Final report

Project Greensand – End of Phase 1 Report

20th September 2021

Greensand Value Proposition
Provide safe, low-emission and cost-effective storage of:
½-1½ million tons of CO_2 by 2025 in Nini Field
4-8 million tons of CO_2 by 2030 in the Greater Siri Area

0. Preface

This report marks the end of Project Greensand Phase 1 – the most evolved Danish CO_2 storage project to this date. The project has been made possible by the foresight by the Consortium partners – who already in 2019 saw the possibility for CO_2 Storage in Denmark to help tackle the climate changes.

The Project Greensand Phase-1 has been made possible by a 60% self-funding by the three commercial companies, as well as the cardinal co-funding by the Danish EUDP Programme.

This report and its underlying appendices contain confidential material under the law of proprietary data as well as business critical information. Consequently, this report and any of the appendices cannot – in parts or in its full length –be exposed to the public without prior consent from the Consortium partners.

INEOS Energy has acted as lead for the Project Greensand Phase-1 – but the strong outcome of the project - is a result of a significant teamwork and ability to adopt to changes. The Consortium filed the application to the EUDP on the 5th of March 2020 – less than a week before the majority of Europe and for that matter the World, was facing the COVID-19 Pandemic. Delivering a project under these circumstances has only been possible by the proactiveness by all the Consortium partners and the strong will from everyone, to deliver this important project in time.

The Project Greensand Phase-1 Steering Committee would like to use this opportunity to thank all the people involved in the project, and all contractors who in one way or the other have contributed to this significant milestone in the Danish Climate effort. A sincere thank you to the members of the Sounding Board, who has given valuable insight and technical fruits for thoughts. Also, a thank you to Lærke Skov Hansen at the EUDP Programme, who throughout the project duration has been helpful and supporting, whenever there was a question from the Consortium

A special thanks to Estela Vázquez Esmerode, who as project manager for the Greensand Phase-1 managed this project through a period of a global pandemic, travel restrictions and restrictions in workspace access. Despite these challenges, she managed to get a team, who for a lot of the members, never have met in real life, up and running and ensured the high-quality product presented here.

On behalf of the Project Greensand Phase 1 Steering Committee

Johan Byskov Svendsen

Chairman of Project Greensand Phase 1 Steering Committee

Contents

1. Project details

Project title	Project Greensand – Safe long-term storage og 0.5-1 mill ton CO_2/year
File no.	64020-1080
Name of the funding scheme	EUDP General Pool
Project managing company / institution	INEOS Oil & Gas Denmark
CVR number (central business register)	73349616
Project partners	Wintershall Dea, Maersk Drilling and GEUS
Submission date	20 September 2021
Additional comment	Due to a significant amount of commercial sensitive and confidential data gather during Project Greensand Phase 1, this report only acts as a publicly accessible summary report. A full End of Phase Report has been provided to the EUDP Secretariat, including all data in detailed appendences and the underlying business cases.

2. Summary

2.1 English version

Project Greensand Phase 1 was initiated in June 2020 and has been running in the troublesome time of COVID-19. Despite this challenge, Project Greensand has been able to deliver three key results:

Project Greensand Phase 1 delivered on time and budget: This demonstrates that when critical climate projects are operated by companies qualified for handling large projects, the right governance and proactiveness can be expected and deadlines be met.

No showstoppers for CO_2 storage in the Nini West Reservoir: Project Greensand Phase 1 received, as the first project in Denmark, a 3rd party certification of the technical work, and a subsequent Statement of Feasibility.

CO_2 storage in the Nini Field is competitive: With the 3rd party certification of the storage potential in Nini West 0.5 mtpa it is reasonable to believe that the adjacent reservoir Nini Main can store approximately the double. As such, storage from the Nini A Platform can cater for 0.5-1.5 mtpa. A preliminary business case shows that this storage cost is competitive.

Main technical conclusions:

- The Horda/Lark caprock has very high strength and integrity
- The Frigg reservoir sandstones are competent and geochemically stable to CO_2 in laboratory tests
- The fracture pressure in the reservoir will not be reached in the planned injection scenarios
- The CO_2 permeability is 100-300mD and no reduction is observed after repeated $ScCO_2$/brine injection cycles
- 10,000t CO_2/d can be injected into a NA-3 look-alike well
- The Statement of Feasibility Volume of 5 mill tons CO_2 into the Nini West storage complex has been confirmed by the more detailed model

The risk assessment and governance structure of the project warrants that the project moves into the next phase, the final phase before the sanctioning of the project. This second phase (Project Greensand Phase 2) will include further laboratory assessments, and will also include an offshore pilot injection, to demonstrate the operational ability of offshore transport and injection into the Nini West Reservoir.

2.2 Danish version

Projekt Greensand Fase 1 blev påbegyndt i juni 2020 og har kørt i den besværlige tid med COVID-19. På trods af denne udfordring har Project Greensand været i stand til at levere tre hovedresultater:

Projekt Greensand Fase 1 leveret til tiden og budgettet: Dette viser, at når kritiske klimaprojekter drives af virksomheder, der er kvalificerede til at håndtere store projekter, kan den rigtige styring og proaktivitet opnås og aftalte deadlines mødes.

Ingen showstoppere til CO_2-lagring i Nini West Reservoir: Projekt Greensand Fase 1 modtog som det første projekt i Danmark en tredjeparts certificering af det tekniske arbejde og en efterfølgende erklæring om gennemførlighed.

CO_2-lagring i Nini Feltet er konkurrencedygtig: Med tredjeparts certificering af 0.5 mtpa lagringspotentialet i Nini West er det rimeligt at tro, at det tilstødende reservoir Nini Main kan lagre omtrent det dobbelte. Som sådan kan opbevaring fra Nini A-platformen tage højde for 0.5-1.5 mtpa. En foreløbig business case viser, at lagringsomkostningerne er konkurrencedygtige.

