Slite CCS – beyond net zero by 2030

Slite CCS

The future of cement production

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GENOMFÖRBARHETSSTUDIE SLITE CCS
Projektreferens P2022-00112

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Slite Carbon Capture and Storage Project/Slite CCS

”GENOMFÖRBARHETSSTUDIE SLITE CCS”

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1 Introduction to the report

1.1 Background

Heidelberg Materials Cement Sverige AB (further Heidelberg Materials, or HM) intends to develop the cement production facility in Slite to produce cement with (beyond) zero net emissions of carbon dioxide by 2030. This is to be achieved through the establishment of an innovative full-scale carbon dioxide separation facility that enables the capture of up to 1.8 million tons of CO_2 per year. In total, this corresponds to a reduction of Sweden's total carbon dioxide emissions today by approximately 4 percent. Once in operation, the Slite plant will, through an increased use of bioenergy, have the potential to also achieve a significant carbon sink.

The overall project goals can then be summarized as follows:

- To reach climate-neutral cement production at the Slite plant no later than 2030 by implementation of post-combustion carbon capture, waste heat recovery combined with increased use of biogenic fuels.
- To clearly demonstrate the scalability of large-scale carbon capture system integration with the purpose of reducing carbon footprint
- To clearly demonstrate the financial viability of transitioning to climate-neutral production via e.g. emission trading rights and support funding to profitable and sustainable production.

To enable this project, careful analyses have been carried out in preparatory project phases in the form of

- The Pre-Feasibility study phase (conducted in 2021), and
- The Feasibility and Concept Freeze Phase (May 2022-March 2024)

The two phases have been financially supported by the Swedish Energy Agency and this report is the final submission to the Agency with the purpose to present activities undertaken during the 22 months period of the Feasibility and Concept Freeze Phase (further referred to as “Feasibility Study” or “FS”) with focus on achievements in relation to objective and set goals of the study.

The report is prepared in English following the language of the public funding application document submitted to the Energy Agency early 2022 on which the Energy Agency issued the decision to support the project.

In this context the report is limited to an overall presentation of the final concepts and technology solutions developed as a result of the study. A separate internal report has been prepared presenting actions undertaken, methodologies applied, results and conclusions reached in all separate tasks. This interna report will function as the main base for the continued development of the project now entering into the Front End Engineering Phase (FEED).

1.2 Slite CCS Feasibility Study and Concept Freeze Phase – primary targets of the study

In the support funding application, the overall project objectives – to which the FS has provided essential contribution – were summarised as below. These project objectives remain also after completion of the Feasibility Study, further demonstrating the project’s overall feasibility.

1.2.1 Overall project objectives

The overall objectives of the Slite CCS project have been set as follows;

- By implementation of post-combustion carbon capture, waste heat recovery combined with increased use of biogenic fuels by no later than 2030, the following project goals will be achieved:
    - Climate-neutral cement production and thus reducing the industry sectors' carbon footprint with 10% and thus taking a leading role in Sweden's commitment to net zero GHG emissions by 2045
    - Clear demonstration of scalability with respect to innovative large scale carbon capture system integration with the purpose of reducing carbon footprint
    - Clear demonstration of financial viability of transitioning to climate-neutral production via e.g. emission trading rights and support funding to profitable and sustainable production

1.2.2 Feasibility and Concept Freeze Phase objectives

The FS has reached its end, aiming to initiate the next phase referred to as the Front End Engineering Phase (FEED phase).

The goals and scope of the FS were fully based on the conclusions and outcomes of the Pre-feasibility phase concluded in December 2021 – continuing the path clearly demonstrating that the project continue to be feasible from a technical, logistic, commercial, footprint, and environmental perspective. All in all 8 overall targets were developed, also forming the concrete actions and organizational structure of the activities;

- **Target 1:** Finalized technical concept selection.
    - Conclusion of relevant studies to bring studied concepts to a high confidence level including necessary fallback plans in case a selected concept proves to be unsuitable during the following project phase (FEED/Basic Engineering phase)

- **Target 2:** Full value chain analysis
    - securing solutions for all relevant components including CO_2 transportation and final storage
    - ensuring power transmission capacity meeting the Slite site's further demand

- **Target 3:** Completed tendering activities for FEED/Basic Engineering phase and finalized contracts

- **Target 4:** CAPEX/OPEX estimates with min accuracy corresponding to AACE 5L (-30/+50%)

- **Target 5:** Project plan for all following project phases finalized and initialized
    - Includes staffing of core project management team, acquired technical competencies as well as finalized procurement, commercial and contractual strategies for the various FEED/Basic Engineering phase contracts
    - Financial strategy including positioning the project for possible public co- funding at local, regional, and EU level

- **Target 6:** Supporting the submission of an overall plant environmental permit application
    - Includes all necessary environmental investigations and adaptation of the project to support the overall permitting process and in particular the EIA.

1.3 Work package structure and organisation

1.3.1 Work package and organizational set-up

The FS have had a comprehensive scope of activities aligned with the overall objectives of this phase. Due to the contextual and system related complexity of the project scope, the project activities have been divided into technical/engineering activities and strategical development activities and processes as described in work packages WP0 – WP9. The organization is illustrated in the chart overleaf.

Overall project management – including Project manager together with supportive staff (controller, environment manager, planner/scheduler) including Steering Committee & Executive Coordination Group – has been operated within a separate WP0 Project Management.

Engineering processes - An Engineering Management team with an Engineering Team Manager together with task managers of each WP 1-3 has been formed to plan and execute all activities and ensure their full integration into the overall results as follows;

- WP1: Carbon capture related units
- WP2: Buffer storage, harbour and logistics
- WP3: Permit preparation activities

Strategic development processes - strategic development processes/work packages have been undertaken with the main goal to secure favourable conditions for the further implementation of the project. These activities have been executed in parallel with (and integrated with) the WP1-WP3 Engineering activities of the study. These processes include the following Work Packages as follows;

- WP4: Full chain/storage and transport solution: value chain from buffer/intermediate storage to final/end storage
- WP5: Procurement Strategy
- WP6: Stakeholder management & Communication
- WP7: Power transmission capacity
- WP8: Legal aspects including permits
- WP9: Business Plan including funding strategy

It should also be noted that an additional WP – separated from the FS - has been introduced to cover process and installation modifications at site that needs to be implemented prior to the CCS units to prepare the site for these new processes. These activities are not considered to be a part of the CCS project as such (and thereby not the FS activities directly), but the different actions of these modification activities have been aligned and integrated with the CCS activities to secure a successful project.

