

Improving Air Quality with NCG Gas Capture and Reinjection at the Hellisheidi Power Plant

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ABSTRACT

The Hellisheidi Power plant was commissioned in 2006 and was fully built in 2011. Initially, the majority of non-condensable gas (NCG) emissions from the plant were vented to the atmosphere at selected cooling towers of the plant, resulting in elevated H₂S concentration levels in neighbouring communities and considerable CO₂ emissions.

The total H₂S and CO₂ discharge from the geothermal reservoir was 10,900 tons/year and 43,000 tons/year respectively in 2014, but had decreased to 9,500 tonnes/year and 37,400 tonnes/year in 2018.

In 2014, a capture plant applying the CarbFix process was commissioned and connected to the main turbine hall of the power plant. That same year, 2,400 tonnes of H₂S from the powerplant were re-injected back into the geothermal reservoir. The plant capacity was doubled in 2016, resulting in re-injection of 4,500 tonnes of H₂S. In 2018, all gas exhaust systems of the power plant were combined into a single system enabling the operation of the capture plant at full capacity resulting in the re-injection of 7,000 tonnes of H₂S. With these new installations the H₂S emissions have decreased stepwise to 2,500 tons/year in 2018 due to the capture and re-injection activities.

Measurements from a network of air quality monitoring stations, located between 600 m to 30 km from the nearest cooling tower, all show a decrease in the mean daily atmospheric H₂S concentration in conjunction with degreasing emissions from the powerplant. In 2018, the mean daily H₂S concentration at three monitoring stations in communities nearest to the geothermal plant (Norðlingaholt, Lækjarbotnar and Hveragerði) never exceeded the regulatory health limits set in Iceland (50 µg/m³ averaged over 24 hours).

Elevated concentrations of H₂S in the air quality monitoring station closest to the power plant (about 600 m from the main emission point) have decreased since the capture plant was commissioned. The mean daily H₂S concentration at the power plant exceeded 50 µg/m³ 12 times in 2018 compared to 106 times in 2014, the year when the capture plant was commissioned.

Over the same period, reinjection of CO₂ has increased from 4,100 tonnes/year to 12,200 tonnes/year, in 2014 and 2018. This is in accordance with Reykjavik Energy's (RE) 15-year goal of reducing RE's and its subsidiaries' carbon footprint by 60% by 2030. Expansion and continued operation of gas capture and reinjection is seen as a key factor in achieving this goal.

1. INTRODUCTION

The Hellisheidi Power plant was commissioned in 2006 and was fully built in 2011. Initially, the majority of non-condensable gas (NCG) emissions from the plant were vented to the atmosphere at selected cooling towers of the plant, resulting in elevated H₂S concentration levels in neighbouring communities and considerable CO₂ emissions. The NCG emissions from the Hellisheidi Power Plant represent by far the largest point source from Reykjavik Energy and its subsidiaries and recently, emphasis has been placed on reducing these emissions.

In 2014, a capture plant, applying the CarbFix process was commissioned and connected to the main turbine hall of the power plant. There NCGs from turbines are compressed to 6 bar-a and equilibrated with condensate in an absorption tower prior to being injected into the geothermal reservoir (heimild). In 2014, 2,400 tonnes of H₂S from the powerplant were re-injected back into the geothermal reservoir. The plant capacity was doubled in 2016, resulting in re-injection of 4,500 tonnes of H₂S. In 2018, all gas exhaust systems of the power plant were combined into a single system enabling the operation of the capture plant at full capacity resulting in the re-injection of 7,000 tonnes of H₂S.

This contribution outlines how NCG emissions and re-injection are quantified and places the emissions in context with air quality that is monitored on several locations near the power plant.

2. METHODS

2.1 Emissions from the Power Plant

2.1.1 NCG emissions from cooling towers

Emissions from the Hellisheidi power plant are monitored on daily basis (Sigfusson et al., 2018). Briefly, steam mass flow is measured continuously with an orifice plate meter at each turbine and NCG concentration measured every three months. Similarly, condensate flow rate through vacuum pumps is measured continuously. This the chemistry of this condensate, now termed seal water after it

becomes saturated with NCG is measured four times per year. The seal water is re-injected with separator water into the geothermal reservoir. NCG captured through the CarbFix process is quantified by measuring condensate flow continuously and measuring the concentration of NCGs in the CarbFix fluid.