De tekniske hovedkonklusionerne er:

- Horda/Lark bjergarten over lageret har meget høj styrke og integritet
- Frigg reservoir sandsten er kompetent og geokemisk stabil ved CO_2 injektion i laboratoriet
- Frakturtrykket i reservoiret vil ikke blive nået i de planlagte injektions scenario
- Laboratorieforsøg på kernemateriale har påvist CO_2-permeabiliteten er 100-300mD, og at denne ikke reduceres efter gentagne $ScCO_2$/brine injektions forsøg.
- 10.000 t CO_2/d kan injiceres i en brønd med samme design som den eksisterende NA-3-brønd
- Gennemførlighedserklæringen på 5 mio. tons CO_2 til Nini West er blevet bekræftet af den mere detaljerede model

Risikovurderingen og styringsstrukturen for projektet garanterer, at projektet bevæger sig ind i den næste fase, den sidste fase inden sanktionering af projektet. Denne anden fase (Projekt Greensand Fase 2) vil omfatte yderligere laboratorievurderinger og vil også omfatte en offshore pilotinjektion for at demonstrere den operationelle evne til offshore transport og injektion af CO_2 i Nini West Reservoir.

3. Project objectives

3.1 Main Objectives

The project aims to confirm that the Paleocene / Eeocene sand in depleted Danish oil fields in the North Sea can be used for safe long-term storage of CO_2. The project will also test the effects of 'cyclic CO_2 injection' to mimic the proposed operational configuration. The main focus has been on the maturation of the Nini West reservoir as CO_2 Storage Site although preliminary, although preliminary evaluations for Nini Main as well as the whole Siri Area have been done (Figure 1).

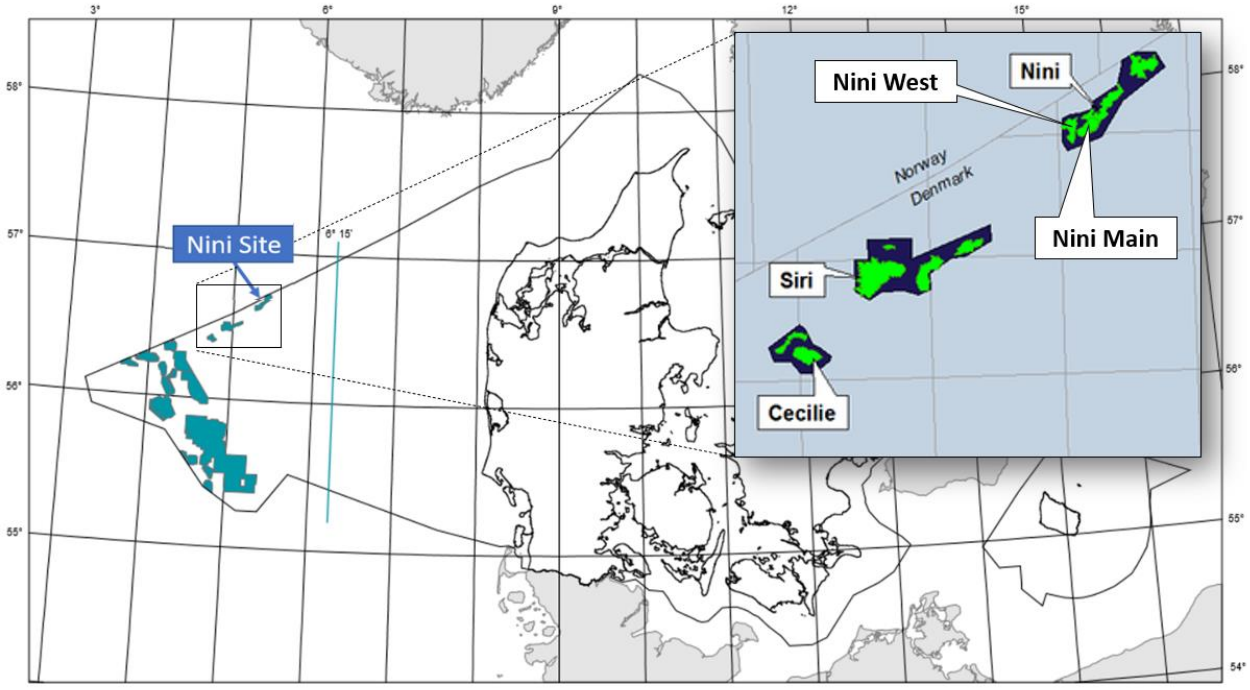

Figure 1. Location map.

The main elements of the work program are:

- Lab testing of the reservoir and seal suitability by using existing rock samples and evaluating both their chemical and mechanical response to dynamic CO_2 injection conditions
- Assessment of the condition of existing wells for risk of CO_2 leakage
- Assessment of the potential to convert oil production wells into CO_2 injectors
- Assessment of the modifications to the existing offshore facilities required to allow CO_2 injection
- Investigation of techniques to monitor the storage site integrity during and after operation
- Volume assessment by utilizing the large data base: seismic, wells, core material and production data
- Risk assessment, to determine 1) Showstoppers and 2) Key risks for further assessment
- Inform about major achievements and key milestones, and communicate to peers and key stakeholders

Further, the project has a strong focus on dissemination of the project mission and results, assisted by public opinion assessments, as this is envisaged as an important action to increase awareness of Carbon Capture and Storage (CCS) in Denmark and facilitate the process towards site permit approval.

