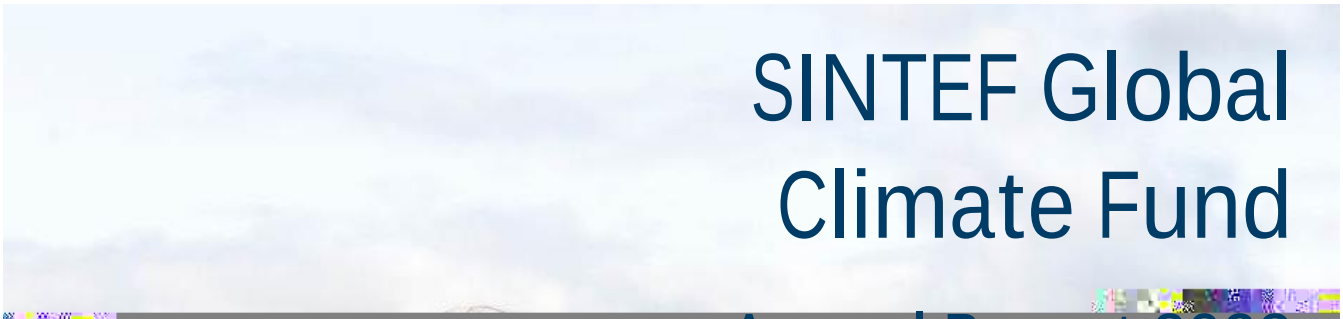
SINTEF

Global Climate Fund



# SINTEF Global Climate Fund

## Annual Report 2022

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# Global Climate Fund

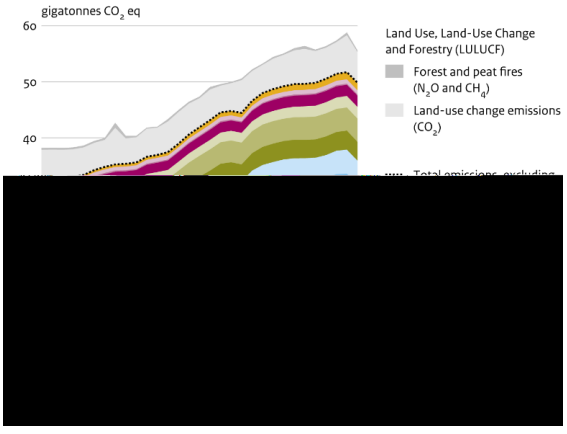
*SINTEF launched its Global Climate Fund in autumn 2021 during the COP26 in Glasgow. Five research projects financed by the fund were initiated at the same time. High levels of activity in 2022 have already generated many encouraging results.*

**The need for carbon removal**

Annual global greenhouse gas emissions are at approx. 50 $GtCO_2$ equivalents (or almost 60 $GtCO_2e$, if we include those linked to deforestation and land use changes). The world is aiming to cut these emissions by 50% by 2030, and to achieve net zero by 2050. Even though the IPCC[1] has stated that emissions reductions and avoidance are the main mechanisms for achieving net zero, carbon dioxide removal (CDR[2]) is presented increasingly as one of the keys to limiting global warming. It is vital to point out here that carbon capture technologies must not confer a 'licence to pollute' or distract our focus from emissions reductions. Nevertheless, we have to acknowledge that reductions alone will not be sufficient to achieve our targets. Carbon removal offers three key benefits:

- It reduces emissions rapidly in the short term
- It neutralises residual emissions from certain sectors (aviation, shipping, agriculture and industrial processes) in the medium term.
- It contributes towards achieving net negative emissions in the long term by removing both residual and historical emissions.

Global greenhouse gas emissions, per type of gas and source, including LULUCF




*Source: PBL Netherlands Environmental Assessment Agency*

CDR is thus essential if we are to avoid a global temperature increase exceeding 1.5 °C.

## The aim of the SINTEF Global Climate Fund is to identify new CDR solutions that can be scaled and commercialised.

A number of reports on CDR have been published in 2022 containing calculations of the volumes of $CO_2$ that have to be removed. They offer a wide range of estimates, but one thing is certain – the more time it takes to achieve emissions reductions, the greater will be the need for CDR.

