Balticconnector
Executive Summary

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Gasum

Introduction

Gasum – with the financial support of the European Commission – has completed a study of an offshore gas pipeline between Estonia and Finland, the so-called Balticconnector offshore pipeline. The objective of the study has been to investigate the possibilities to create a more coherent and diversified natural gas grid within the Baltic Sea Region, more precisely around the Gulf of Finland, and thereby improving the security of supply of this important commodity to the EU member states.

The study for the Balticconnector has been divided into three phases:

- Technical concepts – development of an engineering concept for routing and installation of the marine pipeline between Finland and Estonia
- Pipeline offshore route survey - including bathymetric, seismic and geotechnical investigations of the open sea and archipelago regions
- Environmental impact studies – covering the offshore pipeline, landlines and surface facilities as well as LNG facilities in Inkoo, Finland.

This report presents a summary of the work that has been carried out on the Balticconnector project.

Technical concept study

During the autumn of 2005 the work on the technical studies for the Balticconnector offshore pipeline was commenced. Two discrete route alternatives were identified in cooperation with Gasum and Eesti Gaas – both exiting Paldiski in Estonia and targeting Inkoo and Vuosaari in Finland. The two routes are approximately 80 km and 140 km, see Figure 1.

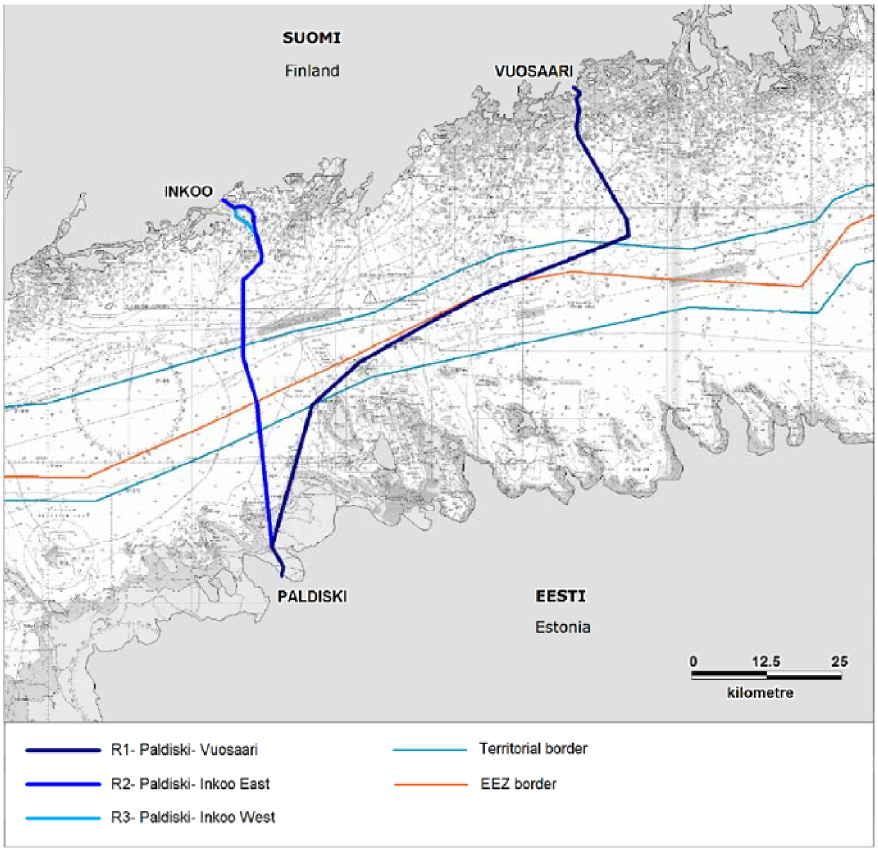

Figure 1: Route alternatives for the Balticconnector Offshore Pipeline

The scope of work for the technical studies included:

- System philosophy and design basis
- Route selection
- Data collection
- Risk assessment
- Pipeline wall thickness design
- Corrosion protection
- On-bottom stability and weight coating evaluation
- Installation considerations
- Free span analysis and seabed intervention
- Trawl impact assessment
- Landfall evaluation
- Pre-commissioning
- Cost estimate

In the following the results and overall conclusions for each of technical topics is presented.

