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D5.3 GICCS - Final Report

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1 Executive summary

The GICCS project was formed based on the needs for a joint effort to find possible CCUS solutions for the industries in Grenland (Porsgrunn and Bamble) in addition to what is already ongoing at Heidelberg Materials with the Brevik CCS project. The primary goals of the project were to prepare for capturing remaining CO_2 from the industry in Grenland and to explore the potential in a joint industrial solution for capture, preparation for transport or utilization and related infrastructure.

The project owner is the industrial cluster - Powered by Telemark- with the following companies, as industry partners: Bluegreen Fusion AS; Bouvet Norge AS; Eramet Norway AS, Heidelberg Materials Norway AS (Norcem), Herøya Industrial Park AS, INEOS Rafnes AS, INEOS Inovyn AS, Nippon Gases AS, Nordic Electrofuel AS, Norsk E-Fuel AS and Pipelife Norge AS. Research partners are SINTEF and USN.

In GICCS, detailed studies of complete CCS facilities have been done. Individual solutions for each industrial site are compared with variants of joint solutions. The energy supply has been studied, including if available surplus heat can be utilized. The joint solution approach is centred around the possibility of having absorbers at each site and connect all to a common desorber, transporting the rich and lean amine solvent between the absorbers and the desorber in pipelines across the Frier fjord. Joint solution site includes also heat integration, liquefaction, intermediate storage and transport solutions. For both the individual capture plants and the joint solution a Techno-Economical analysis are among the most important results in GICCS.

The results shows that a joint solution approach for the industries in Grenland (INEOS/INOVYN and Eramet) on CO_2 capture and handling could be both technically and economically feasible. The most important cost factor is the energy supply cost, and whether this can be available as surplus heat for the desorber operation. This is also important for the choice of individual or joint solutions. The alternatives are, one CC plant (absorber and desorber) at Rafnes and one at Herøya or a joint solution desorber at Herøya, also serving Rafnes, connected with a pipeline.

Energy consumption is crucial for reducing CO_2 emissions. In the process industry, excess heat can be utilized, positively impacting operating expenses (OPEX). For example, if surplus heat covers the desorber operation, the electricity requirement for a carbon capture (CC) plant drops to around 20% of total energy needs, or about 17 MW_{el} for a facility capturing 625 kt CO_2 annually. Without excess heat, the electricity demand rises to nearly 90 MW_{el}. GICCS scenarios fall between these extremes, with electricity needs ranging from 0.25 MW_{el} to 1.2 MW_{el} per tonne of CO_2 removed. GICCS identified that there is surplus heat available at Herøya, but much more limited at Rafnes with current set-up.

It has been shown that building a pipeline between Rafnes and Herøya sites is feasible, and the cost is included in the joint solution. However, there is a need to verify further that the pipeline material, High Density Polyethylene, HDPE can sustain prolonged exposure to the amine solvent under the given parameters.

GICCS has also assessed Carbon Capture and Utilization (CCU). Complementary to storing the CO_2 permanently underground is utilising the CO_2 for other purposes. CCU aims to mitigate climate change by reducing CO_2 emissions while simultaneously creating business from converting CO_2 into useful products. Depending on the conditions, CCU has the potential to contribute to a circular economy and reduce the dependence on fossil fuels.

A first assessment of the shipping to permanent storage at Øygarden, from intermediate storage at Herøya is performed. Current challenge is the lack of access to a suitable quay for transporting the CO_2 by ship to e.g. Øygarden. The logistics to permanent storage sites should be handled thoroughly in a new project.

2 Background and introduction

The GICCS project was formed based on the needs for a joint effort to find possible CCUS solutions in Grenland in addition to what is already ongoing at Heidelberg Materials with the Brevik CCS project.

The industry cluster Powered by Telemark presented in 2020 its roadmap for a climate positive industry region [1]. The roadmap was developed by SINTEF, Periti and USN and in close cooperation with the process industry in the area. The vision to become climate neutral in 2040 and climate positive thereafter was presented. The vision implies that emissions of greenhouse gases must be eliminated or neutralized. This mainly applies to CO_2, but emissions of nitrous oxide and methane must also be included. Several measures, which can bring the industry towards the goal of the vision were presented in the roadmap. Among the measures are electrification and switching of raw materials. For some production processes, CO_2 emissions will be unavoidable. An example is the production of cement where two thirds of the CO_2 emission come from calcination of the raw material which is limestone. This part of the emission is fossil and cannot be avoided even if heating is changed from fossil fuel to renewable electricity. One way of removing such emissions is Carbon Capture and Storage (CCS), where the CO_2 is captured and stored permanently in the ground and thereby not emitted it to the atmosphere. The roadmap described how much of the CO_2 emissions from Grenland could be managed by CCS and a project for following up were suggested. GICCS were initiated based on this.

3 GICCS main findings

Twenty-two technical reports have been issued, before this final report, under GICCS [2].

