SHEBA

Sustainable Shipping and Environment of the Baltic Sea Region

BONUS Research Project

Call2014-41

Deliverable 1.4, type RE

Future Scenarios

Due date of deliverable: project month 14

Actual submission date: project month 14

Start date of project: 1 April 2015 Duration: 36 months

Future Scenarios

Organisation name of lead contractor for this deliverable: IVL

Scientist(s) responsible for this deliverable: Erik Fridell

Authors (name-affiliation): Erik Fridell, Hulda Winnes, Rasmus Parsmo (IVL), Benjamin Boteler, Jenny Troeltzsch (Ecologic), Urszula Kowalczyk, Jakub Piotrowicz (MIG), Jukka-Pekka Jalkanen, Lasse Johansson (FMI), Volker Matthias (HZG), Erik Ytreberg (Chalmers)

Other contributors (name-affiliation): Ida Maja Hassellöv (Chalmers), Thong Tien Nguyen (SDU), Markus Quante (HZG), Jana Moldanova (IVL), Manuel Lago (Ecologic), Ilja Maljutenko (TUT)

Organisation name/names responsible for revision: SDU

Scientist(s) responsible for the review: Eva Roth

Revision: [0]

Future Scenarios

Summary

Scenarios for shipping in the Baltic Sea for the years 2030 and 2040 have been developed. They will be used to assess the impact of shipping on the Baltic Sea region environment and on ecosystem services. A literature survey was undertaken to investigate existing work on scenarios for shipping with emphasis on the Baltic Sea region. Stakeholder consultations were made, mainly during a physical meeting, in order to elucidate trends for shipping and what possible futures that would be of interest to study. A workshop within the consortium was arranged where it was decided which scenarios to investigate within SHEBA.

A business as usual scenario (BAU) was constructed as a reference scenario for all other scenarios. It is based on current trends in shipping and takes into account already decided policy measures. This includes, for example, the EEDI regulations and the grey water regulations for the Baltic Sea, but not the possible introduction of a NECA. The trends in shipping were analysed from AIS data from recent years and combined with an analysis of the different shipping sectors to obtain the development regarding transport work, ship size, ship speed and number of ships for different ship types. In combination with assumptions on ship age distribution and upcoming regulations this gives the possibility to calculate emissions to air and water and underwater noise.

A number of "single scenarios" were constructed in order to answer a certain number of specific questions that came up during the stakeholder consultations and within the consortium. The following issues are addressed and the impact from shipping in these scenarios on the Baltic Sea region will be studied: What is the effect of a further slow steaming of shipping in the Baltic Sea; What is the effect of a modal shift from land to sea?; What is the impact of an introduction of a NECA by 2021?; What would be the effect if emissions to water from shipping are eliminated?; What would a large introduction of LNG as a marine fuel imply?; What can be done with further environmental regulations for leisure boats? Finally, what can be achieved with measures in ports.

Cumulative scenarios have also been developed where different possible futures are analysed. So called Shared Socioeconomic Pathways (SSP) that are developed for the climate community are adapted and the outcome for shipping in the Baltic Sea is analysed. Three SSPs were chosen: SSP1 "Sustainability" with concern for the environment and high degree of technical development; SSP2 "Middle of the road" here interpreted as the same as the BAU scenario; SSP3 "Fragmentation" with regional development, fossil fuel dependence and low degree of environmental concern. For each of these three SSPs the characteristics and volumes of shipping have been analysed to make it possible to calculate emissions to air and water, underwater noise, and socioeconomic effects.

Table of Contents

List of Tables

List of Figures

1 Introduction

The BONUS-SHEBA project studies the impact of shipping on the Baltic Sea region. This is done by modelling emissions to air and water, noise from shipping and by analysing socio-economic factors. The present day situation is analysed but an important part of the project is also to study the changes that could happen in the future. In the present deliverable a set of scenarios for shipping in the Baltic Sea in the future, up to year 2040, are presented. There is a business as usual scenario (BAU) building on a conservative projection of present shipping activities taking into account regulations that will come into force. In addition, a number of single scenarios are developed. These are meant to answer single questions such as “what will be the changes in the eutrophication burden on BS if a NECA is introduced in the BS by 2021?”. Further, a set of cumulative scenarios are developed where the future is described using Shared Socio-economic Pathways (SSPs) developed for the climate community.