Results from technical studies

The Balticconnector gas transmission system will ultimately consist of a single pipeline extending from the Inchukalns gas storage facility in Latvia, through Latvia and Estonia to the Paldiski landfall point, where an offshore pipeline will be routed to a landfall at either Inkoo or Vuosaari in Finland. The Balticconnector gas pipeline system is planned for a gas capacity of 300,000 m^3/h, with a design life of 30 years.

The offshore pipeline will consist of welded steel pipes with an internal drag reducing coating and an external corrosion protection, supplemented by sacrificial anodes. External concrete weight coating will be provided to fulfil the requirements for on-bottom stability and mechanical protection. The sections at the landfalls will be designed in high safety class, and will be equipped with permanent pig launchers/receivers at the dispatching and receiving facilities.

The principal functional design data for the Balticconnector pipeline are summarised in Table 1.

Table 1: Offshore pipeline design data

Design Pressure	80 barg
Design Temperature	Min. - 10°C to max. +50°C
Operating Temperatures:	0°C to +50°C
Design Gas Density	65 kg/m^3

The route selection of the Balticconnector pipeline was based on obtaining the best possible compromise between the following interests:

- To minimize overall pipeline length, this yields a lower cost of procurement and maximizes operational performance of the pipeline system.
- To avoid areas of special concern. These include environment protection areas, areas with delicate flora and fauna or areas with cultural heritage etc.
- To keep a safe distance from existing infrastructure as platforms and wells etc.
- To minimize interference with routing of existing pipelines, cables, known wrecks and obstacles.
- To avoid areas where other marine activities may conflict with the installation and operation of the pipeline. These include areas for fishery; areas for extraction of raw materials, areas of military activity, offshore wind farms or appointed anchoring areas.
- To minimize areas with unsuitable seabed soil conditions and/or bathymetry. These may influence the stability of the pipeline as well as impairing the efficiency of trenching the pipeline into the seabed.
- To minimize interference with ship traffic routes. This minimizes risk from surface vessels (dropped anchors, sinking or grounding ships etc.).

The preferred landfall locations were identified by Gasum and Eesti Gaas and comprised:

- Vuosaari and Inkoo in Finland, and
- Paldiski in Estonia

Based on the described selection criteria two route alternatives shown in Figure 1 were identified.

Data collection

One of the studies carried out was a 'hind cast' study of the wave and current regime of the Gulf of Finland by the Danish Hydraulic Institute (DHI). It was used as input to the analyses of wave and current induced forces on the marine pipeline. The hind cast study took in consideration amongst others wind generated currents in the Baltic Sea and Gulf of Finland, extreme storms in the area, the bathymetry of the seabed- with an improved resolution in the project area of the Balticconnector pipeline.

Risk assessment

A risk assessment was conducted for the Balticconnector pipeline, which included assessment of:

- Ice formations damaging the pipeline
- Ship grounding on the pipeline
- Dragged anchor impacting or hooking the pipeline
- Fishing equipment impacting or hooking the pipeline
- Risks from military activities

From the assessment it was recommended that the pipeline is trenched in certain areas due to ice, grounding of ships near the coast and dragged anchors. Figure 2 illustrates the recommended sections that need trenching.