The daily emissions from cooling towers are then estimated by subtracting the NCG mass flux in condensate and CarbFix water from the NCG mass flux in steam into turbines.

2.1.2 NCG emissions from stacks

The turbine inlet pressure is controlled with control valves and excess steam is vented into the atmosphere at selected stacks in the steam collection system. Although the opening of these control valves is minimized as possible, the emissions have normally been around 1% of the total emissions from the plant. The NCG concentration in this steam is assumed to be the same as is entering the turbines and the mass flow rate is estimated from a characteristic curve describing the relationship between valve opening and mass flow rate at a given pressure.

2.2 Filtering of H₂S concentration at the nearest monitoring station

The wind direction and wind speed as well as H₂S concentration is collected and aggregated into 10 minute averages. For this study only data when wind was blowing from 50° to 80° was used. This is the wind direction when the plume from the nearest cooling tower has the highest probability of being measured at the air quality monitoring station (fig 2.1). The mean daily concentration during this wind direction was then correlated to the power plant emissions. The years 2014 to 2017 were only used when studying the air quality at the nearest monitoring station. This is because in 2018, following the connection all turbines into a single system the excessive gas not captured by the CarbFix process was either vented at the cooling tower 4 or at turbines 5 and 6 (just north of fig 2.1) therefore making all statistical analysis difficult and not comparable to the years before.

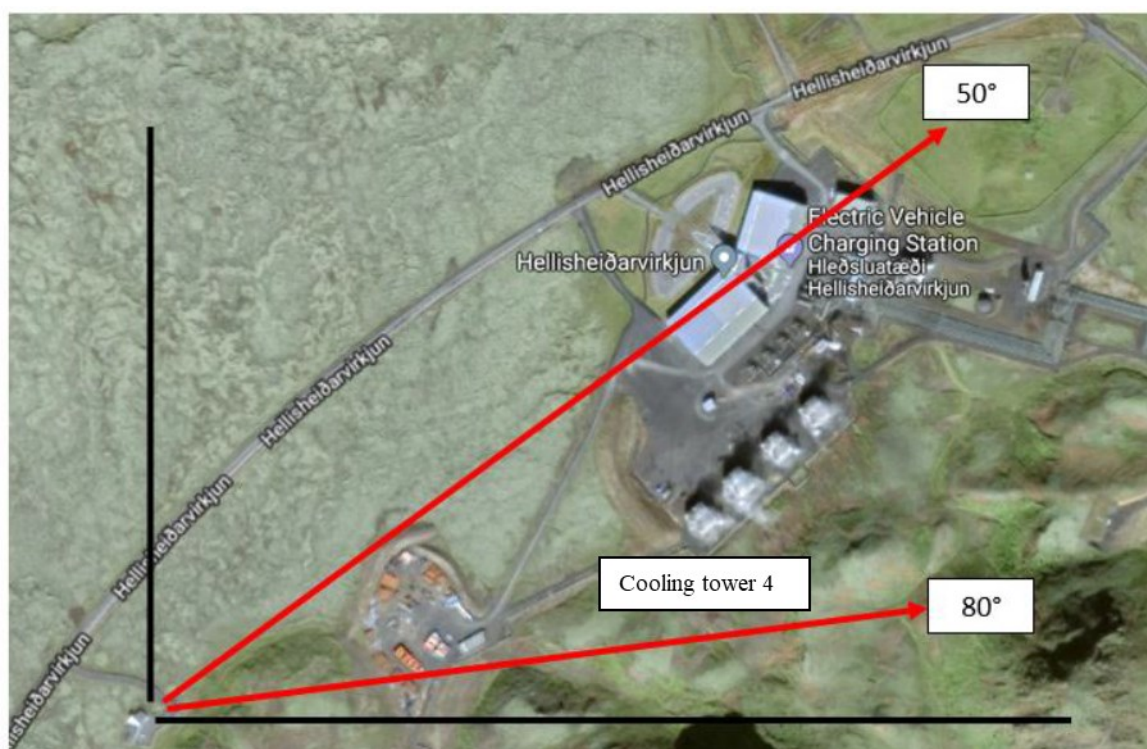


Figure 2.2. An overview of the Hellisheidi power plant and the nearest air quality monitoring station. Emissions from five turbines out of seven and not captured by the CarbFix process were emitted from cooling tower 4 nearest to the monitoring station.

