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## CarbFix – public engagement and transparency

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### Abstract

The history of the CarbFix project spans 12 years. Throughout all this time, CarbFix has not faced problems with public acceptance in relation to carbon capture and storage (CCS) activities. This is noteworthy, as the project's operations are located at Hellisheiði Geothermal Power Plant, which has been contested and scrutinized. It could even be argued that CarbFix has played an important part in increasing the Hellisheiði Plant's acceptance. This paper describes the framework of stakeholder engagement and transparency in relation to industrial scale operations within CarbFix and the impact it has had public acceptance.

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*Keywords:* CarbFix2; CCS; public acceptance; stakeholder engagement

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### 1. Introduction

The CarbFix project, which was initiated in 2006, was formalized in the year 2007, a legendary year in Iceland's recent history. It was the year of financial expedience, ballooning banks, boundless optimism, and the year before the total meltdown of the country's finances. So, in its first phases, this ambitious CarbFix R&D project didn't only face the challenges naturally embedded in all scientific experiments, but also various external tests. These were on various levels.

Reykjavik Energy's Hellisheiði Geothermal Power Plant was under stage-wise construction and up-scaling until 2011. During this time the power plant became contested. The company itself faced dire financial times and, somewhat rightfully, accusations of short-sightedness and mismanagement. In 2010, a stringent new regulation regarding permitted levels of hydrogen sulfide (H<sub>2</sub>S) put high demands on the company to reduce its emissions and, in 2011, unforeseen induced seismicity, related to geothermal fluid reinjection, shook a community near the Hellisheiði plant. In short, the public's trust in the country's institutions, that was rapidly deteriorating, hit Reykjavik Energy and its

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operations heavily. In this article, a story is told how the CarbFix project survived these challenges and how its success contributed to their passing.

### 2. Open source approach and public engagement

Early on in the CarbFix project, the question of patenting arose. The initial partners – Reykjavík Energy, The University of Iceland, Columbia University, and CNRS – resolved not to take that path but, instead, publish project achievements in peer-reviewed publications as well as welcoming undergraduate and graduate-level students to work on the project.

Hitherto, about 60 scientific papers on the various aspects of the CarbFix project have been published as shown in Fig. 1. Furthermore, 15 students have completed their respective degrees with theses on the project, some of whom are currently employed by the project’s partners (the corresponding author of this paper included). This is very much in line with the common practice in the Icelandic geothermal industry; the culture of knowledge-sharing was manifested with an agreement between the largest geothermal companies in Iceland regarding the challenge of H<sub>2</sub>S emissions. In May 2012, Reykjavík Energy, Landsvirkjun and HS Orka, appointed a joint steering group for a collective project to abate H<sub>2</sub>S-emissions. A formal project plan was published in May 2013. This reflects the general attitude of the industry that the benefits geothermal energy has brought the Icelandic people should be made accessible for all. The operation of the United Nation University’s Geothermal Training Programme in Iceland and the continued support for this programme on behalf of Icelandic authorities reaffirms this altruistic approach to the intellectual capital and know-how residing within the geothermal industry in Iceland.

