Negative CO_2

Negative CO_2 Emissions with Chemical-Looping Combustion of Biomass

Newsletter #6
October 2019

This is the sixth edition of the newsletter of The Nordic Energy Research Flagship Project "**Negative CO_2 Emissions with Chemical Looping Combustion of Biomass**". This edition covers the results and progress of the project in the period from January 2019 to September 2019.

The objective of this project is to demonstrate an effective pathway that produces energy while actively reducing the level of CO_2 in the atmosphere. The usage of sustainable biomass in the process called chemical-looping combustion (bio-CLC) is highly efficient and facilitates a more convenient capture of the biogenic CO_2. The permanent geological storage of this CO_2 reduces the level of CO_2 in the atmosphere. For a more detailed explanation of bio-CLC, click here.

Haven't heard about CO_2 capture and storage before? Click here for an introduction.

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About Negative CO_2

Negative CO_2 is a multi-partner and cross-disciplinary project funded by Nordic Energy Research that runs from November 2015 to August 2020. The research topic is CO_2 capture during biomass combustion by means of an innovative and potentially revolutionary technology. The project partners are:

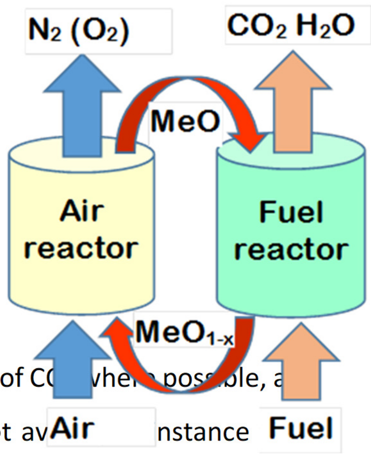
- Chalmers University of Technology
- The Bellona Foundation
- Sibelco Nordic AB
- SINTEF Energy Research
- SINTEF Materials and Chemistry
- VTT Technical Research Centre of Finland Ltd
- Åbo Akademi University

Associated with the project is also an advisory board, consisting of various stakeholders with interest in the project:

- Alstom Power AB
- Andritz Oy
- AKZO Nobel
- Elkem AS
- E.ON Sverige AB
- Fortum Oyj
- Foster Wheeler Energia
- Göteborgs Energi
- Titania A/S
- Arbaflame A/S
- Fores

The Challenge: remove CO_2 from the atmosphere

This project combines technologies and research that will be help us reduce the level of CO_2 in the atmosphere effectively and at a low cost. To achieve the climate goals of the *Paris Climate Agreement*, we need to effectively stop any and all emissions of CO_2 where possible, and compensate for emissions we cannot avoid (for instance agriculture).



Chemical-Looping Combustion

According to the UN Intergovernmental Panel on Climate Change (IPCC), the necessary measures include: the uptake of renewable energy, electrification, and Carbon Capture and Storage (CCS). These solutions alone will, however, not be enough. We need to decrease the amount of CO_2 that is already present in the atmosphere. We need large-scale negative emissions.

In the Nordic countries, there is a large potential for the capture and permanent geological storage of CO_2 from biomass. Norway has 20 years of experience in full-scale CO_2 storage, and is planning for a large-scale CO_2 transport and storage infrastructure ready by 2022 that could receive CO_2 northern and Western Europe. Sweden and Finland have large point source emissions of CO_2 from biomass.

Chemical Looping Combustion

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Negative CO_2 Emissions with Chemical-Looping Combustion of Biomass

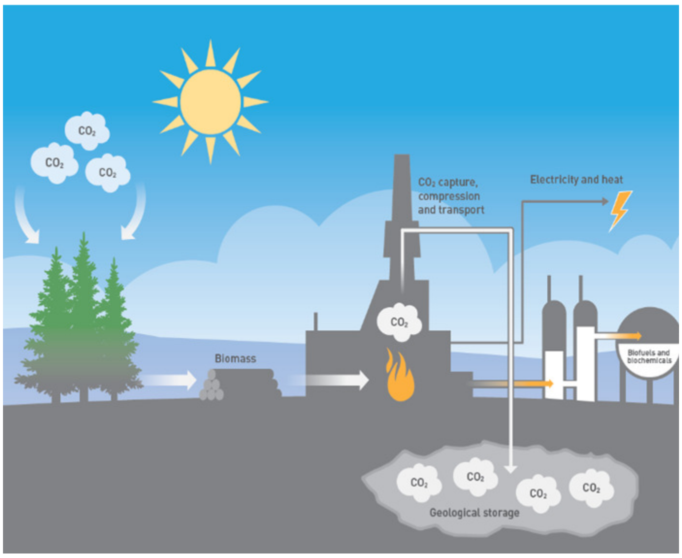
Chemical Looping Combustion (CLC) is a technology able to capture CO_2 from energy production at relatively low cost and with high efficiency. Conventional combustors burn fuel with ambient air, which contains the needed oxygen as well as a lot of nitrogen, and this makes separating the CO_2 after combustion a complex and expensive process. CLC installations solve the nitrogen problem by reacting fuel with solid metal oxide particles that create an oxygen-rich, nitrogen-free combustion atmosphere within the system.

