CCS in the Baltic Sea Region – Bastor 2

Work Package 2 – Knowledge about Environmental Impact

Elforsk report 14:46

Yggdrasil Miljömanagement AB and panaware ab

June 2014

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Preface

Yggdrasil Miljömanagement AB, together with panaware ab, has been commissioned by Elforsk AB to document current knowledge about environmental impacts in the light of a possible CCS field trial project in the offshore Baltic Sea Area. This report is part of the project Bastor2 (Baltic Storage of CO_2), with the overriding objective to assess the opportunities and conditions for CO_2 sequestration in the region. The project, which runs from June 2012 through September 2014, is financed by the Swedish Energy Agency and the Global CCS Institute in collaboration with a number of Swedish industrial and energy companies[1].

[1] SSAB, Jernkontoret, Svenska Petroleum Exploration, Cementa, Nordkalk, SMA Mineral, Minfo, Vattenfall, Fortum and Preem

Introductory remarks and reading instructions

The objective of this study is to document current knowledge, hazards and risks on environmental impacts in a possible future CCS project in the offshore Baltic Sea Area. Another purpose is to also present a tentative EIA[2] work plan for a field trial project as scoped out in Chapter 2. Further, the intention is to add new knowledge, if possible, to what is already known or applicable to CCS activities in the offshore Baltic Sea Area.

Relevant studies for this report have primarily been Nord Stream's EIA for Consultation under the Espoo Convention regarding installation of the offshore gas pipeline in the Baltic Sea and the OPAB's EIA for the Application for permit regarding oil exploration drilling in the Baltic Sea. Other sources of information have been e.g. the Swedish Geological Survey, Helcom, CGS Europe, RISCS and numerous other projects and reports. No EIA data from similar offshore activities in Poland, Kaliningrad, the Baltic States or Finland have been incorporated in this report.

The main methods used have been literature research and key person interviews.

Chapter 1 describes current knowledge and identified gaps linked to environmental impacts from offshore activities which are presented in The Catalogue of knowledge (appendix 2).

Chapter 2 presents the technical scope for an EIA for a field trial project.

Chapter 3 presents a tentative work plan and content for an EIA covering a field trial project. Cost and time estimates are included in this chapter.

Chapter 4 summarises the conclusions and recommendations identified through the work in this work package.

The literature list (appendix 1) encompasses all reference reports, relevant web sites and other sources used in this work package.

[2] EIA= Environmental Impact Assessment is an assessment of the possible impacts that a proposed project may have on the environment, consisting of the environmental, social and economic aspects. An EIA also includes a consultation process which ensures that the public, authorities, organisations and other stakeholders are given an opportunity to influence the activities and the decisions taken. The EIA is a document that will serve as a basis for the permitting process.

Executive Summary

The objective of this report is to document current knowledge, hazards and risks about environmental impacts in the light of a possible future CCS project in the offshore Baltic Sea Area. The objective is also to present a tentative EIA work plan for a future CO_2-injection field trial. The intention is, not to forget, to add new knowledge, if possible, to what is already known or applicable to CCS activities in the offshore Baltic Sea Area.

The Environmental Impact Assessment reports that have been studied have documented the ecological and environmental status both regionally and locally in the offshore Baltic Sea Area.

The regional data could be of generic value in a future EIA for CCS development in the offshore Baltic Sea Area. Locally, data is limited along the Nord Stream natural gas pipelines and OPAB's Dalders location SSE of Gotland. I.e. if the CO_2 injection site will be located in the area described in the OPAB EIA report, a certain extent of the present data can be of use but still most data needs to be reviewed and updated in a new EIA in this area.

The project has studied EIA reports made for specific CCS projects. From these parameters have been derived, which should be included in an EIA. A side effect is that key organisations with substantial competence within CO_2 transportation, storage and environmental impact are identified.

The Catalogue of knowledge will be of use when an EIA team is planning the work and content, especially the identified knowledge gaps which might occur in connection with CO_2 injection activities and site development.

The tentative work plan, proposed EIA content and time/cost estimation in this report can serve as basis documents for a tender process for a field trial EIA. A total cost estimate interval will probably be, in Swedish Kronor (SEK): 3 500 SEK – 5 500 SEK.

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1 Current knowledge and identified gaps

1.1 The Catalogue of Knowledge (appendix 2)

The Catalogue of Knowledge is a compilation of current knowledge and identified gaps linked to environmental impacts from past offshore activities related to; oil exploration; construction of pipelines; subsea electric cables; environmental risks and consequences in the light of CO_2 transport and storage.

The catalogue is divided into three main categories; (i) General environmental knowledge of the Baltic Sea Region; (ii) Risks and consequences from generic industrial activities; and (iii) Environmental risks and consequences from field trials for CO_2, transport and storage activities in the Baltic Sea Marine environment. The first column in the Catalogue identifies the knowledge area. For the first two main categories these knowledge areas are based on how relevant EIAs, primarily those by OPAB and Nord Stream, have structured the content in their EIAs. The reference column shows the source of information and the third column refers to our literature list with further and more detailed information on that specific report or project. A summary and gap analysis for each knowledge area are found in the two remaining columns.

1.2 Regional knowledge

The regional knowledge, i.e. not site specific data, of the ecological and environmental situation in the offshore Baltic Sea Area is well documented in the EIA reports studied in this work package. The current information and data can be used in a future EIA for CCS development in the region. However, the ecological and environmental situation is constantly changing so all data has to be reviewed and updated in a future EIA study.

The results presented in Bastor2 WP1 indicate possible favourableable conditions for CO_2 injection in the northeastern parts of the offshore Baltic Sea Area. In this report, i.e. WP2, only regional knowledge in this geographical area has been identified. Therefore, if a future CO_2 injection site is to be developed in this area a complete and new EIA has to be carried out.

1.3 Local knowledge

The local knowledge along the Nord Stream pipeline corridor and at the Dalders location is high.

Different field studies have initially been carried out in both projects. E.g. from the sea floor of the Dalders area sampling points have produced sediment cores which have been analyzed for metals and environmental pollutants. The sediments were found to be burdened by the metals lead (Pb) and zinc (Zn) and, above all, organic pollutants, and in some cases heavily burdened by the pesticides chlordane and DDT. Oxygen levels and redox values in sediments were also measured.

Detailed seismic surveys together with side-scan sonar and video camera have also been carried out resulting in detailed information about the physical situation on the sea floor.

The local knowledge described above was the situation at the Dalders location in 2007-08 when the site survey was carried out. Obviously, the local knowledge can only be of use if a future CO_2 injection site will be located in, or close to the Dalders area or some point along the Nord Stream pipelines.

2 Technical scope

Development of a future system for storage, transport, injection site and injection operation for CO_2 gives rise to various impacts or hazards, which present risks[3] to the public, third parties, workers and to the environment.

Specifically, knowledge gaps of environmental hazard, risk or impact in the below four areas have been of interest to identify.

2.1 Transport of CO_2 by ship

Transporting liquefied and pressurised gas by ship dates back more than seventy years. In Europe carbon dioxide has been transported by ship for more than twenty years. The shipping industry is regulated by the United Nations affiliate International Maritime Organisation, IMO. The regulation, known as the "International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk" (IGC Code[4]) also covers carbon dioxide and why this must be considered the basis for an EIA in this field (c.f. Figure 1 Scope for ship transport).

Buffer storage of CO_2 onshore and offshore are components in a shipping logistic system. Compressed gas storage in pressure tanks on land is established technology with long standing industrial standards in the merchant industrial gas industry. An EIA for a CCS project should seek to comply with these standards by for instance consulting the European Industrial Gases Association[5]. For buffer storage offshore, less information is obtainable in the public domain and since the projects studied are based on pipeline transport, the environmental concerns have not been an issue. There is ship discharge solutions described as outlined, where the need for buffer storage is eliminated, with the ship staying on site during the process of discharge.

Other design alternatives involve buffer storage, either as a floating storage (stationary barge) or as an integral part of a submerged turret installation. Consequently, once an offshore buffer storage solution has been selected and designed, a complete environmental risk analysis needs to be implemented.