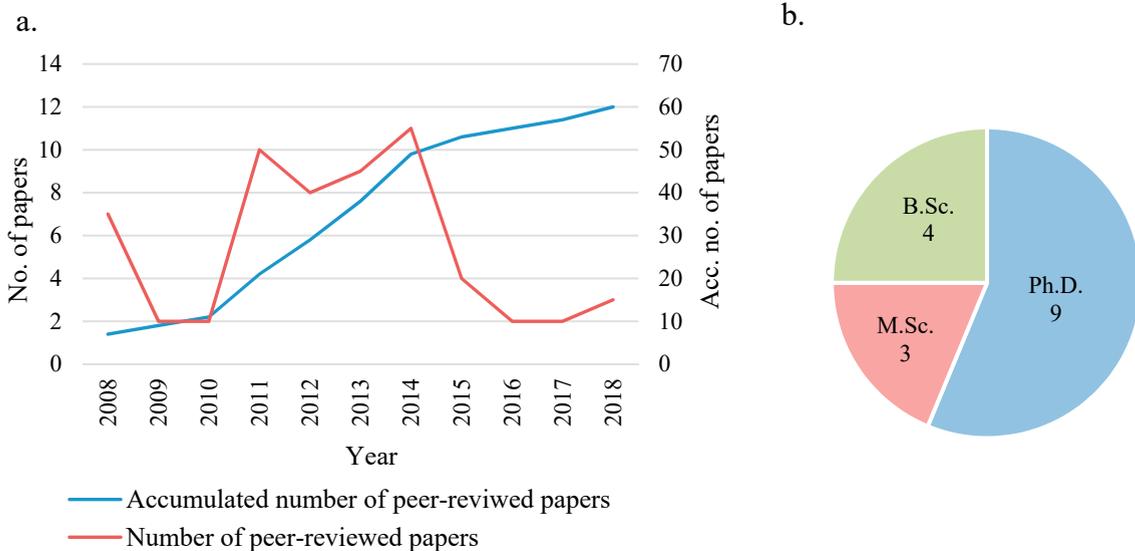


Fig. 1. (a) Peer-reviewed papers on CarbFix by year; (b) Number of theses on the CarbFix project 2008-2017.

However important scientific publications may be, transparency towards the scientific community constitutes but a fraction of the public engagement the parties to CarbFix and related activities have undertaken. Especially, the challenges of induced seismicity and H<sub>2</sub>S emissions called for engaging the public and its representatives in municipal councils and regulating institutions.

Since the commissioning of the Hellisheiði Power Plant, in phases from year 2006 through 2011, ambient levels of H<sub>2</sub>S increased. Licensing authorities as well as the public were alarmed, which resulted in regulation no. 514/2010 on H<sub>2</sub>S emissions [1], which is significantly stricter than the World Health Organization (WHO) Air Quality Guidelines [2], and puts high demands on the geothermal industry in Iceland to reduce atmospheric H<sub>2</sub>S concentrations in the vicinity of geothermal power plants. To Reykjavík Energy’s management, it seemed impossible to fulfill the regulation’s requirements. However, CarbFix proved to be the seed from which a solution to this challenge grew.

### 3. Induced Seismicity

Commissioning of the Húsmúli reinjection area in late 2011, where the industrial scale CarbFix injection is currently ongoing, caused significant induced seismicity that was felt in nearby communities. Induced seismicity associated with geothermal production was known in Iceland, but had never caused problems despite a long and vast history of geothermal utilization. In addition, the Húsmúli area was not known to be a particularly active seismic area and the injection pressure was far below the critical stress state of the rock [3].

However, the large-scale reinjection caused significant induced seismicity with about 40 earthquakes registering over magnitude  $M_L$  2.5 and eight earthquakes registering between  $M_L$  3.0–4.0 (Fig. 2). Most of the earthquakes above  $M_L$  2.5 were felt in the nearby town of Hveragerði and the biggest earthquakes were also felt in the capital city of Reykjavík.