For full illustration of the organizational set-up, see organisation chart in Figure 1-1.

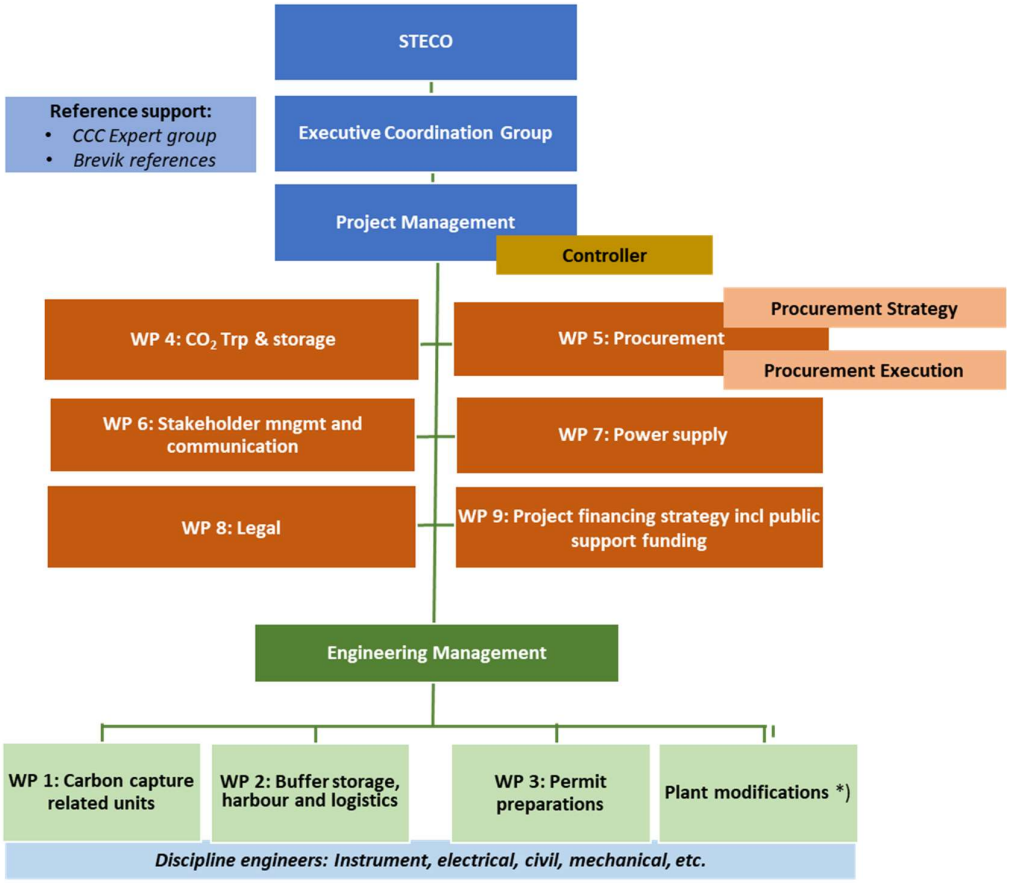

Figure 1-1: Organisation chart - Feasibility and Concept Freeze Phase Slite CCS

1.3.2 Brief activities, studies and analyses undertaken forming the results of the FS

As indicated in previous sections, the Slite CCS project was initiated in the spring of 2021 with an initial pre-feasibility study. The main objective of the pre-feasibility phase was to lay the conceptual foundations to reach full scale carbon capture capacity at HM's cement production site at Slite by no later than 2030 and as such formed the scope and objectives of the current FS phase resulting in a number of parallel analyses and studies undertaken. To realize the objectives of the FS, extensive support has been procured – taking public procurement policies into account - from different Swedish and international consultancy service providers as follows;

- A significant part of the FS cover the development of a Technical Feasibility study, prepared by Ramboll in close collaboration with the HM Engineering Team. The report was presented in 2023 enabling a confirmation of the the decision for an amine-based carbon capture process on a qualified and well-informed basis. The study includes energy optimization and heat recovery options within the carbon capture unit. These are important inputs to the further decision-making process since they have a significant impact on the financial viability of the plant due the 100% electrification. A key element is to recover as much high-grade heat as possible.

- In parallel, the feasibility study[1] of GEA Bischoff GmbH finalized in Q2 2023 assessed the concept for flue gas treatment, heat recovery and heat transfer upstream the future carbon capture unit.
- Moreover, in June 2023 a study was prepared internally by HM dedicated to the choice of cooling techniques that may be used in the future CCS-facility.
- Mid 2023 HM also prepared an internal report focusing on the transportation and storage aspects and how different logistic solutions would influence the infrastructure in the Slite harbour – an internal report resulting in the decision to develop an onshore solution – in favour of an alternative off-shore solution - for the loading and transfer of CO_2 from the Slite site.

Additional to the direct CCS related studies, significant effort has also been put into studies and investment preparing and optimizing the plant performance for implementation of CCS. This involves technical and strategical discussions related to the development of power transmission capacity to Gotland and to the site – activities involving close dialogue and interaction with the TSO (Svenska Kraftnät) as well as the DSO (Gotland Energi AB) – interactions and engineering development supported by Sweco.

Additionally, activities has also included Environmental Impact Assessment and Plant Permit preparation activities which have been completed with an expected submission of the final permit application to the Environmental Court late May 2024. Sweco was selected as main consultant for these activities with additional support for certain analyses from a number of different suppliers including Brekke & Strand together with Akustikkonsulten (noise simulations and mitigation activities), WSP (risk assessments), and AFRY (air emission simulations).

Further, extensive activities have been introduced with respect to the legal, commercial and business development aspects of the project, also including external consultancy support, e.g.

- Mannheimer Swartling to support HM legal department with advice in relation to the permit application preparations as well as procurement strategy matters
- Copenhagen Economics to develop the business development aspects of the project with focus on the project's financial models and commercial sustainability calculations
- Colligio to further assist the HM Procurement Team in relation to Public Procurement Policies.

As a result, during the FS phase the project has advanced from a pre-feasibility phase to a project development phase enabling initiation of the FEED phase where the procurement of FEED suppliers has already been initiated.

