Proceedings World Geothermal Congress 2023
Beijing, China, April 17 – 21, 2023

How an Icelandic geothermal energy and utility company will become carbon negative by 2030

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Keywords: GHG, Greenhouse gases, Hellisheidi, Nesjavellir, Reykjavik Energy, Carbon neutrality, Carbon negativity, Carbon dioxide, climate change.

ABSTRACT

The energy production industry contributes a significant share of global greenhouse gas (GHG) emissions leading to climate change. Geothermal energy production is an interesting case of renewable energy which has direct GHG emissions and other non-condensable gas emissions from its operations. Reykjavik Energy (OR), a leading geothermal energy- and utility company in Iceland, has therefore set the goal of decreasing direct and indirect GHG emissions from its operations by more than 95% by 2030 according to a 2016 baseline. Through additional goals to bind CO_2 through land reclamation, OR aims to achieve carbon negativity - meaning that OR will emit less GHG than it sequesters through natural land restoration and forestry. Measured according to the GHG Protocol, a global GHG accounting standard, OR will meet this goal through the setting of sub-goals encompassing business operations. Emissions from operations include all emissions from electricity and heat production, fuel use, energy use, and other emissions such as commuting, waste, business travel and land reclamation. OR devised a method to measure these sub-goals' annual performance against a yearly target and according to the performance of each, an overall environmental indicator was developed to gauge OR's success in meeting that year's targets. Using this methodology, it is the aim of the OR that the overall goal of being carbon negative will be met by 2030. It is worthy of investigation into how a company producing renewable energy with low GHG emissions compared to other energy sources and a company with varied operations, can achieve deep decarbonization.

1. INTRODUCTION

The climate crisis is a global problem, with energy production accounting for an estimated 73% of global greenhouse gas (GHG) emissions (Ritchie et al., 2020). Countries around the world signed the Paris Agreement with the goal to mitigate the climate crisis predicted by entities such as the Intergovernmental Panel on Climate Change (IPCC) if global warming exceeds 1.5 °C (IPCC, 2018). In the Paris Agreement it was recognized that zero-carbon solutions could be competitive in sectors representing over 70% of global emissions (United Nations, 2015) and with the significant role in global emissions from the energy sector, the expansion of low-carbon renewable energy is considered a key action to attaining a below 1.5 °C future.

A special report by the IPCC on renewable energy sources and climate change mitigation (SRREN) published a range of life cycle GHG emissions from a review of life cycle assessment (LCA) studies on different electricity technologies. The results are presented in Figure 1 and show how fossil fuel technologies are grouped at the high-end of GHG emissions per kWh produced, while renewable technologies are grouped at the lower end of emissions per kWh (Moomaw et al., 2011) The figure illustrates how emissions from geothermal production technologies are around 3% of those of coal.

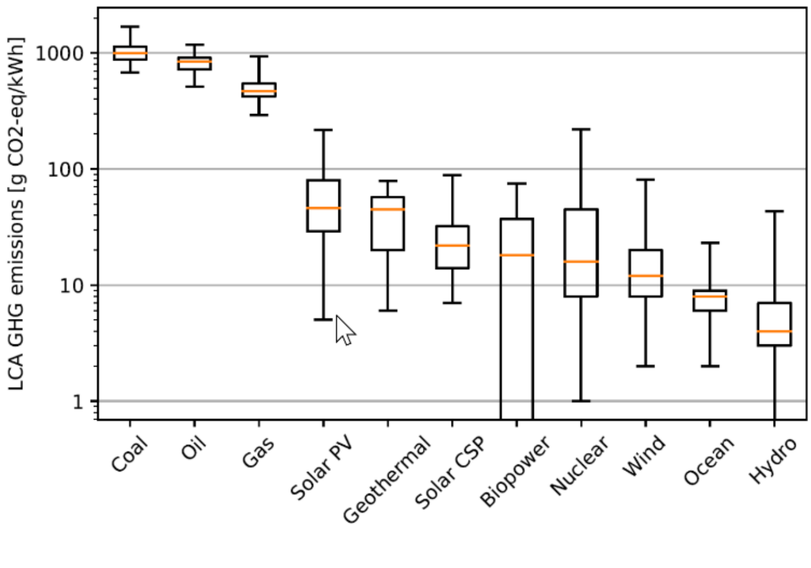

Figure 1. Comparison of life cycle GHG emissions from different electricity generation technologies (Moomaw et al., 2011)**..**

Geothermal energy production is an interesting case of renewable energy which has direct GHG and other non-condensable gas emissions from its operations. This is unlike many other renewable energy technologies, where the GHG intensity of geothermal is largely determined by the geology and geo-chemistry of the reservoir (Aksoy et al., 2015). Fridriksson et al., (2017) reviewed the range of the GHG intensity of geothermal power plants (Figure 2). The result was that geothermal power plants in Iceland had considerably lower GHG intensity as compared to geothermal counterparts globally, with a national weighted average of 34 gCO_2/kWh. Geothermal power plants in Turkey were reported to have the high GHG intensities ranging from 400-1300 gCO_2/kWh and thereby even surpassing the GHG intensity of fossil fuels.