Since the outcomes of the scenarios are to be used in other deliverables to assess the impact of shipping, there are certain requirements on the data produced. Shipping in each scenario needs to be described by volumes divided into ship categories and ship sizes. The activities are described by freight (or passenger) volumes, number of ships, total travelled distance, and fuel consumption. The scenarios will thus be further used in other SHEBA research in varying degree of complexity, i.e. for some scenarios emission and dispersion modelling will be made and for some of these also full modelling of impact on Baltic Sea water quality and ecosystems while others will mainly be used for analysis of impact on ecosystem services.

1.1 Background

It is difficult to forecast future shipping activities, especially on long time horizons. Also, several issues concerning shipping need to be addressed, particularly global warming and the use of fossil fuels. Shipping today depends almost exclusively on fossil fuels but was in spite of this left out of the Paris climate agreement in December 2015. There are projections showing that shipping may increase its annual CO_2 emissions from 800 million tonnes in 2010 to 2000 million tonnes by 2050 if no new measures are taken (Bazari & Longva, 2011). There is therefore considerable pressure on shipping to look for alternatives to fossil fuels. Further, problems with air pollution and with pollution to water as well as being a vector for invasive species will put further constrains on shipping. In addition, there will most certainly be changes in shipping volumes and trade lanes making the total shipping in the Baltic Sea BS vary differently between different segments.

2 Approach and methodology

This section describes the approach and methodology applied to develop scenarios applicable to shipping in the Baltic Sea. This section first provides a general introduction to scenario development and provides initial ideas on how to use scenarios in the context of evaluation. This includes the strengths and weaknesses of using scenarios. In order to provide an overview about different scenarios and its function in different assessments of the Baltic Sea (inter alia shipping and environmental policy), ten studies are compared in Section 2.2. An overview of these studies is provided in a table to enable systematic and easy comparison. The scenario development conducted is described in a stepwise manner in Section 2.3.

2.1 Scenario development

Scenarios are useful to explore future developments and the potential impacts of introduced changes for the evaluation of possible programs, projects, and policies. A baseline or reference scenario can describe the pathway to an endpoint without considering the influences of the evaluation subject, and a set of scenarios can then show possible different developments if the program, project, or policy is taken into account. If a back casting approach has been chosen, the endpoint is already defined. This can also be the case with a forecasting approach with narrative aspects. Descriptive scenarios, however, have no predefined end situation. Thus, this step is not the definition of a desired end stage, but the definition of the end situation depending on the current state and trends, and the evolution of key drivers. Jäger et al. (2007) point out that an integrated, self-consistent snapshot of the end state should be created. Hence, scenarios can be used in ex ante, ongoing, and ex post evaluation to show the possible effects of the evaluation subject in the short- and long-term perspectives. (ICIS, 2000; Notten, et al., 2001; Kok, et al., 2011).

The main strength using scenarios is that they can describe complex developments in a comprehensive manner. However, this may also be the main weakness. Scenarios cannot cover all influencing factors, but rather only a set of the main drivers, which is difficult to determine and is influenced by underlying preferences. The key challenge, therefore, is to find the right balance between attempting to capture everything that could happen by developing many or highly complex scenarios, and trying to simplify things too much, which can mean that risks or shocks and/or extreme developments are not captured in the scenarios. In any case, the aim of scenario development is not to predict the future but to give a comprehensive overview of what could happen, including extreme developments. The scenarios are used to show what happens if extreme changes (in different directions) of key drivers are assumed (Alcamo, 2001; Notten P. v., 2006; Kosow & Gaßner, 2008; EEA, 2011). Generally, scenario exercises use more than just one scenario to depict different possible future developments. The different “types” of scenarios are named according to their purpose. For example, the most common scenario type is probably the “business as usual” (BAU) also called reference or baseline scenario. The BAU-scenario shows the reference point and the additional scenarios are developed to show what will happen if key underlying assumptions are changed. For example, to cover the wide range of possible outcomes, it is reasonable to include so called extreme scenarios reflecting the best case and worst case of a possible pathway. These scenarios, even if they are assumed to be “unrealistic”, provide a good picture of the whole range of possible developments. A scenario exercise could also include probability scenarios which, as the name suggests, reflect the development pathways which are most probable. A lot of scenario exercises narrow the introduced changes down to an adoption of the policy mix; thus, these scenarios are called policy scenarios. (Kok et al., 2011; EEA, 2011)