3. RESULTS

3.1 Emissions from the power plant

The daily emissions of CO₂ and H₂S are shown in fig. 3.1 (Sigfusson et al. 2018). Prior to the commissioning of the capture plant, ~120 tons of CO₂ and ~30 tons of H₂S were emitted daily from the plant. In the end of 2017, the daily emissions had decreased to ~60 tons CO₂ and ~10 tons H₂S per day.

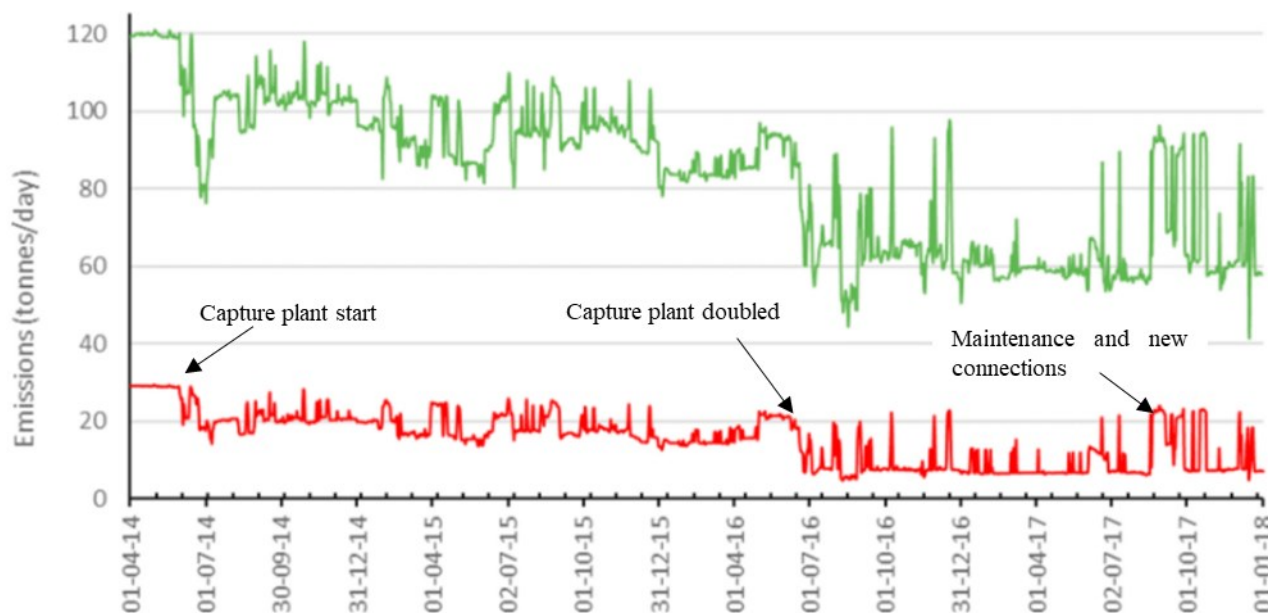


Figure 3.1. Daily emissions of CO₂ (green) and H₂S (red) from the Hellisheidi power plant during the years 2014-2017 (modified from Sigfusson et al. 2018)

3.2 Air quality near the Hellisheidi Power plant

Fig 3.2 shows the relationship between 10-minute mean values of wind direction and H₂S concentration at the nearest air quality monitoring station (fig 2.1) to the Hellisheidi plant. Dark blue dots represent values when wind is blowing directly from the nearest cooling tower to the air quality monitoring station.