[1] *GEA Bischoff GmbH (2023), 50249753 Feasibility Study – CCS*

2 Introduction to the Slite CCS project and the FS results

2.1 Slite CCS project – main objectives

The overall objective of Slite CCS as expressed in the application regarding the feasibility study can be fulfilled and HM has now identified the possibility to move further beyond net-zero and achieve a carbon sink in Slite, hence the developed project objectives are now expressed as follows;

> *…..to transform one of the largest and strategic cement plants in Europe into a carbon-sink CCS facility by integrating and upscaling state-of-the-art solutions to produce unprecedented volumes of net-zero cement beyond 2030 on the island of Gotland, Sweden….*

From this end, and fully in line with Heidelberg Materials Group and Europe's paths to net-zero emissions, the future sub-goals of the Slite CCS project is to

- support the targeted decarbonisation of the Swedish and European construction industry by a phased replacement of emission-intensive materials, supported by a secured and robust supply of evoZero® carbon-neutral cement and clinker
- demonstrate the techno-economic viability of a large-scale carbon-sink cement plant. This to be achieved through an upscaling of the cutting-edge amine CC solution for the cement industry to a unique scale for the sector (4 times larger compared to current state-of-the-art e.g. Brevik project) by 2030
- realise a substantial reduction in GHG emissions of up to 1.8 $MtCO_2eq$ annually (cutting 4% of the Sweden's total emissions)
- enable the further development and realisation of CO2 transport/storage infrastructure with a baseload volume of captured CO_2 during the process.
- facilitate replication of the carbon-sink facility blueprint to other production locations of the Heidelberg Materials Group
- enforce the market uptake of net-zero products by shaping the future market of sustainable building materials with a secured supply of >2 Mtpa of net-zero cement after entering into operation in 2030 with a green premium respected by HM key customers

2.2 Slite CCS project – highlights

2.2.1 Roadmap highlights

Based on the experience of the HM Group as a frontrunner for green innovation in the cement sector, the Slite CCS project fits perfectly with the technical expertise that HM Group (and HM) have been accumulating over the years and it will benefit from the insights and experience of the other projects in pipeline. With the Brevik project soon to enter into operation with others to follow, the CCS projects provide valuable insights in terms of design, technology choice, contracting strategy, construction strategy, transport/sequestration logistics as the CO_2 offtake concept and knowledge sharing potential.

From this end, the Slite CCS project is a logical next step to HM Group, where the project encompass multiple innovations that are scattered amongst several projects. It further develops and integrates them in a more complex environment and in a large-scale system – Slite CCS will be the largest BECCS project, the largest amine-based CCS project and second largest (technology agnostic) CCS project in the cement industry in Europe.

It is also one of the HM's largest endeavors concerning the production volumes with up to 2.09 million tons of net-zero cement (evoZero®) and 2.21 million tons net-zero clinker (evoZero®), by 2031, and up

to 1,8 million tons of CO_2 captured. In addition to up-scaling of the features already achieved in other HM projects, i.e. Brevik (NO), Padeswood (UK), Mitchell (US) and Edmonton (CAN), Slite CCS combines these features with high bio shares of fuel mix (resulting in considerable amounts of biogenic CO2 ~19.5%). Coupling CCS technology with considerable biogenic CO2 emissions, Slite CCS stands-out as a net-zero clinker/cement production plant.

The project demonstration is cost-efficient also thanks to the optimization of the CCS design considering the total cost per ton of CO2, a high capture rate (95% of CO2 generated going to the CC unit inflow) and a reduced energy consumption.

2.2.2 Slite CCS project – main technology highlights from the FS

Baed on the input from the Pre-Feasibility study, the FS now performed has resulted in the selection and further development of a concept for the Slite cement plant that addresses the reduction of GHG emissions from different angles. Starting from the plant inputs, optimising the process up to handling the output. The feasibility of the following technological solutions and decarbonisation investments has been thoroughly assessed, and the outcomes are incorporated in the final result of the FS, i.e;

1) Carbon capture (CC) solution with flue gas (FG) pre-treatment,
2) Advanced process optimisation and
3) CO_2 handling & ship loading and a harbour construction for CO_2 vessels.

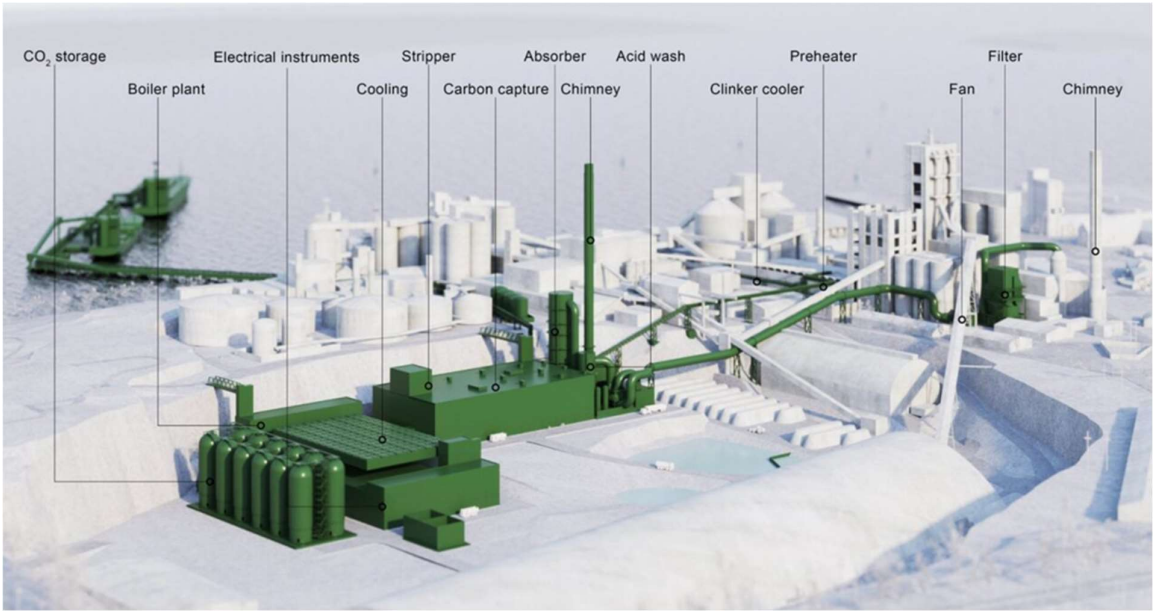

Figure 2-1: Overview carbon capture units installations envisaged for the Slite site