When the fuel reacts with these particles, which are called the oxygen carrier, the oxygen is transferred to the fuel giving the same combustion products as normal combustion. These are CO_2 and water vapor. The essential difference is that the combustion products leave the so-called fuel reactor without any of the nitrogen in the air, and when the gas is cooled, the water vapor condenses resulting in a near-pure CO_2 stream.

The important point is that this can be done without any costly and energy demanding gas separation. The oxygen carrier is easily regenerated in an air reactor where the oxygen in the air is taken up by the oxygen carrier. Thus, oxygen is transported to the fuel reactor by oxygen-carrying particles that travel between a fuel reactor and an oxygen reactor in a steady loop. For oxygen carrier, low-cost natural minerals like ilmenite and manganese or iron ores can be used, and these materials can circulate between the two reactors for hundreds of hours. Because the costly gas separation can be avoided CLC is expected to reduce the cost of CO_2 capture dramatically.

Biomass and CLC

The use of sustainable biomass as the fuel in this process allows for the efficient withdrawal of CO_2 from the atmosphere. Biomass binds carbon as it grows, thus taking CO_2 (carbon dioxide) from the atmosphere. When the biomass is used in energy production, the CO_2 is recreated and returned to the atmosphere. But, if the CO_2 is instead captured and subsequently stored underground, that CO_2 will never end up back in the atmosphere again. This means that CO_2 removed from the atmosphere by the biomass as it grew, is permanently removed from the atmosphere. The result is negative CO_2 emissions.



Electricity and biofuels production with Bio-CCS (Illustration by doghouse.no/sintef)

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Bio-Energy and CCS (BECCS) or Bio-CCS.

Sustainable biomass growth and management, in combination with CLC (Bio-CLC), will achieve negative emissions efficiently, while also providing energy. This project will mature the technology to the semi-commercial scale.

Highlighted results in brief

Work package 2 has completed testing of various new combinations of solid fuels and oxygen carriers. Additional tests are planned in Q4 2019.

Work packages 3 and 4 completed in 2018 their planned programs for this flagship project. A final test activity was completed by WP5 in 2019.

Work packages 6 and 7 have made progress in compiled a comprehensive list of candidates for a real-world case study for a retrofit of an existing facility to operate as a demonstration-size CLC plant. The two best candidates have been selected and initial engineering concept work has begun for a case of Lahti Energia's decommissioned CFB biomass gasifier. Work package 7 has advanced its supporting studies of integrated technical and economic performance since beginning these in 2018.

Our project members have presented at a number of key, high-profile conferences across the Nordic countries this year. These are briefly listed in chronological order below. More details for some of these presentations as wells as a complete list of publications follows the summary sections for the work packages.

Tomi Lindroos help a presentation of bio-CCS at the Spring days of the Finnish Bioenergy association at 24th April. Finnish Bioenergy association represents over 300 member organizations from the entire bioenergy chain in Finland. The topics were about how mature bio-CCS technologies are and what are the current estimates of the cost of the negative CO_2 emissions.

Anders Lyngfelt held a presentation of bio-BECCS/bio-CLC for and for the Swedish Government's Climate Task Force on April 26th, 2019 and for the Swedish Air Pollution Prevention Association on May 6th, 2019. Links to the presentations are given in the section after the work package summaries.

Tomi Lindroos gave a presentation on June 3rd in World Energy Council's event 'Heating is Hot And Cool' in Helsinki (https://wecfinland.fi/events/heating-is-hot-and-cool-circular-energy-future/). He spoke about the future of the district heating in general and one important topic was Bio-CCS and bio-CLC. Result figures from negative CO2 WP7 articles were used as part of Tomi's presentation. There were roughly 100 participants from the ministries, industry, and academy.

Project members Fredrik Norman (Chalmers) and Øyvind Langørgen (SINTEF) held two presentations of results from WP2 and WP4 at the Trondheim CCS Conference 10 in June.

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Todd Flach held a presentation at the EU Sustainable Energy Week (Brussels, June 20th) in the session he helped organise ‘Cities and industry cooperation for net zero emissions. The presentation title was ‘Emerging opportunities for negative emissions solutions for cities’, and highlighted bio-CLC as a potential new negative-emissions solution for district heating/municipal power production.

At the Nordic Flame Days event on August 28-29th (Turku, Finland), representative of our flagship project held two keynote speeches and two session presentations. Anders Lyngfelt held the keynote presentation ‘Negative CO_2 Emissions in the Nordic Countries’. Tomi Lindroos (VTT) held the keynote presentation at this event ‘Estimating profitability of biomass plants in the future district heating grids’. Oskar Karlström (Åbo Akademi) held a presentation (in session 2A) of his results for this flagship project titled ‘Influence of fuel moisture content on NO_x emissions in a biomass fired industrial bubbling fluidized bed boiler’. Toni Pikkarainen (VTT) held a presentation in session 1B titled ‘Negative CO_2 emissions by chemical combustion of biomass: pilot scale results and status of technology demonstrations’, based on his work for our flagship project. Fredrik Hildor (Chalmers) held a presentation on char conversion using LD slag as oxygen carrier.