In its sixth assessment report (in the subsidiary report addressing climate change adaptation), the IPCC calculates that in order to counteract remaining residual emissions, all scenarios that limit global warming to 1.5 and 2 °C will require major and immediate emissions reductions in all sectors, changes in demand patterns and the use of CDR systems.

There is a significant gap between the volumes of carbon currently being removed and those that must be removed if we are to achieve the 2030 and 2050 targets. According to the SSEE report 'The State of Carbon Dioxide Removal', published in January 2023, the annual total volume of global CDR is approx. 2 $GtCO_2$. Ninety-nine per cent of this is derived from conventional carbon uptake mechanisms in natural terrestrial settings, and only 0.1% (2 million tonnes) from the use of new technologies such as BECCS[3], DACCS[4] and biochar. The report presents calculations showing that if we are to avoid a temperature increase in excess of 2 °C, a further 0.96 $GtCO_2$ must be removed annually in the years leading up to 2030, and 4.8 $GtCO_2$ annually approaching 2050. The IPCC estimates that between 5 and 10 $GtCO_2$ must be removed annually by 2050 using all available methods. In the context of current Norwegian emissions figures and targets, this is equivalent to about between 1$MtCO_2$ and 5 to 10$MtCO_2$ annually by 2050. The report concludes that new technologies will have to be upscaled by a factor of 30 by 2030 and by 1,300 by 2050, compared with 2020.

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# Global Climate Fund

## The CDR portfolio

CDR methods are usually subdivided into nature-based and technology-based approaches, although combinations are also possible. Both approaches have their strengths and weaknesses, so development is needed across a broad range of methods. Permanence (durability of $CO_2$ storage) and reversion (the risk that $CO_2$ will escape back into the atmosphere) are topical areas of discussion in this context. Nature-based solutions may have positive impacts on the natural world and biodiversity, but CDR and storage using soil and natural vegetation are easily reversed by human activity or events such as wildfires, making storage durations shorter. Technology-based solutions, such as the use of offshore subsurface reservoirs, are generally more secure, promoting longer-term storage outcomes and a lower risk of reversion.

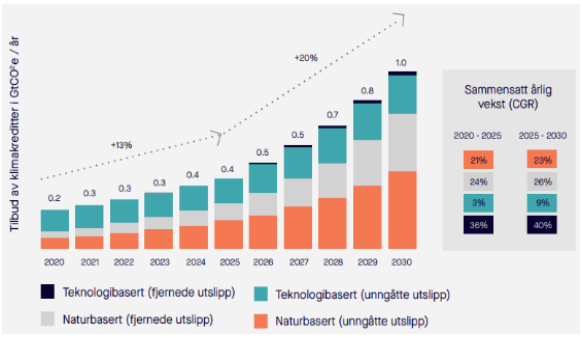
Currently, by far the largest volumes of CDR are achieved using nature-based, biological storage mechanisms that are less permanent. There is thus a major need for more permanent solutions. No single solution or technology is able to meet our CDR requirements alone, hence the need of a portfolio of CDR approaches.

The CDR industry is in its infancy and many projects will be the first of their kind, with all the inherent risks that this entails. The industry will thus require massive levels of future investment. An additional barrier to development is that there currently exist no quota or certificate-based systems recognised under the Paris Agreement or the EU Emissions Trading System (ETS). While we wait for such systems to be established, the CDR business model is currently linked either to a voluntary quota market or philanthropic investment.

The Climate Fund's project portfolio involves research into both nature-based and technological approaches. The fund intends that research shall be focused on a broad range of solutions.

## Net zero

More and more companies are adopting targets linked to the Norwegian national targets of a 55% reduction in emissions by 2030 and net zero emissions by 2050. In order to achieve these targets, many are making use of carbon credits purchased on the rapidly developing voluntary carbon market, for which massive growth is predicted. However, the market is currently characterised by a high proportion of low-quality credits and only very limited access to credits derived from CDR. According to a report published by PWC and Zero (a Norwegian not-for-profit environmental foundation), only 2.3% of the credits currently in circulation are linked to CDR. Credits linked to technology-based solutions are in particularly short supply. We also lack a universal system for calculating accurately the impact of the levels of CDR that the various projects are claiming to achieve.