The results of the project are expected not only to progress the maturation of the studied reservoir as carbon storage site, but also to open for the potential maturation of several analogue reservoirs accessible by the existing infrastructure in the Siri Area. Benefiting from the large amount of data readily available and infrastructure already in place, the overall project aims to deliver a site suitable for CO_2 storage in a safe and cost-effective manner by 2025. The results of this phase of Project Greensand, Phase 1, will not only make it possible to develop the maturation of the investigated field as a storage site for CO_2, but it will also open up for the possible maturation of more analogue depleted oil fields in other areas.

3.2 Storage Site Complex

A basic part of any CO_2 Storage Site Assessment is the definition (description, mapping and technical assessment) of a storage site complex. The technical results from the Storage Site Complex (SSC) are further described in Chapter 5. The definition of the Nini West CO_2 SSC is discussed here.

The storage unit evaluated for CO_2 injection in the Project Greensand is the Lower Eocene Frigg Member (Hefring Member) of the Horda Formation (Figure 2). The Frigg sandstone unit is located on the western flank of the Nini salt dome structure at a depth of approximately 1700–1800 m TVDSS. It consists of highly porous and permeable glauconitic sandstones 12-30 m thick and embedded in laterally very extensive shale units of the Horda Formation (above) and the Balder Formation (below). The Horda and lower part of the Lark formations constitute the primary seal with a thickness of more than 300 m. The bottom seal is formed by an approximately 50 m thick shale section spanning from the Top Vile to the Top Balder formations. The capacity of the seals are documented by the oil accumulations in the Siri Area oil fields.

The **storage complex** is thereby defined to extend stratigraphically from Top Vile to the lower part of the Lark Formation (red box in Figure 2). The areal extent of the storage complex is defined by the up-dip pinch-out of the storage unit onto the salt induced Nini structure to the east and downdip to the defined limits of the CO_2 storage project (Figure 3). This includes but is not restricted to the former hydrocarbon accumulation in the Nini West Field. Three legacy wells (Nini-4, NA-3 and NA-5) and two sidetracks correponding to 5 reservoir penetrations are located within the boundary of the storage complex. Seismic mapping and well data indicate that the Frigg sandstone unit continues downdip of the defined storage complex towards the south and west where it has been drilled by the Sofie-1 and -2 wells. The full extent of the sandstone unit represents the **Frigg hydraulic unit** defining the boundary for the static and dynamic modelling.

3.2.1 Definition of legacy wells

Legacy wells are, in accordance with the ISO Standard guidance, defined as “the pre-existing wells within the area of review of a CO_2 storage project that were drilled for a different purpose than CO_2 injection or monitoring of the respective CO_2 storage project”. The legacy wells within the Nini West SSC are shown in Figure 3 and listed in Table 1.

	Well type	Well Status	Future use	Integrity status
Nini-4/-4A	Exploration	Plugged and abandoned	N/A	Permanent abandonment barriers in place
NA-3A/B	Oil producer	Inactive/no use since 2018	Potential production test before P&A	No integrity issues
NA-5	Water injector	Intermittent use	Used until P&A	No integrity issues

Table 1. Legacy well status overview

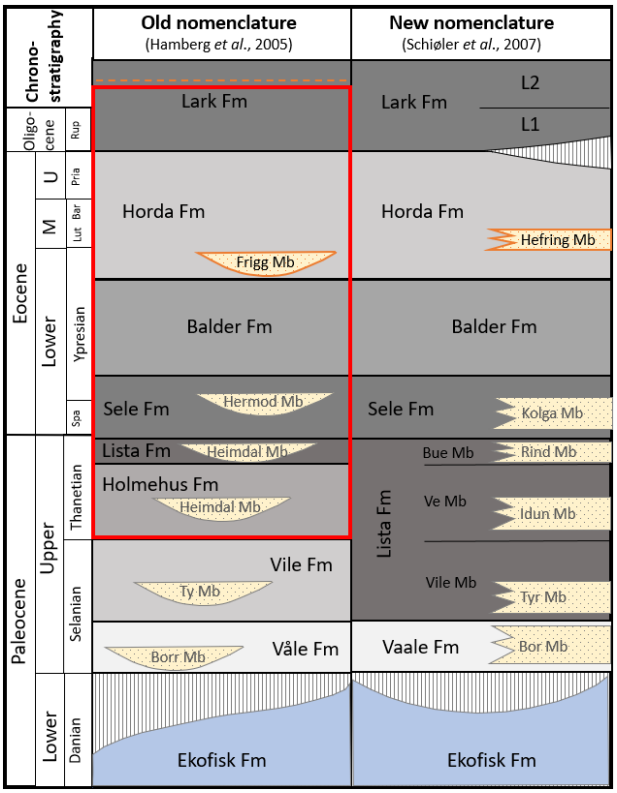

Figure 2. Lithostratigraphy of the Siri Canyon. The Nini west storage complex is stratigraphically defined from Top Vile Fm to a sandstone marker in the lower part of the Lark Fm. The storage unit is defined as the Frigg Mb sandstone of the Horda Fm. Note that the sandstone members Borr, Ty, Heimdal and Hermod are not represented in the Nini West storage complex which is dominated by mudstone deposition in the Upper Paleocene-Lower Eocene.