Toni Pikkarainen gave a presentation on 19th September in Finnish Energy Day arranged in Finlandia Hall, Helsinki, Finland (https://koulutus.almatalent.fi/suomalaisen-energian-paiva/ in Finnish only). The presentation “Incomes, technology export and essential solution to climate crisis - Bio-CCS” dealt with importance of immediate actions for demonstration and commercialization of carbon dioxide removal to limit global warming. Bio-CLC was introduced as a technology with superior potential for cost reduction of CCS with net-negative CO_2 emissions. About 45 high-level energy sector influencer from industry, politics and academy participated in the event.

Mika Anttonen (St1, chairman of the board) giving a presentation in Finnish Energy Day.

More detailed highlights on these and other activities within each work package are given below.

WP2 Pilot Plant Operation

The work in WP2 aims to increase the scale of Bio-CLC operations to demonstrate the commercial and technical feasibility of the technology. This will bring it closer to industrial application. Earlier, a very few studies on continuous CLC operation with biomass has been reported in literature, and for these, the fuel power has been limited. The Negative CO_2 project has access to unique infrastructure for performing CLC experiments with biomass under realistic conditions. Three pilot units are available, at VTT, Chalmers and SINTEF, with a design size ranging from 50–150 kW_{th}. In addition, a semi-commercial CFB boiler located at Chalmers has been used to demonstrate Bio-CLC at larger scale (1–4 MW_{th}) and conditions truly relevant for industrial applications. This scale of operation is far larger than what we have been able to find from literature.

All the units are based on fluidized bed technology, but they have some differences in design. All have been successfully operated in the course of the project. Thus, we have now the proof-of-concept, and the experiences expected and needed in the project. Together they provide real data on the performance of Bio-CLC depending on factors as reactor design, choice of oxygen carrier and choice of fuel and fuel preparation.

Trondheim CCS Conference 10th (TCCS-10)

The 10th Trondheim CCS conference (TCCS-10) was arranged on June 17th - 19th. The bi-annual conference has become a globally leading scientific CCS technology conference. Since its inception in 2003, the Conference has developed into an essential meeting place for over 400 CCS experts. The Conference has 150 oral presentations, five or six parallel sessions, over 100 posters and world leading keynote speakers. The Conference is hosted jointly by SINTEF and NTNU and is organized by the Norwegian CCS Research Centre (NCCS).

The conference homepage provides web access to most of the presentations as well as a photo gallery from the conference: https://www.sintef.no/projectweb/tccs-10/ .

The Negative CO2 project WP2 participated with a presentation in the session B6 on calcium and chemical looping. A presentation was also held by WP4 at this conference, as described in the section below covering the WP4 Highlights.

https://www.sintef.no/globalassets/project/tccs-10/dokumenter/b6/b6-normann.pptx.pdf

'Solid fuels operation in a 150 kWth CFB-based chemical looping combustion pilot unit'. Presented by Mr Øyvind Langørgen. This was a joint presentation from work in WP in the Negative CO2 project

and related work in the EU H2020 project CHEERS.
https://www.sintef.no/globalassets/project/tccs-10/dokumenter/b6/tccs10-sessionb6-langoergen.pptx.pdf

WP3 Oxygen carrier materials

This work package has completed its planned work.

WP4 Flue gas treatment

Members of WP4 contributed with a presentation to the The 10th Trondheim CCS conference (TCCS-10, June 17th - 19th) session B6 on calcium and chemical looping. Dr. Fredrik Normann(Chalmers). held the presentation ‘*Design of integrated NOx and SOx removal in pressurized flue gas systems for carbon capture applications*’.