*Source: PWC and Zero (2022). Taken from Shell and BCG (2021).*

A company may not use its contributions to the Climate Fund to 'reduce' its own emissions in an accounting system, or as a basis for claiming carbon neutrality. Nevertheless, SINTEF believes that a contribution to the fund will have a greater impact on climate change mitigation than the purchase of voluntary credits that claim to represent emissions avoided or reduced.

The Fund is financing early-stage research due to limited available funding in this field and a major need to develop new solutions. In cases where a project succeeds in identifying effective solutions, the issuance of CDR credits will become a possibility in the future. This is a field undergoing massive development.

At the end of 2022, the EU Commission presented a proposal for CDR certification as part of a system based on monitoring, reporting and verification. It will require science-based calculations of the volumes of carbon removed over stipulated periods of time, and of the sustainability of the methods used. A universal CDR certification system will make it more attractive to companies with residual emissions to invest in CDR credits.

The Climate Fund has been awarded the highest (Dark Green) rating issued by the independent CICERO 'Shades of Green' system, which assesses an organisation's levels of environmental financing and governance. Read the CICERO report here.

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# Global Climate Fund

## The CDR projects

At its launch in 2021, the Climate Fund advertised for 'climate-positive' research concepts, and in 2022, the following five projects were awarded funding on the basis of offering the greatest potential;

- 'Seaweed CDR' is looking into the potential for CDR linked to seaweed cultivation. The project is focusing on various storage methods.
- 'BiOxyChar' is investigating how biogenic waste can be converted into climate-positive energy and biochar.
- 'C&H2AR' is looking into methods by which biocarbon and hydrogen can contribute to climate-positive metals production.
- 'Algae4Clay' is investigating the use of biochar in the stabilisation of quick clay deposits achieved by carbon storage. The project is also addressing the risks involved to wider society.
- 'eCDR' is looking into the removal of the potent greenhouse gases methane and nitrous oxide.

All the projects were launched in the summer and autumn of 2021. 2022 has thus been the first full year of research activity. More information is provided in the project summaries that make up the remainder of this report.

Each project has its own steering committee, which reports on a quarterly basis.

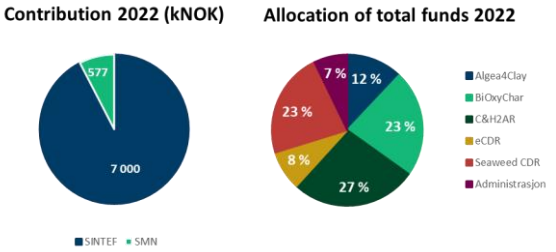
A Climate Fund technical committee conducts an annual review of progress and results and determines whether the projects are qualified for further funding. A review conducted in the second half of 2022 concluded that all the projects were making satisfactory progress and generating promising results. Funding will thus continue into 2023.

During 2022, the projects generated a number of positive outcomes in addition to their research results. For more information, we refer to the individual project summaries:

- External funding for further research via both the EU Horizon Europe and the Research Council of Norway's Green Platform programmes, amounting to approx. MNOK 60.
- Initiation of a Joint Industry Project with funding from several external industry partners to support a budget of MNOK 42.
- Scientific publications
- Media coverage
- Dissemination of the Climate Fund and the topic of 'carbon removal' at COP26, COP27, the Arendal Political and Business Forum, and the Zero Conference.