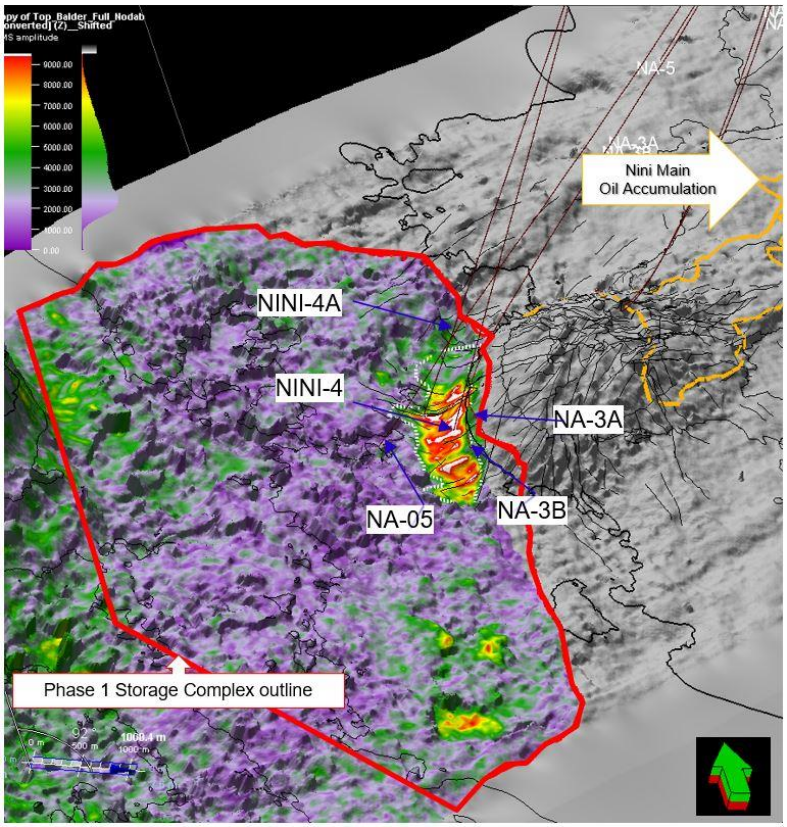

Figure 3. Outline of the Nini West storage complex, legacy wells and area covered by the geomodels.

4. Project implementation

The Consortium filed the application to the EUDP on the 5th of March 2021 – less than a week before the majority of Europe and for that matter the World, was facing the COVID-19 Pandemic. Delivering a project under these circumstances has only been possible by the proactiveness by all the Consortium partners and the strong will from everyone, to deliver this important project in time.

The commercial part of the consortium (INEOS, Wintershall Dea and Maersk Drilling) quickly saw the risk of COVID-19 impacting the schedule of Project Greensand Phase 1. In order to mitigate this, the parties agreed to pre-invest in a number of parts for the GEUS lab as well as relevant consumables. These costs were not reimbursed through the EUDP but were mandatory to secure the laboratory to run efficiently. During the 2020 shortcoming and delay of multiple items, this decision demonstrated to be well chosen.

A non-technical risk incurred during the project was the narrow scope of the project and hence the consortium. For any input on elements regarding transport and emitters, it has been necessary to reach out to companies outside the consortium, and the validity of such information can always be questioned. It is strongly recommended that the next phase of the project covers the entire CCS value chain.

The fact that **Project Greensand Phase 1 delivered on time and budget** can be ascribed to a very strong project management/lead as well as by a very committed consortium.

5. Project results

The results from Project Greensand can be grouped into: Technical, Commercial, Communication/Dissemination and Public Opinion. These four areas are further discussed below.

5.1 Technical

5.1.1 Subsurface

The examination of the subsurface of the Nini West has resulted in a number of key findings.

5.1.1.1 Core Assessment

The evaluation of the reservoir and the overlying seal has demonstrated a huge storage potential under safe condition sin the Nini West storage site.

The extensive amount of core material (acquired through the period of oil exploration and appraisal) has been exposed to cyclic injection of CO_2 and has documented that no concern exists as to the intermittent nature of the proposed operational setup, with cyclic CO_2 injection.

No changes are seen in rock properties as a function of the cyclic injection.

5.1.1.2 Subsurface Mapping

The utilization of the available 3D seismic cubes, the extensive well database and the production data from the more than 15 years of production, have led to a very detailed subsurface model. This model has been used to make uncertainty assessment as to number, length and location of future injection well(s). The detailed study has confirmed the initial view of the storage potential in the Nini West storage complex, and that the injection capacity can be obtained by one 1,000m long horizontal well.

5.1.1.3 Geomechanical Assessment

A cardinal point for any CO_2 storage site is that the caprock integrity is high enough to sustain the CO_2 induced pressure so the injection of CO_2 does not comprise the caprocks ability to hold back the injected volume of CO_2.

A thorough study was carried out by Baker Hughes, which illustrated that the proposed injection volume can be contained, without compromising the caprock by reaching the fractures pressure.

The main technical results of the Greensand Phase 1 are:

- The Horda/Lark caprock has very high strength and integrity
- The Frigg reservoir sandstones are competent and geochemically stable to CO_2 in laboratory tests
- The CO_2 permeability is measured to 20% of the air permeability – reaching a level of CO_2 permeability of 100-300mD
- Cyclic injection at core scale does not generate any reservoir deterioration
- The frac pressure assessment demonstrates that keeping reservoir pressure below 280 bar is well within safe zone
- 10,000t CO_2/d can be injected into a NA-3 look-alike well
- Injection in horizontal well will ensure substantial headroom to frac pressure
- The Statement of Feasibility Volume of 5 mill tons CO_2 into the Nini West Storage Complex has been confirmed by the more detailed model

5.1.2 Risk Assessment

The risk assessment carried out has demonstrated that no showstoppers have been identified. The most important risks still remaining to be addressed are:

- The planned injection rates cannot be reached
  - #203: Salt clogging around wellbore
  - #204: Swelling of glauconite
- Leakage via well
  - #310: Cement integrity
  - #314: Chemical degradation of cement in legacy wells NA-3 and NA-5
  - #313: Corrosion of tubulars in legacy wells NA-3 and NA-5
- Troublesome well conversion to CO_2 injector
  - #312: Drilling and completing a new well as a slot recovery of NA-3 re-using the 13-3/8" casing for sidetracking, not feasible due to excessive wear. Need to kick off shallower and include new casing section.

The entire overview of the risks are shown in the Project Greensand Risk Register (Appendix 1).