[3] The words hazard and risk are often used interchangeably in everyday vocabulary. Therefore it is useful to make a conceptual distinction between a "hazard" and a "risk" as follows:

- Hazard: the potential for harm arising from an intrinsic property or disposition of something to cause detriment.
- Risk: the chance that someone or something that is valued will be adversely affected in a stipulated way by the hazard. Risk can be calculated for all potential accident scenarios associated with a system, operation or process.

[4] http://www.imo.org/OurWork/Environment/PollutionPrevention/ChemicalPollution/Pages/IGCCode.aspx

[5] https://www.eiga.eu/

Figure 1 Scope for ship transport

2.2 Transport of CO_2 by pipeline

High pressure pipelines are a safe and environmentally acceptable way of transporting large volumes of CO_2 and the technology has been in use onshore and offshore for decades. There are well-established industry standards for pipeline transport of hydrocarbon gas, to a large extent deemed applicable also for carbon dioxide. However, specific standards need to be developed, taking into account the physical properties of CO_2 and the related risks involved. The environmental risks with offshore CO_2 pipelines have been extensively studied in both the ROAD project (NL) and by National Grid (UK). A future Baltic Sea Area EIA project would need to interact with these organisations and specifically compare with the Nord Stream EIA. In addition, the specific Baltic Sea Area conditions and the terrain involved would need to be assessed and a separate EIA for transport of CO_2 by pipeline has to be carried out.

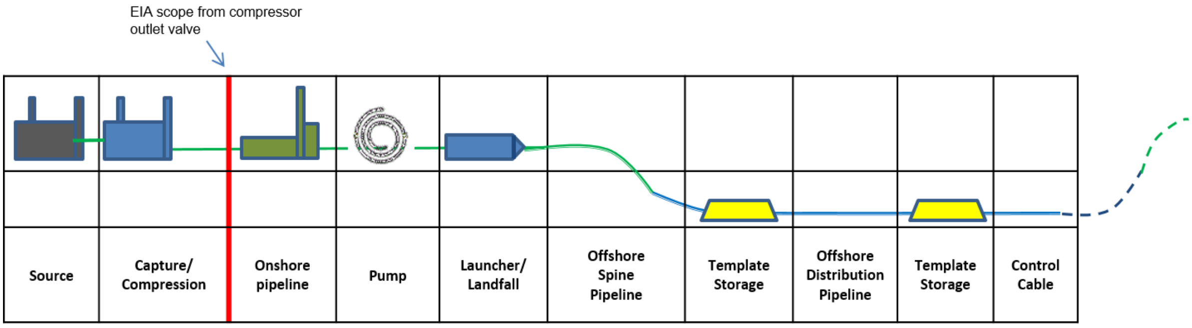

Figure 2 Scope for pipeline transport

2.3 Site activities

Construction and operation of a future injection site for CO_2 give rise to various hazards which present risks to the public, to third parties, to workers and to the environment. However, comparable constructions and operations are successfully developed and operated all over the world in the petroleum industry and EIAs have been carried out for these developments. Hazards and risks are well known and documented for developments in the petroleum industry. Therefore, this report only highlights the gaps which might occur in connection with CO_2 injection activities and site development.

The EIA reports that have been studied have documented the ecological and environmental status both regionally and locally. The regional data could be useful in a future EIA for CCS development in the Baltic Sea Area. The present local data will mainly be useful if the CO_2 injection site will be located in the area described in the OPAB EIA report, i.e. the Dalders area. Of course, the data in the present OPAB EIA report has to be updated with current environmental knowledge as well as new aspects on CO_2 storage exploration. It has to be considered that in the case hydrocarbons are found in the formation where CO_2 is intended to be injected this has to be regarded as a risk.

2.4 Injecting and monitoring of CO_2

Much research on establishing safe and reliable methods for characterising suitable geological storage locations has been performed. Applying strict and scientific geological methods is most likely the most important prerequisite for safe storage with the least risk for leakage of CO_2 to the atmosphere. Both academic research and industrial pilot project EIAs have primarily focused on the risks for leakage and how these can be assessed and avoided. For a Baltic Sea Area CO_2-storage site, it is imperative to systematically apply acknowledged characterisation methods and to document the work accordingly. The same applies to the monitoring of gas migration and potential leakage during and after injection, where e.g. the work of CGS Europe is a valid benchmark.

A focused orientation towards ecological receptor risk assessment has been thoroughly addressed by the RISCS consortium, the ECO2 project and the American Vulnerability Evaluation Framework (VEF). These provide valuable but generic insight into the effects of increased concentrations of carbon dioxide on various receptor environments. Complemented by the results of the corresponding studies for the Baltic Sea Area, done by Nord Stream and OPAB, they will constitute a base line from where to undertake additional and site specific studies for a potential Baltic Sea Area CO_2 storage project.

In a thesis presented at University of Stavanger the possible reasons for why leakage occurs in well barrier elements such as tubing, casing, cement, blow out preventer (BOP) and annulus safety valve (ASV) are discussed. In the thesis the authors identify some of the well integrity challenges in injection wells, including CO_2 injection, production wells (including wells on gas lift), multilateral wells and temporarily abandoned wells.

3 Tentative EIA work plan for field trials

An Environmental Impact Assessment, EIA, is an assessment of the possible impacts that a proposed project may have on the environment, consisting of the environmental, social and economic aspects.

An EIA also includes a consultation process which ensures that the public, authorities, organisations and other stakeholders are given an opportunity to influence the activities and the decisions taken. In addition, the EIA is a document that will serve as a basis for the permitting process.

3.1 Applicable regulations

The EIA process on the continental shelf and in the Swedish economic zone is regulated by Swedish law[6].

Due to lack of relevant legislation on e.g. abandonment of wells in the offshore Baltic Sea Area, Norwegian regulations have been applied in the past. Such regulations have earlier been used for demobilisation of offshore drilling activities (OPAB) in the Baltic Sea [7].

3.2 Scope

A proposal for the scope of an Environmental Impact Assessment covering a field trial project is presented below. Time and cost estimations of gathering data and preparing the report are also included.

Note that a full scale CCS development has to include the onshore or offshore buffer storages, export, loading and CO_2-injection facilities in an EIA.

<u>The EIA for field trials should be carried out for the following activities:</u>

- Export point on shore (EIA time and cost estimates not included in this report
- Transport of CO_2 by ship[8]
- Discharge, buffer storage and processing on site
- Mobilisation at site
- Drilling
- Test injection and storage of CO_2 [9]
- Demobilisation of drilling rig and test injection platform

[6] - The Law (1966.314) on the continental shelf,
- The Law (1992: 1140) for Sweden's economic zone
- According to the Swedish Environmental Code Ds 2000:61 (Miljöbalken) an EIA shall include identification and description of direct and indirect effects that the planned activities and development may have on humans, animals, plants, ground, water, air, climate, landscape, culture etc.

[7] - NORSOK D-0106 on demobilisation of drilling and injection hole.

[8] - According to the Ministry of Environment an EIA is not required for ship transport. A permit is needed for the transport of dangerous goods from the provincial government. For CO_2 transport, the Swedish civil contingencies Agency, MSB, should be contacted https://www.msb.se/en/

[9] DNV CO2QUALSTORE Guideline, Scope of the EIA

3.3 Proposed work plan for field trials

We propose that the process to produce an EIA consists of the following steps (not necessarily in the below order):

A. Establish project management, budget and time schedule for the field trials project.

B. Identify:
- Area for export point
- Transportation contractor
- Contractors for EIA, field studies, building of storage/export facilities, transportation of CO_2, drilling, injection of CO_2, etc.
- Control program for storage, export, transportation, drilling and injection
- Monitoring Measuring and Verification Program (MMV)

C. Prepare documents for consultation and identification of the need for additional information/studies etc.

D. Verify the processes and permits required to obtain approval to develop infrastructure for buffer storage, transport, drilling and geological storage of carbon dioxide within project guidelines (dates, locations etc.). This preferably includes a flowchart or diagram showing the pertinent agencies, required reports or data, and the estimated timeframe to obtain approvals from each agency.

E. Prepare and conduct the EIA, see proposed EIA content in table 1 below. The EIA content is regulated by Chapter 6 §7 in Ds 2000:61 The Swedish Environmental Code (Miljöbalken)[10].