2.2 Overview of studies developing scenarios and conducting assessments of future changes

Prior to beginning the scenario development, a literature review was conducted in an effort to understand and assess relevant studies useful for understanding potential scenarios in regard to shipping in the Baltic Sea region. Table 1 provides an overview of the main studies identified and reviewed. Twelve studies are summarized including a short description, their main methodology, coverage and developed scenarios. Due to the limited number of studies on the Baltic Sea, also studies with a broader geographical coverage were included.

Table 1 - Overview of scenarios found in the literature

Name	Description:	Methodology:	Coverage:	Scenarios:
Future Trends in the Baltic Sea (WWF, 2010)	The study describes the growth of maritime activities, concluding that growth will increase demand for limited sea space & resources. (Could lead to increased conflicts within & between maritime sectors, between human uses & nature.	Method: Forecasting; Descriptive / explorative; Analytical; Participatory Using literature, studies, or industry the report multiplies this by 2010 data to provide a projection for growth to 15 human activities including climate change.	Baltic Sea 2010 - 2030	The report outlines scenarios (i.e. future sector growth) for the future development of the various sectors operating in the Baltic Sea region over the next 10 to 20 years.
Blue Growth Study (EC, 2012)	Conducted for the European Commission, the study describes the current European maritime sector & expected future trends for specific industries ("blue economy").	Method: Forecasting; Descriptive / explorative; Analytical; Participatory The authors used e.g. past studies & expert judgement to project expected changes to the European maritime economy. The exact methodology & related assumptions varies due to the available information.	Europe 2020	1. General background scenarios; from a top-down approach, four more or less realistic futures have been painted for a timeframe of 10 – 15 years. 2. Micro-future Scenarios; bottom-up approach, likely futures for maritime economic activities, timeframe of 10 – 15 years.
Global Marine Trends 2030 (Loyds Register Marine, 2014)	The report aims to define key global trends using demography, economy, resources & environment. The authors share their research 'to encourage a broader understanding of global issues that affect the marine industry & their impact in the form of key drivers & scenarios'.	Method: Forecasting; Descriptive / explorative; Analytical The study is descriptive & uses major global forces (e.g. population growth) to draw indications for the future marine trends. It mentions a 'scenario developing methodology' but this is not explained in detail.	Global 2030	1. Global commons scenario: Primary interests shift to concern over resource limitation & environmental degradation, desire for a more sustainable world & fairness in wealth distribution. Government will act to forge agreement for common goods. 2. Competing nation: voice of the people is not heard the state will mainly act in its own national interest: little effort to forge agreement amongst governments for sustaina-