The remaining risk of moderate impact (#203, 204, 310, 312, 313 and 314) will be further addressed in Project Greensand Phase 2 (see chapter 7).

5.1.3 Monitoring

A critical part of the Greensand Phase 1 has been to demonstrate that a future storage site can be duly monitored. The Monitoring Plan is subdivided into the following eight elements (as proposed by EU CCS Directive Guideline. For all cases, continuous or intermittent monitoring is mandatory (Table 2).

1	Fugitive emissions of CO_2 at the injection facility (and vessel + SAL)
2	CO_2 volumetric flow at injection wellhead
3	CO_2 pressure and temperature at injection wellhead
	CO_2 pressure and temperature within well (and well integrity)
4	Chemical analysis of the injected material
5	Reservoir pressure and temperature (CO_2 phase behaviour)
6	Location and migration paths of CO_2 (subsurface, surface)
7	CO_2 plume (pressure, volume and areal/vertical behaviour) purpose: refinement of 3D simulation
8	Potential leakage pathway (areal dimension)

Table 2. Items which should be considered mandatory (from to EU CCS Directive Guideline).

Each element is further subdivided into wellhead and downhole measurement, shallow focused monitoring, and deep focused monitoring. Different methods and techniques suitable for monitoring are compiled in appendix 2, including the frequency and duration of the monitoring activities.

The assessment of the feasibility of adequate monitoring at the Nini West site builds on the conducted risk assessment (see Risk Register in Appendix 1). Following on the identification of the key risks to containment, a compilation of adequate equipment and techniques has been performed. The required frequency of data sampling has also been estimated. The above has been conducted for three time steps to cover the full life cycle of the project:

- Pre-injection (baseline)
  - Establishment of a baseline to monitor changes which might occur during/after CO_2 injection.
  - The selection of tools according to the planned monitoring practice.
  - Study regarding seafloor properties to distinguish between natural variability and potential leakage impacts.
- Injection phase
  - Surveillance of all aspects regarding safe CO_2 storage (Table 2)
- Post-injection phase
  - Monitoring the advances of the CO_2 plume regarding a satisfactory closure of storage
  - Initiating and reporting preventive and remediate actions in case of leakage
  - Removing the injection facilities

At the time of transfer of responsibility to the competent authority (to be defined by Danish Regulators, when the licence rounds are being opened), documentation regarding pre-/injection and post injection phase will be required as prove of stable and safe CO_2 storage.

5.1.3.1 Monitoring Technologies

Effective and efficient monitoring technologies are available for the identification of possible leakage from a geological site of a CCS application. Threshold values have to be defined to limit monitoring costs especially regarding plume boundaries and local CO_2 saturations inside the storage site. An optimized monitoring plan is directed to all potential risks according to their impact and combine this with a cost-effective approach. In

compliance with laws and regulations, the strategy of the monitoring technology is to enable a safe operation regarding the offshore CO_2 storage complex in the most-efficient manner.

The primary focus is on available techniques that meet the Greensand Project demands considering an appropriate balance between environmental benefit of applying the respective technique versus impact and the cost on its implementation. The planned methodologies/techniques within each item are discussed in Appendix 2. Moreover, an assessment is considered for alternative/optional tools/devices.

5.1.4 3rd party verification

Project Greensand has selected to follow the requirements set out by the ISO standard 27914:2017. Verification of the screening work performed during the Phase 1 has been conducted by DNVGL. In October 2020, the project received a Statement of Conformity – Site Feasibility from DNV, supporting the feasibility of the Nini West site for long-term storage of CO_2 (Appendix 3).

5.2 Commercial

Making a business in a traditional sense is about making more revenue on your product, than the cost of generating it. For the CO_2 Transport and Storage Business Models (CTSBM) this is also the case, but where the cost stream is tangible (it builds on 90% of the existing oil & gas knowledge) the revenue stream is more intangible, and varies from country to country, and region to region.

In June 2020 the Danish Parliament agreed to set up a Marked Based Pool (MBP), by which the first CCS project can be supported "The parties agree to establish a technology-neutral, market-based pool that will help promote technology and deliver greenhouse gas reductions by 2030 and beyond. DKK 202 million is set aside. in 2024, DKK 406 million. DKK in 2025, 406 in 2026, 626 million. DKK in 2027 and 626 mill. DKK in 6 2028 and 815 mill. DKK in 2029 and onwards (calculated in 2020 prices and including derived tax losses), which is estimated to deliver a CO_2e reduction effect of 0.4 mill. tonnes of CO_2e in 2025 and 0.9 mill. tonnes of CO_2e in 2030. The support runs for 20 years. The political parties will decide on concrete implementation on the basis of a proposal from the government". In summary the pool offers 120-130 €/t CO_2 reduced by CCS.

The MBP can be considered a plausible revenue stream, though the actual implementation and setup is still unknown. Another revenue stream will be the avoidance of paying the CO_2 tax/tariff/quotas for the emitters. The increase in ETS price over the last two years, has increased the probability of the ETIS in itself to be the base revenues stream by the end of this decade.

The Siri Area has four platforms and eight underlying hydraulically separated reservoirs. As the depth to the reservoirs, the composition of the reservoirs and the reservoir parameter to a large extent are identical, the storage capacity of each reservoir is solely determined by the pore-volume of the reservoir. In contrast to the assessment of the storage potential/volume of saline aquifers, the pore-volumes of depleted hydrocarbon fields are well known, as it can be determined by the number of produced hydrocarbons. Hence, the uncertainty of the storage potential of the Siri Area is low. The produced volumes and the corresponding storage potential for the fields of interest are calculated based on the work done in Greensand Phase 1 for the Nini West potential – the storage potential has been estimated for all the Siri Reservoirs (Figure 4).