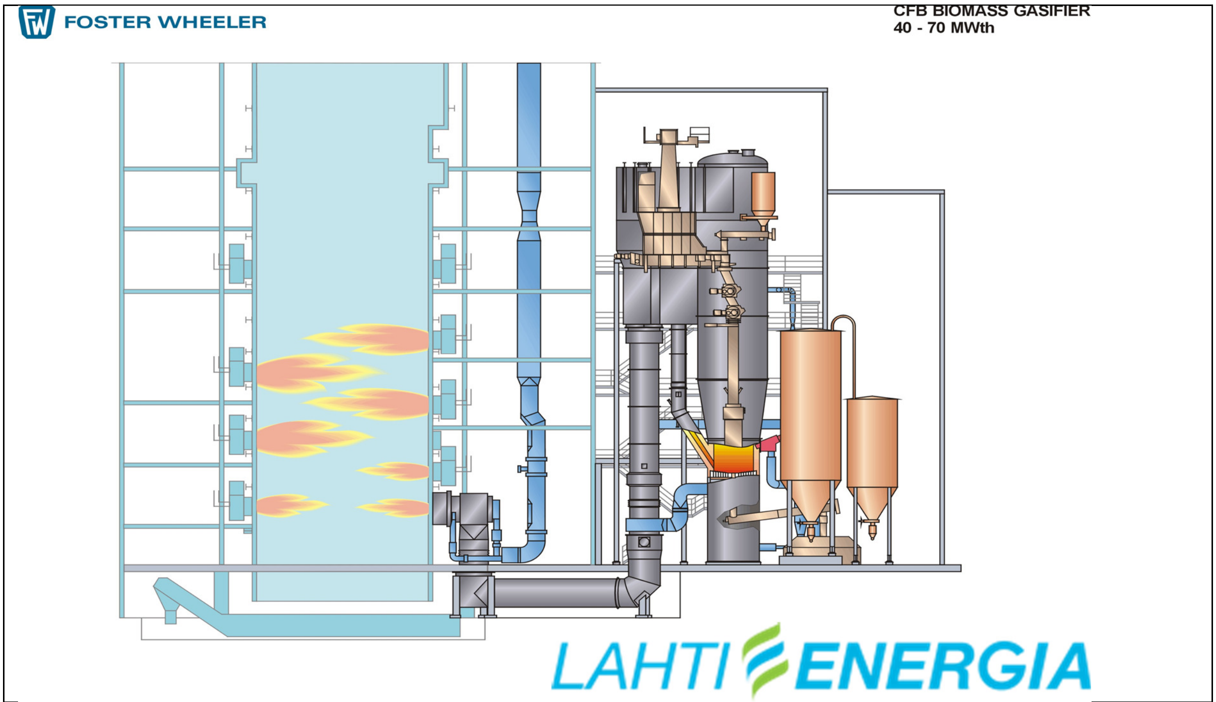
WP5 Ash and corrosion

A report summarizing the results of the corrosion testing is under preparation. During this reporting period one complementary corrosion test has been carried out to complete the picture of corrosion risks in the oxy-polishing unit. Cooperation with Chalmers University of Technology on bed materials has continued. This has resulted in Felicia Eliasson’s Master’s thesis supervised by Dr. Maria Zevenhoven from Åbo Akademi University and Dr Henrik Leon from Chalmers. in the early summer of 2019 André Rudnäs finalized his Masters’ thesis on manganese based bed material. He was supervised by Prof. Leena Hupa from Åbo Akademi University.

WP6 Upscaling and implementation

In WP6, a comprehensive plan for how bio-CLC could be implemented in the Nordic countries will be compiled. The plan will include identification of potential site(s) for a demonstration plant, fundamental plant design, a techno-economic analysis of the concept, and determination how to minimize economic risk of demonstration plant. The prospects for providing funding for a demonstration plant will be examined, with the possibility of co-funding between industrial end-user and funding agencies being an option.

Lahti Energia’s power plant in Lahti, Finland, has been selected for a demonstration plan. The existing, but recently decommissioned, CFB biomass gasifier is planned to be utilised as bio-CLC fuel reactor. In addition, also other existing infrastructure and fuel supply will be utilized to minimize the demonstration costs. Heat generated in the bio-CLC plant is planned to be used for the city of Lahti's district heating. The demonstration plan will be ready at the end of 2019.



Lahti Energia's decommissioned CFB biomass gasifier which is planned to be utilized as fuel reactor in bio-CLC demonstration plan.

WP7 Bio-CCS in a low-carbon Nordic energy system

Representatives from WP7 have published results from energy system and techno-economic analysis in scientific journals and several conferences. The journal article 'Robust decision making analysis of BECCS (bio-CLC) in a district heating and cooling grid' found that, in the selected case study, a Bio-CLC unit had a 50% chance to be profitable (10% Internal rate of return or better) around the level of 10 €/tCO_2 net income from captured bio-CO_2. Performed robust decision making analysis provides a systemic background for both technology developers and DHC operators when considering the competitiveness of the technology in an uncertain future. (https://www.sciencedirect.com/science/article/pii/S2213138818306520)

We have presented the bio-CLC technology and our results in following conferences and seminars: Finnish Bioenergy association Spring days (24th April in Helsinki, approx. 100 persons in the audience from Finnish industry and ministries), World Energy Council's event Heating is Hot and Cool (3rd June in Helsinki, approx. 100 persons in audience from Finnish ministries, academia, and industry), and in Nordic Flame Days (28th August in Turku).

The results in WP7 are based on the information produced in other work packages. Currently when other work packages are mostly finished, we are preparing a second journal article where we model the need for negative CO_2 emissions in selected, established emission reduction pathways in the Nordic countries, and how much easier bio-CLC technology could make it to achieve given ambitious targets.

WP8 Dissemination

The following text lists publications, events, newspaper articles, web articles, other outreach activities and more.

Keynote talk from Toni Pikkarainen (VTT) spells out the increasing importance of achieving negative CO_2 emissions by bioenergy with CCS (BECCS). BECCS is fast becoming an essential technology to limit global temperature rise to <2°C.

Presentations, publications, and submissions

The 10th Trondheim CCS conference (TCCS-10) June 17th - 19th. A presentation was also held by WP4 at this conference.