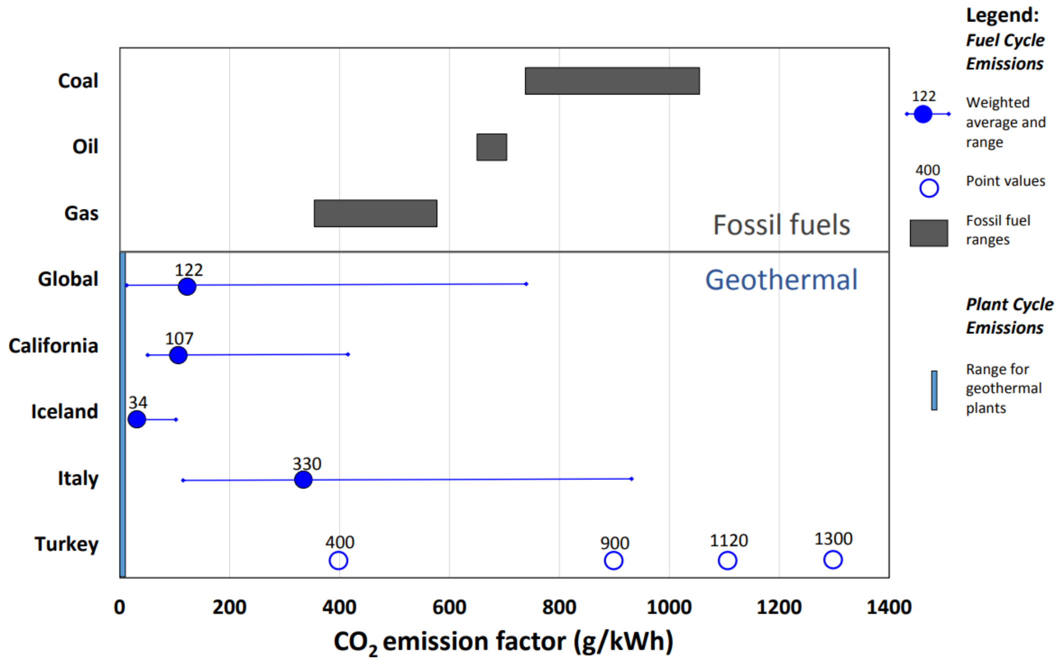

Figure 2. A range of GHG intensities from geothermal power plants (Fridriksson et al., 2017).

Iceland, who's government is one of the signatories of the Paris Agreement, is noted globally for its 99.9% use of renewable energy in national energy production and 90% of its primary energy coming from renewable sources (Orkustofnun, 2021b). Icelandic electricity is almost entirely produced from hydropower and geothermal energy. In 2020, hydropower contributed 69% of Icelandic electricity and geothermal power 31% (Orkustofnun, 2022b). In Iceland, while most geothermal plants see a low carbon intensity, they are still a significant source of emissions in the national context. In 2019 geothermal contributed to 10% of Iceland's energy sector (Orkustofnun, 2021a).

In 2020, Iceland published its climate action plan where relevant actions were identified to meet Iceland's goal of 40% reduced GHG emissions in 2030 compared to 2005 and carbon neutrality by 2040 (Ministry for the Environment and Natural Resources, 2020). In this action plan, the estimated reduction of emissions from geothermal power plants is 67% in 2030.

Reykjavik Energy (OR) is Iceland's largest geothermal energy producer. OR's electricity production from its geothermal power plants accounted for 60% of the total geothermal electricity generation in Iceland in 2020 (Orkustofnun, 2022b) and thermal production for space heating accounted for almost 60% of total heat production in Iceland (Orkustofnun, 2022a). OR's own energy use is 99% with renewable energy. OR spans across multiple utility industries and is the parent-company of four subsidiaries: ON Power (energy (electricity and hot water) generation), Veitur Utilities (utilities and distribution of cold and hot water and sewerage), Reykjavik's Fibre Network (fibre-optic network services), and Carbfix (carbon capture and storage, CCS). Collectively, the OR group provides services across southwest Iceland, including the capital area og Reykjavik, where more than two thirds of the country's population live. ON Power is the second largest producer of renewable power in the country and the largest producer of geothermal power, operating two combined heat and power (CHP) power plants with a combined 423 MWe and 500 MWth. These geothermal power plants supply most of the hot water for space heating to the capital area of Reykjavik and supply electricity nationwide.