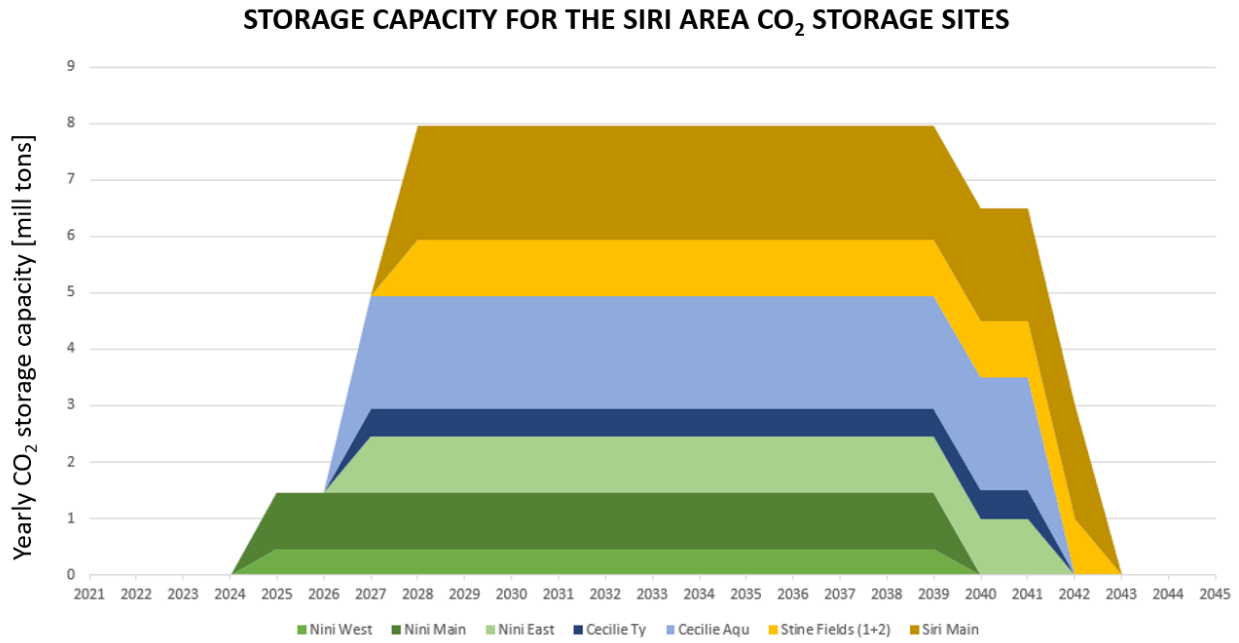

Figure 4. Storage potential in Nini West (lower most green) and the entire Siri Area (full build-up).

If a storage site is to be qualified by a single number, it would be the cost of storage, although each project has some specific areas of concerns or assumption, whereby the storage cost might vary. As discussed in chapter 8 in Main Application, the storage cost can also include the transportation cost, as this will allow for the emitter to have only one number to consider. When comparing the Storage or Transport/Storage cost from one project to another, it is important to bear in mind, that the reported costs often are constructed to serve a certain value chain configuration, or a certain funding option, ie Greensand will look at a 0.9 mtpa case, as this is the available funding from the Marked-based Pool, whereas Northern Lights will look at a 0.8 mtpa case, as this is the emission from the associated cement factory and waste incineration in Project Longship.

Two different Greensand Business cases are being assessed. A 0.9mtpa case utilizing the Nini Platform, and an 8mtpa case, where all Siri Area platforms and fields are used. In order to give a comparable picture, the break-even cost for CO_2 Transport and Storage is calculated for each case. Greensand Transport & Storage Cost are competitive when compared to main competitors, who have made their costs publicly accessible. Project Greensand can deliver a Transport & Storage of CO_2 cost of ~60-80 €/t in 2025, with the option to cut this with 20€/t, if a decision to develop all 8 mtpa in the Siri Area is taken from the start. The need for scale is critical.

5.3 Communication/Dissemination

The communication and dissemination of the results of Project Greensand Phase 1 have taken place through three channels, described below.

5.3.1 Presentation at conferences, reports and scientific papers

The scientific dissemination of the findings and conclusions of this study has been impacted by a number of delayed and cancelled conferences due to COVID-19. Based on the more normal setup in 2nd half 2021, more presentations will be given. Presentations given and planned include: Participation in EAGE 2021 conference (82nd EAGE Conference and Exhibition), the Baltic CCS (14-15 October 2021) and the "International Energy Forum 2021"in Oslo (2 November 2021). At conferences an abstract on the laboratory testing will be presented (included as WP 2 Delivery 6). In addition to this, a scientific paper is in preparation and expected to be submitted during 2021 and to be published in 2022. This effort will be made as post project scientific work based on the reports and data gathered during the project. Dissemination of all scientific reports including all data that GEUS has produced will be made through the GEUS report series wherein all GEUS deliveries are published. These reports have a confidentially period of 1-2 years after project closure to allow the post project scientific work to be finalised. Hereafter the reports will be available from the GEUS website and from the Project Greensand web site to the general public.

5.3.2 Presentation through SoMe, homepage and media

Project Greensand has been active in communicating status and achievement on social medias like LinkedIn and Twitter. The project has invested in developing a homepage (www.projectgreensand.com) and a number of status videos.

Through the media, Project Greensand has been very active in presenting results and achiemnets. This has primarily been through the relevant media EnergiWatch, but also through Borsen, Jyske Vestkysten and other media.

A highlight of the media interactions is shown in Appendix 4.

5.3.3 Presentation through Sounding Board

Project Greensand has benefitted hugely from the close interaction between the project team and the Sounding Board. This board consists of other CO_2 Storage projects, emitters, NGOs, trade organisation, working union organisation, Universities and other Industrial players within CCS.