F. Carry out environmental field studies at site location, see table 2. The field study results are to be included in the EIA.

G. Identify environmental risks and consequences from the development, construction and operation of infrastructure for transport and geological storage of carbon dioxide, designated for field trials. This work includes risk analysis (zero activity related to best and worst case scenarios, probabilities, general contingency planning issues) and effects on ecology, physical conditions, socio-economic resources and other identified aspects.

H. Carry out the consultation process.

3.3.1 The EIA content

The listed items in table 1 are considered to be the minimum required topics of investigation to be included in an EIA. This may be modified, depending on the results of especially the CO_2 related aspects identified. The data should be broad enough to provide a regional characterisation of the offshore Baltic Sea Area and yet specific enough to adequately describe the local areas around the proposed transport and storage of CO_2.

Table 1 EIA content*

[10] The Swedish Environmental Code (Ds 2000: 61) requires that an EIA should be done from an overall perspective and provides a basis for a comprehensive assessment of the project's environmental impact.

*Structure compiled from EIAs by OPAB and Nord Stream		**Time Estimates (work days)**
1	A NON-TECHNICAL SUMMARY	4-6
2	ADMINISTRATIVE DATA	
3	BACKGROUND	
4	ACCESS TO AVAILABLE DATA	5-10
5	PLANNED ACTIVITIES Localisation Description of planned activities Chemical products - classification and listing of chemicals Energy Consumption Water Supply Discharges to water Emissions to air Waste	4-7
6	PREREQUISITES The Baltic Sea- Influx areas; Islands Coastal areas; Bathymetry Climate- Wind Conditions; Visibility/fog; Air Temperature; Precipitation Oceanographic data- Currents and tides; Waves; Ice Conditions; The water's chemical composition Sediment Ecology- Benthic zone - Flora & Fauna; Pelagic zone - Flora & Fauna Current pollution- Point Releases; Fugitive emissions; Eutrophication; Metals; Persistent organic pollutants; Oil Socio-economically sensitive areas- Fish stocks and the fishing industry; Marine mammals (seals, etc.) and their breeding areas; National parks; Recreational Areas; Fish Farms; Other Activities; Archaeologically valuable objects; Sea bird areas; Marine reserves; Endangered species Other conditions- Historical military activities (dumping of munitions, etc.)	40-60
7	APPLICABLE REGULATIONS Global conventions Regional conventions EU legislation National legislation	4-6
8	ENVIRONMENTAL CONSEQUENCES – HAZARDS AND RISKS Visual appearance Natural/cultural values Discharges to water (impact on ecosystems, zooplankton, fish, birds, marine mammals, etc.) Emissions to air Noise/sound Waste	20-40
9	HAZARDS AND RISKS DURING FIELD TRIALS Normal operations Drilling (Cuttings and additives) Drainage from the platform Sanitary waste water Other emissions Waste Air Emissions	34-60

	Geological storage of CO_2 Transport of CO_2 Injection of CO_2 Offshore CO_2 buffer storage Offshore CO_2 transport Injection of CO_2 Accidents and breakdowns Shipping Risks associated with: - Storage of CO_2 - Transport of CO_2 - Injection of CO_2 The risks of military material being disposed of (fighting gas, ammunition, mines) Natural Disasters Breakdown of equipment/human factor Sabotage and terror activities Unplanned releases Dispersion (scattering models) Impact/consequences	
10	THE IMPACT ON INDIVIDUAL AND PUBLIC INTERESTS	4-6
11	ALTERNATIVE DESIGN (E.G. BAT-QUESTIONS) AND ZERO OPTION[11]	4-6
12	ANTI-POLLUTION MEASURES	10-15
13	MONITORING AND FOLLOW-UP	4-6
14	CONSULTATION Consultations according to the applicable national legislation International consultation	20-40
15	NATIONAL ENVIRONMENTAL OBJECTIVES	2-4
16	REFERENCES	3-6
TOTAL ESTIMATED TIME FOR EIA		**162-278**

3.3.2 EIA cost estimate

At the moment there is no decision taken for a future CO_2 injection site and therefore it is difficult to estimate the time or cost to perform the EIA. However, the available EIA at the Dalders structure (OPAB) can be used as a base line for time and cost estimation. Note, that the estimated time and cost only encompass the field trials phase.

In Table 1 and 2 the time/cost estimates are shown as intervals. The lower end shows the approximate time/cost related to the contracted work for the OPAB EIA project[12] and the higher end intends to show a possible time/cost for a similar project today. However, these estimations are difficult to make depending on several factors e.g. site location, number of countries concerned by the activities, distance to base or supply harbour, availability and price for contractors, extent of field studies, availability and prices of consumables and materials, when will the project be carried out, extent of the consultation process, etc. Therefore, the estimated time/cost has to be regarded only as an indication of possible time/cost.

[11] A presentation of alternative sites, if such is possible, as well as alternative designs along with a statement of reasons why a particular option is selected, a description of the consequences of the action or the action does not come to fruition.

[12] OPAB's in-house costs for the EIA are not included

Table 2 Field study activities

	Estimated cost[13] (SEK excl. VAT)
Sediment sampling and analyses (10 stations)	120-200
Survey Ship for sampling	180-300
Report sediment sampling	30-50
Benthic fauna including report	250-400
Physical-chemical analyses 10 levels	100-200
Oil/chemical spill model and scenarios	150-300
Sampler for chemistry	70-100
Mob and demob transport	120-200
Travel and expenses	30-50
Report	60-100
ESTIMATED COST – TOTAL FOR FIELD STUDIES	**1110-1900**

The above estimated time/cost can be summarised in SEK. With a standard cost of 10 000 SEK per consultancy work day, the total cost interval will be approximately 2 750 SEK – 4 700 SEK. However, OPAB's in-house costs for the EIA are not included and have to be added to the estimate. OPAB provided support and knowledge to the consultants and OPAB in-house man hours for this were not included in the final cost for the EIA. With these costs included[14] the total cost estimate interval will probably be 3 500 SEK – 5 500 SEK.

[13] Estimated costs are based on comparable earlier field studies in the Baltic Sea Area by OPAB
[14] Approximate costs by OPAB

4 Conclusions and recommendations

4.1 Conclusions

The bulk of this information has been compiled from the EIAs carried out by OPAB and Nord Stream. The OPAB EIA is the most relevant reference for a future CO_2 field trial project, apart for the specific CO_2 related activities.

There is extensive knowledge of regional geological, ecological and environmental conditions in the offshore Baltic Sea Area. Local knowledge on these topics is high in many places but in general the detailed local knowledge is limited or non-existing. Therefore, as shown in the gap column in the Catalogue of Knowledge, the most frequent comments are "Site specific studies must be undertaken to describe local conditions" or "To be considered for local site conditions".

Knowledge about environmental impact from CCS activities in the offshore Baltic Sea Area is low, which is reflected by the comments in the gap column in the Catalogue of Knowledge. However, there is a lot of research on environmental impact and consequences from CO_2 transport and storage available. Also a number of EIAs specific for CO_2 projects have been carried out in the UK and Holland. Therefore the future EIA project can get input from the knowledge and experiences made in these projects.

Swedish regulations point out what to include in an EIA for offshore activities and measures. Mandatory items are pinpointed as well as recommended items. All these items have been included in the proposed EIA content in Table 1.

Future EIA for field trials will probably involve more items to be investigated, especially for CO_2 activities. It is also possible that another location of the site will affect the content of the EIA. Most certainly these additional items, a new location and other circumstances will affect the time/cost estimates provided in this report. A total cost estimate interval will probably be 3 500 SEK – 5 500 SEK.

4.2 Recommendations

As mentioned, a number of EIAs specific for CO_2 projects have been carried out in the UK and Holland. Therefore, we recommend to seek collaboration and possibly direct project interaction with the organisations in these countries.

It is important to compare EIA work plan methodology and structure, if applicable, and to benchmark risk assessment.

Direct exchange with the ROAD project is recommended.

In a future consultation process it is necessary to investigate and identify the public perception for the future CCS/CO_2 project. Public perception studies have been carried out both by OPAB for the Dalders EIA and by Nord Stream for the gas pipeline EIA. The knowledge and experience from these studies would be very useful in the future consultation process.