From this end, the FS has resulted solutions which demonstrate the utilization and full system integration of several distinct innovative solutions for the first time at large-scale allowing for replicability along the whole cement sector and beyond. The main highlights of the project solutions developed through the FS phase are summarized below:

- A phased integration of a BECCS energy pathway on an existing cement plant, ensuring a large scale (49%) use of biogenic inputs where the carbon of biomass is captured and stored, enabling a first of its kind carbon-sink cement plant. This will be supported by the

demonstration of a full-scale 1.8 Mtpa (mega tonnes per annum of inflow capacity of CO_2) CCS facility using advanced amine capture technology at the HM's Slite plant by 2030;

- Highly energy efficient and 100% electrified amine absorption carbon capture unit, which thanks to the planned process optimizations will require only in the range of 450 kWh/t CO_2 captured, in line with the energy requirements of alternative CC technologies like Oxyfuel (without their distinct disadvantages). It is the first CCS project in which one CC unit serves multiple flue gas sources (two kilns);
- Maximisation of energy re-use and energy efficiency through the application of Waste Heat Recovery System (WHRS) via extensive heat harvest from the kiln's operation, CO_2 compression and reuse of high-grade heat sources for two large scale electrified high temperature heat pumps with an estimated COP of 2.5 (1MW electricity input => 2.5 MW thermal output). This will lead to a reduction of 38% in external power demand;
- Integrate an innovative solution for the pre-treatment of cement plant flue gases, enabling the removal NO_x (72%) and SO_x (80%);
- A zero-liquid discharge (ZLD) system to avoid liquid waste streams, while reducing the water consumption on site by ~ 90% in normal operation compared to operation without Direct Contact Cooler (DCC) and Carbon Capture (CC), saving over 300,000 m^3/y of fresh water per year;
- Maximisation of site electrification, including heating processes through e-boilers, allowing to make use of 100% fossil-free electricity for the cement production process and Carbon Capture process, lowering site emissions to a minimum;
- New harbour solution accommodating both additional cement related operations and CO_2 ship loading operations allowing large 20,000 t ships into the harbour, representing the first on-site CO_2 terminal facility for cement plants of the HM Group (see also Figure 2-2)

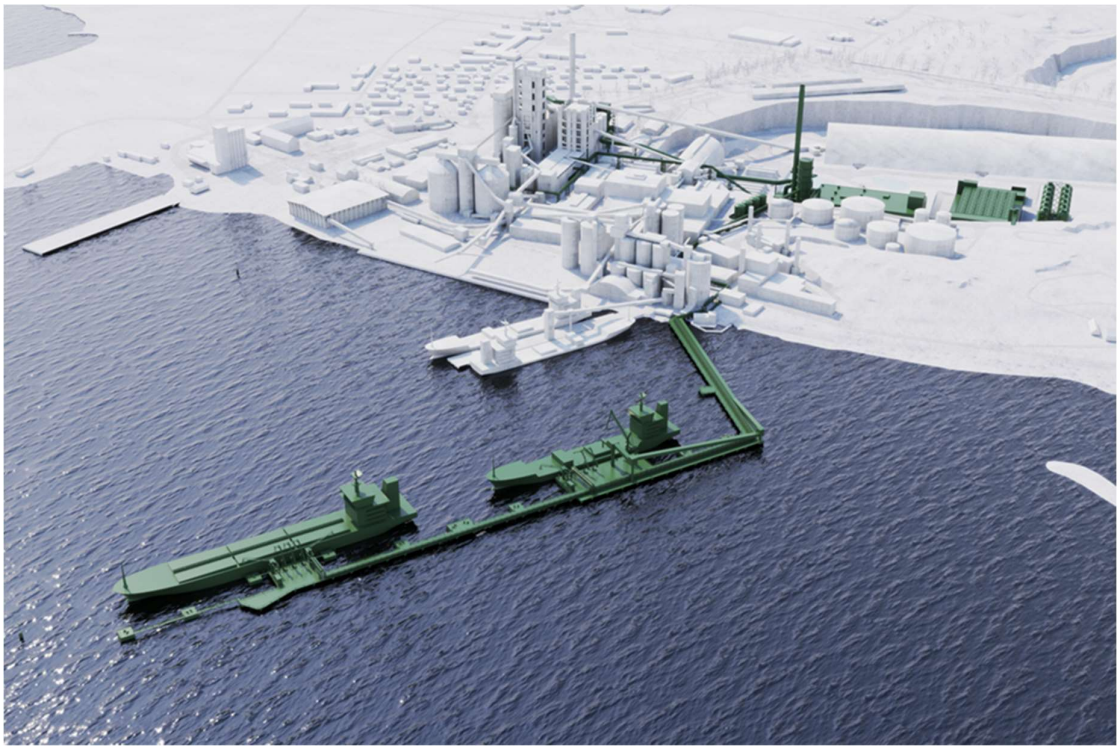

Figure 2-2: Future layout extended harbour to accomodate additional CO_2 vessel activities at the Slite site

2.3 Way forward - Project implementation and execution

2.3.1 Project implementation – overall plan

The further implementation of the project continues to follow the overall project implementation plan as presented and agreed as a part of the Pre-Feasibility study, see overall structure below. From this end, following the FS, the project is now to enter the Front-End Engineering Design Phase (further FEED phase).

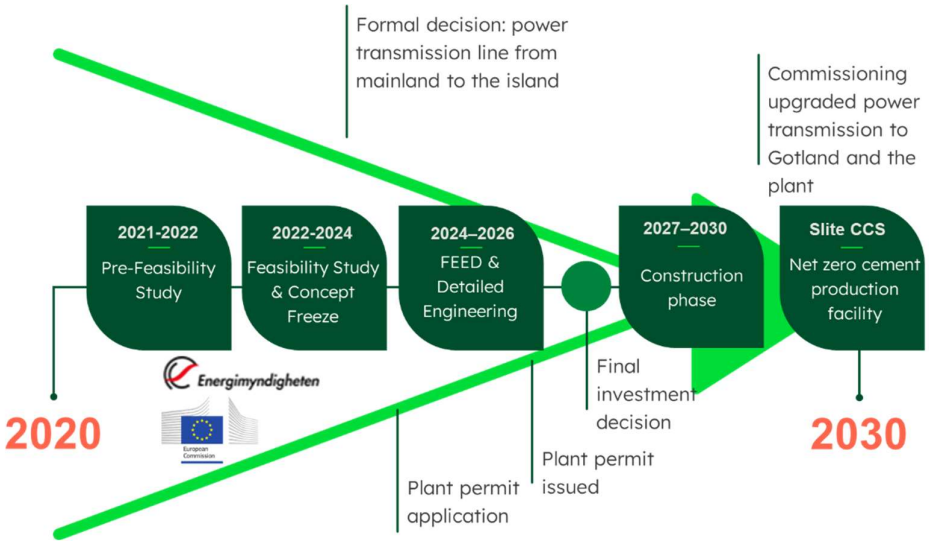

Figure 2-3: Project's overall implementation timeline

As a part of the FS, the FEED phase activities have been prepared as follows;