More than a decade ago, OR's board of directors presented an ambitious environmental and resource policy (Reykjavik Energy, 2022a). In 2016 the board displayed climate goals, and since 2020, the vision of the company has called for the achievement of carbon neutrality by 2030. In achieving this, paired with on-site carbon sequestration, OR aims to become a carbon negative company.

To achieve this lofty goal, the company's climate goals were structured in accordance with the GHG Protocol (WBCSD & WRI, 2001) and the Science Based Target Initiative (Science based targets, 2021). Within the system boundaries of OR's GHG accounts are its geothermal power plants, vehicle fleet, waste generation, staff commuting, business flights by staff, and construction work done by contractors. Within each emission generating category, a goal was set with the most ambitious one being the 95% reduction of geothermal power plant emissions, which account for more than 95% of OR's total GHG emissions (Reykjavik Energy, 2022a).

Carbon emissions per unit of electricity and hot water at OR's power plants have decreased since 2016, estimated to be 7.4 g of CO_2 equivalents per kWh in 2021 (Reykjavik Energy, 2022a). With projected carbon capture and storage measures, this intensity figure will fall below 1 gCO_2 eq./kWh. OR's decarbonization goes far beyond the calls of Science-Based Target initiative for the power sector to have a carbon intensity of ~150 g CO_2eq./kWh by 2030. By doing so, OR hopes to act as a leader, providing a framework for other energy companies which can aim to achieve similar carbon negativity once they have decarbonized a large amount of their power production-based emissions (SBTi 2020).

Reykjavik Energy (OR) has a significant role in providing essential services to Icelandic society as the country's largest geothermal energy producer. Therefore, it is worth investigation into how a company producing renewable energy with low GHG emissions compared to other energy sources and a company with varied operations can achieve deep decarbonization.

This work achieves this task by first describing OR's GHG accounting methods, target setting, and the means of establishing OR's aggressive decarbonization target (Section 2) and describes the results of this work (Section 3), both in terms of target setting as well as actual performance the past years, since the goal was set in 2016. The results also describe how OR works to manage GHG operationally. Lastly, the results of OR's deep decarbonization work are brought into perspective in the discussion (Section 4) to illustrate how this work can help support decarbonization visions for other energy and utility companies. Section 5 concludes.

2. METHODS

A first step in the process of climate action was to determine the system boundaries of Reykjavik Energy's (OR's) carbon accounting and therefore identify the relevant emissions categories to OR's operations. This was done using the operational approach methodology in accordance with the GHG Protocol - Corporate Accounting and Reporting Standard (WBCSD & WRI, 2001). The system boundaries include the emissions of all the GHG classes covered by the UNFCCC/Kyoto Protocol (United Nations, 2015).

A second step was to select a base year, where 2016 was selected, as this year is representative of OR's typical GHG profile and is a sufficient baseline for the GHG target to show forward-looking ambitions. Furthermore, the selection of 2016 as base year ensures continued relevance and alignment to GHG accounting best practices.

A third step was to develop ambitious but realistic near-term climate goals, and to define who holds the responsibility of receiving the goals. This is a key issue in the plan to achieve carbon neutrality. OR developed climate goals for each of its emission categories, goals suitable across the OR Group. These goals were determined based on dialogue with key managerial roles in those operations affecting emissions. The target-year of the goals is 2030 when carbon neutrality shall be achieved according to (Reykjavik Energy, 2022a). Finally, to be able to approach decarbonization in an organized way, it was decided to monitor the climate goals on an annual basis. Each goal is monitored specifically, and the overall decarbonization performance monitored with an indicator which summarizes the goals. Yearly or near-term goals and monitoring can be instrumental for identifying inefficiencies and opportunities for emission reductions along the way and gives an opportunity for managers and boards to verify them and improve them.

3. RESULTS

The overall climate goal of Reykjavik Energy (OR) is, as stated above, to achieve carbon neutrality by 2030, and in doing so by sequestering more than the company emits, become carbon negative. The GHG emission identified within OR's system boundaries include the following categories: power plant emissions, emissions from vehicle fleet, waste, commuting of staff, business flights and construction work. Figure 3 shows the relative emissions for each of these categories for the latest reporting year 2021. Power plant emissions from heat and electricity production evidently comprise more than 95% of OR Group's emissions.