Individual Capture and Methods (report D1.1- D1.4, D4.1, D4.2)

Based on detailed information about processes, challenges and opportunities, GICCS has assessed which CC technology is best suited for the individual plants. This work includes the use of process simulation software. The choice of technology largely depends on the CO_2 concentration in the flue gases. It is found that for both INEOS/INOVYN and Eramet the chemical absorption technology with amine-based solvents is suggested as a suitable capture technology. This post-combustion amine-based process is a natural choice due to a high TRL (Technology Readiness Level) and a reasonable energy consumption.

Joint Solution (report D3.1, D3.3/D4.3, D3.4, D4.2)

The assessment includes the technical and economic feasibility of different alternatives. It is found that technical solutions are available, and the expected cost (Capex and Opex) for alternative solutions are calculated. The opex varies a lot with the energy price. It is assumed in GICCS that availability of "excess heat" is favourable towards electricity.

The joint solutions assessed in GICCS is possible, but any joint solution for CCS will lead to ties between the industrial companies, operationally and financially. A common business plan is needed to be able to move forward with a joint solution concept.

Energy (report D2.1 – D2.4)

Energy consumption is essential in all work to reduce CO_2 emissions into the atmosphere.

In the process industry, excess energy (as heat) is often available, and utilization of this energy is particularly important. CO_2 capture by chemical absorption (as in GICCS) can utilize this energy and thereby limit the use of valuable renewable electricity.

Utilization of excess heat in the desorber operation impacts the OPEX very positively as well.

For a joint solution case there are plausible sources for supply of heat to the desorber at Herøya site serving Eramet, INEOS and Inovyn (Capture of 600-650 kt of CO_2). This includes heat (as steam) also from other industry at Herøya and the use of novel technology (High Temperature Heat Pumps).

If all the heat for the desorber operation can be covered by surplus heat, then the electricity requirement for the CC plant will only be max. 20% of the total energy requirement. The electricity requirement is then approx. 17 MW for a facility that can capture approx. 625 kt CO_2 per year. If no excess heat is available for the desorber and all the heat must be provided by electricity (electric boiler), the electricity power requirement will be close to 90 MW in total for the same plant. In other words, the electric energy requirement will be somewhere between approx. 0.25 MWh_{el} and 1.25 MWh_{el} per tonne of CO_2 removed. GICCS's scenarios are in between these extremes This level should be compared to other means of CO_2 reduction like electrification of processes (in MWh_{el}/tonne CO_2 removed).

Amine Pipeline for Joint Solution (report D3.2)

The overall idea behind a joint solutions infrastructure is that there are significant benefits to having only the absorber placed at the emission sites and served by a joint desorber (and heat supply system), as opposed to having a full CO_2 capture installation on each emission site. However, transporting the solvent has its challenges and the chemical composition, temperature, and pressure will likely put constraints on how this can be done. GICCS has reported two pipelines can be built between Herøya and Rafnes for transportation of lean and rich amine. Diameter of pipelines are 450 mm and the length approx. 6 km each. The cost for pipelines is calculated and included in the cost for the Joint Solutions. There is limited data on specific amines and their compatibility with HDPE. Still, HDPE offers attractive properties at relatively low cost. To confirm the applicability of HDPE, it must be confirmed through testing when the solvent/amine to be used in such a system is known.

Transport to storage (report D3.4)

A first assessment of the shipping to permanent storage at Øygarden, from intermediate storage at Herøya is performed. The main challenge currently for the scenarios developed both for single plant and joint solutions are the lack of access to a suitable quay for transporting the CO_2 by ship to Øygarden. For the development of the cases two locations that could be available for a joint solution scenario have been identified by Herøya Industrial Park (HIP).

CCU (report D3.5)

CCU is a challenging topic, and the ultimate CO_2 reduction potential of a CO_2 utilisation pathway must be assessed in each case. Further, it is ultimately up to the owner of the CO_2 emission (assuming it is in a sector covered by the EU-ETS) to judge what is the best "use" of the CO_2 that they potentially capture.

The current consensus seems to be that using fossil-based CO_2 is expected in a transition phase until 2041, to facilitate for increased share of renewable products in accordance with EU regulation. After 2041 there will be limitations, at least in the EU economic area, regarding the origin of any CO_2 utilised. In the case of a CO_2-based products, customers are likely to demand a documentation on sustainability and the GHG footprint of the product.

Digitalisation (report D3.6)

Elements of process digitalisation have been assessed for a joint solution. The industry most commonly utilizes multiple different solutions for control, monitoring, decision support, and information. Increasingly, such solutions are linked to data platforms for data collection and aggregation. History shows that these exercises are demanding even when individual actors develop their own systems. This aspect, that in a project like GICCS involving multiple collaborating partners and actors, should be given extra consideration. Through proper planning and preparation before selecting control systems, complexity and the risk of errors or unnecessarily challenging integrations during implementation and operational phases can be reduced.