'Design of integrated NO_x and SO_x removal in pressurized flue gas systems for carbon capture applications', held by Fredrik Normann (Chalmers).

https://www.sintef.no/globalassets/project/tccs-10/dokumenter/b6/b6-normann.pptx.pdf

A presentation was also held by WP2.

'Solid fuels operation in a 150 kWth CFB-based chemical looping combustion pilot unit'. Presented by Mr Øyvind Langørgen. This was a joint presentation from work in WP in the Negative CO2 project and related work in the EU H2020 project CHEERS. https://www.sintef.no/globalassets/project/tccs-10/dokumenter/b6/tccs10-sessionb6-langoergen.pptx.pdf

Plenary Keynote Address to the Nordic Flame Days by Anders Lyngfelt.
Åbo Akademi, August 28-29, 2019

Negative CO_2 Emissions in the Nordic Countries
Key Messages:
Carbon dioxide budget soon exhausted - large negative emissions are needed
Several principles for negative emissions - several needed (but don't rely on Direct Air Capture)

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Negative CO_2 Emissions with Chemical-Looping Combustion of Biomass

BECCS / Bio-CCS safest - capture of CO_2 from biomass + geological storage
Storage - eternal storage is not needed, less safe storage also relevant (“e.g. forestation")
Bio-CCS
- climate-efficient use of limited resource
- biogenic carbon dioxide is valuable waste (can give minus emissions) - significant potential
- technology well known (simple), but few large-scale plants

Negative emissions must be financed
CCS not really expensive - corresponds to a few % of GDP
-Rational solution, "producer liability “, emitters pay for removing the CO_2 from the atmosphere
Chemical-Looping Combustion of biomass, Bio-CLC, has potential for dramatic reduction of CO_2 Capture cost
The Nordic region - great potential for bio-CCS, plus very good storage facilities.

Meeting with the Climate Assessment Task Force (link to the presentation, in Swedish, here: *Möte med klimatutredningen*)
Möte med klimatpolitiska vägvalsutredningen, Chalmers, April 26, 2019

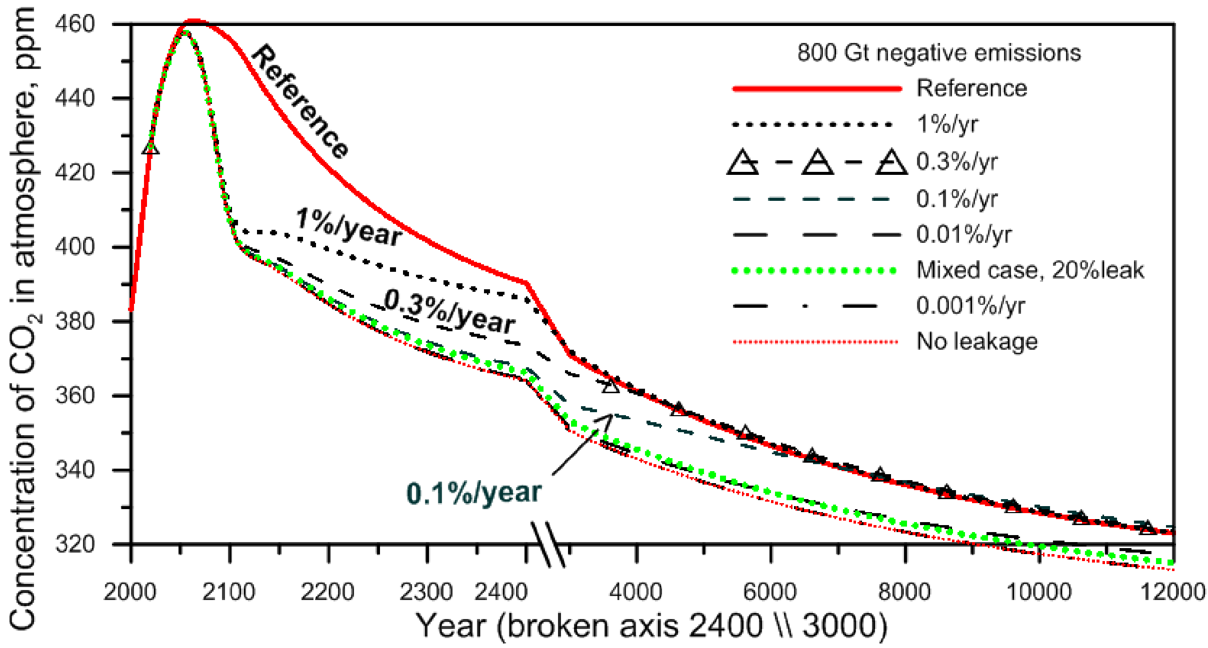
Presentation for the Swedish Air Pollution Prevention Association (link to the presentation, in Swedish, here: *Koldioxidinfångning och lagring (CCS)*)
Svenska luftvårdsföreningen, May 6th, 2019

Several paper submissions reported in previous newsletters have now been confirmed for publication. The list below summarizes these.