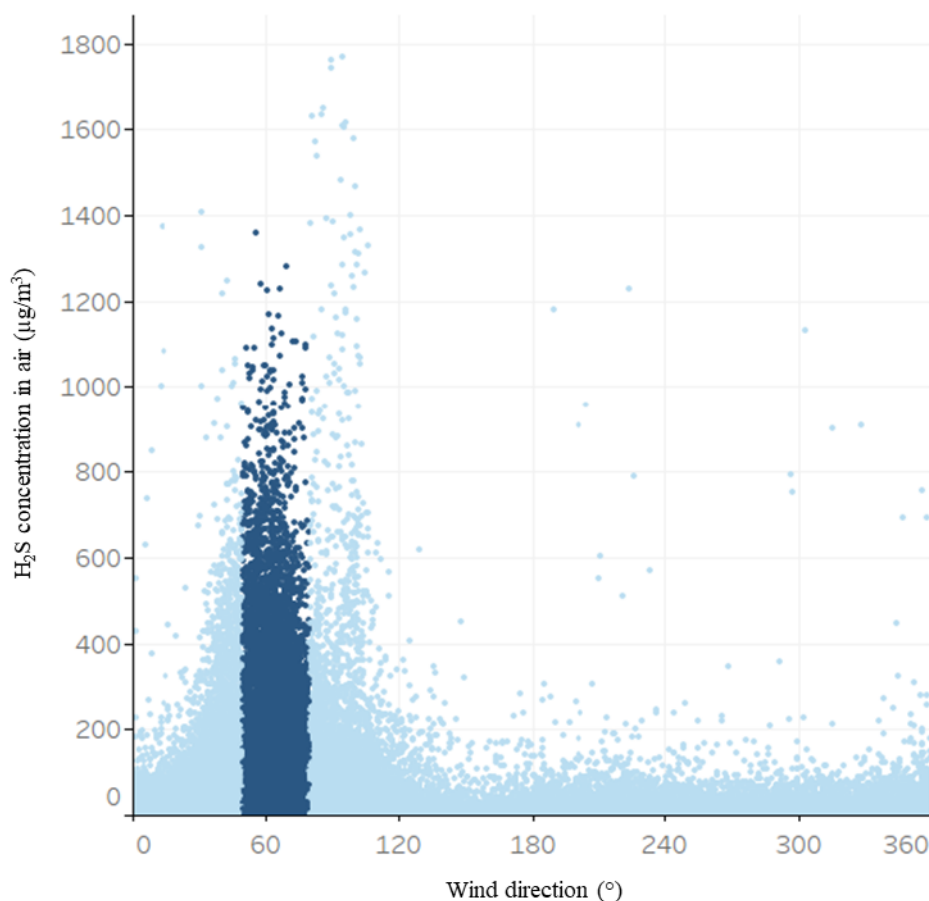


Figure 3.2 H₂S concentration (10 minute average) in air at the nearest air quality monitoring station to Hellisheidi power plant.

Fig 3.3 shows the relationship between daily H_2S emissions and the H_2S concentration in air when wind was blowing directly from the power plant to the monitoring station. The blue dots indicating emissions above 26 tons/day are mainly from the period prior to the commissioning of the capture plant. As time progressed downtime of the capture plant decreased with less change of high emissions coinciding with wind being blown directly from the power plant to the air quality monitoring station.

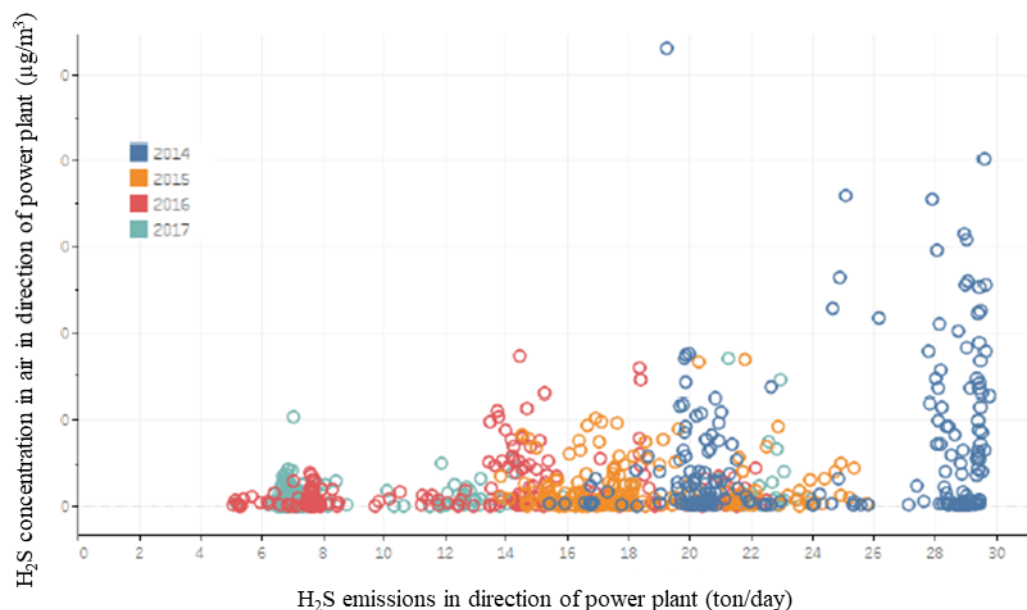


Figure 3.3. The relationship between H_2S emissions and H_2S concentration at the nearest air quality monitoring station when wind was blowing from the power plant ($50^\circ - 80^\circ$).