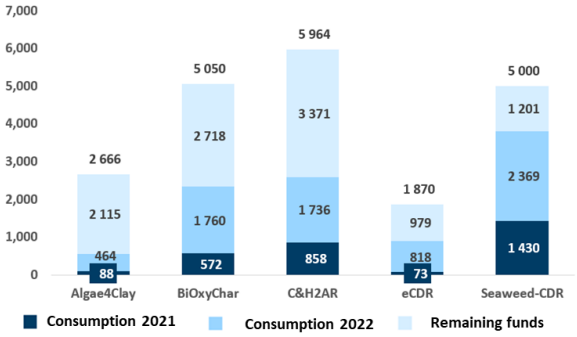
## Finances and administration

In 2022, the fund received contributions from both SINTEF and the bank '*Sparebank 1 SMN*'. At the end of 2022, all the projects had received one third of their total funding for the entire project period. For a number of different reasons, progress in individual projects may deviate from the proportion of funds received. We refer to the individual project summaries for details.




The aim of the fund is that it shall continue to grow and finance even more projects looking into new CDR solutions.

The graph below shows consumption of funds and budget figures for the entire project period based on the contributions from SINTEF (MNOK 21 over three years) and the bank (SMN).




**Notes:**

1. IPCC: Intergovernmental Panel on Climate Change
2. CDR: Carbon Dioxide Removal
3. BECCS: Bioenergy with Carbon Capture and Storage
4. DACCS: Direct Air Carbon Capture and Storage

**Sources:** IPCC Sixth Assessment Report, Mitigation of Climate Change, Summary for Policymakers; the SSEE report 'The State of Carbon Dioxide Removal'; The Zero Foundation report '*$CO_2$-fjerning – Løsningen som tar oss til null*' (CDR, the solution that get us to zero).

**For further information, visit:** sintefclimatefund.org

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# Seaweed CDR

*This project is looking into growth and carbon uptake in cultivated seaweeds from which large volumes of carbon can be harvested and stored as CDR products. We are also measuring how much of each plant dissociates as fragments during a growing season. We run cultivation experiments using sugar wrack on the island of Hitra and are using the results to quantify the CDR effect in a separate seaweed model.*

**Objective:** To quantify CDR potential linked to seaweed cultivation
**Project Manager:** Jorunn Skjermo, SINTEF Ocean
**Duration:** 1 June 2021 – 31 May 2024
**CDR methods:** Nature- and technology-based
**Potential:** 20,000 tonnes of seaweed per $km^2$ have an annual uptake of between 2,500 and 3,000 tonnes of $CO_2$. The total annual potential under ideal marine conditions is 3 million tonnes $CO_2$ per 1,000 $km^2$.

**Summary of activities (Q1 – Q4, 2022)**

We conduct seaweed cultivation studies in a facility on the island of Hitra in Trøndelag, laboratory experiments at SINTEF's Sealab, and simulations using our mathematical seaweed model. The cultivation facility is used to study seaweed growth and carbon uptake. In winter, we plant out minute seaweed cuttings, and take samples in the spring and summer up until the time when the plants are mature for harvesting.

Since, during the growing season, the plants dissociate naturally into fragments of different sizes, we have conducted lab tests to measure their sinking velocity. We need to know this so that we can simulate where on the seabed the particles are deposited, and to what extent this 'passive' fraction can be incorporated as stored carbon.

The greatest CDR potential lies in the harvestable biomass, and we are now planning how to carry out an experiment involving the 'active' sinking of a large volume of seaweed to great depths with limited water exchange in order to see how the impacts on the environment within the sediments can be measured. This is a challenging task, and it is important to be clear about exactly what can be accomplished in the field and what must be simulated using the model.

**Results**

We have now started our second cultivation season. Experimental data related to seaweed growth, erosion, sinking velocity and environmental variables are now being applied in the model to quantify how much carbon a seaweed facility can capture, and how much of this carbon can actually be incorporated into passive and active seaweed storage solutions.

**The next stage**

- Seaweed deposition experiments.