Lyngfelt, A., Johansson, D.J.A., Lindeberg, E., Negative CO_2 Emissions - An Analysis of the Retention Times Required with Respect to Possible Carbon Leakage, *International Journal of Greenhouse Gas Control*, **87** (2019) 27–33.

ABSTRACT
With present emissions the global CO_2 budget associated with a maximum temperature increase of about 1.5 to 2ºC will likely be spent within a few decades, Thus, it will be very difficult or perhaps even impossible to meet the climate targets agreed upon in Paris only by decreasing emissions of greenhouse gases. Scenarios presented in the IPCC reports accommodate for this by introducing so-called negative CO_2 emissions. The idea is that the cumulative CO_2 emission budget will be exceeded, but that massive negative emissions, especially during the latter part of the century, will remove the surplus of CO_2 in the atmosphere.
A number of different Negative Emissions Technologies (NETs) have been proposed, including Biomass Energy with Carbon Capture and Storage (BECCS), afforestation/reforestation, altered agricultural practices, biochar production, enhanced weathering and direct air captured. However, many of the options proposed could be associated with carbon leakage which could compromise the purpose of negative emissions, e.g. storage in of carbon in growing/dead biomass that leaks to the

atmosphere. Furthermore, it may be difficult to safely assess the long-term leakage rates. To reach the large negative emissions needed it is expected to require a mix of approaches having different expected retention times, and different safety in terms of leakage rates.
Could the risk of leakage mean that we are just delaying the problem and transferring the problem to coming generations? The short answer to this is that it all depends on the leakage rates. Different leakage rates and mixes of leakage rates are investigated in the paper. For the case of a mixture of leakage time scales of 300, 1000 and 10,000 years and assuming that 80% or more was permanently stored, the contribution to the atmospheric stock was small, peaking at about 3 ppm CO_2. It was concluded that leakage would not significantly compromise the benefits of negative emissions unless leakage is substantial and rapid. To quantify what could be meant by substantial and rapid, examples are discussed and analyzed in the context of climate change mitigation. The figure below summarizes the analysis.



Lyngfelt, A., Brink, A., Langørgen, Ø., Mattisson, T., Rydén, M., and Linderholm, C., 11,000 h of Chemical-Looping Combustion Operation – Where Are We and Where Do We Want to Go? , *International Journal of Greenhouse Gas Control*, **88** (2019) 38-58

ABSTRACT
A key for chemical-looping combustion (CLC) is the oxygen carrier. The ultimate test is obviously the actual operation, which reveals if it turns to dust, agglomerates or loses its reactivity or oxygen carrier capacity. The CLC process has been operated in 46 smaller chemical-looping combustors, for a total of more than 11,000 h. The operation involves both manufactured oxygen carriers, with 70% of the total time of operation, and less costly materials, i.e. natural ores or waste materials. Among manufactured materials, the most popular materials are based on NiO with 29% of the operational time, Fe2O3 with 16% and CuO with 13%. Among the monometallic oxides there are also Mn3O4 with 1%, and CoO with 2%. The manufactured materials also include a number of combined oxides with 11% of operation, mostly calcium manganites and other combined manganese oxides. Finally, the natural ores and waste materials include ilmenite, FeTiO3 with 13%, iron ore/waste with 9% and manganese ore with 6%. In the last years a shift towards more focus on CuO, combined oxides and natural ores has been seen.
The operational experience shows a large variation in performance depending on pilot design, operational conditions, solids inventory, oxygen carrier and fuel. However, there is at present no experience of the process at commercial or semi-commercial scale, although oxygen-carrier materials have been successfully used in commercial fluidized-bed boilers for Oxygen-Carrier Aided Combustion (OCAC) during more than 12,000 h of operation.
The paper discusses strategies for upscaling as well as the use of biomass for negative emissions. A key question is how scaling-up will affect the performance, which again will determine the costs for purification of CO_2 through e.g. oxy-polishing. Unfortunately, the conditions in the small-scale pilots do not allow for any safe conclusions with respect to performance in full scale. Nevertheless, the experiences from pilot operation shows that the process works and can be expected to work in the large scale and gives important information, for instance on the usefulness of various oxygen-carriers. Because further research is not likely to improve our understanding of the performance that can be achieved in full scale, there is little sense in waiting with the scale-up.
A major difficulty with the scaling-up of a novel process is in the risk. First-of-its-kind large-scale projects include risks of technical mistakes and unforeseen obstacles, leading to added costs or, in the worst case, failure. One way of addressing these risks is to focus on the heart of the process and build it with maximum flexibility for future use. A concept for maximum flexibility is the Multipurpose Dual Fluidized Bed (MDFB). Another is to find a suitable existing plant, e.g. a dual fluidized-bed thermal gasifier.
The global CO_2 budget for maximum temperature increase of 2ºC may be spent in 20-25 years, and in just 10 years for the 1.5ºC limit. Thus, the need for both CO_2 neutral fuels and negative emissions will become increasingly urgent. Biomass may turn out to be a key fuel for CCS, because CO_2-neutral processes do not necessarily need CCS, but negative emissions will definitely need Bio-CCS.

