its kind in the world (Orca) was commissioned in ON Power's Geothermal Park. In 2022, construction began on the air capture plant Mammoth in Hellisheidi, in collaboration with Carbfix and ON Power, which will tenfold the current capacity of capturing and disposing of carbon dioxide from the atmosphere in the area. The new station is expected to be commissioned in 2023. The ongoing development and expansion of the project will weigh on the scales of keeping global warming within the bounds of the Paris Agreement.
- **Experiments to sequester CO₂ in the bedrock with sea water in Helguvík.** Carbfix started drilling in Helguvík in 2022, and the borehole will be used for experiments using seawater to sequester CO₂ in the bedrock. The project is called CO₂SeaStone and is a joint project between Carbfix and ETH Zurich, the University of Iceland, Iceland GeoSurvey, the universities of Geneva and Lausanne and University College in London. The project is part of a larger development

project, DemoUpCARMA, led by ETH Zurich, which aims to test and develop several different technological solutions to capture, use, transport and dispose of CO₂ from Switzerland, either to achieve negative emissions or to reduce them by capturing it from industry that is in trouble reducing its emissions. Among the solutions that DemoUpCARMA is considering is capturing CO₂ from industry, transporting it to Rotterdam and from there by ship to Iceland, where it will be dissolved in seawater for injection and mineral fixation using the Carbfix method. The first containers from Switzerland have arrived in Iceland for injection at Hellisheiði, but it is expected that Carbfix will dispose of 1,000 tons in this trial phase, which will last one year. The project is funded by Eurostars, Rannís, and the energy and environment offices of the Swiss government. Reykjanesbær Municipality is participating in the project by providing Carbfix facilities in Helguvík. Samskip also supports the project by transporting CO₂ in containers from Rotterdam to Iceland.

- **Coda Terminal in Straumsvík, Iceland.** In 2022, Carbfix received a grant of 16 billion from the European Union's Innovation Fund for the development of the reception and disposal hub Coda Terminal in Straumsvík. The hub will be the first of its kind in the world. Drilling began in the area in 2022, and operations are scheduled to begin there in mid-2026 and reach full capacity in 2031. An environmental impact assessment for the project began in 2022. In connection with this, a memorandum of understanding was signed in December 2022 on the development of the Coda Terminal between Carbfix, Coda Terminal, Hafnarfjörður Municipality and Rio Tinto in Iceland.
- **Hydrogen production at Hellisheiði.** ON Power produces hydrogen at the Hellisheiði geothermal power plant for experimental purposes, which started as part of a development project run by the European Union, Hydrogen Mobility Europe. Energy production in the power plant is used for hydrogen production at times when there is less demand for electricity, and the hydrogen is used for the public and the economy due to energy shift in transport. Hydrogen production was commenced at the end of 2020 and is still the only hydrogen producer in Iceland. Hydrogen can be used alone to power vehicles or mixed with carbon dioxide for methanol or related production. Shell has distributed the hydrogen. There are great possibilities in hydrogen as an energy source e.g., for heavy vehicles, work machines, ships and aircrafts and energy related matters in Iceland.
- **Energy shift in transport in Iceland.** The "Improved Charging" (IS: Hlöðum betur) project is part of a larger European research project, SPARCS, in which Reykjavik Energy together with ON Power, Veitur Utilities and the City of Reykjavik are participating. It is funded by the European Union's innovation fund, Horizon 2020. The "Improved Charging" project is partially financed by the grant. The research in Iceland will give good insight into how electric car owners charge and use their cars and provide important information for load management on a large scale.

"Improved Charging" will test different load management methods with EV owners over a two-year period, but the methods can be divided into two main categories. On the one hand, there are methods based on changes in the price list, and on the other hand, methods based on direct control of charging power. Please see more: <https://www.or.is/um-or/nyskopunfraedsla/hlodum-betur>

- **Deep drilling** is a project that involves drilling deeper into geothermal systems in high-temperature fields - i.e., into their roots. The aim is to develop methods to extract the heat energy from these deep hot strata and thus expand the workable geothermal system downwards. Technical challenges still need to be addressed to make this possible. ER and ON Power participate in several grant projects under the auspices of the European Union (GeoPRO, HotCase, GeConnect) and the Geothermica Fund (HEATSTORE, DEEPEN), which aims to meet these challenges. It is planned that the third deep drilling well in Iceland, IDDP-3, will be drilled in

the Hengill area in the next five years in collaboration with other energy companies, and preparations for this project have begun.