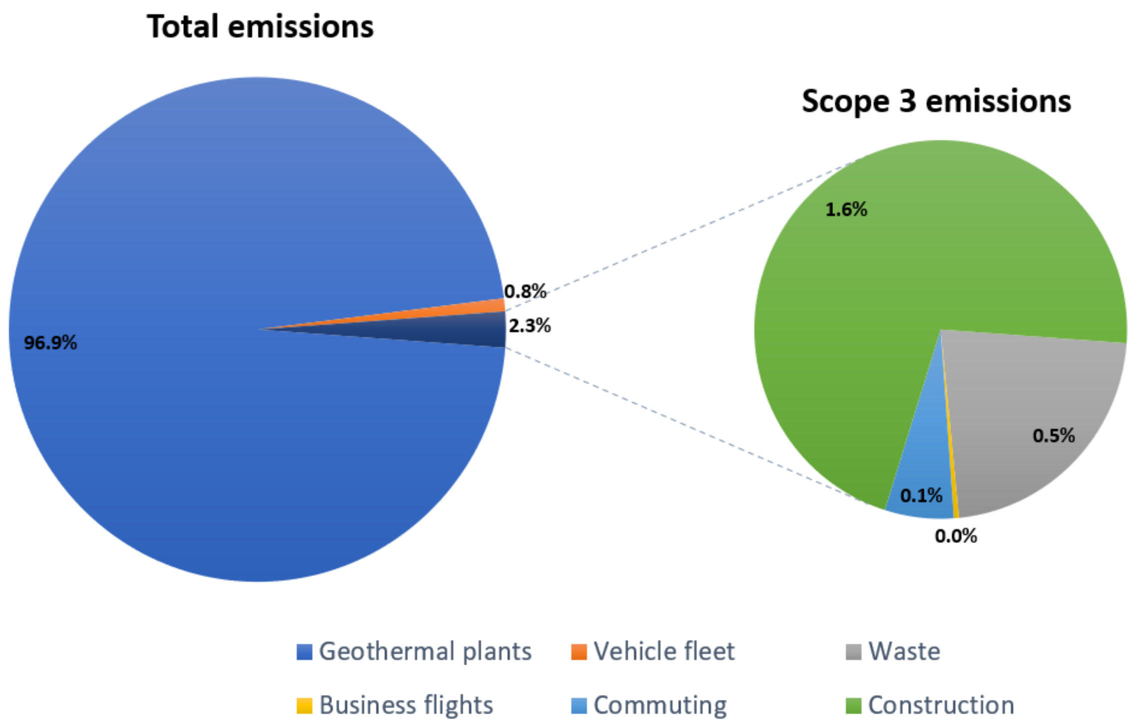

Figure 3. Emissions breakdown for the latest reporting year 2021. The figure above presents the overall emissions broken down into geothermal power plants and vehicle fleet (scope 1), and scope 3 broken down into waste, business flights, commuting and construction.

Going into more detail, **Fehler! Ungültiger Eigenverweis auf Textmarke.** displays the GHG emissions in each of the abovementioned categories for the base year, 2016, the latest reporting year, 2021, and in the target year 2030. Furthermore, Table 1 displays the scopes for each category and their relative contribution to OR's carbon footprint in 2016, 2021 and 2030.

Table 1. GHG emissions in each of OR's emission category during base year, 2016, latest reporting year, 2021 and estimated emissions in target year, 2030.

Emission category	Base year, 2016		Latest reporting year, 2021		Target year, 2030	
	Emissions (tonnes CO_2-eq)	Relative emissions (%)	Emissions (tonnes CO_2-eq)	Relative emissions (%)	Emissions (tonnes CO_2-eq)	Relative emissions (%)
Scope 1	46,000		47,500	-		
Geothermal power plants	45,700	96.5	44,100	96.9%	2,900	79.7%
Vehicle fleet	540	1.1%	400	0.8%	50	1.4%
Scope 2*	0	-	0	-	0	-
N/A			-	-		
Scope 3	1120		1122	-	330	
Waste	300	0.6%	250	0.5%	90	2.5%
Business flights	60	0.1%	5	0.0%	50	1.4%
Commuting of staff	110	0.2%	67	0.1%	30	0.8%
Construction work	650	1.4%	800	1.6%	520	14.3%

* Scope 2, or indirect emissions due to usage of electricity and hot water in the OR Group's core operations, is not applicable since the Group produces electricity for the national grid and emissions from that production are already accounted for in scope 1.