Lyngfelt, Anders and Rydén, Magnus and Linderholm, Carl and Mattisson, Tobias, Chemical-Looping Combustion (CLC) of Solid Fuels (SF-CLC) - A Discussion of Operational Experiences, Costs, Upscaling Strategies and Negative Emissions (Bio-CLC),
14th International Conference on Greenhouse Gas Control Technologies, GHGT-14, October 21-26, Melbourne, Australia 2018. Available at SSRN: https://ssrn.com/abstract=3365577

ABSTRACT
Chemical-Looping Combustion (CLC) is a technology which ideally is able to avoid all the costs associated with gas separation, well known to be the major cost, as well as the major reason for large loss in energy efficiency, of CO_2 Capture and Storage (CCS). The reason is that the oxygen is transferred from air to fuel using an oxygen-carrier, thus avoiding the mixing of air and fuel, meaning that the combustion products, CO2 and H_2O, end up in a separate stream. The H_2O is easily removed by condensation resulting, ideally, in a pure CO_2 stream.

Furthermore, when applied to solid fuels a CLC boiler may be constructed very similar to a circulating fluidized bed (CFB) boiler, and analyses of the cost differences indicate a low added investment cost for a CLC boiler as compared to a CFB boiler.

The CLC process has been operated in more than 39 smaller pilots, for a total of more than 10,000 h. The experience with solid fuels shows a large variation in performance depending on pilot design, operational conditions, solids inventory, oxygen carrier and fuel. However, there is at present no experience of the process at commercial or semi-commercial scale, although oxygen-carrier materials have been successfully used in commercial boilers for a related process, Oxygen-Carrier Aided Combustion (OCAC) during more than 20,000 h of operation.

The paper discusses the lessons learned from pilot operation, the costs, strategies for scale-up, as well as the use of CLC for biomass combustion, i.e. Bio-CLC, in order to attain negative CO_2 emissions.

Linderholm, Carl; Anders Lyngfelt; Christian Azar; Sally Benson; Göran Berndes; Thore Berntsson; Josep G. Canadell; Philippe Ciais; Annette Cowie; Sabine Fuss; James E. Hansen; Filip Johnsson; Jasmin Kemper; Klaus Lackner; Fabian Levihn; José Roberto Moreira; Kristin Onarheim; Glen Peters; Tobias Pröll; Phil Renforth; Joeri Rogelj; Pete Smith; Thomas Sterner; Detlef van Vuuren and Jennifer Wilcox,
1st International Conference on Negative CO_2 Emissions - Summary and Highlights, held for the 14th International Conference on Greenhouse Gas Control Technologies, GHGT-14, 21st -25th October 2018, Melbourne, Australia Available at SSRN: https://ssrn.com/abstract=3366362

ABSTRACT
Negative CO_2 emissions technologies include a number of technologies and biospheric storage options, the objective of which is the removal of atmospheric CO_2 and thus the limitation of future global warming. An international conference on negative emissions technologies was conceived to meet the need for a broader understanding of the possibilities and challenges facing these

technologies. The International Conference on Negative CO_2 Emissions was held in May 22-24, 2018, at Chalmers University of Technology, Gothenburg, Sweden. The conference was organized by Chalmers with support from the Global Carbon Project, the City of Gothenburg, Nordic Energy Research, ECOERA, the Center for Carbon Removal, Göteborg Energi, Stockholm Exergi, and the International Energy Agency, i.e. IEAGHG, IEAIETS and IEA Bioenergy. The purpose of the conference was to bring together a wide range of scientific and technological disciplines and stakeholders, in order to engage in various aspects of research relating to negative CO_2 emissions. This included various negative emission technologies, socio-economic and climate modelling, and climate policies and incentives. The conference was a major scientific event and the first in a conference series. The next conference will be held in the spring of 2020. This paper reports highlights and important messages from the conference.

Gogolev, I., Linderholm, C., Gall, D., Schmitz, M., Mattisson, T., Pettersson, J.B.C., Lyngfelt, A., Chemical-Looping Combustion in a 100 kW Unit Using a Mixture of Synthetic and Natural Oxygen Carriers - Operational Results and Fate of Biomass Fuel Alkali, International Journal of Greenhouse Gas Control, 88 (2019) 371-382

ABSTRACT
Previous investigations have shown that both natural and manufactured manganese materials may be feasible and cost-effective choices for oxygen carriers in chemical-looping combustion (CLC). In this experimental study, a mixture of a synthetic calcium manganite perovskite material and natural ilmenite was used as oxygen carrier in a 100 kW CLC unit with different biomass fuels. Designed as to allow operational flexibility, the 100 kW CLC system includes two interconnected circulating fluidized beds, i.e. air reactor (AR) and fuel reactor (FR), as well as a carbon stripper. By controlling the flows to the air reactor and the circulation riser it is possible to control the fuel reactor inventory and the global circulation independently. The suitability of the material as oxygen carrier in CLC was evaluated mainly with respect to fuel conversion.