The Sounding Board has met five times throughout the project duration.

A Terms of Reference was developed by the initiation of Project Greensand. It is confidential who the members of the Sounding Boards are.

5.4 Public Opinion

Climate change is one of the greatest threats to our planet and society. The Danish Social Democratic government has set an ambitious goal to reduce CO_2-emissions by 70 percent by 2030 (compared to 1990 levels) - with broad support across parliament - in order to arrest the global temperature increase observed during the past decades. Among others, the Danish Council on Climate Change has actively voiced support for CCS as a solution which can effectively and substantially reduce carbon emissions at a competitive price.

Project Greensand could provide the transport and storage for the first large scale CCS project in Denmark with a large long-term emission reduction potential. However, with a sub-optimal communication strategy, even the most obvious energy projects can get public resistance and fail to receive political approval. Not In My Backyard (NIMBY) movements are effective for rallying support and influencing the political decision processes at both local and national level. This combined with low public and political knowledge about CCS could represent a threat for the project's success. A shared strategic approach in the consortium is paramount in order to mobilize and maintain public support for CCS in Denmark. The current project has conducted a media analysis, stakeholder mapping and analysis, and public opinion survey to help building the right communication strategy.

The thorough desktop research conducted for the media analysis, included social media, has identified the following key conclusions:

- The amount of coverage on CCS is increasing exponentially showing a momentum in 2021
- The debate on CCS primarily takes place in niche media
- There is significantly more media coverage on PTX compared with CCS
- The arguments against CCS are currently primarily based on logical argumentation
- The emotional debate has not begun or has not been defined yet

The poll of a representative sample of the Danish population on their knowledge around and attitude towards has shown that:

- The knowledge level of CCS is moderate, and together with the media analysis it is concluded that there not an established public knowledge about CCS
- Every fifth person states that CCS does not sound like a good idea based on the short factual explanation. This indicates that the starting point for many Danes would be scepticism, when they hear CCS explained
- There is an overall positive reaction to oil companies being responsible for the storage operations
- It is worth noting that it does n0t affect people's support for CCS positively that it is necessary in order to reach Denmark's climate goals
- The argument that CCS can create jobs in Denmark has very positive traction

The stakeholder analysis has been based on interviews with the key stakeholders identified during the media analysis and identified by the Project Greensand Consortium in order to assess the position of politicians, relevant alliance partners, NGOs, as well as to assess political challenges and opportunities. The main conclusions from this analysis are:

- Overall, CCS is seen as a good solution to the climate challenges in Denmark and as a step towards meeting the climate goals
- There is a concern whether CCS becomes a false security and perception that CCS is not a real reduction. CCS is perceived as a development potential rather than a ready solution
- Several respondents mention the price; CCS is considered a relatively expensive solution, but several respondents also point out that it is worth the investment. A handful of the respondents highlight jobs as a major factor in the discussion about CCS
- The attitude towards CCS is generally positive but some concerns exist around speed, false security and price.

Based on the above-mentioned analysis, the following challenges have been identified:

a. CCS is not perceived as a real reduction. The experts' expectations and faith in CCS is not reflected in the general public nor entirely across a wide political spectrum. Amongst many political stakeholders, CCS is not perceived as a "real reduction" but more as a postponement of the issue.
b. Uncertainty about timeframe for Greensand. A challenge in order to position Greensand as a viable solution is that the project is not considered a short-term solution that could already come into work within a short amount of time.
c. Limited knowledge and emotional support for CCS in the general public. The Danes only have a limited knowledge about and understanding of CCS. With this low level of knowledge, it would be easy to raise opposition in the general public against CCS with arguments that are more emotional than fact-based.

6. Utilisation of project results

The scope of Project Greensand Phase 1 has been to make the first of three steps, to mature the first CO_2 Storage Site in Denmark. The utilization of Project Greensand Phase 1 is therefore primarily meant for the ability to move forward into the next phase.

Based on the conclusions and the remaining risks (see Chapter 5.12 and Appendix 1), the following three areas are to be addressed further:

1) More laboratory experiments
    i. Testing reservoir rock
    ii. Testing well cement
2) Pilot injection of 1/10 volume can address the upscaling risks
    i. Inject 5-15 batches of CO_2 to qualify cyclic injection
3) Development of cost-effective monitoring technologies
    i. Develop and test state-of-or monitoring technologies

The three main areas define the outline of Project Greensand Phase 2. An application for EUDP co-funding of Project Greensand Phase 2 was filed to EUDP on 3rd of September 2021.

The results, and especially the laboratory configuration and methodology at GEUS, will allow the next CO_2 storage sites in Denmark to be matured faster, when and if they decide to start the maturation. Consequently, the utilization of the Greensand results is not only for the next steps of the Project Greensand, but for all of the CO_2 Storage projects in Denmark.

6.1 competitive situation

Since the filing of the application of Project Greensand Phase 1 on 5th of March 2020, there has been a massive development in public view and interest in CCS and CO_2 storage (see Chapter 5.4). The main national developments are:

6.1.1 Climate Agreement of 22 June 2020

The Climate Agreement of 22 June 2020 for Industry and Energy outlined CCS as the technology to provide the largest contribution to the CO_2 emission reduction in both 2025 with 0.4 mt and in 2030 with 0.9 mt.

6.1.2 Danish advisory councils March 2020 and February 2021

The Danish Climate Law dictates that the Danish Council on Climate Change (Klimarådet) once a year shall comment on the progress of the climate initiatives. The Danish Council on Climate Change outlined the need for CCS to contribute with 3.4 mt in 2030. The Danish Economic Councils stated the need for CCS to contribute with 6.5 mt in 2030, to give the most economical sensible way to the reach the 70% target, and furthermore stated that 5.5 mt should arise from BECCS (BioEnergy Carbon Capture Storage)

6.1.3 Danish Climate Program September 2020

The Danish Climate Program laid forward by the Danish Government in September 2020 pointed to a contribution from CCS in the order of 4 (low) to 9 (high) mtpa.