Along with OR's overarching goal to reach carbon neutrality and if possible, carbon negativity by 2030, several climate sub-goals are monitored, whose purpose is to realize the overall climate goal. Table 2 shows OR's emission categories and their respective primary reduction activities. The primary actions are the actions which have the greatest mitigation potential for that category. OR will mainly use the Carbfix carbon capture and storage (CCS) technology to counteract the direct emissions from the geothermal power plants by 95% in 2030 compared to base year of 2016. Vehicle fleet emissions comprise around 1% of OR's emissions and through the electrification of the company's vehicle fleet (or other clean vehicle technologies) OR aims to decrease these emissions by 90% by 2030. For scope 3, OR has set indirect climate goals which aim to reduce emissions by 36% from 2016 to 2030. Construction work comprises less than 2% of the group's emissions. Use of environmental criteria in purchases, in selecting suppliers and contractors will help counteract these emissions by 20% from 2016 to 2030. Waste, business flights and commuting of staff comprise less than 1% of the group's emissions. Increased sorting of waste, reduced food waste from the group's canteen, increased biodegradable waste use could reduce emissions by 10% from 2016 to 2030. Setting of criteria for application of business flights aim to reduce emissions by 10% from 2016 to 2030 and subsidies for ecofriendly commuting and increased working from home have the goal of reducing these emissions by 70% in the period.

Table 2. OR's emission categories and their respective emission reduction activities.

Target	Scope	Primary actions
Geothermal Power plants	Scope 1	Carbfix carbon capture and sequestration
Vehicle fleet	Scope 1	Energy transition of the fleet
Waste	Scope 3	Decrease waste, increase sorting and recycling rate
Commuting	Scope 3	Support commuting using sustainable transport and support for remote working
Construction	Scope 3	environmental criteria in purchases, support usage of sustainable energy sources in machinery and equipment
Business flights	Scope 3	Setting of quota on number of flights

OR's actual performance in carbon reduction from the base year 2016 to the last reporting year 2021 are shown in Figure 4, along with the forecasted performance from 2022 to the target year 2030. All goals except for geothermal power plant emission reductions aim to reduce emissions linearly. However, the geothermal power plant emissions will be reduced in a stepwise manner, with the largest step occurring in 2025 when the CCS plant Silverston at Hellisheidi will be fully commissioned with the aim of near-zero carbon footprint of energy production at the power plant (Reference). A second large step should occur in the target year 2030, when a similar CCS plant for Nesjavellir geothermal power plant will be commissioned. As shown in Figure 4, from 2018 to 2020, emissions from Hellisheiði geothermal power plant increased due to increased energy production at the plant High concentration of carbon dioxide in powerful boreholes further added to the emissions along with the CCS unit at the power plant had to be adjourned for a prolonged period, due to unforeseen malfunctions.

Finally, offsets/mitigation measures will be applied to achieve carbon negativity in 2030 (Figure 4). These measures are separately accounted for as they are used to compensate for GHG emissions on OR's green fields and elsewhere (WBCSD & WRI, 2001) . Examples of such offset measures include land reclamation on OR's land, wetland reclamation on land not owned by OR (UNFCCC, 2022a) as well as the purchase of UN Certified Emission Reductions (CER's) (UNFCCC, 2022b).