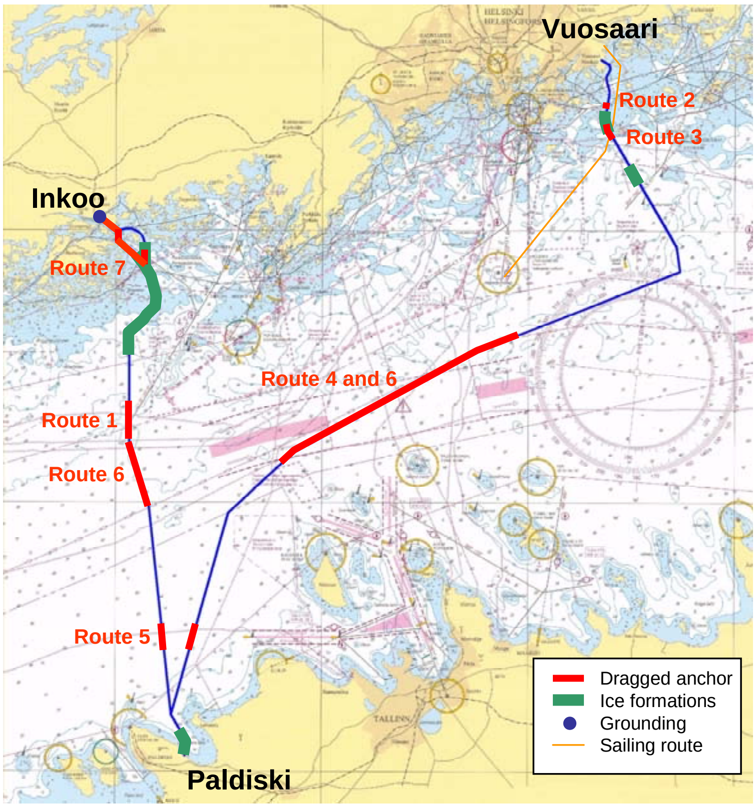

Figure 2: **Parts of the pipeline recommended to be trenched.**

The offshore pipeline will consist of welded steel pipes (size 20", i.e. OD 508 mm). The line pipe material should be SAWL 450 I F D with a density of 7850 kg/m^3 and have a wall thickness of 12 mm. The line pipe properties are summarised in Table 2.

Table 2: **Steel line pipe data**

Linepipe Material (cf. /1/)	SAWL 450 I F D
Yield Stress	450 MPa
Tensile Strength	535 MPa
Density	7850 kg/m^3
Wall Thickness	12 mm
Thickness Fabrication Tolerance	+/- 0.5 mm
Corrosion Allowance	0 mm

For corrosion protection a sacrificial anode system, supplemented by an anti-corrosion coating, will be employed for the protection of the pipeline system, as stipulated by the DNV OS F-101 *Submarine Pipeline Systems*. The cathodic protection requirements for the offshore pipeline system have been determined in accordance with DNV RP-F103 *Cathodic Protection of Submarine Pipeline by Galvanic Anodes*, for buried as well as for exposed conditions, the most onerous case being adopted for design. The dimensions of the anodes are summarised in Table 3.

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Table 3: Anode dimensions and spacing

Item	Unit	Value
Inside bracelet diameter	mm	518
Wall thickness of anode	mm	40
Anode length	mm	350
Anode net weight	kg	62.4
Anode spacing	m	293
	pipe joints	24

Pipeline wall thickness design

Pipeline on-bottom stability analysis has been carried out for the Balticconnector pipeline, using bathymetric data, wave, current and design data.

High density (3300 kg/m3) concrete coating with minimum practical thickness of 40 mm has been selected as weight coating. The concrete thickness required to obtain on-bottom stability along the two route alternatives varies between 40 mm to 70 mm - predominantly in the lower range.

Installation

The offshore pipe-laying is envisaged to be carried out by S-lay, using a 2^{nd} or 3^{rd} generation laybarge, possibly with dynamic positioning (DP) capability.

During an S-lay pipe configuration the pipeline is describing an S-curve from the laybarge to the seabed. In the upper part (the hogbend) the curvature is controlled by the laybarge stinger, a steel structure protruding from the stern of the vessel, which supports the pipeline on rollers. The curvature in the lower part (the sagbend) is controlled by lay tension transferred to the pipeline by tension machines gripping the pipe string on the laybarge. The tensioners are equipped with rolling tracks to allow movement of the pipeline whilst under tension.

Figure 0-3 Illustration of S-laying.

In most cases the laybarge is moored to eight or twelve anchors, and moves forward by pulling on the anchor cables. The anchors are relocated by tugboats, which together with the supply ships, survey boats and possibly diving support vessels constitute the laybarge spread. The anchors may, however, be replaced by dynamic positioning (DP), the laybarge keeping station by powerful thrusters and satellite navigation. Dynamic positioning is most suited for large water depths, where the suspended pipe string is sufficiently flexible to absorb minor displacements at the surface without buckling.

The coated pipe joints are transported to the laybarge on pipe supply ships, see Figure 0-4, and stored onboard. Some major laybarges have double jointing facilities, implying that two 12.2 m pipe joints are welded together, usually by automatic submerged arc welding before they are transferred to the end of the pipe string (the firing line), and welded onto the pipeline. To save time the welding on the firing line is carried out at a number of stations, and as the weld is completed the pipeline goes into the tensioners. The field joint coating, however, is carried out just before the stinger, usually at two stations working in parallel. The laybarge advances one pipe joint (or two joints, in case of double jointing and two field joint stations), moving under the pipeline, which is let out over the stinger, see Figure 0-5. The lay rate is highly dependent upon pipe size, welding conditions, etc, but under optimal conditions a daily production (working 24 hrs) of 4 - 5 km is not unusual.