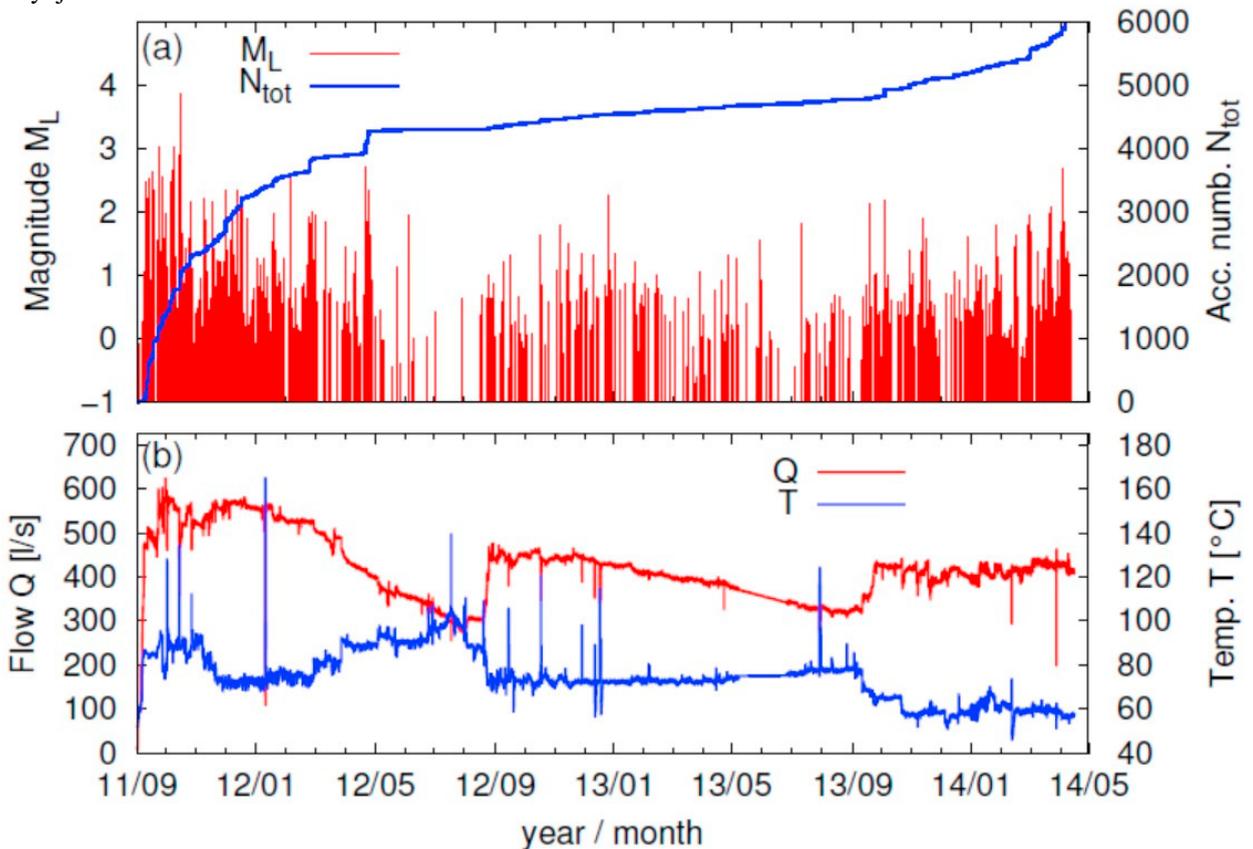


Fig. 2. (a) Seismicity in the Húsmúli area from the start of large scale reinjection in September 2011 until the end of April 2014. The magnitude ( $M_L$ ) and the accumulated number of events ( $N_{tot}$ ) are plotted vs. time; (b) Total flow of reinjected water ( $Q$ ) and its temperature ( $T$ ). Both (a) and (b) are shown in the same time scale. Figure from Thorsteinsson and Gunnarsson [4].

The induced seismicity in 2011 generated a strong response from the general public, the media, as well as local and national authorities and regulators. Two days after the biggest events occurred, Reykjavík Energy held a town meeting in the nearby town of Hveragerði to discuss the reinjection operation. During the meeting, it was decided to appoint a panel of independent experts to evaluate the current reinjection and to provide recommendations for future reinjection operations. The panel consisted of experts from Iceland GeoSurvey, the Icelandic Metrological Office (IMO), the University of Iceland, Reykjavík Energy and the town of Hveragerði. The panel found that seismic risk had not been taken sufficiently into account during the commissioning of the Húsmúli area. Monitoring equipment had not been sufficient and a risk mitigation plan for seismic events had not been in place [5].

#### 4. Formal communication channel

Communications with local communities and their leaders were increased immediately after the seismic events, but it took time to find the correct balance between alerting the public when seismic risk was thought to be increased without over alerting the public. The resulting protocol has been in operation since 2014. The protocol guarantees distribution of information through three channels when situations for increased seismic risks arise in power plant operations. Firstly, the IMO's seismic monitoring watch is notified, as they are responsible for monitoring all seismic activity in Iceland. Secondly, the Icelandic Civil Protection Department is notified. They in turn notify the nearby communities both through direct communication with local civil protection committees and through a public announcement on their website. Finally, Reykjavik Energy puts out a notice on its website alerting the public of the increased risk. Once the reinjection operations are stable again, these same three lines of communication are used to alert the public of the decreased seismic risk [4]

This formal communication framework with national and local authorities of induced seismicity risks was an addition to already established monthly meetings, held since 2013, with all bodies granting different permits for the power plant. In those, state regulators and local permitting agencies are informed of operational changes and challenges the Hellisheiði plant's operators are facing.

Furthermore, following the publication of annual environmental reports, which provide open access to all waste and emissions data from Reykjavik Energy's operations, larger meetings are held with permitting agencies and health inspection authorities from all municipalities affected by the operations. CarbFix relies on and applies this communication framework to maintain a trustful collaboration and engagement of its stakeholders.

#### 5. Conversation bears fruit

The CarbFix team itself has not faced problems with public acceptance in relation to its carbon capture and storage (CCS) activities, as the public and authorities were engaged in the project from its inception. It could be argued that CarbFix has played an important part in increasing the Hellisheiði Plant's acceptance. The project has enjoyed much positive attention by media, both domestic and foreign. The latest acknowledgement CarbFix received was the Environment Agency of Iceland pinpointing it as one of the contributors to Iceland's climate action in its National Inventory Report 2018, submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol [6].