4 Further work

The GICCS project have provided new knowledge about CCUS solutions for the project partners. The increased knowledge may instigate further discussions in the industry cluster how to organize future CCS plants and related necessary infrastructure and logistics. A next step could be to look at different alternatives for joint CO_2-hub for Grenland and transport to permanent storage. Joint solution challenges the individual industry partners and forces them to a close and long-term cooperation. This might be the biggest obstacle for a joint solution. The prerequisite for a joint solution is a business plan that gives benefits for all involved parties.

Access to renewable energy will be a limiting factor for how the electrification of processes can become a substitute for fossil raw materials and fuel. If this is the case, CO_2 capture with less input from renewable power, but with high utilization of excess heat should be high on the list of measures for CO_2 reduction.

There is a potential of increased utilization of existing surplus heat. The total energy consumption for the industry cluster should be assessed and a plan for optimum energy use among the major stakeholders, industry and local communities should be developed and implemented.

5 Concluding remarks

Carbon Capture and Storage make it possible for industries with processes that have fossil CO_2 emission to avoid emitting it to the atmosphere. The GICCS project has assessed several CCUS options for some of the major emitters in Grenland.

Possible advantages and disadvantages/uncertainties of a joint solution approach:

- Advantages
    - There might be economy of scale, especially for the CO_2 handling infrastructure (liquefaction, export terminal)
    - Steam supply to one location instead of two or more
    - One export terminal – should reduce the cost of CO_2 transport (transport to permanent storage)
    - Existing infrastructure for CO_2 handling could be used to attract other industries to HIP
- Disadvantages/uncertainties
    - Cross fjord transport of amine
        - Feasibility needs to be verified
        - HSE aspects must be better understood
    - Amine inventory in pipelines
    - Design of a robust/flexible capture plant
        - Operational profile of the plants needs to be assessed and consequences of unplanned and planned shut-down will affect the common installations. The desorber and CO_2 liquefaction plant needs to be able to operate efficiently at lower loads
        - Could result in need for two smaller desorbers/strippers and a back-up system for steam generation
        - In case of a prolonged shutdown, the consequence on the amine inventory left idle needs to be understood
    - Value of waste heat/steam
        - Negotiations – trade-off between benefit from economy of scale and loss of potential income
    - Different time schedule for implementation amongst the partners

- The calculated cost assumes that all partners are ready for implementation at the same time

A joint solution approach for the industries in Grenland (INEOS/INOVYN and Eramet) on CO_2 capture and handling, could be economically feasible. However, the attractiveness is highly dependent on the possibility of significantly reducing the energy supply cost as this needs to more than offset the increased investment cost. In a case where excess or waste heat could be made available on the Frier Vest side, individual solutions for CO_2 capture is most likely the most optimal. In such a case, a joint solution for CO_2 logistic handling should be assessed.

6 References

[1] K.L. Aas, S. Kvisle, K.J. Jens, J. Hovland, H.A. Haugen, Veikart for en klimapositiv industriregion, SINTEF-report 2020:0067, Porsgrunn, 2020

[2] 22 Technical GICCS reports, Internal reports for the partners.

7 Abbreviations

GICCS – Grenland Industrial Carbon Capture and Storage
CCS- Carbon Capture and Storage
CCUS- Carbon Capture Utilization and Storage
HDPE – High Density Polyethylene
OPEX – Operational Expenditure
MW – Mega Watt (e.g. electrical power)
MWh – Mega Watt Hour (Energy)
MWh_{el} – Mega Watt Hour $_{electrical}$ (Energy, in the form of electrical energy)
kt – kilo tonne

8 Appendix – overview of reports in GICCS

D1.1 Design basis and individual plant characteristics – Part A
D1.1 Design basis and individual plant characteristics – Part B
D1.1 Design basis and individual plant characteristics – Part C
D1.2 CO_2 Capture Technologies for Individual Plants and Sites-Part A
D1.2 CO_2 Capture Technologies for Individual Plants and Sites-Part B
D1.3 Energy need and waste heat integration – Part A
D1.3 Energy need and waste heat integration – Part B
D1.4 Technical basis for cost estimation
D2.1 Waste Heat Survey
D2.2 Waste Heat Assessment
D2.3 Alternative Energy Supply
D2.4 Energy Integration System for GICCS
D3.1 Joint CO_2 capture design
D3.2 Transport of amine
D3.4 Joint Solutions for Transport to Øygarden
D3.5 CCU
D3.6 Solutions for digitalization
D4.1a Cost estimate for INEOS and INOVYN
D4.1b Cost estimate for Eramet
D4.2 Defined cases for techno-economic assessment
D 3.3 / D4.3 Joint solutions case studies and techno-economic assessment
D4.4 / D4.5 Discussion on Timeline and Implementation