**Spin-off projects/other outcomes/dissemination**

- 'Seaweed Carbon Solution' is a so-called Joint Industry Project (JIP) launched in April with funding from DNV, Equinor and Aker BP. It will install and test modules designed to capture 100 tonnes of $CO_2$ annually along the Trøndelag coast, with major upscaling in the following year involving storage solutions such as biocoal and dumping. Several industry partners are joining the project, which has a budget of NOK 42 million over the period 2022–2025.
- The project was presented at COP26 by the Climate Fund, at the UN Global Compact 'Blue Road to COP26' (Seaweed as a Nature-Based Climate Solution), and at COP27.
- It was presented at NTNU's Energy Transition Week, accompanied by a policy brief.
- A new project: 'GP Seaweed – new products from cultivated seaweed for blue-green value-chains' has been launched as part of the RCN's Green Platform programme with a budget of NKOK 50 million extending from 2023 to 2025.

**Finances**

| | In the period 01.01.22 – 31.12.22 | To date: 01.06.21 – 31.12.22 |
|---|---|---|
| Budgeted | kNOK 2,290 | kNOK 3,720 |
| Expended | kNOK 2,369 | kNOK 3,799 |

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# BiOxyChar

*Work during 2022 has involved the scaling and simulation of a facility based on the project concept, as well as experimental work linked to the characterisation of biochar produced in a $CO_2$ atmosphere.*

**Objective:** To develop an integrated concept for converting renewable bioproducts into climate-positive energy and biochar, while at the same time removing $CO_2$ from the atmosphere using both Bio-CCS and biochar.

**Project Manager:** Elisa Magnanelli, SINTEF Energy Research

**Duration:** 9 June 2021 – 30 June 2024

**CDR methods:** Nature- and technology-based

**Potential:** Preliminary calculations indicate that a concept-based facility will be able to store approx. 8 $tCO_2$ per day. Sufficient residual biomass will be available for about 1,000 facilities of this type in Norway, which will be able to absorb about 7% of the country's annual $CO_2$ emissions.

### Summary of activities (Q1 – Q4, 2022)

A workshop with external actors was held to discuss what unexploited resources might be available in Norway for use in the project. The market potential of biochar and barriers to its use were also discussed. Specific technological solutions have been selected for the various principal aspects of the integrated concept. A gas turbine similar to that selected is currently installed in SINTEF's laboratories, and can be used for experiments, as required. A concept model has been developed in the simulation software Aspen Plus, incorporating the main concept components (pyrolysis, oxyfuel combustion and the gas turbine). Biochar has been produced under both $N_2$ and $CO_2$ atmospheres, sourced from Norwegian forestry waste. Properties relevant for agricultural applications have been analysed in detail.

### Results

The process model showed that a facility based on the BiOxyChar concept can utilise about 5 tonnes of residual biomass per day and convert it into 1.3 tonnes of biochar and about 1.5 MWt of electricity. Biochar storage and Bio-CCS will together achieve a little in excess of 8 $tCO_2$ stored each day. Surplus heat will also be produced from the process, although amounts have not been estimated to date. Experiments involving pyrolysis in a $CO_2$ atmosphere have demonstrated that the presence of $CO_2$ results in a much higher yield of biochar with enhanced properties. The gas products of $CO_2$ pyrolysis also exhibit a higher energy content.

### The next stage

- Experimental characterisation of the pyrolysis oil/gas as a basis for further improvement of the model.
- A literature study of kinetic combustion mechanisms for pyrolysis condensate as a basis for implementation of the open-source tools suite Cantera.
- Development of an experimental pyrolysis rig, combined with oxycombustion of the pyrolysis oil/gas.

### Spin-off projects/other outcomes/dissemination

- A workshop with external actors who may develop into relevant stakeholders.

### Finances

Budget progression is in step with the progress of the activity plan and results. A small part of the 2022 budget was moved to 2023 due to delays in the receipt of analytical results carried out by external laboratories. This constitutes less than 10% of the annual budget.

| | In the period<br>01.01 – 31.12. 2022 | To date:<br>09.06.21 – 31.12.22 |
|---|---|---|
| Budgeted | kNOK 1,800 | kNOK 2,810 |
| Expended | kNOK 1,760 | kNOK 2,337 |

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# C&H2AR

*The production of a variety of biocarbons, assessments of their properties, and the development of an integrated process for CCS in the metallurgy sector.*

**Objective:** To achieve a climate-positive solution for the metallurgy sector.

**Project Manager:** Roger Khalil, SINTEF Energy Research

**Duration:** 9 June 2021 – 09 June 2024

**CDR methods:** Technology-based

**Potential:** There is a limit to the amount of biomass resources available. We estimate a potential reduction in emissions of 1Mt $Co_2$/year if we replace manganese producer Eramet's consumption of fossil coke in Norway with biocoal. This potential will be much greater if we include the other Norwegian and global metallurgical industries.