Fig. 4.4 shows the daily H_2S emissions from the Hellisheiði power plant and the mean daily H_2S concentration in air when wind was blowing directly from the plant to the monitoring station.

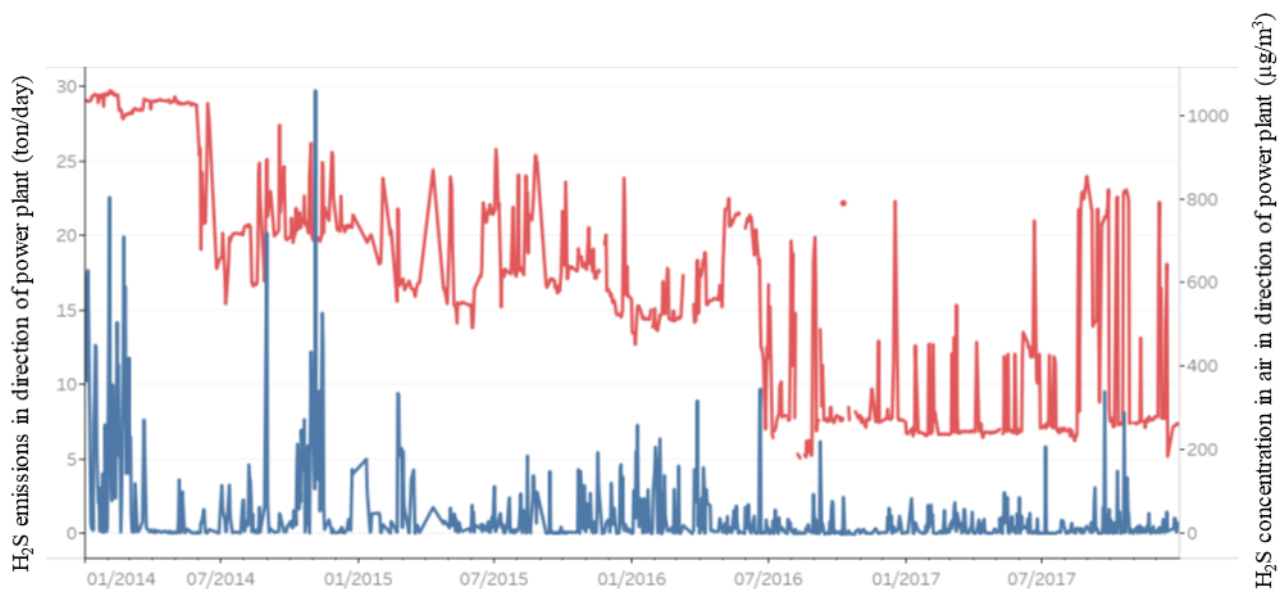


Figure 4.4 Daily averages of H_2S emissions (red line) and mean H_2S concentration in air (blue line) only for the periods within the day when wind was blowing from the power plant ($50^\circ - 80^\circ$)

Fig. 4.5 shows the weekly mean H_2S emissions from the Hellisheiði power plant and the weekly mean H_2S concentration in air when wind was blowing directly from the plant to the monitoring station. Dashed lines show the linear trend for both time series.