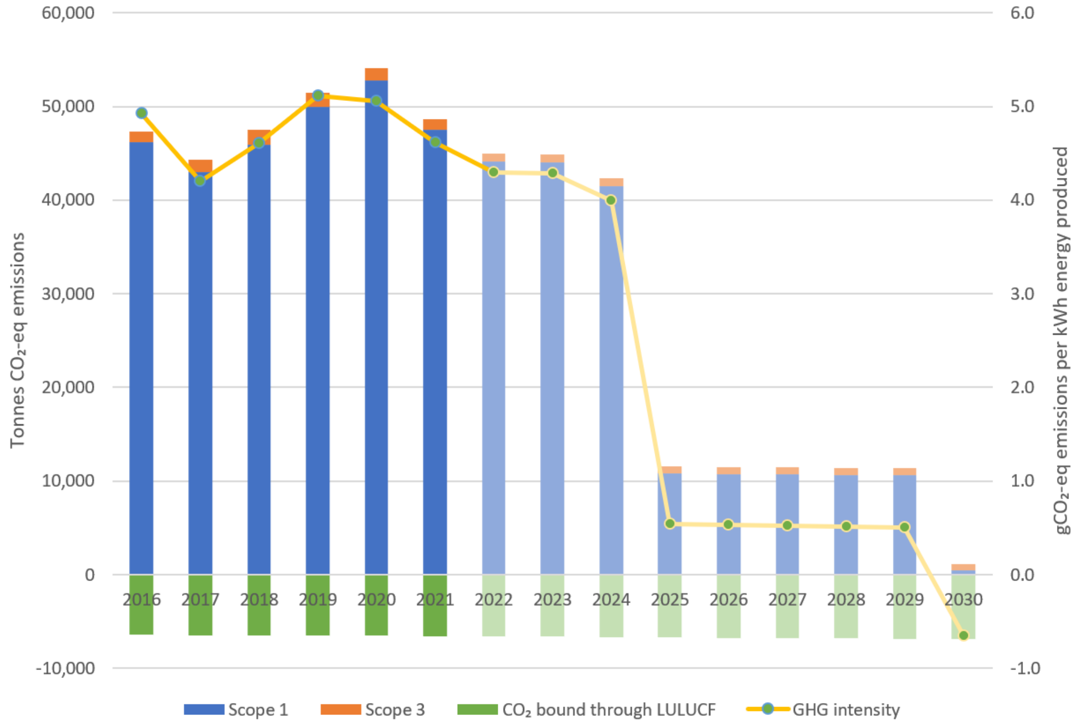

Figure 4: The actual performance in carbon reduction of Reykjavik Energy (OR) for direct (Scope 1) and indirect (Scope 3) emissions from the base year 2016 to the latest reporting year 2021, along with the forecasted performance from 2022 to the target year 2030.

Reykjavik Energy (OR) has recently developed an internal dashboard that measures the status of climate goals in real-time. This provides an overview of OR's past climate performance as well as its goals to the target year 2030. Additionally, the dashboard presents real time information on emissions which gives OR's managers and employees an opportunity to counteract deviations from climate goals. Figure 5 displays this dashboard. Where it states, "through approximately 50% of the particular year, OR's GHG emissions are 45% of the total overall target for the year", this means that the measured emissions are below the goal for that period into the year. However, the "60% of the annual target for the emissions of fossil fuel have been reached" goal illustrates the case where more emissions have occurred than expected and therefore marked with red warning color to show the danger of the goal potentially not being met.