Media coverage and public opinion of the seismic events of October 2011 were, however, very unfavorable. The aforementioned measures had been in effect for a few years when another wave of seismic activity connected to re-injection occurred in September 2016. The effects on society were minimal as reflected in the content analysis of media coverage, shown on Fig. 3. The figure shows the impact of Reykjavik Energy's public and stakeholder engagement following the event of 2011. An independent company evaluates each news-story's impact on Reykjavik Energy's image. October 2011 saw 48 stories with negative impact on the company's image, while none such story was published in September 2016.

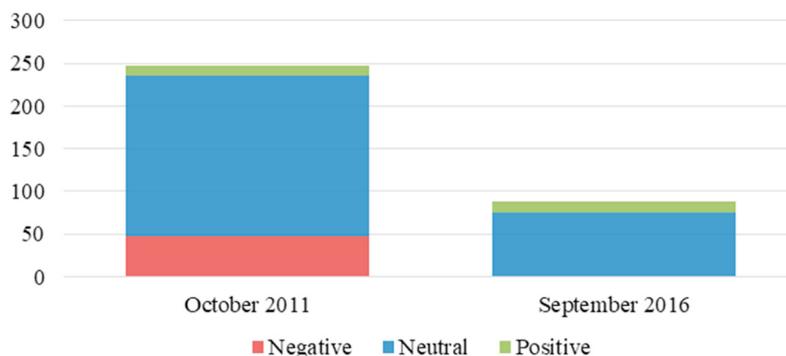


Fig. 3. Results of content analysis on Reykjavik Energy in two months when seismic activity connected to re-injection occurred. A formal communication channel with stakeholders and the public was established in 2013-2014.

## 6. GSAP audit

Engagement with key stakeholders was among the factors under scrutiny in a recent comprehensive sustainability test of the Hellisheiði Project. In January and February 2018, independent assessors audited the Hellisheiði Geothermal Project according to the Geothermal Sustainability Assessment Protocol (GSAP). The protocol is based on the Hydropower Sustainability Assessment Protocol, a proven tool initiated by the International Hydropower Association in 2000 and endorsed by various leading organizations, among others financial institutions as well as NGOs [7].

GSAP is under development by the Icelandic energy and environmental authorities, geothermal power companies and Icelandic NGOs. It is a framework to assess the performance of geothermal power projects according to a defined set of sustainability topics, encompassing environmental, social, technical, and financial issues [8]. The Hellisheiði project is the first geothermal project in operation that has been put to this sustainability test. The operations are measured on several levels. They are graded on a scale ranging from 1 to 5 where 3 is considered basic good practice and 5 proven best practice. Gaps against those are identified and spelled out. Each gap lowers the grade by 1.

In short, no significant gaps were found between the operations at Hellisheiði and basic good practice. However, ten significant gaps were found when operations were tested against proven best practice. This is shown in Fig. 4.