Figure 0-4 Coated pipe joints on pipe supply ship

Figure 0-5 Pipelaying over the stinger

For hydrodynamic stability and mechanical protection the entire pipeline will be concrete coated, and sections will be trenched and backfilled as protection against anchor impact or ice ridge scouring.

Analysis of free spans and seabed intervention has been conducted as part of the technical analysis. Spans that are unacceptable in the unstressed, air filled condition must be rectified before installation of the pipeline (pre-lay intervention). Other free span rectification may be postponed until after the pipe string has been placed (post-lay intervention).

To the extent that unacceptable free spans cannot be avoided by route deviations, they are rectified by removing seabed material (trenching or excavation) or by establishing intermediate contact points (rock dumping), depending upon which method is economically most attractive. In any case pre-lay intervention is most costly, and may be reduced by early flooding of the pipeline.

For some sections trenches may be required in hard rock, which is unsuitable for post-lay trenching. In that case the only option is pre-lay trenching, using digging equipment or blasting, see Figure 0-6. Trenching for protection only may be replaced by rock dumping.

Figure 0-6 Example of drilling and blasting barge (left) and a dredging barge (right) working on the Vuosaari harbour project, year 2004.

Trawl impact assessment

Sections of the Balticconnector offshore pipeline are exposed to trawl impact from fishing activities. The trawling frequency is estimated at 1 to 100 events per km per year. Trawling is not relevant to consider for the Finnish archipelago, and the problem is therefore only relevant to study in the vicinity of the Paldiski landfall.

The only fishing equipment which may be harmful to a pipeline installed on the seabed is bottom trawls. Three situations have been considered in the trawl impact analysis:

- Direct impact
- Pull-over
- Hooking.

The studies have shown that the pipeline can resists the load cases from the different trawl scenarios.

Landfall evaluation

Three landfall locations were identified: Paldiski in Estonia and Inkoo and Vuosaari in Finland. During later phases of project execution it became clear that the Balticconnector pipeline project would be linked to the introduction of LNG to Finland. Inkoo was identified as an optimum location for the LNG import terminal, and thus the pipeline route option from Paldiski to Vuosaari became irrelevant and was abandoned.

Figure 0-7 Landfall location at Paldiski

Pre commissioning

Pre-commissioning, also known as RFO (ready for operation), was outlined and described. It covers all activities from performance of acceptance pressure test, normally part of the scope for the installation contractor, up to the filling of product into the completed pipeline, and the commencing of product transportation:

- Flooding
- Hydrotesting
- Cleaning
- Gauging
- De-watering
- Drying
- Nitrogen filling.

The activities of de-watering and drying are particularly important for gas pipelines, because any remaining water may react with the gas to form hydrocarbon hydrates, which can obstruct the flow and in particular the proper functioning of valves.

Cost estimate

A cost estimate for the Paldiski-Inkoo route was prepared. The total amount for establishing the Balticconnector offshore pipeline was estimated to approximately 96 million Euros, corresponding to a price of 1.2 million Euros per km. The costs are split as follows:

Table 0-4 Capital cost estimate

Materials	30.0 million Euros
Construction	47.0 million Euros
Engineering and Certification	2.7 million Euros
Management and Supervision	7.7 million Euros
Contingencies	8.7 million Euros

Pipeline route survey

An offshore pipeline route investigation programme was carried out during June and July 2006. Both pipeline route options – to Inkoo and Vuosaari – were surveyed. The investigations were conducted by the Swedish company Marin Mätteknik AB (MMT).

The survey consisted of two parts: a geophysical survey and a geotechnical survey.

Geophysical survey

The geophysical route survey comprised survey along one centerline. The survey was divided into a near shore and offshore part. The survey vessel Franklin surveyed to water depth greater than 15 m and the smaller vessel Ping was used to survey the near shore areas.

Water depth measurements were collected using a Multibeam Echo sounder, see Figure 8. For the project an EM1002 Simrad Multibeam was used.