6.1.4 The impact of Greensand

As can be seen, there is a firm belief that storage of captured CO_2 can cover up to 40% of the required CO_2 emission reduction by 2030 (see Figure 5). As such, CO_2 storage has moved from a niche/frontier area when the Greensand Phase 1 Application was written, to be an unavoidable key element in the Danish Climate Strategy.

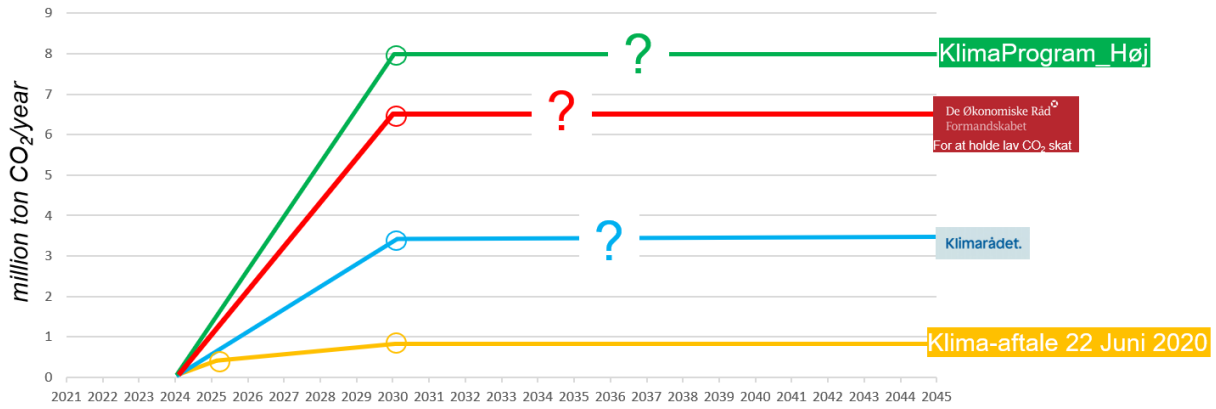

Figure 5. Overview of the Climate Agreements, Strategies and Ambitions laid out since the onset of Project Greensand. When compared to Figure 4, it can be seen, that implementing CO_2 storage in the entire Siri Area, will meet the storage potential laid out from the various national bodies.

This development has to some extent been governed by the active dissemination and communication from the Greensand Consortium.

6.2 contribute to realise energy policy objectives

Project Greensand Phase 1 has demonstrated which assessment and processes are required to carry out, and shown how these can be done in an expedient and at the same thorough maturation of a CO_2 Storage Site. In this respect, the project has played a very important role in the realisation of the energy policy objectives. This is probably best exemplified by the proposed CCS Strategy by the Danish Government (Appendix 5) stating that “samt INEOS, Wintershall Dea, Mærsk Drilling og GEUS (lagring) arbejder også på fangst- eller lagringsprojekter” (as well as INEOS, Wintershall Dea, Maersk Drilling and GEUS (storage) also works on capture or storage projects).

It is clear, that Project Greensand has been a main contributor to bring CO_2 Storage closer to realization, and hence has played a fundamental role in achieving the Danish Climate Targets.

7. Project conclusion and perspective

7.1 Project Conclusions

Project Greensand was launched as the most ambitious CO_2 storage project in Denmark and has received attention from other European projects and CCS industrial parties for the very ambitious timeline and scope. The Greensand Consortium managed to deliver in due time, and all the targets set forth for completion were achieved. These includes:

Project Greensand Phase 1 delivered on time and budget: This demonstrates that when critical climate projects are operated by companies qualified for handling large projects, the right governance and proactiveness can be expected and deadlines be met

No showstoppers for CO_2 storage in the Nini West Reservoir: Project Greensand Phase 1 received, as the first project in Denmark, a 3rd party certification of the technical work, and a subsequent Statement of Feasibility. Despite several sites in Denmark have been considered, no site has ever made it to this critical milestone

CO_2 storage in the Nini Field is cost-effective: With the 3rd party certification of the storage potential in Nini West Storage Ste Complex 0.5 mtpa, it is reasonable to believe that the adjacent reservoir Nini Main can store approximately the double. As such, storage from the Nini A Platform can cater for 0.5-1.5 mtpa. A preliminary business case shows that the storage cost is competitive and that the politically approved Market Based Pool is sufficient to initiate CO_2 storage in Denmark

7.2 Project Perspective

The aforementioned conclusions allow for Project Greensand to move into Phase 2, upon a successful grant award of 197mill DKK through the EUDP Special Pool for CO_2 Storage Development and Demonstration Projects. Project Greensand is following a stringent stage gate model, and thus- despite the very promising and encouraging results – technical, commercial and regulatory maturation have to follow a process.

However, the perspectives of the Greensand Phase 1 are promising. The vast amount of data and insight into the depleted reservoirs, which initially kick-started the project, have proven to support the storage potential as well as the risk assessment. Furthermore, the project has demonstrated a very competitive storage cost, which will bring Greensand in play for the Green Transition, not only in Denmark, but in the whole of Northern Europe.

The promising potential could be the onset of a new growth adventure, where the Danish subsoil, the capabilities and competences and the ability to import CO_2 from other countries, will pave the road for a Green CO_2 Adventure for the decades to come.

8. Appendices

Appendix 1. Risk Register

Appendix 2. Monitoring Plan

Appendix 3. Statement of Feasibility

Appendix 4. Media Highlights

Appendix 5. Køreplan for CO_2-lagring i Danmark Del 1 af regeringens strategi for kulstoffangst og lagring i Danmark