- **Management of induced seismic activity.** The COSEISMIQ project aims to understand what affects induced seismic activity and how it can be controlled. The project is funded by the Geothermica Fund. An extensive measuring network is operated around Hengill and ON Power meters in the area are a good addition. So-called reserve models are used to simulate how temperature, pressure and pressure change with processing and injection and predict how it affects seismic activity. The aim is to develop a tool that can help predict seismic activity due to planned processing and injection, so that it can be dealt with before it occurs.
- **Improved resource utilization in low-temperature areas for the future.** The RESULT project, funded by the Geothermal Fund, will look at improved resource utilization in geothermal areas in urban areas. In Iceland, the focus will be on the Elliðaár area, which has long been used for hot water production, and attention will be paid to how the utilization has affected the area. Furthermore, proposals will be made on how best to utilize the area for the future in a sustainable way.
- **Experimental Study of Mixing Groundwater with Geothermal Water, Towards Full Integration of Reykjavík's Two District Heating Systems.** In 2018, a research project was started to solve the problem of mixing water produced at Hellisheiði and Nesjavellir with water from low temperature geothermal wells in the city. The mixing of heated groundwater with geothermal water has proven problematic due to the different chemical properties of the two types of water and the resulting scaling in any instance the waters mix. The proposed solution is to unify the district heating system in Reykjavík is to change the production of hot water at the Hellisheiði and Nesjavellir geothermal power plants without the formation of scaling. In addition to this, the project will increase the maximum power utilization from the existing resources, increase the utilization rate of geothermal power plants, which results in less resource depletion as well as reducing the environmental impact. The results are promising and have already been used for water exchange and summer rest in low-temperature fields in the capital of Reykjavik. If the project is successful, the installation of the process will begin on a small scale at Hellisheiði to prove the effectiveness of a similar system and will eventually be built up on a full scale. The research part of the project is scheduled to be completed in 2024.
- **Water quality.** Implementation of real-time microbiological measurements is ongoing, with the aim of creating a real-time understanding of i) of the interplay of microbial pollution of water with meteorological and environmental factors, ii) to control water harnessing always according to the best quality and thus maximizing consumption treatment, especially when meteorological events threaten water quality in water abstraction areas and iii) ensure water quality to the consumer.
- **Future vision of drinking water resources.** A future vision has been prepared for the municipalities of Reykjavík and Akranes, based on a forecast of drinking water demand until the year 2060. Future forecasts also assess the possible maximum demand that can be created on dry and sunny summer days. Climate models indicate that the frequency of extreme weather events will increase in the coming years, so it can be expected that conditions leading to maximum stress will become more frequent in the coming decades. However, more time is needed to assess how the effects materialize.
- **District heating resources:** A project finished 2022 where a Roadmap for all heating utilities to map the resources for district heating and demand forecast for the future is prepared. The capital

region's district heating utility system and HAB was finished 2022. The next project will deal with the heating utility at Stykkishólmur in West Iceland.

- **Increased overview of collection- and distribution systems.** Number of projects are in progress which aim at an increased overview of status, supply and failures in Veitur Utilities' systems with the aid of digital meters, automatic data analysis methods and system models.

Veitur's electric utility, together with Reykjavik Energy and ON Power, launching in 2022 the project "Improved Charging", which aims to examine the possibilities for controlling / shaping electric carload with the aim of reducing capacity and thus making better use of the existing infrastructure. Preliminary results indicate that the load due to electric cars is significantly higher than was previously indicated. Please see "Energy shift in transport in Iceland" above.

An initiative is ongoing regarding control and giving overview of the flow of energy through the electricity distribution system. With better information, the system can be operated closer to the tolerance limit and delay or ignore certain investments, but at the same time build the system where the data shows that there is a need for.

Veitur's district heating utility is working on projects aimed at a better overview of the condition, use and failures of the systems with digital meters, automatic data analysis methods and system models.

- **Future vision of the electricity distribution system.** An overall vision for the electricity distribution system was finished 2022. A system that examines a holistic approach, compares different ways of building the system with the aim of meeting the increased load. A load due to energy shift in a timely manner and in a way that minimizes the construction required to operate a secure distribution system.
- **Utilization of sewage waste.** A large amount of waste is generated by Veitur from the sewage that the sewer receives from customers. Some of the waste is high in energy and can be rich in nutrients and other valuables. It has been landfilled with associated greenhouse gas emissions and waste of valuables. Veitur are in favour of reducing this landfilling, especially the part that is biodegradable and prioritize research into possible ways of utilizing biodegradable sewage waste. Veitur Utilities are preparing the reuse of sewage waste such as sand, sludge, fat and garbage as part of the implementation of the circular economy. The feasibility of recycling sand from sewage treatment plants started early 2022, a project that received funding from the Ministry of the Environment, Energy and Climate. The results are promising, and the project is expected to be completed in the summer of 2023.
- **Innovation and development projects related to more efficient and improved utilization of geothermal energy.** ON Power participates in three H2020 European grant projects that focus on improved operation, efficiency, and utilization; GeoHex, GeoSmart and OptiDrill:
 - **GeoHex:** The project started in 2019 and is expected to be completed by the end of 2023. The goal is to develop a new metal coating for heat exchangers to increase their efficiency through increased thermal conductivity and reduced adhesion of scaling. Amorphous coatings to reduce corrosion and adhesion of deposits on heat exchangers will be used. Tests have been carried out on the anti-corrosion and anti-scaling coatings, along with the thermal expansion tests on the coatings in a dual-fluid system (ORC) in a real environment at Hellisheiði Geothermal Power Plant.

- **GeoSmart:** The project started in 2019 and is scheduled to be completed in 2024. The goal is to design methods to increase the profitability of geothermal utilization, considering energy storage, energy cycle and energy efficiency. Technology will be developed to store excess thermal energy produced during off-peak hours (at night) and use it during high-peak hours (during the day). With these technologies, it will be possible to spread and equalize the load on the geothermal plant during the 24 hours, thus increasing flexibility in production. Efficiency in such a system will be increased with a "hybrid" cooling system and a system designed to reduce scaling.
- **OptiDrill:** The project started in 2021 and is expected to end in 2024. The goal of the project is the best drilling technology to reduce drilling costs, up to 30% of the total cost. Part of the drilling will be automated with artificial intelligence, where relevant tunnels from different geological zones/layers will be fed into the simulation software.