- Project plan with specific targets for each work package established, also forming an application for public funding support from the Swedish Energy Agency. The work packages cover both engineering part (project management team as well as externally procured technology suppliers for FEED preparations) and parallel workstreams essential to reach timely and successful implementation of the project (e.g. actions to reach plant permit, actions enabling timely installation and commissioning of required power transmission capacity to the site, establishment of mature and efficient supply chain agreements for transportation and storage of captured CO_2).
- Procurement process to ensure that efficient and professional selection of suppliers and contractors for the FEED and EPC phases has been initiated. First steps taken towards procurement of FEED supply contracts also enabling transfer to EPC contracts for the execution phase (see separate section “Procurement Strategy”)
- Project funding activities – both via extensive financial modelling to understand the project’s financial viability as well as preparation of public funding applications in line with an overall funding strategy aiming for maximized public national and EU funding – mainly demonstrated by the EU Innovation Fund application submitted early April 2024.

Although with certain timeline risk components all main activities and achievements until now - including external decisions and processes - comply with the overall timeline aiming for final investment decision not later than end 2026 and initial commissioning mid 2030.

3 Review of actions undertaken, achievements and deliverables.

The review is structured in the same way as the work package set-up of the activities undertaken, i.e. WP 1 – 9.

3.1 WP1: Carbon capture related units & WP2: Buffer storage, harbour and logistic

3.1.1 WP1 & WP2: Scope and target fulfilment

The initial action plan for the Engineering activities were divided in WP 1 CC related units as well as WP 2 Buffer storage, harbour and logistic. As the activities have been implemented within the same organization and external main consultant supplier, the presentation of the two WPs have been merged as follows.

Along the implementation of the activities, the scope has developed to some extent but in general the main action points remained. In the table below planned actions are presented together with brief FS target fulfilment comments.

Action point/target	FS achievements
Finalisation of concept selection including all relevant studies to bring selected concepts to a high confidence level and prepare all necessary fallback plans in case a selected concept proves to be unsuitable during the FEED phase.	Target achieved
Preparation of a project organization to handle the FEED phase including procurement and commercial handling of the various FEED contracts and acquire all technical competencies necessary to review and approve all technical matters during FEED.	Target achieved
Take final decision on the contractual set-up of the FEED works	Target achieved
Complete the tendering activities for the FEED and finalize the contracts.	Tendering activities initiated, suppliers pre-qualified followed by Supplier Dialogues and completion of draft RFP documents
Prepared fallback alternatives for all project components.	Target achieved
Prepare a so-called Project Design Memorandum (PDM) that includes all the info necessary for the FEED contractors to complete their work, this could include the selected concepts for the various sub-projects, the preliminary technical specifications for the future plants, results from offshore sea bottom investigations, flue gas composition etc.	Draft RFP prepared covering the aspects of a PDM including Design Basis and FEED Scope
Screen and select technologies and concepts to be used in the different project components throughout the whole value chain at site	Target achieved
Prepare preliminary process design, plot plans and other input for the FEED. Operations principles to be determined, i.e. what flue-gas flows should be covered by the flue-gas pretreatment, carbon capture and liquefaction units, technical operating life of facilities, etc.	Target achieved

Action point/target	FS achievements
Excess heat cooling options – wet cooling towers vs sea water cooling study including plume distribution	Target achieved
Prepare preliminary process design, plot plans and other input for the FEED.	Target achieved
Geophysical and geotechnical seabed investigation of the corridors and offshore facilities locations that could become involved in the project.	Comprehensive geophysical investigations completed giving input required to FEED scope, complementary geotechnical investigations to be carried out in parallel with FEED studies
Operations principles need to be determined, i.e. logistics in the harbor and how to handle ship loading, boil-off gas flows, and size of buffer storage, technical operating life of facilities, etc	Target achieved

3.1.2 Deliverables WP1 & WP2

The main deliverable from these activities is the Technical Feasibility Study presented by Ramboll late 2023. The report was based both on separate topic related sub-reports, where a selection is presented in the table below.

Report /Topic/Main content	Date	Prepared by
Fluegas pre-treatment and WHRU Feasibility Study ○ *including design basis, process diagrams, material balance, operation & control philosophy, cost estimates etc.*	May 2023	GEA Bischoff
Technical Feasibility Study Annexes, including separate reports with ○ *Design basis* ○ *Process Flow Diagrams (all system components)* ○ *Technical lists* ○ *Layouts* ○ *Harbour and Logistics* ○ *Civil* ○ *HSE* ○ *Pro Max calculations* ○ *CCS cooling technologies* ○ *CAPEX & OPEX modelling* ○ *Project risk analysis*	December 2023	Ramboll
Gas Characterisation for Slite CCS	March 2024	Internal/CCC
Simulation study – new pier CO2 at Slite	November 2023	RI.SE
Nautical risk assessment expansion of Slite harbour (in Swedish)	March 2024	RI.SE
Transport Study for bringing the pre-assembled CO2 tanks from Harbour to their destination in Eastern Quarry		Internal
Drone scanning and laser scanning of existing plant site	June 2022	AFRY
Pre-design Report Slite CCS WP2 – onshore vs offshore solutions	July 2023	Ramboll
CCS – architectural design/layout (in Swedish)	January 2024	Tham & Videgård
Heidelberg Materials Slite – design vision 2030 (in Swedish)	October 2023	Tham & Videgård

In addition to the studies and reports mentioned above, a number of workshops, site visits etc has been conducted with findings and learnings presented in separate documents, e.g.

- Environmental and technical reports related to amine capture from Technology Centre Mongstad.