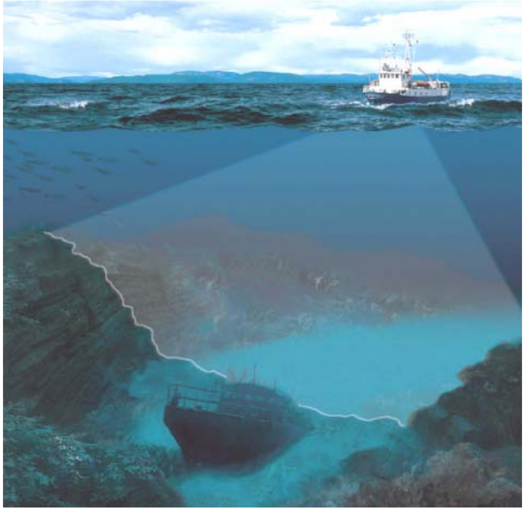

Figure 8: Bathymetric survey performed with a multibeam echosounder.

Digital side scan sonar was used to detect type and size of obstacles and seabed features on the seabed. The system was also used to identify and classify different seabed types. During the project an Edgetech DF1000, dual frequency (100/384 kHz) side scan sonar was used. A range of 100 meters to each side, producing 200-metre swath coverage, was used for the centre line.

Sub bottom profiles were recorded with two types of seismic equipment. A Benthos Chirp II, dual frequency (2-7 kHz and 10-20 kHz) was used to provide a high resolution of the upper layers, but with limited penetration in the coarse sediments (sand, gravel, stones). A Geosparker system was used to profile the deeper and coarser sediments. The frequency of the Geosparker is lower, thus giving a better penetration in the coarse sediments. The Geosparker was towed behind the vessel with a separate hydrophone streamer.

The results from the geophysical survey showed that the seabed topography in the Finnish archipelago is very undulating. The water depths are changing from only a few meters and up to tens of meters. In the middle part of the Gulf, the seabed is more flat, but still interrupted by areas with irregular bedrock outcrops. The water depths are ranging from 35 m to 80 m. Generally a more smooth and regular topography is found in the southern part of the Gulf towards Estonia, with water depth gradually increasing from the coast. 15-20 km's outside the northern coast of Estonia the bottom slopes down to 100 m depth.

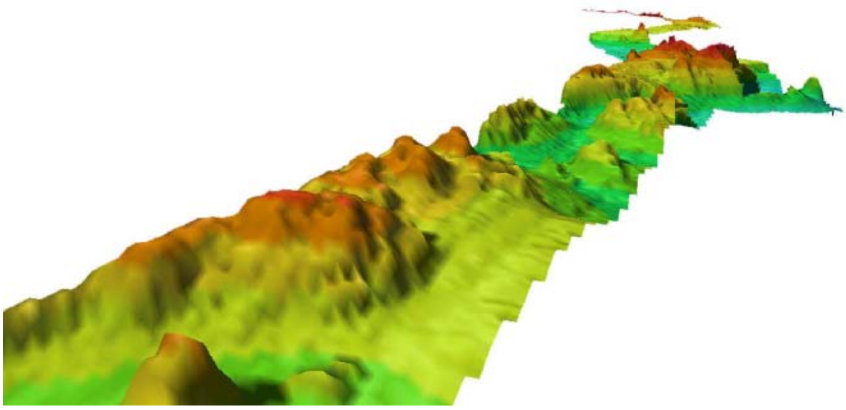

Figure 9: Bathymetry image from the Finnish archipelago, where exposed crystalline bedrock dominates the seabed with irregular outcrops and steep slopes.

Sediments

Till is deposited over the bedrock practically all over the Gulf of Finland. It is deposited as ridges and infills in the basement depressions. In the northernmost part the till is dominated by a high content of large boulders, locally very large, while on the Estonian side it is rich in clay and low coarse grained content.

Clay normally overlies the till. The lower part consists of late-glacial lacustrine deposits, represented by clays, and over this marine sediments are found, represented by homogeneous clay. The late-glacial sediments are conformed to the underlying topography, while the postglacial clay deposits occur as basin fill-type sediments. The content of organic matter increases in the later deposits.

In the western part and central part of the Gulf of Finland the bottom sediments are dominated by marine mud's. The thickness of the mud is often over 3 meters. On the Estonian Shelf the youngest deposits often consist of sands.

Geotechnical survey

In order to investigate seabed stability a geotechnical survey was conducted for the Balticconnector project. The survey was commenced immediately after the geophysical survey was completed.

The geotechnical survey consisted of seabed sampling, which through laboratory analyses reveals physical and chemical characteristics of the seabed soil and enhances and verifies the interpretation of the geophysical survey.