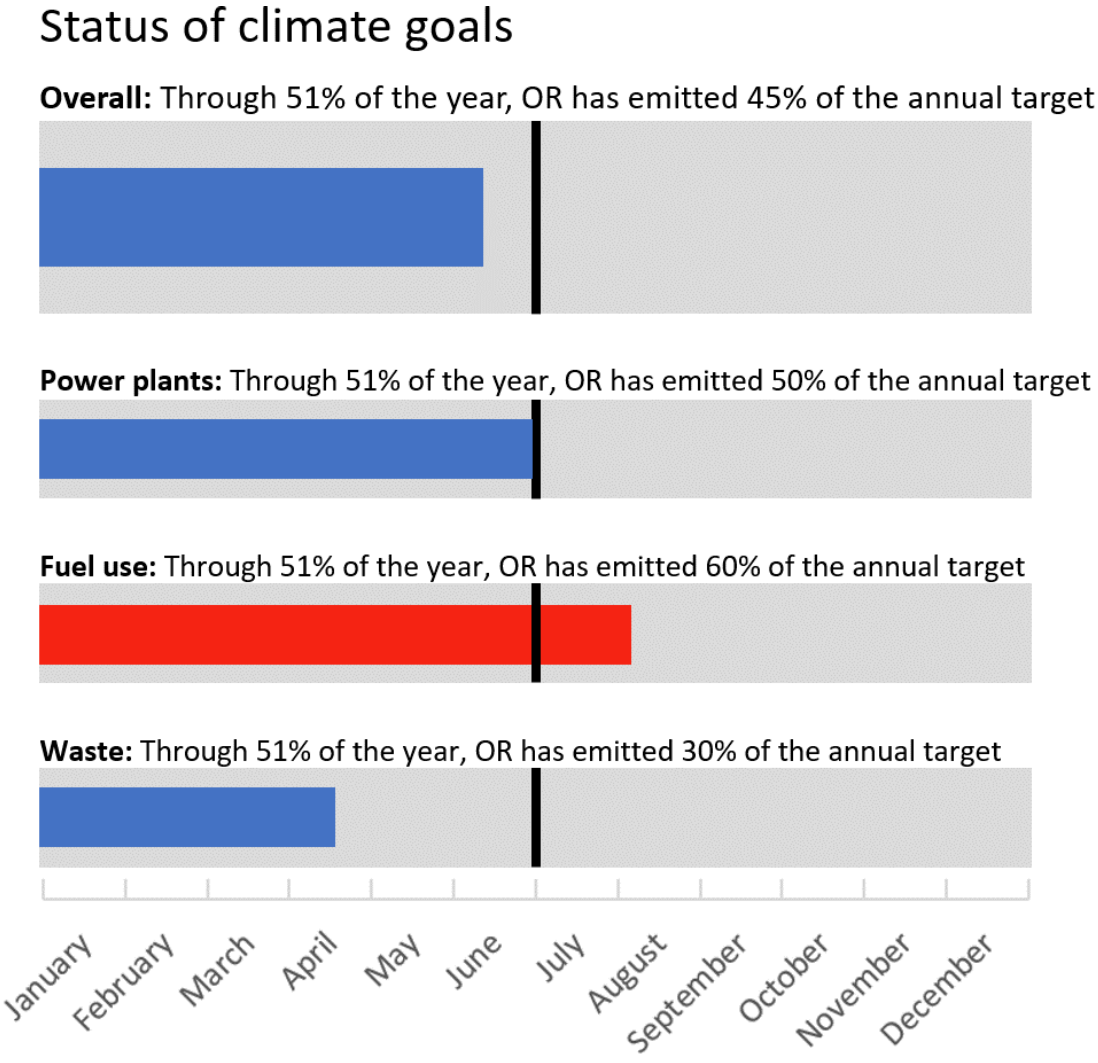

Figure 5: The example of a real time carbon footprint dashboard through approximately 50% of the year, OR's GHG emissions are 45% of the overall target for the year. 50% of the annual target for emissions from geothermal power plants has been reached as expected. 60% of the annual target for the emission of fossil fuel has been reached which is more emissions than expected and 30% of the annual target for waste which is less emissions than expected. The emission categories are coming closer to the end-of-year goal than expected apart from the goal for waste.

4. DISCUSSION

With the global energy industry's vital role in the climate crisis, Reykjavik Energy (OR) recognizes the importance of achieving carbon neutrality and even carbon negativity as soon as possible - even though OR's geothermal power plants emit only a fraction of the GHGs as compared to fossil-fuel power plants of comparable size (Fridriksson et al., 2017). Therefore, it is worth considering why a company that produces green energy with such a low carbon intensity, is considering reducing its emissions even further.

Ambitious and sincere goals of performing better than required by laws and regulations has proven to pay off both environmentally and economically for OR. An example of this is the young innovation company Carbfix, a subsidiary of OR, founded in 2019. In 2007 i.e., 15 years ago, OR and an academia consortium laid the foundation of industrial scale gas capture and storage at Hellisheidi geothermal power plant in Iceland (Gislason et al., 2018). The challenges in these projects fostered cooperation between scientists, engineers, tradesmen and -women, and workers. OR's managers continued to fund this project, even in the middle of the economic crisis in 2009. Now OR is working on the Silverstone project (Reykjavik Energy, 2022b), which aims at near-zero energy production at the Hellisheidi power plant by 2025. Furthermore, OR is working on a pilot project at Nesjavellir geothermal power plant which aims at near-zero energy production by 2030 (Reykjavik Energy, 2022a). The Carbfix CCS technology has been developed further with plans to inject CO_2 from external sources (Carbfix, 2022), thereby acting as a lighthouse project along with other CCS projects (Ringrose, 2020). As an example of this, Carbfix, subsidiary of OR, has started a project called CODA Terminal, which will be a cross-border carbon transport and storage hub in Iceland, starting in 2025 and slated to be completed 2030 (Carbfix, 2022). The CODA Terminal will receive and permanently mineralize CO_2 captured at industrial sites in Northern Europe, which is then shipped to the Terminal, injected into basaltic bedrock and transformed into solid minerals in less than two years. This expansion of a research and development project funded to address OR's climate goals illustrates the benefits of investing in technologies aligned with a net-zero future.

With OR's already low-carbon energy production and the ability of the Carbfix CCS technology to sequester virtually all the plant's emissions in the future, the question is then how OR can decarbonize the remaining hard-to-decarbonize sources of emissions such as the company's vehicle fleet, commuting of staff, business flights, fuel use of contractors, and waste. To serve society, OR must still bring its employees to work, lay pipes, and provide electricity and hot water for space heating and lighting up new homes, and thus these emissions are hard to decrease as these activities still need to happen. With visions for a net-zero future however, it is here where OR has also worked to decrease emissions and why OR has set targets and emission reduction strategies for these categories as well.