- Site visits to production facilities of large-scale CO_2 compressors
- Site visits to CO_2 capture pilot plants and CO_2 production sites

3.2 WP3: Permit preparation activities

3.2.1 WP3: Scope and target fulfilment

The initial action plan for the WP3 Engineering activities to be undertaken included all environmental aspects related to the installations and the permit application preparations (closely integrated and aligned with the WP1 and WP2 activities as well as the Strategic Process WPs, especially WP 4 and 8). In the table below planned actions are presented together with brief FS target fulfilment comments.

Action point/target	FS achivements
Develop all necessary material for the overall permitting process and in particular for the EIA. This also involves further investigation of risk related aspects, including	Draft material prepared (EIA, Technical Description, Application Document) – final submission to Environmental Court planned for end May 2024
Noise distribution study	Target achieved
HAZID (continuation)	Target achieved
Quantitive risk analysis (QRA) related to release of LCO2 or CO2 (compression, liquefaction, storage, loading). Includes comprehensive dispersion modelling/CFD	Target achieved
Quantitative risk analysis (QRA) related to release of capture solvent at the absorber/desorber.	Target achieved

The preparation of the permit application is still ongoing with targeted submission date May 31st, 2024 – hence, some writing activities are still remaining.

3.2.2 Deliverables WP3

As indicated above, the final materials – i.e. the permit application to be submitted to the Environmental Court – is still pending. The final documentation set will – in addition to the actual application and other documents – include an Environmental Impact Assessment as well as a Technical Description.

From this end, a selection of examples of deliverables (both completed and still pending) from the Permit preparation is presented in the table below. Note: all documents to be submitted to the Environmental Court is prepared in Swedish only.

Report /Topic/Main content	Date	Prepared by
Plant Permit Consultation Document	September 2023	Sweco, MSA, Internal HM
Technical Description, future operations of the plant	TBC	Sweco, MSA, Internal HM
Field investigations: Birds	2023	Sweco
Analysis of BAT & BREF	2024	Sweco
Natura 2000 – impact analysis	2024	Sweco
Field investigations: Porpoise	2023	Sweco
Noise simulations & analysis	2024	Brekke & Strand, Akustikkonsulten
Emissions to air – dispersion modelling	2024	AFRY
Amine dispersion and deposition modelling using ADMS-5	2023	AFRY
Environmental risk analysis	2024	WSP
Storm- and extinguishing water analysis	2024	WSP
Traffic risk analysis	2024	WSP
Risk Assessment of different refrigerant medias used in heat pumps and liquefaction chiller	2024	WSP
Computational Fluid Dynamics [CFD] analysis of an accidental CO2 release	2024	WSP
Natural values inventory	2023	Ecogain
Maritime operations risk investigation	2023	RI.SE
Exploration permit application (to allow for marine geophysical and geotechnical investigations, Harbour extension)	Sept 2022	Internal HMNE, Ramboll, MSA

3.3 WP4: Full chain/storage and transport solution: value chain from buffer/intermediate storage to final storage

3.3.1 WP4: Scope and target fulfilment

The initial action plan for the WP4 Engineering activities focused on establishment of a long-term strategy and action path for transportation and final storage of captured CO2 aiming for the most preferred solution with respect to costs, technical solution, safety etc. The strategy – and subsequent actions – to be based on the planned activities as presented in the table below (including brief comments on target fulfilment).

Action point/target	FS achivements
Intensified discussions with final storage suppliers regarding technical specifications and commercial conditions with focus on Northern Lights but also a selection of alternative suppliers in the North Sea	Target achieved
Define overall value chain requirements in terms of overall availability requirements with respect to expected operational permits and preferred commercial arrangements in terms of shipping operational model (ownership,TC, CoA)	Target achieved
In-depth discussions with shipping/cargo companies regarding technical specifications and commercial conditions for long distance transportation from Slite harbour to selected final storage suppliers.	Target achieved
Based on the technical/engineering activities set the ship-loading conditions, enabling further development of the conditions with respect to naval architecture – shipping models, routes, cost estimates etc. from the Slite site up to selected final storage location.	Target achieved

Action point/target	FS achivements
Improved cost estimate accuracy by obtaining budget quotes for OPEX and CAPEX estimates via RFI-processes.	Target achieved
Intensified discussions with final storage suppliers regarding technical specifications and commercial conditions with focus on Northern Lights but also a selection of alternative suppliers in the North Sea	Target achieved
Define overall value chain requirements in terms of overall availability requirements with respect to expected operational permits and preferred commercial arrangements in terms of shipping operational model (ownership,TC, CoA)	Target achieved
In-depth discussions with shipping/cargo companies regarding technical specifications and commercial conditions for long distance transportation from Slite harbour to selected final storage suppliers.	Target achieved

3.3.2 Deliverables WP4

Deliverables from this Work Package include the material below. In addition to this a number of MoUs, LoI's and draft Heads of Terms have been elaborated together with potential partners/transportation & storage suppliers (e.g. Equinor, Fidelis, Northern Lights), documents not included here.

Report /Topic/Main content	Date	Prepared by
Slite CCS – Identification and analysis of transportation & storage options in the region	December 2023	Ramboll
Review of active transportation & storage projects and activities in the North Sea area – updated long list and status	March 2024	Internal HM, Ramboll

3.4 WP5: Procurement Strategy

3.4.1 WP5: Scope and target fulfilment

The initial action plan for the WP5 Procurement Strategy focused on the need to meet the complex and timeline critical nature of the project and its execution, hence calling for more detailed procurement strategy compared to a customary procurement process. From this end this strategic process have been fully accountable for the procurement processes of the CCS project supporting the project with the actions presented in the table below (resented together with brief FS target fulfilment comments).

Action point/target	FS achivements
Setting and implementing the procurement strategy, based on the proposals developed in the Pre-Feasibility Study,	Target achieved
Preparation of well-defined and appropriate procurement documents for the coming FEED, Engineering and Construction contracts	Draft versions prepared
Ensuring an efficient procurement of service supplier and construction contracts meeting the EU and Swedish public procurement rules, and at the same time consider the limited flexibility that comes with technology suppliers' proprietary rights	Routines developed and implemented applying the conditions of the Slite CCS project

3.4.2 Deliverables WP5

The Procurement strategy work package represent two main tasks, i.e. 1) ensuring an efficient procurement of services suppliers within the ongoing activities and studies, and 2) to prepare for large scale procurement of FEED suppliers and EPC contractors.