We strongly recommend that a future tender process for EIA contractors will include requirements on high competence and experience from CO_2 activities.

We also recommend establishing contacts with OPAB and Nord Stream in order to be able to get practical advice on EIA work in the Baltic Sea Area.

5 Figures and tables

Appendix 1 Literature list

#	Reference	Project/report	Summary	Year	Link	Length
1	**AMESCO**	ROAD project, Menno Ros, *General Study Environmental Impacts of CO_2-storage*	The AMESCO study aims to supply environmental background information on CO_2 storage in the Netherlands.	2007		26 pp
2	**CGS Europé**	Key report 1: *State-of-the-Art of Monitoring Methods to evaluate Storage Site Performance*	The main objective of this report is to identify and review monitoring methods for a performance assessment of geological CO_2 storage sites.	2013	http://repository.cgseurope.net/eng/cgseurope/knowledge-repository/key-reports/Monitoring.aspx	115 pp
3	**CGS Europé**	Key report 2 and 3	Not finished, may be of interest.		-	
4	**CHEMSEA**	Chemical Munitions, Search and Assessment (CHEMSEA)	The project aims at mapping and characterising dumping sites in the Baltic Sea.	2011-2014	http://chemsea.eu/	
5	**Chevron, Gorgon JV**	Gorgon CO_2 separation from LNG-plant, NW Australia, *Phase III: technical assessment*	The objectives for this Phase III technical assessment are to review, assess and verify the effectiveness of the four different GJV plans.	2006-2008	http://www.dmp.wa.gov.au/documents/Executive_Summary_from_Gorgon_DueDilligence_08_1028.pdf	26 pp
6	**CO2Care**	*Europe's longest-operating on-shore CO_2 storage site at Ketzin, Germany: a progress report after three years of injection*	An extensive monitoring program integrates geological, geophysical and geochemical investigations at Ketzin for a comprehensive characterisation of the reservoir and the CO_2 migration at various scales.	2012	http://www.co2care.org/SciPublicationsData.aspx?IdPublication=29&IdType=327	12 pp
7	**DNV** CO2QUALSTORE Guideline	Report No.: 2009-1425 Rev 4, 2010-02-12	EIA domain: surface/subsurface volume where air or water containing artificially elevated concentrations of CO2 due to leakage from the storage volume may have a negative impact on human health or the environment. This includes also the ground surface or sea floor and atmosphere immediately above this area.	2010		
8	**ECO_2**	ECO_2	ECO2 is an EU-FP7 project: to evaluate the likelihood, ecological impact, economic and legal consequences of leakage from sub-seabed CO_2 storage sites.	2011	http://www.eco2-project.eu/	

#	Reference	Project/report	Summary	Year	Link	Length
9	**ECO_2**	Briefing Paper No. 2: *Potential impacts of CO_2 leakage from sub-surface storage on seabed biology*	Researchers within this Work Package seek to quantify the short- to long-term effects of CO_2 leakage on marine biota and ecosystems, assess the ability of organisms to adapt to CO_2 exposure over a prolonged period, and identify biological indicators which show a strong response to high CO_2 levels.	2013	http://oceanrep.geomar.de/20810/1/D5.5.pdf	29 pp
10	**Gassnova, DNV**	*Konsekvensutredning Transport og lagring av CO_2 fra Kårstø* DNV Referansenr: 122ONYP-3	Impact assessment with a standardised illustration of values and vulnerability for a given resource and the expected effects of the activity; Summarised - consequences and release to air.	2009	-	116 pp
11	**HELCOM**	*Red List of Baltic Sea underwater biotopes, habitats and biotope complexes (BSEP138)*	The report identifies biotopes, habitats and biotope complexes at risk of collapse by quantitative criteria.	2013	http://helcom.fi/helcom-at-work/publications/	69 pp
12	**HELCOM**	*HELCOM core indicators. Final report of the HELCOM CORESET project (BSEP136)*	The report lists core indicators that form the critical set of indicators that are needed to regularly assess the status of the Baltic Sea marine environment against targets that reflect good environmental status.	2013	http://helcom.fi/helcom-at-work/publications/	74 pp
13	**HELCOM**	*Maritime Activities in the Baltic Sea - An integrated thematic assessment on maritime activities and response to pollution at sea in the Baltic Sea region (BSEP123)*	The report describes the maritime activities that have an impact on the Baltic Sea.	2010	http://helcom.fi/helcom-at-work/publications/	68 pp
14	**HELCOM**	*Hazardous substances in the Baltic Sea (BSEP120 a + b)*	The reports describes and documents the degree of contamination and effects of pollution by hazardous substances in the Baltic Sea area.	2010	http://helcom.fi/helcom-at-work/publications/	20 pp + 119 pp
15	**HELCOM RESPONSE**		HELCOM RESPONSE group works to ensure swift national and international response to maritime pollution incidents		http://www.helcom.fi/helcom-at-work/groups/response	

#	Reference	Project/report	Summary	Year	Link	Length
16	**National Grid**	*Yorkshire and Humber, CCS Cross Country Pipeline (10-2574-RPT-0033 Scoping Report)*	An Environmental Impact Assessment (EIA) for a proposed Carbon Dioxide transportation and storage system to support the provision of CCS technology in the Yorkshire and Humber region.	2013	http://infrastructure.planningportal.gov.uk/wp-content/ipc/uploads/projects/EN070001/1.%20Pre-Submission/EIA/Scoping/Scoping%20Request/130218_EN070001_Scoping%20Report%20Low%20Res.pdf	377 pp
17	**Nord Stream**	*EIA for Consultation under the Espoo Convention*		2009	-	
		- Volume I: Summary Documents	Non-Technical Summary; Key Issue Papers; National EIA Papers			620 pp
		- Volume II: Chapter 1-8	Introduction and Guidance to the Reader; Information about Nord Stream; Legal Framework and Public Consultation; Description of the Project; Risk Assessment; Alternatives; Impact Assessment Methodology; Environmental and Socioeconomic Baseline			858 pp
		- Volume III: Chapter 9-13	Impact Assessment and Mitigation Measures; Natura 2000; Transboundary Impacts; Environmental Management and Monitoring; Gaps and Uncertainties			846 pp
		- Volume IV: Atlas	The Atlas describes the general physical, chemical and biological environment in the Baltic Sea around the pipelines.			203 pp
18	**OPAB**	Application for permit regarding oil trial drilling in the Baltic Sea, Attachment 1 - EIA	A detailed EIA for the Dalders region.	2007	-	111 pp

#	Reference	Project/report	Summary	Year	Link	Length
19	**RISCS**	*Scenarios for Potential Impacts from Hypothetical Leakage from Geological Storage Facilities for Carbon Dioxide*	The report summarises the output of work undertaken to date in this area for interested parties both inside and outside the RISCS project.	2012	http://www.riscs-co2.eu/SciPublicationsData.aspx?IdPublication=5&IdType=183	60 pp
20	**SFT7 Norway**	*Management of Pollution from the Offshore Oil and Gas Industry in Norway*	In the Norwegian offshore industry a classification of chemicals is developed and presented by SFT7. Classification used by the oil industry for activities in the Baltic Sea.	2009	http://www.sft.no/english/ http://www.google.se/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0CDoQFjAC&url=http%3A%2F%2Fwww.norad.no%2Fen%2Fthematic-areas%2Fenergy%2Foil-for-development%2Fnews-archive%2F_attachment%2F133258%3F_download%3Dtrue%26_ts%3D12384d5b007&ei=pMwdU8PNIeON4wSVqYHgBQ&usg=AFQjCNHDem2kB_yfMwMWETIt38r2q9BC6Q	
21	**Swedish Geological Survey**	Letter from Linda Wickström, 131030	Environmental consequences and risks of CCS.	2013	-	
22	**SwePol Link**	*EIA for HVDC cable between Sweden and Poland - attachement 13*	Description of physical effects on the marine environment from HVDC cables on the sea floor.	1998	-	
23	**US Environ-mental Protection Agency**	*Vulnerability Evaluation Framework (VEF) for Geologic Sequestration of Carbon Diocixide*	Figure 3.1 VEF Conceptual Model	2005	http://www.epa.gov/climatechange/Downloads/ghgemissions/VEF-Technical_Document_072408.pdf	85 pp
24	**University of Stavanger**	*Contribution to well integrity and increased focus on well barriers from a life cycle aspect*	Paper presenting well integrity surveys performed on the Norwegian Continental Shelf and in the Netherlands, the well integrity challenges in CO_2 injection wells and adjacent wells.	2011	http://www.icrard.org/Documents/Contribution%20to%20well%20integrity%20and%20increased%20focus%20on%20well%20barrieres%20from%20life%20cycle%20aspect.pdf	