Name	Description:	Methodology:	Coverage:	Scenarios:
				ble development & international norms.
Shipping 2020 (DNV, 2012)	The report (is produced by DNV Maritime and Oil & Gas) reviews policy & technology uptake to create scenarios for shipping industry.	Method: Forecasting; Descriptive / explorative; Analytical; Participatory The scenario development is based on extensive literature review, questionnaires, external forecasts & guesstimates. No further information on methodology is provided.	Global 2020 & beyond	SCENARIO A: High economic growth & fuel prices; little regulatory or stakeholder pressure on the environment. SCENARIO B: High economic growth; LNG prices low & decoupled from oil prices; high regulatory & stakeholder pressure on environment. SCENARIO C: Low economic growth & fuel prices but high demand keeps the marine gas oil (MGO) prices up; high regulatory & stakeholder pressure on the environment. SCENARIO D: Low economic growth; LNG prices decoupled from oil prices; low regulatory or stakeholder pressure on environment.
European Lifestyles and Marine Ecosystems (Langmead, McQuatters-Gollop, & Mee, 2007)	The study explores the links between lifestyles, social & economic causes & marine ecosystems. The approach is to study the immediate & deeper economic & social causes of key problems on a catchment scale. Focus on EU enlargement & other large scale policy processes & to model the likely consequences.	Method: Forecasting; Descriptive / explorative The study uses a multidisciplinary approach integrating relevant information on current major state changes affecting Europe's marine, pressures on the environment, social & economic & plausible scenarios for social & economic change across Europe.	European sea catch-catch-ments 'next 2 to 3 decades'	Four scenarios based on different underlying value systems & governance & policy approaches were used: 1. National enterprise – "Pull up the drawbridge", 2. Local responsibility –"Think local, act local", 3. World markets – "Growth is good", 4. Global community – "We've got the whole world in our hands"
OECD Environmental Outlook to 2030 (OECD, 2008)	This study explores possible ways in which the global environment may develop, emphasizing the economic rationality of ambitious environmental policy & showing why it is desirable for the OECD to work with large developing countries.	Method: Forecasting; Descriptive / explorative; Quantitative modelling Scenario development (not specified), modelling (multiple models were used)	Global 2030	Single baseline scenario with policy variants on climate policies and different types of carbon taxes. OECD Environmental Outlook to 2030 is based on projections of economic & environmental trends to 2030.
UNEP GEO-4: Environment	UNEP GEO-4: Environment for Development shows how both current & possible future deterioration of	Method: Forecasting; Descriptive / explorative; Quantitative modelling Scenario development, modelling	Global 2050	1. Markets First; 2. Policy First; 3. Security First; 4. Sustainability First

Name	Description:	Methodology:	Coverage:	Scenarios:
for Development (UNEP, 2007)	the environment can limit people's development options & reduce their quality of life. This assessment emphasizes the importance of a healthy environment, both for development & for combating poverty.	(multiple models were used)		The scenarios examine different policy approaches & societal choices. They are presented using narrative storylines & quantitative data at both global & regional levels.
SOER 2015 (EEA, 2015)	This EEA report identified the transition towards a green economy as needed & provides limited evidence of progress in effecting this fundamental shift.	Method: Normative; Descriptive / explorative; Consideration of values/interests Baseline, with discussion about variants in policy	Eionet Europe 2050 vision	1. Mitigate; 2. Adapt; 3. Avoid; 4. Restore
Alternative future scenarios for marine ecosystems (Pinnegar, et al., 2006)	The report sets out four contrasting AFMEC (Alternative Future Scenarios for Marine Ecosystems) 'futures' are developed, detailing how marine ecosystems might look & how activities in the marine environment might develop given assumptions about climate change & socio-political development.	Method: Forecasting; Descriptive / explorative	Global & UK 2026 to 2036	World Markets scenario assumes prevalence of materialist & libertarian social values. Fortress Britain scenario assumes individualistic & conservative social values, a reinforcement of national governance system & identity. Local Stewardship scenario assumes tolerant, community-oriented social. The Global Commons scenario attempts to reconcile growth & sustainability.
OECD environmental outlook to 2050: the Consequences of Inaction (OECD, 2012)	Based on joint modelling by the OECD & the Netherlands Environmental Assessment Agency (PBL), it finds out what demographic & economic trends might mean for the environment if the world does not adopt more ambitious green policies	Method: Forecasting; Descriptive / explorative Scenario development (not determined), modelling	Global 2050	Undetermined due to limited access to study.
Shared Socioeconomic Pathways (SPPs) (IIASA, 2016a;	SSPs are quantitative and qualitative narratives of possible socio-economic futures up to the end of the century. SSPs consist of qualitative narratives for five distinct socio-	Method: Forecasting; Descriptive / explorative; Quantitative modelling Scenario development, modelling (multiple models were used)	Global 2100	SSP 1: Sustainability (environmental awareness and resource-efficiency is increasing), SSP 2: Middle of the Road, SSP 3: Regional Rivalry (reversed globalization trend), SSP 4: Inequality (across- and within country inequality due to