20 locations of geological interest were selected for geotechnical sampling. Lankelma Andrews worked as a sub-contractor for MMT, carrying out the seabed sampling, and together with selected English laboratories performed the analyses of the seabed samples.

The sampling equipment – a 6 m hydraulic vibrocorer, see Figure 10– was mobilized in Helsinki harbour on the 30th of June, mounted on the A-frame of M/V Franklin, and samples were taken over the next few days. On each of the planned 20 sites and on one additional site 5 m long samples were taken. The samples was cut in 1 m lengths on the vessel and brought to shore for laboratory testing. The laboratory testing consisted of classification testing, chemical and electrochemical testing, compressibility testing, strength index testing, strength testing and flotation testing.

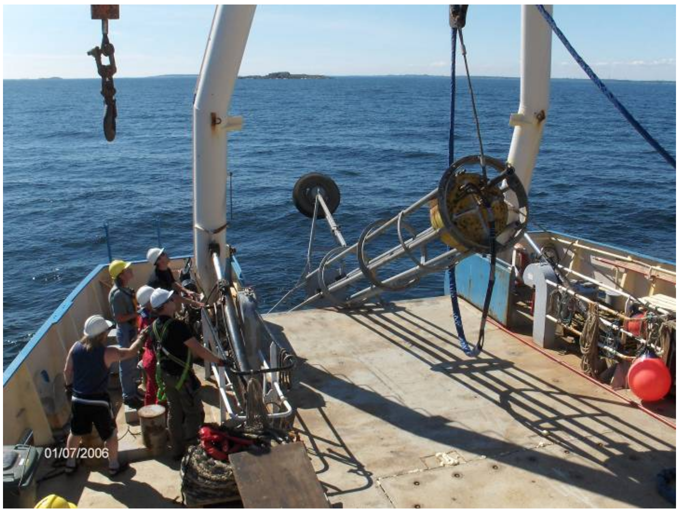

Figure 10: Vibrocorer used for the Balticconnector geotechnical sampling.

Environmental impact studies

A preliminary Environmental Impact Assessment programme (EIA programme) for the Balticconnector project was prepared in 2010. The environmental studies included:

- Considerations related to import of LNG to Finland
- Study of legislation requirements in Finland and Estonia
- EIA procedures
- Study of alternatives for offshore pipeline and LNG terminal
- Baseline desktop study of:
  - The Gulf of Finland
  - Birds
  - Mammals
  - Fish
  - Nature conservation areas
  - Ship traffic
  - Military areas
  - Munitions
  - Cultural heritage
  - Economic and human living conditions
  - Tourism and recreational use of area
  - Existing and planned infrastructure
  - Nature and landscape at onshore LNG terminal site
  - Land use and land ownership

EIA procedure

Environmental consequences have to be investigated in accordance with international agreements and conventions. For the Balticconnector project there are two primary international procedures to be followed: The Espoo Convention and the bilateral agreement on EIA between Finland and Estonia.

The need for assessing the environmental impacts of the project for the part concerning Finland is based on the Finnish Act on Environmental Impact Assessment Procedure. In Estonia, the assessment is based on the EIA and Environmental Management System Act.

Present situation of the project area

The Gulf of Finland is the easternmost part of the Baltic Sea, bordering Finland, Estonia and Russia. The proportion of the Gulf in the water volume of the entire Baltic Sea is about 5 % (1100 km^3). Length of the Gulf is 400 km, and the width varies between 48 and 135 km. The area of the Gulf of Finland is 29,600 km^2. The average depth is 38 metres and the greatest depth is 123 metres. The Baltic Sea has unique brackish water conditions. Its salinity is highly dependent on saline water pulses from the North Sea and the Kattegat through the narrow straits of Denmark. These narrow straits limit the water exchange between the Baltic Sea and the North Sea.

The traffic distribution in the Gulf of Finland among various vessel types differs from the vessel distribution of the whole Baltic Sea. A significant number of tourist car ferries and travel vessels travel in the Gulf of Finland. Small boat traffic is very vivacious in the Inkoo archipelago area due to the great amount of holiday and summer residences.

The area of the planned onshore pipeline from Inkoo to Siuntio is a mosaic where forest and crop field areas alternate. The project area is highly affected by human actions, mainly farming and forestry.