### Summary of activities (Q1 – Q4, 2022)

Pyrolysis experiments with a variety of biomass types were carried out to produce biocarbons with different properties and qualities.

Case studies based on Norwegian Eramet facilities in Sauda and Kvinesdal have been used as the basis for CCS in combination with the use of sustainable carbon. We are now working to select appropriate carbon capture technologies – a process that entails the optimisation of process parameters that keep energy consumption to a minimum.

### Results

Many types of biocarbon have now been produced using pyrolysis. Their properties have been assessed and this will help us to understand which of these offers the greatest benefits during methane cracking. We are preparing an article based on these results.

$CO_2$ separation modelling from the aforementioned case studies has now been completed. Work will continue with CCS integration in the metallurgical industry. The technologies evaluated so far are based on carbon capture following combustion, using amines, membranes and the liquefaction of $CO_2$, 'pressure swing' adsorption with liquefaction, and oxycombustion. We have also started to prepare a scientific publication on this topic.

### The next stage

- The biocarbon produced to date shall be used as a methane cracking catalyst. The aim of this is to produce a stronger and less reactive biocarbon that can replace fossil coke in the metallurgy sector. Cracking methane in this way also produces hydrogen, which is a carbon-free energy carrier. These experiments will help us to identify the biocoal best suited to the process, and at the same time arrive at parameters most beneficial to the production of hydrogen and a stronger/less reactive biocarbon.
- We will assess the $CO_2$ reactivity of sterilised charcoal to see if the sustainable alternative is a realistic replacement for the fossil option.
- We shall complete development of an integrated carbon capture process for metallurgical processes and continue work to identify carbon capture synergies from a biocarbon production process. We shall then conduct techno-economic analyses of the process and make more detailed calculations of the potential of CDR from the atmosphere.

### Spin-off projects/other outcomes/dissemination

- Eramet has been informed of our results and is participating in meetings being held to disseminate our findings. The project is highly relevant to Eramet and has the potential to generate spin-off projects if it emerges that it is possible to replace coke with sustainably produced and upgraded biocarbon.

### Finances

The project is progressing as planned. One delivery has been delayed due to issues linked to an experimental methane cracking rig.

| | In the period 01.01 – 31.12. 2022 | To date: 09.06.21 – 31.12.22 |
|---|---|---|
| Budgeted | kNOK 3,240 | kNOK 4,098 |
| Expended | kNOK 1,736 | kNOK 2,594 |

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# Algae4Clay

*This project has a dual purpose; to investigate the use of marine biomass (macroalgae) to stabilize quick clay, and the extent to which stabilization structures can be turned into carbon sinks.*

**Objective:** To investigate the use of biochar in quick clay stabilization.

**Project Manager:** Kathrin Weber, SINTEF Energy Research

**Duration:** 1 June 2021 – 30 June 2023

**CDR methods:** Nature- and technology-based

**Potential:** Biochar from algae contains 40% carbon. If three Norwegian stabilization projects could replace even 10% of standard materials with biochar, this would result in between 2,000 and 10,000 tonnes of stored $CO_2$. The reduction in the use of standard materials would reduce emissions by 9%.

### Summary of activities (Q1 – Q4, 2022)

The project aims to produce biochar from algae for use in quick clay stabilization. In the first half of 2022, a series of pyrolysis experiments were carried out to produce biochar from seaweed. The chemical composition of the material was analysed to provide an estimate of its carbon storage potential. Biochar from seaweed and woody feedstocks has previously been used in direct mixtures with quick clay. Two options have been considered; (i) direct addition to quick clay and (ii) the mixing of biochar with lime-concrete in piles that are used in quick clay stabilization projects.