The tender documents related to procurement of FEED suppliers is available in draft formats still to be developed to final versions. The documents cover basis of design, request for proposal, evaluation criteria, FEED and EPC contract structure and content etc. To prepare the procurement strategy and policies related to procurement of FEED suppliers and EPC contractors a number of internal documents have been prepared often together with the external supplier Colligio (experts in public procurement management) including

Report /Topic/Main content	Date	Prepared by
Introduction of Public Procurement (ppt based memo, in Swedish)	December 2022	Colligio
Potential Procurement Procedures and Processes towards FEED and EPC (ppt based memo)	Feb 2023	Colligio
Procurement Strategy outline (ppt based memo)	September 2023	Internal HM
Invitation to apply for participation in procurement - Pre-qualification documents, FEED suppliers Carbon Capture and Storage Facilities	October 2023	Internal HM, Colligio

The documentation also includes contract formats, NDAs etc. following the procurement documents – see also WP 8 Legal aspects including permits.

3.5 WP6: Stakeholder management & Communication

3.5.1 Scope and target fulfilment

The initial action plan for the WP6 Stakeholder management and Communication focused on the further development and implementation of the communication and dissemination strategy. In the table below planned actions are presented together with brief FS target fulfilment comments.

Action point/target	FS achivements
Activities to reach a common understanding and acceptance of the CCS project.	Target achieved
Knowledge management and sharing activities to be developed in line with the EU strategies securing dissemination of experiences and lessons learned in the project.	Target achieved
External communication not only to target general public stakeholders but also covering specific stakeholders such as authorities involved in the development of regulatory aspects, infrastructure development etc. that is essential for the realization of the project.	Target achieved

3.5.2 Deliverables WP6

As presented in the main report a number of actions/initiatives and relevant communication presence have been introduced as a part of the project activities, i.e. advertising in local and national media, active presence on social media, participation in certain seminars and branch networking activities etc.

Another important deliverable is the project's own website slitecce.se (now available both in Swedish and English language).

These communication and stakeholder management activities will not be further presented here but are based on the main deliverables from this work package as presented in the table below.

Report /Topic/Main content	Date	Prepared by
Communication Plan	May 2023 (draft) November 2023 (final)	Internal HM
Knowledge Sharing Plan	April 2024	Internal HM

3.6 WP7: Power transmission capacity

3.6.1 Scope and target fulfilment

With the expected significant increase in power requirement the current transmission capacity to the site needs to be increased. Activities in WP7 Power Transmission Capacity is presented in the table below together with brief target fulfilment comment.

Action point/target	FS achivements
Secure a future power transmission capacity meeting the Slite site's future demand. Activities undertaken has supported the development of a new power transmission line with the mainland as well as other development processes such as promoting off-shore wind power solutions. Activities to a high extent aligned with stakeholder management and communication activities.	Target achieved

3.6.2 Deliverables WP7

The documentation deliverables from the activities focus on the relationship with the DSO (Gotland Energi AB, GEAB) and installation preparations of transmission lines all the way to the Slite plant, see selection below.

The relationship and discussions with the TSO (Svenska Kraftnät) has not really resulted in concrete reports or documents, rather informal and formal dialogue with relevant stakeholders including TSO, political interactions etc. to facilitate a favorable development.

Report /Topic/Main content	Date	Prepared by
Localization local switchgear/sub-station GEAB/HM	Sept 2023	Internal HM, Sweco
Pre-projecting new 145 kV feeding to Heidelberg materials in Slite	January 2024	Sweco
New electricity supply to CCS plant at Cementa AB on Gotland (*report in Swedish*)	September 2022	Granitor
Design Agreement, projecting electrical installation Gotland Energi (GEAB) and Heidelberg Materials Cement Sverige (*agreement in Swedish*)	May 2023	Internal HM, GEAB
Risk Assessment – placement of new substation GEAB (*memo, ppt format)*	2023	Internal HM, Sweco

3.7 WP8: Legal aspects including permits

3.7.1 WP8: Scope and target fulfilment

This strategic process planned actions are presented in the table below together with brief FS target fulfilment comments.

Action point/target	FS achivements
Preparatory actions of all legal aspects during the preparation and implementation of the project – financial, environmental, market and procurement related etc.	Target achieved

3.7.2 Deliverables WP8

Given the overall scope of the work package, only limited Legal Work Package documentation has been developed as the activities from internal legal department and/or external support from Mannheimer Swartling (MSA) has resulted in significant input in almost all other work packages, i.e.

- Procurement strategy development
- Contract format development – service supply contracts, EPC contracts, NDAs, Heads of Terms transportation & Storage etc.
- Business Development, e.g. legal advisory support related to state aid regulations, grant agreement discussions etc.
- Plant Permit application development
- Exploration permit for marine based investigations required for the CCS project

3.8 WP9: Business Plan including funding strategy

3.8.1 WP9: Scope and target fulfilment

The initial action plan for this WP included development of a project business plan meeting the expected high level of CCS deployment in Europe. Activities have been organized as an agile business plan with specific sprint periods in line with external deadlines for the different possible financial measures. In the table below planned actions are presented together with brief FS target fulfilment comments.

Action point/target	FS achivements
Secure that support funding opportunities on national, regional and EU level are utilized to the extent possible decreasing the financial risk of the climate neutral cement related projects.	Target achieved
Position the project as a strong and innovative project and forerunner in climate neutral cement production. This to be reached by engagement in relevant European working groups identified supporting EU regarding development of new grant programs as well as development of improved policy- and regulatory frameworks and standards enabling climate neutral cement.	Target achieved

3.8.2 Deliverables WP9

The deliverables related to the Business Development could be divided in Business Plan development and documentation related directly to obtaining public funding support.

Report /Topic/Main content	Date	Prepared by
Funding Gap Calculation (early stage)	April 2023	Copenhagen Economics
Just Transition Fund – application for funding support "CCS Preparatory projects"	November 2023	Internal HM
Swedish Energy Agency "Industriklivet" – application for FEED & Detailed Engineering funding support	February 2024	Internal HM
EU Innovation Fund Application, including mandatory documents Feasibility Study, Knowledge Sharing Plan, Business Plan	April 2024	Internal HM based on FS deliverables and documentation
Revised Funding Gap Calculation	April 2024	Copenhagen Economics
Business Plan including detailed Financial Model (	April 2024	Internal HM, EGEN, Copenhagen Economics
Swedish Energy Agency "Industriklivet" – revised application for FEED funding support	April 2024	Internal HM

3.9 Self defined deliverables and milestones

This section includes a follow up of the achievements in relation to the so called “self defined deliverables and milestones” indicated in the original project plan.