Surroundings of the Balticconnector landfall place in Paldiski, Estonia, are dominated by forest lands and bosks on former agricultural lands. At the location of the LNG compressor station there is a meadow on a relatively dry soil growing over due to the cessation of traditional activities.

The LNG terminal site in Inkoo is located about 4 kilometres southwest from the centre of Inkoo municipality. The LNG terminal site is allocated for industrial use, denominated as ‘harbor development area’ and ‘handling and storage of emergency liquid fuels and LNG'. The surrounding land consists mainly of forest and farm land.

The EIA legislation requires that various alternatives should be considered in the context of the EIA, as well as the zero-alternative (if the project is not implemented).

Various pipeline route options (variants to the Paldiski-Inkoo route) have been identified and will be assessed. Also, various locations for construction of the LNG import terminal will be addressed as indicated in Figure 11 and Figure 12.

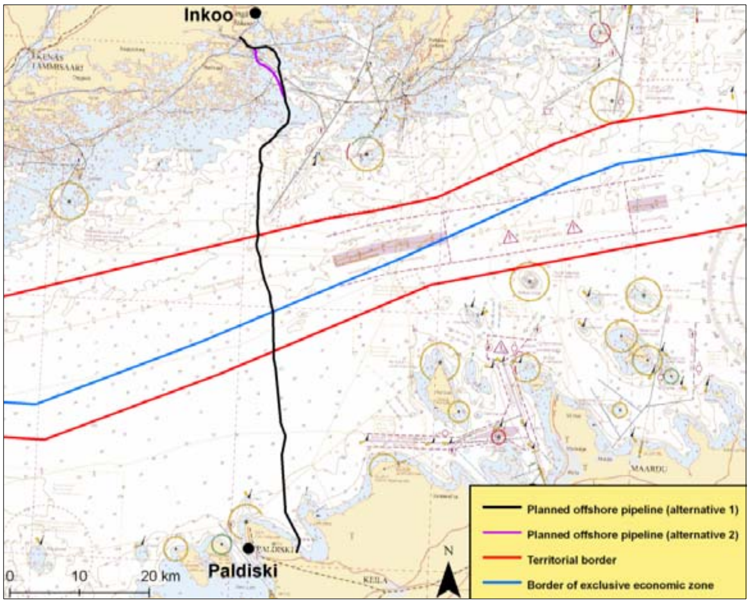

Figure 11: Alternatives of the Balticconnector offshore pipeline

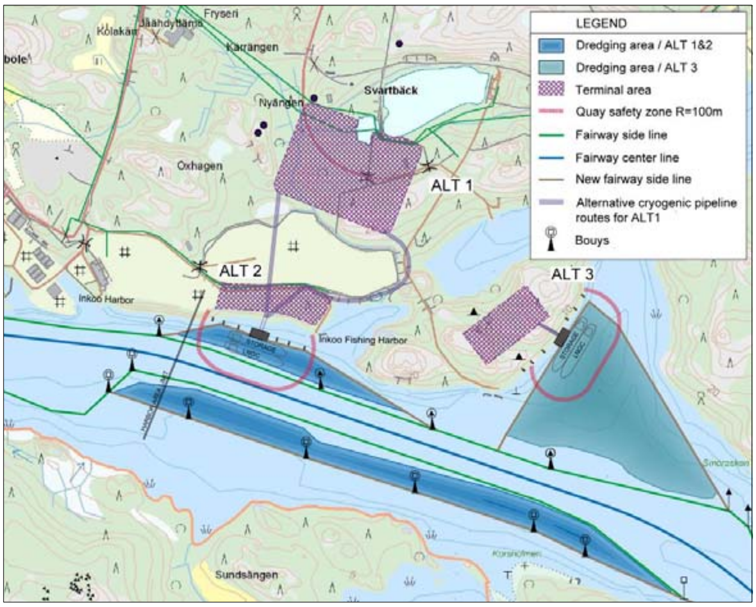

Figure 12: LNG terminal alternatives 1, 2 and 3, offloading jetty and the dredging areas at Inkoo

The EIA programme prepared under the Study explains how the EIA will assess all impacts on the environment through all phases: construction, pre-commissioning, operation and decommissioning of the pipeline or the LNG terminal.