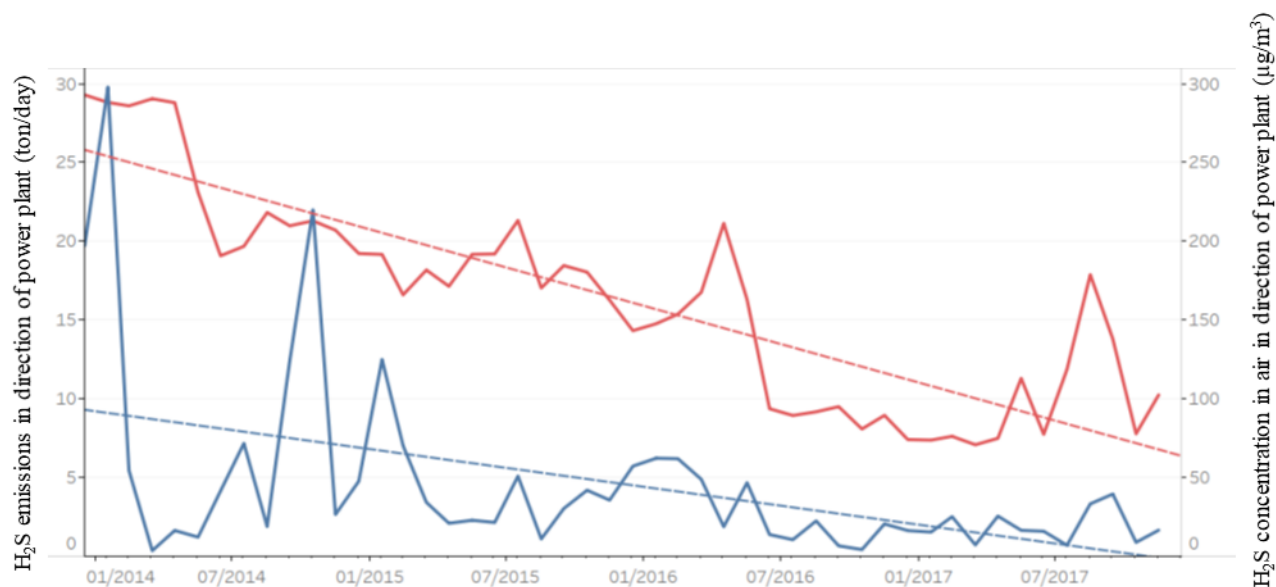


Figure 4.5 Weekly averages of H₂S emissions (red line) and mean H₂S concentration in air (blue line) only for the periods within the week when wind was blowing from the power plant (50° - 80°)

3.3 CO₂ emissions from the Hellisheiði power plant

Fig. 4.6 shows the annual emissions from the Hellisheiði power plant where the blue bars show the amount of CO₂ emissions released into the atmosphere and the orange bars illustrate the amount of emissions sequestered by CarbFix. This graph illustrates the impact of the implementation of CarbFix at the plant, where the amount of CO₂ emissions released Hellisheiði decreased roughly 45% from 2013-2018.

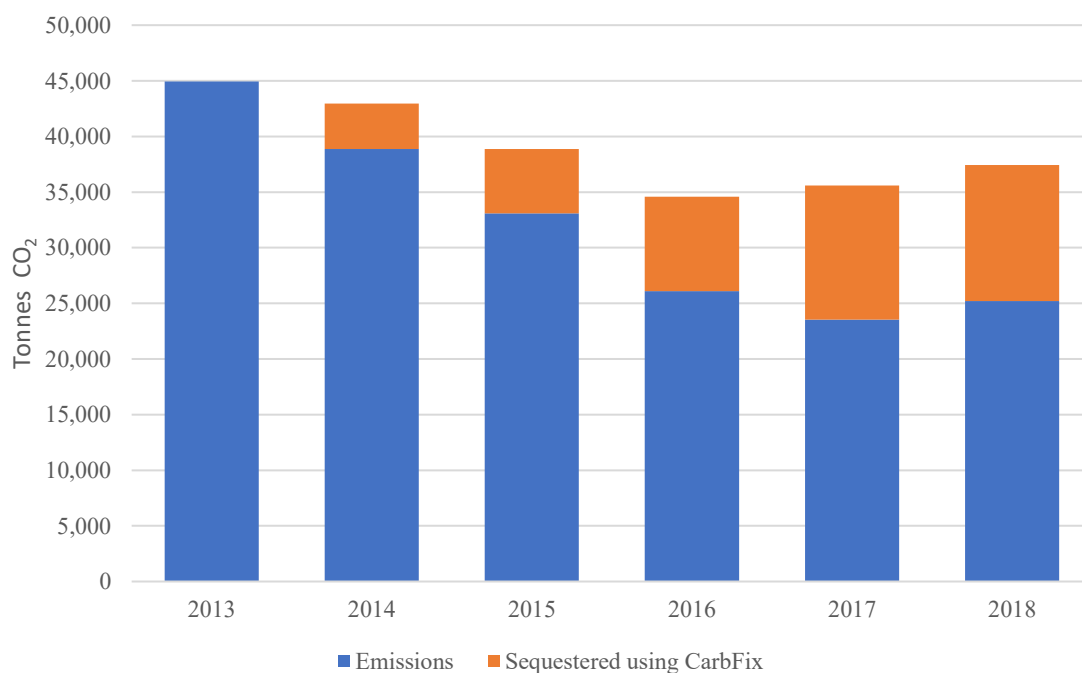


Figure 4.6 CO₂ Emissions from Hellisheiði over time with the implementation of CarbFix