The use of biomass as fuel in CLC opens the possibility of negative CO_2 emissions through the BECCS (Bio-Energy Carbon Capture and Storage) concept. Four biomass fuels were used in the experiments: black pellets of steam-exploded stem wood (BP), BP impregnated with K_2CO_3, a mixture of 50% BP with 50% straw pellets, and wood char. The preliminary results show high fuel conversion and very high capture of CO_2. The overall performance was considerably higher as compared to previously tested oxygen carriers, for example ilmenite. More than 95% gas conversion was achieved with wood pellets as fuel at around 950°C.
The alkali content of biomass is in many cases considerably higher in biomass than in fossil solid fuels, i.e. coal. Experience from conventional fluidized bed combustion and gasification suggests that alkali can significantly influence the CLC process, although experiments at CLC conditions are very limited. This study includes measurement of gas phase alkali released in the raw flue gases of the fuel reactor (FR) and air reactor (AR). Gas phase alkali were measured using a surface ionization detector. The sampling and dilution system showed good performance, although further investigation is

required to understand and control sampling stability which was observed to be influenced by the reactor pressure fluctuations and the response lag of the gas analysis system measurement. Release levels were found to generally correlate with the fuel alkali content. The measurements suggest that most of the fuel alkali is accumulated in the bed material of the reactor and that the gas phase release occurs in both the FR and AR, with AR exhibiting an equal or higher rate of release vs. the FR.

Ajdari, S, Normann, F., and Andersson, K., Evaluation of operating- and design parameters for pressurized flue gas systems with integrated removal of NO_x and SO_2, Energy Fuels 33:4 (2019) 3339-3348

ABSTRACT
This study investigates the operating and design parameters of product gas compression and integrated control of nitrogen oxides (NO_x) and sulfur oxides (SO_x) in large-scale oxy-fuel and chemical looping combustion processes. A process model that includes a comprehensive description of nitrogen and sulfur chemistry and mass transfer is developed. The results show that the fraction of NO oxidation into NO_2 will be 10−50% in a multistage compressor to 30 bars (1−4% O_2 in the gas) depending on the residence times in intercoolers and pressure levels. At lower O_2 concentrations (<0.1% O_2 in the gas), the oxidation is limited but still active. Nitric acid formation in the compressor condensate is, thus, inevitable, although limited, as most water is condensed in the early stages, whereas the acid gases are formed in the later stages. The NO_2/NO_x ratio has an important effect on the total amount of NO_x absorbed and extra residence time should be added after the compressor to increase this ratio. Evaluation of the process behavior in relation to simultaneous absorption of SO_2 and NO_x revealed that increased SO_2/NO_x ratio and bottom liquid recycling enhanced the total NO_x absorption. In addition, maintaining the pH in the absorbing solution above 5 improves the removal efficiencies of NO_x and SO_2. NO_x removal rates of up to around 95% can be achieved for $SO_2/NO_x > 1$ in the flue gas with appropriate design of the absorber. For $SO_2/NO_x < 1$, increasing the packing height or addition of S(IV) solutions could enhance the NO_x removal rates to 95% or more. The model predictions are compared with the experimental data from a laboratory-scale absorber. The process model developed in this work enables design studies and techno-economic evaluation of absorption-based NO_x and SO_x removal concepts.

Other Outreach activities

SINTEF at Arendalsuka (Norway's largest political/societal festival, held annually in Arendal)

SINTEF participated with researchers and experts in more than 30 open events during Arendalsuka 2019, that was arranged from August 12th - 16th. Among them were SINTEF CEO, Alexandra Bech Gjørv who presented a new SINTEF report describing 24 new possibilities and value chains that may come especially important to secure industrial and commercial development in Norway.

One of the 24 examples is "Climate positive solutions and value chains –removing CO_2 from the nature cycle for subsequent storage". This is exactly what the Negative CO_2 project is about.

The report (Norwegian) can be downloaded here:
https://www.sintef.no/siste-nytt/nye-muligheter-for-verdiskaping-i-norge/?utm_campaign=konsern_nyhetsbrev&utm_content=unspecified&utm_medium=email&utm_source=nyhetsbrev)

Upcoming events

Baltic Carbon Forum BCF 2019 BASRECCS
Tallinn, Estonia, October 22-23rd , 2019
https://www.norden.ee/en/about-us/events/event/896-baltic-carbon-forum-2019

Bioekonomiriksdagen 2019
Göteborg, Sweden, October 23-24th, 2019
https://www.johannebergsciencepark.com/bioekonomiriksdagen2019

Nordic bioenergy conference
Göteborg, Sweden, November 4-6th, 2019
https://www.nmbu.no/en/services/centers/bio4fuels/news/node/36666

COP25 https://unfccc.int/Santiago
Santiago, Chile, December 2019

2nd International Conference on Negative CO2 Emissions
http://negativeco2emissions2020.com/
Gothenburg (hosted by Chalmers University), May 12-15, 2020