For example, transport emissions from OR's vehicle fleet currently account for around 1% of OR's overall emissions (Scope 1). However, once CCS technologies have been scaled up at OR's geothermal power plants, this percentage will increase as shown in Table 1. Therefore, OR plans to electrify the company's vehicle fleet almost entirely by 2030. Further, OR has been supporting the electrification of transport in all of Iceland by installing a network of electric charging stations within urban areas, as well as with a focus to connect rural municipalities, allowing for electric vehicles to travel between them. To address emissions from commuting, OR has established both a remote work policy, as well as offers its employees a stipend if they use active or public transport modes to travel to work. For business flights, OR has worked to build a stronger culture surrounding the "need" to take business flights. When approving flights, managers are also informed about the carbon emissions of the requested flight. For waste, OR has established a continuous improvement plan with the goal of having no unorganized waste, where all waste would be organized into appropriate recycling categories to support a more circular economy. Lastly, for contractors, this is a particularly difficult category to decarbonize due to lack of operational control, but also lack of electrification of heavy machinery. However, OR still plans to address these emissions by use of environmental criteria in purchases, when selecting suppliers and contractors. An important tool to monitor and provides an overview of OR's climate performance is to establish an internal dashboard that measures the status of climate goals and emissions in real-time. This additionally gives OR's managers and employees an opportunity to counteract deviations from climate goals instantaneously.

Recognizing these persisting emission sources and the challenges of being net-zero first mover in a global carbon-fueled economy, to achieve OR's net-zero negative goal, OR additionally works to sequester ever more emissions on the company's owned land. OR has in place a funded effort to reforest its lands, a notoriously difficult task in Iceland where forest cover is nationally only ~2% due to soil erosion, historical deforestation, and difficult climate conditions (Mattsson & Grossnickle, 2016). Currently, OR has restored and reforested 1,300 hectares of land and plans to increase this to 1,500 hectares by 2030. With an estimated 4.4 tCO_2 sequestered per hectare for such Icelandic forests (Owona, 2019) and 2.75 tCO_2 sequestered per hectare with soil reclamation (Hallsdóttir et al., 2008), by 2030 this would represent 6,900 tonnes of CO_2 sequestered, helping OR achieve its climate neutral and or net-zero negative goals.

While Reykjavik Energy (OR) has taken as rigorous and scientific an approach as possible in establishing its net-zero negative carbon vision, there are limitations to this methodology. OR is aware of the challenges in setting the Scope 3 goals in respect to up-stream and down-stream procurement in wide respect. Other companies are struggling with this field as well (Sroufe & Watts, 2022). The Scope 3 goals, however, will help OR's managers and employees to better understand whether current business models are compatible with a low-carbon future. For example, embedded emissions from purchases are not included in the current calculations, though this is largely due to the nascent state of the global marketplaces in terms of providing this data (Sönnichsen & Clement, 2020). Future research and policy objectives should ensure that companies can provide this, and OR is working to incorporate environmental criteria into purchasing decisions.

This paper additionally recognizes that not all companies operate in a context where the means of decarbonization, followed by OR, may be available or of use. For example, the suitability of the Carbfix technology in varying geological conditions is still being studied further. Additionally, electrifying a vehicle fleet in an area where the grid has a high carbon intensity may just displace emissions from Scope 1 to Scope 2, where the emissions would come from electricity use as opposed to direct combustion (Dillman et al., 2020). Therefore, this paper recognizes ORs place in the vanguard of deep decarbonization and thus these results help to illustrate how a highly decarbonized company, perhaps what hopefully much of Europe may look like in 10-20 years, can tackle its remaining persistent emissions. The challenges of doing so should hopefully decrease as the global economy decarbonizes and environmental information such as Environmental product declarations (EPDs) (EPD International, 2022) become more widely available (EPD International, 2022).

5. CONCLUSION

Reykjavik Energy's (OR's) vision for a carbon neutral future is firm and based on the experience of recent years, which has shown that there is a high return on investment for the time, scientific application, and money invested into environmental and climate initiatives. This work illustrates the potential to reduce net emissions by 2030, even in an already highly decarbonized context. This paper illustrated how through OR's use of the new and innovative Carbfix CCS technology and through the establishment of company-wide environmental and climate goals, the company aims to achieve its target of becoming carbon neutral, and even further, carbon negative by 2030 (Add Reference Annual Report 2021). Hopefully, this case study has illustrated how a net-zero negative future can be reached and can act as a lighthouse example for future energy companies achieving a similar state.

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