Deliverable/ milestone	Description (as per applicaotn to the Energy Agency April 2022)	Fulfilment comment
Project phase kick-off	Comment: Date subject to final approval of application by the Swedish Energy Agency, at least two weeks aftersubmission. Deliverable: An important result of the kick-off is theconfirmation of the project organisation and staffing together with a detailed project plan prepared by the Project management.	Fulfilled – kick of held in June 2022
Submission Exploration Permit application	Comment: Identified as a result of the Pre-Feasibility Study, exploration permit application is required for thegeophysical and geotechnical seabed investigations of the preferred LCO2 pipeline corridors and offshore facilities locations that could become involved in the project. Time critical process as no investigations can be initiated prior to permit is obtained. Deliverable: Exploration Permit application in line withthe Swedish Continental Shelf Act.	Fulfilled – permit application submitted July 2022
Concept Freeze carbon capture units	Comment: Based on the pre-feasibility study, the technology concepts for carbon capture related units together with the heat recovery installations and integration with existing operations to be finally decided. Based on the concept freeze, RFP for detailedbasic engineering of the capture units in the FEED phase can be prepared. Deliverable: Technical report describing the results andconclusions from the detailed analyses related to carboncapture units. The report will form a base for Cementa management decision confirming the concept freeze.	Fulfilled – technical feasibility study presented in December 2023
Exploration Permit approved	Comment: Allow for initiation of geophysical and geotechnical seabed investigations of the preferredLCO2 pipeline corridors and offshore facilities. Deliverable: n.a.	Fulfilled – permit approval reached early fall 2023

Deliverable/ milestone	Description (as per applicaotn to the Energy Agency April 2022)	Fulfilment comment
Completed marine geotechnical surveys	Comment: The results from these activities enable continued in depth development of harbour and ship loading facilities, aiming for concept freeze during thefinal stages of the study. Deliverable: Report presenting the investigations made,results and conclusions forming the base for continued development of the harbour and ship loading system solutions	Geophysical surveys completed March 2024. Complementary geotechnical analyses as may be required to be managed FEED phase
Concept freeze harbour and ship-loading facilities	Comment: Concept freeze of the downstream on site units completing the carbon capture system at Slite siteenable preparation of RFP for the basic engineering of the downstream units in the FEED phase can be prepared. Deliverable: Technical report describing the results andconclusions from the detailed analyses related to harbour and ship loading facilities. The report will forma base for Cementa management decision confirming the concept freeze.	Fulfilled – decision towards onshore system reached in Juley 2023, further developed in the Technical feasibility study of December 2023
Environment alpermit application submission	Comment: Alongside with the preparation of the concept freeze for the whole value chain at site, environmental impact investigations will be prepared (mainly within the framework of an EIA) forming the base for an environmental permit application. This permit application – following public consultations andother activities as per the authority demands and processes – will be submitted in the end of the Feasibility and Concept Freeze Phase. Deliverable: Permit application documents meeting thedemands of the authorities/environmental court.	Partly fulfilled – draft documents (EIA, Technical Description, Application Doument) prepared, further refining actions remain until submission of application planned for May 2024.
Final report	**Comment: Completing the activities of the Feasibilityand Concept Freeze Phase a Final Report will be prepared. This report will constitute a summary and compilation of other deliverables that will be preparedduring the study.** **Deliverable: Final report in line with the requirements of the Swedish Energy Agency together with a popularexecutive summary version to be available to a wider stakeholder group.**	Fulfilled – internal comprehensive report prepared and presented March 30th. Report meeting Energy Agency requirements prepared for submission May 15th, 2024

4 External suppliers involvement

The range of studies and analyses undertaken is also reflected by the various external suppliers procured for specific activities complementing the internal efforts by HM staff, see further Table 4-1 presenting a selection of main collaboration partners up to this point.

Table 4-1 - Examples of external suppliers assigned to contribute to specific components of the Slite CCS FS

Main tasks/services/capacities	Engineering contractors
• Amine core process incl. liquefaction/storage	Linde* (pre-study) and Ramboll* (feasibility study)
• DeSOx gas cleaning	GEA, Germany
• Catalyst DeNOx and DeTOC gas cleaning	GEA, Germany
• Direct Contact Cooler (DCC)	GEA, Germany
• WHRU kiln and clinker cooler	GEA, Germany
• Engineering heat pump	Norsk Energi, Ramboll, Siemens
• Heat Pumps	Siemens Energy, MAN, Atlas Copco
• Fabric Filter Clinker Cooler	Redecam, Scheuch, GEA
• Effluent spray drying & evaporation	Redecam with either Lechler or Caldyn as sub-supplier for the spray system
• Hybrid Water Cooling/Air Cooling	Babcock, Norsk Energi, Ramboll, Kelvion, TT Coil
• Effluent Treatment Engineering	Ramboll, Denmark
• Mechanical Erection	Midroc/Aenigma, Ramboll
• Electrical System Engineering	Ramboll and Sweco
• Civil Works	Ramboll, Sweden
• Geophysical investigations	Ramboll, Sweden
• Specialist design support	Technology Centre Mongstad, Norway
• 3D laser scan and drone scan	AFRY, Sweden
• Architect	Tham & Videgaard, Sweden
• Risk Analysis, blasting	Nitrokonsult
• Flue Gas measuring campaign	Engie Laborec, Belgium
• CO_2 Tank design	Idesa, Spain
• Harbour expansion and vessel entry simulations	RISE/SSPA
• CO2 transportation and sequestration	RISE/SSPA, Ramboll
• Geotechnical Investigations	To be decided

Main tasks/services/capacities	Engineering contractors
• Numerous environmental analyses, EIA, etc.	Sweco
• Different risk analyses – environment, traffic, CO2 etc.	WSP
• Marine environment investigations and analyses	Calluna
• Noise analysis and modelling	Brekke & Strand, Akustikkonsulten
• Legal Advice	Mannheimder Swartling
• Public Funding Support, preparation of EU applications	EGEN/PNO
• Financial Analysis, Financial Model	Copenhagen Economics
• Communiction and PR services	Geelmuyden Kiese
• Communication strategy	Diplomat Communication