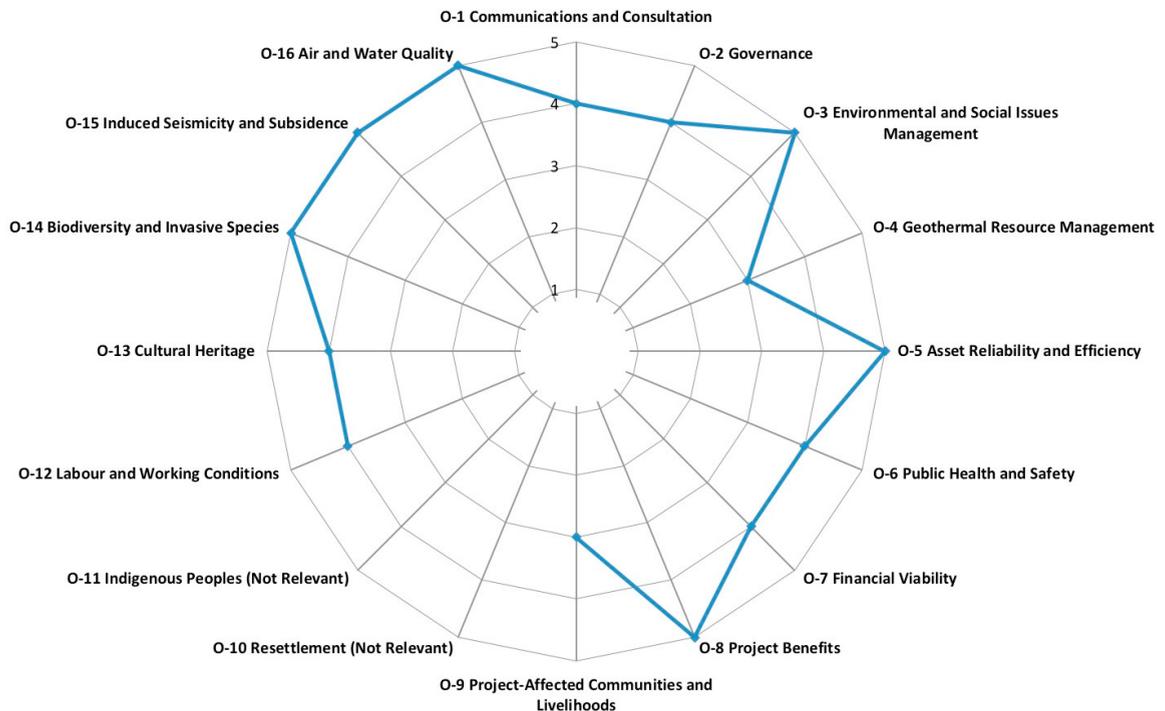


Fig. 4. Sustainability profile of the Hellisheiði project

As shown in Fig. 4, the operations at The Hellisheiði Geothermal Power Plant passed successfully the sustainability test in accordance with proven best practice. The CarbFix project attracted special attention by the independent GSAP auditors that state they constitute "...globally ground-breaking advances in technology which have been frequently publicized in high-impact scientific journals such as Science, and on international TV" [8].

The figure also shows ten significant gaps from proven best practice. Four of those can, at least in part, be traced to the special status of the nearby community of Hveragerði. It is the town in closest proximity to the Hellisheiði Plant

but the regulating municipality and the sustainability report call for more interpersonal relations with the inhabitants there.

## 7. Indefinite fixation

Carbon sequestration is here to stay. Already, the CarbFix project has delivered results that now are both a regular and integral part of the operations of the Hellisheiði Power Plant. Through it, over 23,000 tons of CO<sub>2</sub> have been mineralized and the H<sub>2</sub>S challenge has been all but eliminated. In 2017, the overall annual reduction in gas-emissions was 34% for CO<sub>2</sub> and 68% for H<sub>2</sub>S [9]. Despite the issues with seismicity discussed above and the fear of gas-leaks some other CCS-projects have faced, CarbFix has succeeded at least in part through the successful and regular engagement of public and other stakeholders.

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## References

- [1] Regulation on Hydrogen Sulphide concentration in the atmosphere no. 514/2010 (in Icelandic). Ministry for the Environment (2010).
- [2] World Health Organization ROFE.: Air quality guidelines for Europe, European Series No. 91 (2000).
- [3] Gunnarsson G. "Temperature Dependent Injectivity and Induced Seismicity – Managing Reinjection in the Hellisheiði Field, SW-Iceland" *GRC Transactions* 37 (2013): 1019-1025.
- [4] Thorsteinsson H., and G. Gunnarsson. "Induced Seismicity – Stakeholder engagement in Iceland" *GRC Transactions* 38 (2014): 879-881.
- [5] Bessason B., E.H. Ólafsson, G. Gunnarsson, Ó.G. Flóvenz, S.S. Jakobsdóttir, S. Björnsson, and Th. Árnadóttir. "Protocol for induced seismicity in geothermal systems" (in Icelandic) Reykjavik Energy, Reykjavik (2012).
- [6] Hellsing V.Ú.L., A.S. Ragnarsdóttir, K. Jónsson, N. Keller, Á.K. Helgadóttir, Þ. Jóhannsson, J. Guðmundsson, A. Snorrason, and J. Þórsson. "National Inventory Report 1990-2016". The Environment Agency of Iceland, Reykjavik (2018).
- [7] The Hydropower Sustainability Assessment Protocol: <http://www.hydrosustainability.org/> [accessed on the 15<sup>th</sup> of June 2018]
- [8] Hartmann J., and B. Rydgren. "Hellisheiði Geothermal Project" *GSAP Report*, Reykjavik (2018).
- [9] Sigfússon B., M.Þ. Arnarson, S.O. Snæbjörnsdóttir, M.R. Karlsdóttir, E.S. Aradóttir, and I. Gunnarsson. "Reducing emissions of carbon dioxide and hydrogen sulphide at Hellisheiði power plant in 2014-2017 and the role of CarbFix in achieving the 2040 Iceland climate goals" *Energy Procedia* (2018), this issue.