### Results

Biochar from seaweed contains a large proportion of ash (up to 70 wt.%) which reduces its carbon storage potential. Pre-washing with fresh water before drying and pyrolysis can significantly reduce the ash content. The direct addition of biochar to quick clay does not seem to have a significant effect on clay stability. Biochar has thus been mixed with concrete used for quick clay stabilization. Strength measurements were made after 7 and 28 days, and preliminary results show that biochar can indeed be added to a concrete without negative effects on stability.

### The next stage

- Biochar behaves quite differently from traditional concrete additives. Mixing and testing procedures will thus be adapted to ensure that the biochar functions effectively with the new material.
- Calculations will be made to reveal how much biochar must be used in concrete mixtures to achieve carbon-neutral stabilization.

### Spin-off projects/other outcomes/dissemination

- A contribution to the Nordic Biochar Network, including co-organization of an annual Biochar Summit, will be launched in June 2023. The summit (www.biochar-summit.eu) offers a dissemination channel to the biochar community.

### Finances

Progress has been slower than originally planned due to a lack of resources. Some workstreams have been moved to 2023.

| | In the period<br>01.01 – 31.12 2022 | To date:<br>09.06.21 – 31.12.22 |
|---|---|---|
| Budgeted | kNOK 1,800 | kNOK 2,110 |
| Expended | kNOK 464 | kNOK 552 |

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# eCDR

*The project 'Equivalent Carbon Dioxide Removal' (eCDR) focuses on the removal of non-$CO_2$ greenhouse gases from air in recognition of the fact that the global warming potential (GWP) of $CH_4$ and $N_2O$ are sufficiently high at approx. 28 and 270, respectively, to make their removal more cost-efficient than the direct removal of $CO_2$ from air (DAC).*

**Objective:** To identify and quantify the CDR potential of the non-$CO_2$ GHG gases methane ($CH_4$)and nitrous oxide ($N_2O$).

**Project Manager:** Rahul Anantharaman, SINTEF Energy Research

**Duration:** 9 June 2021 – 30 November 2023

**CDR methods:** Technology-based

**Potential:** Total global methane emissions are approx. 600 MT $CH_4$/yr. Given a $CH_4$ GWP100 value of 28, this corresponds to 18 GT $CO_2$e/yr. The potential resulting from $CH_4$ removal alone is thus of the order of hundreds of MT of $CO_2$e/yr.

**Summary of activities (Q1 – Q4, 2022)**

A framework for the benchmarking and development of a method for removing methane from air was established based on experience derived from direct air capture (DAC).

The main activity involved the development of a conceptual design for the $CH_4$ (and $N_2O$) removal process. The first step was to perform thermodynamic analyses of a number of $CH_4$ conversion pathways, with a focus on identifying those that mimic natural/biological processes.

Concepts involving moving large volumes of gases through reactors with minimal pressure drop and energy consumption were analysed.

**Results**

A preliminary concept for the removal of methane and nitrous oxide from air was developed. A detailed conceptual design of the process is currently under development.

**The next stage**

Following completion of the detailed conceptual design, including energy and material balance calculations, estimates for unit operation design will be developed.

This process, combined with equipment information, will be used to perform an early-stage techno-economic analysis.

This will be followed by an early-stage life cycle analysis of the process with the aim of identifying the net negative emissions resulting from the process, inclusive of indirect emissions.

Finally, a roadmap for technology development will be prepared.

**Spin-off projects/other outcomes/dissemination**

- Integration with the EU Horizon Europe project REPAIR (2022–2026)
- Integration with the RCN's Green Platform project KSP NCS C+ (2022–2024)

**Finances**

The project has been delayed due to a lack of resources and an absence of synergies with spin-off projects.

| | In the period 01.01 – 31.12. 2022 | To date: 09.06.21 – 31.12.22 |
|---|---|---|
| Budgeted | kNOK 1,370 | kNOK 1,870 |
| Expended | kNOK 818 | kNOK 891 |

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