Appendix 2 Catalogue of current knowledge about environmental impacts in the Baltic Sea Area

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
General environmental knowledge of the Baltic Sea Region				
Ecoregions, Sub Basins and Ecological Sub-Regions	NordStream EIA Figure 8.2	17	In order to facilitate the environmental management of the Baltic Sea, HELCOM has divided the Baltic Sea into a series of sub-basins, based on water exchange characteristics.	Identify applicable sub-basin
	OPAB EIA, Figure 10.7	18	Map showing coastal types.	Identify coastal type at site location
	SwePol Link EIA, Chapter VII A	22	General description of physical effects on the marine environment from HVDC cables on the sea floor.	N A
Protected areas	OPAB EIA, Figure 7.25	18	Map showing areas considered worth to preserve; bird protection area and UNESCOs World Heritage Sites.	Identify areas worth protection for the pilot location
	OPAB EIA, Figure 7.26	18	Map showing cod reproduction areas.	Identify if applicable
	OPAB EIA, Figure 7.28	18	Map showing three important areas for sea birds; i.e. the Hoburgs bank, norra Midsjöbanken and södra Midsjöbanken	N A.
	NordStream EIA, Chapter 8.6.8 Atlas Maps: PA-1 PA-2 PA-3 PA-4 PA-5	17	Describes nature conservation areas in the Baltic Sea that have been designated to protect sensitive habitats and species of local, national and international importance, under both national and international legislation. Protection varies from strict international legal protection (e.g. Natura 2000 and Ramsar sites), to recommendations of protection (For example, BSPA or UNESCO sites). A description of each designation type follows. The conservation areas are: - Natura 2000 sites - Ramsar sites - Baltic Sea Protected Areas (BSPAs) - UNESCO Biosphere Reserves - Protected areas in the Russian part of the Baltic Sea	Investigate if applicable
Bathymetry	OPAB EIA, Figure 7.4	18	Bathymetric map of the Baltic Sea.	Specify for the selected site
	NordStream EIA	17	Table and figure showing the mean depth of the Baltic Sea.	

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
	Table 8.4 and figure 8.1		The Baltic Sea is approximately 56 meters, and the total volume is approximately 20,900 km3. The deepest parts, up to 459 meters, are found in the Landsortsdjupet Area.	
Salinity	OPAB EIA, Chapter 7.1.4	18	The salinity conditions is described. The Baltic Sea is the world's second biggest sea with brackish water. In the northern part, i.e. the Bothnian Bay the salinity is approx. 3 ‰ and in the southern Baltic Sea the salinity is 7 ‰ (oceans ~35 ‰).	Specify for the selected site
	OPAB EIA, Figure 7.3	18	Profile illustrating the bathymetry vs. the salinity variations.	
	OPAB EIA, Figure 7.14	18	Figures showing: A) the correlation between number of species and salinity and B) the average salinity level in the three major regions of the Baltic Sea.	
	NordStream EIA, Figure 8.3 - figure 8.9	17	Three principal characteristics are described, namely salinity, dissolved oxygen and substrate type which mainly influence the flora and fauna in the Baltic Sea.	
	NordStream EIA, Figure 8.10 Figure 8.11 Table 8.5 Figure 8.12	17	A stratified brackish Baltic Sea is described. The level of salinity changes in three dimensions; it decreases in the horizontal direction from west to east and also from south to north, and it increases vertically from the surface to the bottom. The bottom layer comprises the heavy salt rich water from the North Sea. The upper layer comprises of less saline water.	
H2S vs oxygen concentration	OPAB EIA, Figure 7.5	18	Figure showing general oxygen levels in the Baltic Sea.	Specify for the selected site
	OPAB EIA, Figure 7.6	18	Map showing weather stations in the South Baltic Sea.	
	NordStream EIA, Chapter 8.5.3 (The Water Column – Oxygen)	17	Surface waters are generally oxygen saturated, either as a result of exchange with the atmosphere or (during spring and summertime) due to the generation of oxygen by photosynthetic phytoplankton. Both processes lead to oxygen storage in the upper water layer. The deeper water (below the halocline) frequently experiences hypoxia however. This is because the halocline restricts vertical water movement and the diffusion of oxygen from above. Re-oxygenation of the deeper water occurs from time to time through episodic inflows of water from the North Sea.	

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
Oceanography	OPAB EIA, Chapter 7.3	18	There is almost no tidewater in the central parts of the Baltic Sea. Surface water has low salinity as a result from all the river water flows to the Baltic Sea. Deep water has higher salinity due to the inlet of salt water via the Straits of Öresund spreading to the Baltic Sea.	Specify for the selected site
	NordStream EIA, Chapter 8.5.2	17	Large Scale Oceanographic Patterns are described.	
Sedimentology	OPAB EIA, Chapter 7.4	18	The results from sediment cores regarding elements and environmental toxins are analysed and reported from the sea floor in the Dalders Area.	Specify for the selected site
	NordStream EIA, Chapter 8.5.4. - Atlas Map GE-2 and Atlas Maps GE-4 to 23 and GE-30 to 30d.	17	Quaternary sedimentary deposits cover the sea bed almost complete. These deposits were formed during the last ice age and during different post-glacial Baltic Sea development stages. The surficial sediment structure in the Baltic Sea ranges from clean sands and rocks in exposed areas, to mud in sedimentation zones and hard clay where erosion of the seabed has exposed lag sediments. In general, the seabed in the north east is clay or mud with stony areas, while the sediments in the southern Baltic Sea comprise fine sands to gravel and boulders.	
	SwePol Link EIA, Chapter VII B3c.	22	Description of the ecological conditions on hard sea floor and soft sea floor.	
Ecology	OPAB EIA, Chapter 7.5 Figure 7.14	18	The biodiversity of the Baltic Sea is described. Organisms present in the Baltic Sea are adapted to a life in brackish waters. Due to this, such organisms are often smaller compared to organisms living in oceans with a higher salinity. This adoption is a “stress factor” resulting in a lower biodiversity in the Baltic Sea. An eco-system with low biodiversity is more fragile for stress factors.	Site specific studies must be undertaken to describe local, ecological conditions
	OPAB EIA, Figure 7.14	18	Figure showing the correlation between number of species and the salinity.	
	NordStream EIA, Chapter 8.6.1.	17	The species diversity of a brackish ecosystem is described. Compared to other seas, the species diversity of the brackish ecosystem of the Baltic Sea is relatively poor. The limited number of species that comprise the Baltic food webs means that each individual species has disproportionately high importance in terms of the structure and dynamics of the entire Baltic Sea eco-system. Certain species, termed “keystone species”, are thus critical to the functioning of the whole system.	
	SwePol Link EIA, Chapter VII 3b.	22	Characterisation of shallow coastal areas is described. The shallow coastal areas (depth <3 meters) are charaterised by high biological production, mainly during the period May- October.	
	HELCOM (BSEP136)	12	The report lists core indicators that form the critical set of indicators that are needed to regularly assess the status of the Baltic Sea marine environment against targets that reflect good environmental status.	