Name	Description:	Methodology:	Coverage:	Scenarios:
IIASA, 2016b; O'Neill, et al., 2014)	economic futures, mainly used in the climate research community. SSPs are applied in similar BONUS-projects, e.g. BalticApp.			unequal investments in education, skill-based technological development), SSP 5: Fossil Fueled Development (accelerated globalisation and rapid development of developing countries)

Out of the 12 studies identified as highly relevant for this approach, most focus on forecasting. Due to the focus on future challenges for policy in the Baltic region, forecasting is often used to show possible scenarios under different economic and policy conditions. None of the studies used backcasting to explain why the current status is how it is. Past development and trends provide information about dynamics and causalities in a system. However to incorporate these information, past studies and expert judgement is integrated (e.g. Blue Growth Study) or information on current major state changes (e.g. European Lifestyles and Marine Ecosystems). The different forecasting scenarios differ in their methodological details, e.g. whether they used quantitative modelling etc. Four of these 12 studies focused on European seas, one of them just on the Baltic Sea. Seven studies have a global approach. One study combines a global catchment with a more detailed look on UK seas. The time horizon varies between studies and different scenarios from 2020 to 2100.

2.3 Approach for choosing scenarios

The specific steps taken to develop scenarios for this work are outlined in the following section. These steps include developing a common understanding amongst experts developing scenarios, conducting a literature review, consulting relevant stakeholders, identifying key themes to be evaluated, determining key drivers and critical uncertainties, and choosing appropriate methods for scenario assessment.

As a first step, a clear view of the scenario development process was determined. This included choosing specific methods to be used and the determination of targeted characteristics of the scenarios.

As a second step, the developers created a list of relevant stakeholders who were involved in the elaboration of the scenarios. The stakeholders were invited to a stakeholder consultation workshop in September 2015. The development of scenarios in SHEBA included experts from a broad range of fields.

After establishing the scope of the scenarios and the selection of stakeholders, as third step the important themes of the scenario exercise were determined. At this point, the following questions had to be addressed:

1. What are the key themes on which the scenarios should focus?
2. What (if any) are the key targets and/or goals that should be considered?
3. What are the most relevant and useful indicators for de-scribing the system of interest?
4. What (if any) are the key policies that need to be explored as part of the exercise?

Based on research on drivers for the shipping sector in SHEBA Deliverable 1.1 (Boteler, et al., 2015), questions were prepared and discussed during the stakeholder workshop in September 2015. Questions focused on potential future policy and socio-economic developments, as well as possible updates in regard to shipping technology. A World Café format was used to team experts up with stakeholders and elicit their views on the various topics. The discussions included the key themes on which the scenarios should focus, the key targets, relevant indicators and key policies that should be considered in the scenario development. An example is given in Table 2.

Table 2 - Example of themes, targets, indicators and policies

Theme	Target	Policy	Indicator
GHG emissions	Reduce carbon emission intensity of shipping by 2025	EEDI standard	CO_2 per tonne km

Based on the input during the stakeholder workshop, as a next step, the drivers were defined and a set of the most important drivers, or key drivers, were discussed and selected by experts in a workshop in February 2016. The key drivers are those that are especially important in determining the future and whose future developments are highly unpredictable. These key drivers are also called critical uncertainties. They serve as the basis to set up the scenario framework. In other words, the scenario framework is a way of explaining the relationship between the critical uncertainties. The scenarios to be developed are mainly determined by the driving forces. Thus, the key trends and dynamics, which drive the developments for shipping in the Baltic Sea, needed to be determined in order to depict possible futures. Hence, it was important to first consider all possible drivers and reduce them in a next step.