The following impacts have been listed in the Finnish legislation as impacts to be studied:

- impacts on human health, living conditions and comfort
- impacts on soil, water, air, climate, organisms and biological diversity
- impacts on the community structure, buildings, landscape, townscape and cultural heritage
- impacts on utilization of natural resources
- impacts on the interaction between the above factors

In the assessment, direct and indirect impacts will be assessed during both construction and operation. Assessed impacts of all the alternatives, comparison of alternatives, uncertainty factors as well as mitigation measures and monitoring programme will be presented in the EIA report.

Permits and decisions

Construction of the Balticconnector pipeline and LNG terminal requires several permits and decisions. Permits are needed for routing, cross-bordering, laying, construction, operation and safety use of the Balticconnector pipeline in Finland and Estonia and LNG terminal activities in Finland. Activities require for example water permit on ground of Water Act and EEZ consent on ground of EEZ Act (Exclusive Economic Zone) in both Finland and Estonia, and environmental permit on ground of Environmental Protection Act as well as several construction licences in Finland.

Conclusion

The Study of the Balticconnector pipeline was initially intended to pave the way for a rapid implementation of an offshore pipeline connecting Finland and Estonia for the provision of a more coherent and diversified natural gas grid within the Baltic Sea Region, and thereby improving the security of supply of natural gas to the north-easterly EU member states. However, latest developments took its course and the scope of the Study was altered in the way that the Study was structured to provide a good basis for creating a diversified gas grid with the introduction of LNG as an important additional supply source.

Since members states in the Region are still investigating how to cooperate on establishing an integrated market for piped natural gas and LNG – assisted by the EU Commission under the BEMIP process – Gasum will not be in a position to conclude the original scope for the Study, but has in agreement with the Commission changed the target thereof to provide an excellent basis for both offshore pipeline and LNG import terminal with associated land-based facilities should the EU member states around the Gulf of Finland decide to implement the plans for such integrated natural gas market.

The Study ascertained that it was indeed possible to lay an offshore pipeline between Finland and Estonia, and that the installation thereof could be done with generally available equipment and within budgetary limits commonly known within the industry.

The Study also gave valuable information as the nature of the seabed: its degree of undulations, the soil types and their physical characteristics.

Finally, the Study provided an excellent basis for initiating an authority approval process for the combined installations consisting of offshore pipeline, LNG import terminal, associated land lines and facilities – both in Finland and Estonia.

Addendum

List of reports available

Technical reports:

- Ramboll Denmark. 'Balticconnector Project Description' 13.10.2005. Document number 102001, version 0.
- Ramboll Denmark. 'Balticconnector Risk Assessment' 05.05.2006. Document number 102003, version 0.
- Ramboll Denmark. 'Balticconnector Route Selection Report' 20-07-2006. Document number 102005, version 0.
- Ramboll Denmark. 'Balticconnector Design Basis Report' 19-07-2006. Document number 102004, version 0.
- Ramboll Denmark. 'Balticconnector Pipeline Mechanical Design Report' 19-07-2006. Document number 102007, version 0.
- Ramboll Denmark. 'Balticconnector Corrosion Protection Report' 19-07-2006. Document number 102006, version 0.
- Ramboll Denmark. 'Balticconnector On-bottom Stability Report' 19-07-2006. Document number 102009, version 0.
- DHI Water and Environment. 'Balticconnector Finland, Wave and Current Modelling' Final Report, January 2006.
- Ramboll Denmark. 'Balticconnector Installation Report' 13-12-2006. Document number 102011, version 0.
- Ramboll Denmark. 'Balticconnector Free Span and Intervention Report' 05-02-2007. Document number 102010, version 0.
- Ramboll Denmark. 'Balticconnector Trawl Impact Report' 09-02-2007. Document number 102012, version 0.

Survey reports:

- Marin Mätteknik. 'Marine Survey Report. Balticconnector Marine Survey 2006. Final report' Revision 4, 17-11-2006.
  - Appendix 1: Acceptance Tests Reports
  - Appendix 2: Daily Reports
  - Appendix 3: Route Position List
  - Appendix 4: Geotechnical laboratory results

- Marin Mätteknik. Survey alignment sheets for all route alternatives. Horizontal scale 1:5000, vertical scale 1:200.
- Marin Mätteknik. 'MMT Final Geotechnical Report. Balticconnector Marine Survey 2006' Revision 6, 15-02-2007.

Environmental reports:

- Ramboll. 'Balticconnector Natural gas Pipeline between Finland and Estonia, LNG Terminal in Inkoo, Finland, International Environmental Impact Assessment Programme' 15.09.2010.