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
Endangered species	OPAB EIA, Chapter 7.5.1	18	The Red List of endangered species is described. The Swedish Taxonomy Initiative (ArtDatabanken) manages the Red List which contains endangered species in Sweden. There are 235 marine organisms listed at present.	Site specific studies must be undertaken to describe local conditions
	HELCOM (BSEP138)	11	The report identifies biotopes, habitats and biotope complexes at risk of collapse by quantitative criteria.	
Benthic organisms	OPAB EIA, Chapter 7.5.2	18	Monitoring results of present/abundant benthic species 90 meters below sea level at the national observation station BY5, Dalders Area.	Site specific studies must be undertaken to describe local conditions
	NordStream EIA, Chapter 8.6.3 Figure 8.14	17	Sediment type is an important factor in determination of the species in the benthos. Benthic communities are composed of both epifauna (living on or above the seabed) and infauna (living within the seabed).	
Plankton	OPAB EIA, Chapter 7.5.3	18	Algae in the Baltic Sea is described. Surface waters are often covered by algae in thick layers. Silica algae, dinoflagellates and cyano bacteria are very common in the Baltic Sea. 2005-2006 were extreme years.	Site specific studies must be undertaken to describe local conditions
	NordStream EIA, Chapter 8.6.2.	17	Plankton is defined by their ecological niche rather than their genetic classification. - Phytoplankton comprises a variety of plants as well as photosynthetic protists and bacteria. Their key role is in converting solar energy to biomass that forms the basis of almost all marine food webs on earth (with the exception of hydrothermal vents). - Zooplankton comprises the animal component of the plankton. It can include holoplankton (animals that spend their entire life in the plankton) or meroplankton (animals that spent part of their life in the plankton; usually eggs and larvae of larger invertebrates or fish).	
Fish	OPAB EIA, Table 7.15 Table 7.16	18	Table (7.15) showing reproduction time and reproduction areas for some fish species in the Baltic Sea. Table (7.16) showing reproduction areas for cod in the Baltic Sea.	Site specific studies must be undertaken to describe local conditions
	NordStream EIA, Chapter 8.6.4. Table 8.8	17	Fish species of the Baltic Sea can be divided into the following groups according to their importance/value or key function in a community or ecosystem: - Keystone species - Indicator species - Commercially exploited species	

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
			- Threatened or protected species - Invasive species	
	SwePol Link EIA, Chapter VII 3a	22	Reproduction areas in the SW Baltic Sea are described. The shallow marine areas in Pikaviksbukten and Listerlandet are important reproduction areas for sea trout and silver eel. The Hanö Bay is a reproduction area for herring, cod and flatfish.	
Marine mammals	OPAB EIA, Chapter 7.5.5	18	The mammals of the Baltic Sea are described. Four species of mammals are living and reproducing in the Baltic Sea, i.e.: - Harbour porpoise - Ringed seal - Harbour or common seal - Grey seal	Site specific studies must be undertaken to describe local conditions
	NordStream EIA: Chapter 8.6.6 Figures 8.21 - 8.24	17	There are few marine mammal species inhabiting the Baltic Sea in comparison to ocean populations. The four resident species present comprise of one cetacean and three species of seal, as follows: - Harbour porpoise - Ringed seal - Harbour or common seal - Grey seal Each of the marine mammals listed above have been described as threatened and/or declining species of the Baltic Sea by HELCOM. Although not native to Baltic waters, species such as the mink whale, common dolphin and white beaked dolphins have been sighted in the south-western part of the Baltic Sea.	
Birds	OPAB EIA: Chapter 7.5.6 Figure 7.17	18	Approx. ten million birds representing over thirty species stay over the winter season in the Baltic Sea.	Site specific studies must be undertaken to describe local conditions
	NordStream EIA: Chapter 8.6.5 Figures 8.18 – 8.20 Table 8.9	17	The ornithological important areas in the Baltic Sea are described. The Baltic Sea and its varied coastline and islands support a wide range of bird species throughout the year. As a result large areas of the coastline and islands are designated for their international and national ornithological importance as they support large proportions of geographic populations of particular species (including migratory species) and/or species which are in need of conservation (for example, due to small or declining populations, localised populations).	
Invasive species	OPAB EIA, 7.5.7	18	About one hundred of invasive species have been found in the Baltic Sea. They are regarded as a threat to the biological life in the Baltic.	

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
	NordStream EIA, Chapter 8.6.7	17	Biological invasions of The Baltic Sea are discussed. Over 100 non-native species have been recorded in the Baltic Sea, and almost 80 of them have been able to establish viably reproducing populations. Most of these invasive species originate from freshwater or brackish-water environments, particularly from North America or the Ponto-Caspian region. The relatively low number of species makes the Baltic Sea vulnerable to the introduction of new species.	Site specific studies must be undertaken to describe local conditions
Present pollution situation	OPAB EIA, Chapter 7.6	18	Emissions are often classified as point sources or diffuse sources. HELCOM has reported approximately 4000 point sources from waste water treatment plants, industries and fish farms.	Air, water and sediment pollution to be investigated at selected location
	NordStream EIA, Chapter 8.5.4 Box 8.2	17	The concentration and variation of contaminants in sediments in the Baltic Sea are reported. Physical factors like dredging, trawling, extreme weather conditions and bio perturbation may have significant influence on the three-dimensional distribution patterns of some chemical species. Increased re-suspension not only mixes the top sediment, but also facilitates transport and localised distribution of contaminants within the sediment. The oxidation of these metal sulphides upon exposure to O2, as a consequence of sediment resuspension or bioturbation, can lead to the release of associated trace metals.	
	SwePol Link EIA, Chapter VII 8	22	The local emissions along the Blekinge coast are described. The emissions listed are: - heavy metals - oxygen consuming substances - stable organic substances - nutrients - halogenated organic substances - Hg, Cd and Pb	
	HELCOM (BSEP120 a + b)	14	The reports describes and documents the degree of contamination and effects of pollution by hazardous substances in the Baltic Sea area.	
Over-fertilisation	OPAB EIA, Chapter 7.6.1	18	During the 20th century the Baltic Sea has developed from an oligotrophic clear water sea to a eutrophic sea. This process has changed the ecosystem. The numbers of cyanobacteria has increased resulting in a particularly high degree of algal bloom covering the sea surface.	Site specific studies must be undertaken to describe local conditions
Metals	OPAB EIA, Chapter 7.6.2	18	The Baltic Sea has received extensive emissions of toxic metals and therefore sea floor sediments contain high concentrations of such toxic compounds, for example lead, copper and zinc.	Site specific studies must be undertaken to describe local conditions

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
Persistent organic compounds	OPAB EIA, Chapter 7.6.3	18	A large number of organic compounds are released to the Baltic Sea. Many of these are persistent substances and cause environmental problems.	Site specific studies must be undertaken to describe local conditions
Oil	OPAB EIA, Chapter 7.6.4	18	The concentrations of petroleum derived hydrocarbons in the Baltic Sea are three times higher than in the North Sea. The hydrocarbons are released into the sea via the atmosphere, rivers or direct release from ships into the water.	Site specific studies must be undertaken to describe local conditions
Fishing	OPAB EIA, Figure 7.27	18	Map showing areas of national interest for commercial fishing.	Site specific studies must be undertaken to describe local conditions
	NordStream EIA, Chapter 8.12.1 Table 8.40 Figures 8.48, 8.53, 8.54, 8.55, 8.56, 8.57, 8.59 Boxes 8.43-46	17	The Baltic Sea is managed in line with the EU's Common Fisheries Policy (CFP). Each year, total allowable catch (TAC) quota for different fish species are determined mutually by the countries permitted to fish in the Baltic Sea. Around 30 species of fish are regularly caught in the Baltic, but commercial fisheries are dominated by just three species; cod, herring and sprat. These species make up about 90-95 percent of total weight of commercial catches in the Baltic Sea. Several types of fishing gear are used in the Baltic fisheries industry.	
	SwePol Link EIA, Chapter VII 4a-h	22	The fishing activities and methods in the Hanö Bay are described.	
Shipping	OPAB EIA, Figure 7.30	18	Map showing frequent fairways in the Baltic Sea.	Site specific studies must be undertaken to describe local conditions
	NordStream EIA, Chapter 8.12.2 Figures 8.61, 8.62, 8.63	17	Major sailing routes in the Baltic Sea are described. The Baltic Sea is one of the busiest seas in the world, connecting surrounding nations through the constant movement of commercial vessels, passenger ferries and leisure boats. The main types of vessel using the shipping routes in the Baltic Sea are cargo ships and tankers.	
Installations	OPAB EIA, Figure 5.1	18	Map showing areas for exploration drilling, oil fields and oil findings.	Existing and planned infrastructure have to be identified in the selected area
	NordStream EIA, Chapter 8.12.5 Tables 8.55-58 Figures 8.74-75	17	Existing and planned infrastructure in the Baltic Sea are discussed: - Existing telecommunication and power cables and pipelines - Offshore wind farms - Exploitation of natural resources including mineral extraction and exploration and production of new oil and gas resources.	
	SwePol Link EIA, Chapter VII 7	22	The Swedish Maritime Archeological Archives documents sunken ships/wrecks in the Baltic Sea.	