4. FINAL REMARKS

The CarbFix process discussed within this report has proven to be a revolutionary method in terms of decreasing the H₂S and CO₂ emitted from Reykjavik Energy's geothermal power stations. The effect on better air quality has already been verified in terms of H₂S and the CO₂ footprint of the Hellisheidi plant has been reduced by a third. This project plays a leading role in RE's larger ambitious climate strategy. RE has made a commitment towards decreasing the amount of greenhouse gas (GHG) emissions associated with the operations of a geothermal power company as well as along the company's subsidiaries, ON Power, Veitur Utilities and Reykjavik Fibre Network. RE has set a 15-year goal to decrease the company's carbon footprint by 60% by 2030. RE aims to have decreased emissions associated with operations through the setting of emission targets across the following operative segments, listed in decreasing order of impact towards reaching this 2030 goal: Expansion and continued operation of CarbFix, utilization of CO₂ within ON Power's Geothermal Park, decreasing emissions associated with the company's vehicle fleet (through the electrification of the car fleet), decreasing emissions caused by construction, borehole drilling, employee commuting, waste, business travel, and food waste coming from the company's canteens. Additionally, considered is the amount of CO₂ bound in nature (Land Use and Land Use Change) through RE's work in forestry and recovery of wetlands.

CarbFix is the leading route in which RE can decrease the company's emissions (with the aim of sequestering ~30% of emissions), and the addition of the following additional goals is what will allow RE to achieve its ambitious 2030 goal. The use of CO₂ within the Geothermal Park will help create value out of waste, where previously unused and harmful emissions can instead be captured and siphoned to entrepreneurial companies within the geothermal park. The use of CO₂ for algae production, greenhousing, and other potential applications will allow companies to turn these previously environmentally negative emissions into economic benefit, while at the same time using CO₂ that would have already occurred as opposed to using man-made CO₂.

The third category in which RE can make the largest impact in terms of largest step is decreasing emissions is the company's vehicle fleet. With operations including installation and maintenance of utility infrastructure, power plant operations, and multiple facilities throughout the greater Reykjavik area, RE has a sizable vehicle fleet nearing almost 200 vehicles. To date, ~40% of these vehicles are non-conventional, such as EVs, hybrids, methane, or hydrogen vehicles that avoid the use of hundreds of thousands of liters of petrol, diesel and hundreds of tonnes of GHG emissions per year.

The next greatest potential to decrease GHG emissions is through construction and drilling completed by contractors. RE has committed to the use of only electrical drilling and has only performed digs using an electrical drill since 2016. This has helped avoid over 100 tonnes of GHG emissions annually. RE also aims to place pressure on contractors performing trench work to electrify as much of the process as possible as well as taking environmental factors into the work being completed. RE can then take these environmental factors into account during contractual decision-making.

The final steps of Reykjavik Energy's climate strategy are to target emissions associated with employees and employee decision making. These emissions are associated with commuting to and from work, quantity of waste generated and sorted, business travel, and decreasing the amount of food waste coming from the company's canteens. Reykjavik Energy has worked to motivate employees to find alternative environmentally friendly means of commuting to work through the introduction of a commuting contract, where employees receive a small monthly stipend. This has helped decrease the number of employees traveling to work using an ICEV by nearly 10%. Goals of reducing business travel and waste from canteens have further been set. While this final category of employee decision making may play the smallest role in terms of avoided GHG emissions from company operations, it is nevertheless one of the most crucial, because these are the goals every employee can focus on and make a difference, regardless of role in the company.

Lastly, RE sees its responsibilities not just in preventing emissions caused by the company's operations, but also in helping remove already existing CO₂ from the atmosphere. Therefore, the sequestration of CO₂ in nature, a measurement of how much CO₂ is being absorbed annually from OR's reforestation and land reclamation efforts, has also been set as one of RE's climate goals. RE seeks to avoid damaging this nearby vegetation through CarbFix's ability to sequester H₂S emissions as well. The sequestration of these harmful H₂S will help avoid acidification of the nearby air, protecting local flora and fauna in the area.

Through the development of CarbFix and the setting of ambitious CO₂ reduction targets, RE aims to improve the local environment through the sequestration of H₂S, as well as the global environment through the reduction of CO₂ emitted, lowering the company's emissions leading to the delivery of less carbon intensive electricity and heat to RE's customers.

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