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
	HELCOM (BSEP123)	13	The report describes the maritime activities that have an impact on the Baltic Sea, such as shipping activities and energy-related activities, like wind power production, oil extraction and gas pipelines, as well as fisheries and leisure boating.	
Military activities/areas/ deposits	OPAB EIA, Figure 7.34	18	Map showing Russian and German mines and dumping sites from the 1st and 2nd World War.	Existing and planned activities has to be identified in the selected area
	NordStream EIA, Chapters 8.12.6 - 8.12.8 Tables 8.59, 8.60 Figures 8.76, 8.77, 8.79	17	The Baltic countries maintain various types of military practice areas at sea. The areas can be classified according to the nature of their use.	
	CHEMSEA	4	The CHEMSEA project aims at mapping and characterising dumping sites in the Baltic Sea. Expected outcomes: develop guidelines in order to reduce potential threats to the environment and fishermen and to prepare a region-wide contingency plan to deal with cases of leakage.	
Risks and consequences from generic industrial activities in the Baltic Sea Marine environment				
Drilling activities	OPAB EIA, Chapter 9	18	In general the risk and consequences from exploration / test drilling are regarded to be minor / small and short-lived. The main consequences derive from drill cuttings.	Preventive procedures to be proposed in EIA, compliant with legislation
Accidents	OPAB EIA, Chapter 10	18	Consequences of accidents are described in this chapter. Generally it is the same consequences as during normal operations.	
	OPAB EIA, Table 10.2	18	A compilation of risks and effects of an offshore oil leakage.	
	OPAB EIA, Table 10.4	18	The frequency and effect of an earthquake is discussed.	
	HELCOM RESPONSE GROUP	15	HELCOM RESPONSE works to: - ensure swift national and international response to maritime pollution incidents - ensure that in case of an accident the right equipment is available and routines are in place to respond immediately in co-operation with neighbouring states	

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
			- analyse developments in maritime transportation around the Baltic and investigate possible impacts on international cooperation with regard to pollution response - coordinate the aerial surveillance of maritime shipping routes to provide a complete picture of sea-based pollution around the Baltic, and to help identify suspected polluters	
	NordStream EIA, Chapter 5.1	17	A risk assessment is a careful examination of what, in the project activities, could cause harm to people or the environment, consideration of the likelihood of the harm being realised and the severity of the impacts, thereby allowing an estimation of the risks. Risk assessment can be either qualitative or quantitative: - *Qualitative* (for example assessing likelihood and consequences using scales from "very low" to "very high") - *Quantitative* (for example assessing likelihood in terms of annual frequencies of occurrence and estimating consequences in terms of specific numbers of casualties) -	
	NordStream EIA, Chapter 5.3	17	The methodology adopted for the risk assessment is in accordance with the recommended risk management practice from DNV and consistent with the approach and criteria suggested by the International Maritime Organisation (IMO) in its formal safety assessment guidance on risk evaluation.	Risk assessment methodology adapted to local site conditions
	NordStream EIA, Chapter 5.3.1	17	Construction activities/hazards is addressed and discussed. The assessment covers the whole construction phase of line 1 (West) and line 2 (East) including preparation of the landfall facilities, pre-lay and post-lay intervention (works/rock placement including vessel loading operation), the main pipe-lay operations (including the pipe load out and transportation) and pre-commissioning operations.	Risk assessment adapted to local site conditions
	NordStream EIA, Chapter 5.3.2	17	For pipeline operations, the following potential causes of failure of the pipeline have been considered: - Corrosion (internal and external) - Material and mechanical defects - Natural hazards, e.g. current and wave action, storm - Other/unknown, e.g. sabotage, accidental transported mines - External interference, e.g. fishing, navy and commercial ship traffic, etc. These were derived based on a hazard identification exercise and a literature review of gas pipeline incidents. Identification of the potential causes of incidents is important as this can affect how an event may develop. For example, pipeline damage caused by a sinking ship is generally likely to result in a greater damage (for example gas release) than a dropped anchor, due to the far greater mass of a ship.	To be considered for local site conditions

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
	NordStream EIA, Seismicity of Study Area, Figure 5.5	17	Geological data has been collated and evaluated and an extensive seismic hazard assessment has been performed.	To be assessed for local site conditions
	NordStream EIA, Figure 5.6	17	Extreme wind speed and wind direction data for 1, 10 and 100 year return periods at one location of the pipeline.	
	NordStream EIA, Figure 5.8	17	The frequency of interaction is discussed. This is the frequency with which contact is made with the pipeline (for example by a dragging anchor or sinking ship), irrespective of the damage to the pipeline that may be caused as a result (which is assessed separately in the pipeline damage assessments). This interaction frequency assessment takes into account the following: - The pipeline size and location - The location and width of shipping lanes - The ship traffic intensity, crossing angles, and the distribution of ship classes and types based on Automatic Identification System (AIS) data - Ship characteristics (for example length, beam, weight, speed, anchor mass) - Cargo ship containers sizes and weights - Ship accident and incident data (for example frequency of collisions, machinery failures and steering failures which may result in emergency anchoring) - Various conditional probabilities (for example that a sinking is in the vicinity of the pipeline)	To be considered for local site conditions
	NordStream EIA, Chapter 5.3.2.	17	Analysis focusing on the consequences of a subsea gas release from the pipeline operation. This involves several stages, from underwater release rate and associated depressurisation calculations, through the effects at sea surface and the atmospheric modelling of gas dispersion, to the assessment of the physical effects of the final outcome scenario. There are several outcomes to consider (for example jet fire, flash fire, explosion, harmless dispersion) depending on whether an ignition takes place (immediate or delayed) and on the degree of confinement.	To be considered for local site conditions in the light of CO_2 activities
	NordStream EIA, Chapter 5.4.3 Figure 5.17	17	Environmental risks during pipeline construction are shown in the risk matrix.	
	NordStream EIA, Chapter 5.4.5 and 5.5.2 Table 5.15 and 5.16	17	Global Warming Potential is described. Considering all critical pipeline sections together, a full-bore pipeline rupture is estimated to occur once every 20,000 years, as described previously in Section 5.4; hence such an event is extremely unlikely to occur in the lifetime of the pipeline.	

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
	NordStream EIA, Chapter 5.5.1	17	In the extremely unlikely event of a major subsea release of natural gas, the gas will be released to the water column and rise to the surface as a gas plume. On the surface there will be region where the gas disperses into the air. The size of this region will vary depending on the water depth of the release, the nature of damage and pipeline operating conditions at the time of damage. The extent of the gas cloud from a major gas release depends on the actual nature of the damage and the weather conditions (primarily wind speed and stability). No loss of buoyancy of a vessel should occur when passing over the gas plume. Natural gas is much lighter than air and therefore will rise quickly. Therefore the risk that people onshore are affected by an offshore gas release is extremely low.	
	NordStream EIA, Chapter 5.5.2	17	The risk to the environment during construction of a pipeline is discussed. Risk arises from the potential for oil spills following a third party vessel collision with the construction vessels, or during refueling of the construction vessels. In compliance with the MARPOL regulations, all vessels are required to carry a shipboard oil pollution emergency plan (SOPEP) which must be approved by a ship classification society. This includes procedures to control discharge and the reporting requirements in the event of an accidental spill.	
	NordStream EIA, Chapter 5.5.2	17	Pipeline construction operations in spawning grounds could have a serious environmental impact and the possible need to restrict access during the spawning season.	
	NordStream EIA, Chapter 5.7	17	The results of the comprehensive analyses of the risks to people and the environment during the construction and operation of the Nord Stream pipelines are discussed. The result show that *no risks are considered unacceptable* when compared to the risk tolerability criteria agreed for the Project. This is not surprising given that natural gas pipelines are used worldwide and considered as a safe means of transporting large volumes of gas. For example, there are more than 122,000 km of gas pipelines in Europe; over 548,000 km of natural gas pipelines in the US; 21,000 km of pipelines are used to transmit natural gas in Australia; and there are many more kilometers of gas pipelines in Russia and Canada. Offshore pipelines have only minimal and temporary impact on the environment during installation and hardly any impact during operation. More than 6,000 km of pipelines are operated in the North Sea, some of which have been in operation since the 1970s, which indicates the feasibility and impact of the offshore pipeline. The most significant risks to the environment during construction arise from the potential for oil spills as a result of tanker collisions with the construction vessels.	To be considered for local site conditions
Chemicals	SFT7	20	In the Norwegian offshore industry a classification of chemicals is developed and presented by SFT7. Classification used by the oil industry for activities in the Baltic Sea. Useful guidelines are also found in HOCNF (Harmonised Offshore Chemical Notification Format) according to the OSPAR (The OSPAR Convention, protecting and conserving the North-East Atlantic and its resources).	

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
			Environmental risks and consequences from field trials for CO_2, transport and storage activities	
General	SGU	21	Environmental consequences and risks of CCS. Provides general information of areas worthwhile considering when establishing an EIA plan.	To be considered for local site conditions
	DNV	7	*EIA domain*: surface/subsurface volume where air or water containing artificially elevated concentrations of CO2 due to leakage from the storage volume may have a negative impact on human health or the environment. This includes also the ground surface or sea floor and atmosphere immediately above this area. *SPF domain*: the SPF domain covers the storage volume (source domain) and all pathways between the source and the receptor (EIA domain). • Storage volume: Domain designated for CGS, including the shallowest identified containment formation and an appropriate thickness of the top caprock to allow for partial penetration of CO2. The lateral extent of the storage volume should include the maximum predicted extent of the CO2 plume and the area where the elevated pressure as a result of the CO2 injection may drive CO2 or formation fluids into the EIA domain. • Pathways: Above the storage volume there may exist a volume of overburden rocks that can contain pathways (e.g., faults and wellbores) through which CO2 potentially may migrate into the EIA domain. Analysis of these pathways should be included in the scope of the SPF.	To be considered for local site conditions
Monitoring	CGS Europé (Key report 1)	2	The main objective of this report is to identify and review monitoring methods for a performance assessment of geological CO_2 storage sites. The report discusses state-of-the-art monitoring techniques and gives recommendations for how to set up site specific monitoring programmes. In addition, it gives an overview of monitoring applications used at storage sites or in field tests. A comprehensive monitoring framework is presented, with a matrix for different types of injections sites and the three activity phases, pre-injection, operations and post closure.	Monitoring program for trial injections to be included in EIA plan
	CGS Europé (Key report 2)	3	The main objective of this report is to identify and review site selection and characterisation methods. This report presents and discusses all the steps required to assess the capacity, performance and integrity of a site. The pre-injection assessment and characterisation is the most important element in screening, evaluating and selecting a target reservoir, where the geological properties for actual containment are the selection criteria. In short, the report is a handbook for site characterisation.	Verify and compare actual reservoir characterisation with the methodology suggested by CGS Europe

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
	CO_2Care	6	An extensive monitoring program integrates geological, geophysical and geochemical investigations at Ketzin for a comprehensive characterisation of the reservoir and the CO_2 migration at various scales. On site experience from operation of a large number of monitoring techniques is documented.	Literature study to find suitable monitoring techniques that could be applied offshore.
Risk Assessment research	RISCS	19	An EU 7th Framework, four year research program with 24 partners, RISCS provides comprehensive understanding of environmental risks associated with CO_2 storage. The 2012 report summarises the output of work undertaken to date in this area for interested parties both inside and outside the RISCS project. A set of European reference receptor environments has been defined. Scenarios for marine systems include impacts to marine biota, habitats and other sensitive receptors in both the biologically active sediments and in the overlaying water column, caused by different types of release. Based on simplified scoping calculations and a review of published literature concerning natural CO_2 seepages and modelled CO_2 behaviour, illustrative CO_2 leakage fluxes and areas that would be plausible for the alternative leakage scenarios are presented. In the 2013 paper *Hypothetical Impact Scenarios for CO_2 Leakage from Storage Sites*, different leakage scenarios and their consequences in marine environments are analysed with regard to specified receptors and also in different time perspectives.	Literature study to find support for site specific analyses in target reservoir area and the specific Baltic Sea marine environment.
	US Environmental Protection Agency	23	The US Environmental Protection Agency (EPA) led a multi-disciplinary team of physical and social scientists in a project, resulting in this report. Vulnerability assessment examines conditions that lead to increased or decreased susceptibility to consequences, whereas risk assessment measures the probability and severity of consequences. The project systematically identifies those conditions that could increase the potential for adverse impacts from geological storage, regardless of likelihood or broad applicability. The VEF identifies attributes of CO_2 storage systems that may lead to increased vulnerability to adverse impacts, potential impact categories and thresholds that may indicate low versus elevated vulnerability. The report does not cover capture or transport of CO_2 nor operational aspects of storage.	Testing of the VEF aspects applied in an offshore transport and storage scenario.
	ECO2	7	ECO2 is an EU-FP7 project: to evaluate the likelihood, ecological impact, economic and legal consequences of leakage from sub-seabed CO_2 storage sites. "The project will establish a framework of best environmental practices to guide the management of offshore CO_2 injection and storage." ECO2 undertakes to study the potential effects of leakage on benthic organisms and the marine ecosystems, to assess the risks of sub-seabed carbon storage and to develop comprehensive monitoring strategies, which makes it interesting for Bastor2 to follow and use as benchmark.	Literature study and checklist for EIA work plan

Knowledge area	Reference	Lit. List #	Content	Knowledge gap
Case study	AMESCO	1	The ROAD project prepared an extensive EIA, covering the capture facility, the construction and operation of a pipeline and the construction and operation of a storage facility for 1.1 million tons p a. The AMESCO study aims to supply environmental background information on CO_2 storage offshore the Netherlands. By bringing together the information from the scientific world, companies and authorities and by analysing relevant policies it is intended to describe: - Which are the possible environmental effects of CO_2 injection and storage? - Which are the possibilities for risk reduction and/or risk mitigation? - Where are the gaps in knowledge and legislation with regard to CO_2 storage? - Which existing legislation is of relevance for CO_2 storage in the deep surface? In comparison with natural gas the report describes the risks with CO_2 handling as lower since it is neither flammable nor explosive. The study presents an indication of the relevance of the different paths for leakage, of the time interval between leakage and arrival of leaked CO_2 at the surface and of the relative amounts that may leak from the reservoir per path. Additionally, the relation between CO_2 exposure and its consequences has been analysed.	Compare EIA work plan methodology and structure, if applicable. Benchmark risk assessment. Direct exchange with the ROAD project is recommended.
	National Grid	16	An Environmental Impact Assessment (EIA) for a proposed Carbon Dioxide transportation and storage system to support the provision of CCS technology in the Yorkshire and Humber region. The Offshore Scheme comprises the construction of a 90km sub-sea 600mm wide pipeline and geological storage approximately 1000m below the seabed, sized to accommodate up to 17mt of CO_2 p a. The report focuses on compliance with the legal requirements for an EIA, within the EU and British jurisdictions. The approach taken is to clearly show what is scoped in and out respectively of the EIA.	Compare EIA work plan structure for the offshore scheme, if applicable. Possibly seek direct project interaction.
	Gassnova, DNV	10	Impact assessment with a standarised illustration of values and vulnerability for a given resource and the expected effects of the activity; Summarised - consequences and release to air.	Compare EIA work plan structure if applicable
	Chevron, Gorgon JV	5	The objectives for this Phase III technical assessment are to review, assess and verify the effectiveness of the following GJV plans: • the Data Well programme to evaluate the injectivity and safety requirements of an effective injection programme in the Dupuy Formation beneath Barrow Island; • the monitoring programme for detection of migration of the CO_2 plume away from the injection site over the life of the project; • the well remediation programme to ensure that existing wells that intersect the Dupuy Formation near the proposed injection site have been properly secured and do not pose a CO_2 containment risk; • the management plan for the remediation of CO_2 seapage, should it occur, through the geological column to within 1 km of the surface.	Compare EIA work plan structure if applicable

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