A further broad discussion took place in February 2016 including project partners from different disciplines and backgrounds. The workshop aimed to select single scenarios and cumulative scenarios. After selecting a set of single scenarios, describing key drivers, cumulative scenarios were developed based on the selected single scenarios. Regarding socio-economic indicators, the widely used and accepted SSPs were chosen as basis. It is important to check if the chosen set can provide the desired outputs, such as if the set covers a wide range of possible futures, if important concerns of stakeholders are considered and most importantly, if the set will provide answers to the key questions defined in the beginning.

All scenarios were described, while including the current state and trends, the end picture depending on the critical uncertainties, and the timeline describing the route from the current state to the end picture. Based on this input, a coherent narrative was created for each cumulative scenario incorporating a suitable name (e.g. using a metaphor which represents the essential content of the scenario: Sustainability, Middle of the road and Fragmentation).

For SHEBA, the development of descriptive scenarios, without predefined end situation, was chosen. After the description of the current state and the end picture, the timeline must connect these two points through a plausible route. Finally, a coherent storyline or narrative based on the current state and trends, the end picture, and the timeline was developed. The quantitative analysis was elaborated with specific and scientifically defensible quantitative information. They were developed to enhance the understanding and acceptance of the scenario narratives and produce results that can be used. The impact on shipping was analysed for each scenario using results from the STEAM model[1].

2.4 Stakeholder consultation

Besides performing analytical and modelling research, governance structures, policy performance and policy instruments are looked at. SHEBA has a very wide spectrum of participants from a number of different disciplines. Because the scenario development is closely related to policy, society, and industry, the interaction with relevant stakeholders from these groups is of high importance. The project involves stakeholders in two levels. First, there is an advisory board associated to the project, which involves some of the key stakeholders. Second, stakeholders include the shipping industry, Baltic Sea policy organizations, harbours/port organizations, associations for recreational boats, research programmes, national maritime agencies, local governments, and a number of NGOs. This group of important stakeholders is consulted concerning input data for the project and it will be informed about the project progress and results and is asked for its feedback on the interim results.

A SHEBA stakeholder meeting was held in Hamburg, Germany from the 29-30th of September 2015. During the two days meeting more than 15 invited stakeholders discussed, brainstormed and exchanged knowledge of the different working package topics with scientists of the participating institutions. The meeting's focus was on interactive sessions, during which experience of the stakehold-

[1] The STEAM model is used to assess emissions to air from shipping using AIS data as input for the activity combined with data from ship registry and emission factors. The model is described in Jalkanen et al. (2012). and Johansson et al. (2013).

ers with shipping, environmental protection and sustainability issues was discussed to bring in additional knowledge regarding the scenarios.

The discussions on scenarios were made in two sessions; one focusing on the technical development and one focusing on socio-economic development. The main messages from the stakeholders are summarised below.

2.4.1 Technical development

The technical development of the shipping sector is incremental and cannot be seen as a short-term solution. The following parameters are identified as factors influencing influences the scenario development:

- Increase in vessel size and operations (especially cruises)
- Fossil fuels will continue to play an important role for a long time. Shift from fossil fuels to renewables will occur if resources can be saved. Nuclear will not have an impact on shipping. LNG – short, medium term solution, no interest from industry, expensive, no infrastructure, but potential backing from US, Russia, Israel, Egypt, Norway. Methanol – very expensive, highly poisonous, high costs, low availability, no infrastructure, little industry interest, saves space in bunker allowing for increased carrying capacity of ships. Knowledge about methanol already exists in harbours and methanol is also a common industrial chemical. Biofuels – low availability of second generation, competition with food production depends on biofuel generation. Electric – major issues with storage and batteries. Wind – kites, rotors, hull (windskip), sail. The technology is not very developed. Hydrogen – good solution, but difficult to store, dangerous, lacks infrastructure. It has been tested in cars, buses, and small ships.
- Stakeholders agreed that the long-term solution probably will be that shipping sector shifts towards hybrid propulsion systems (e.g. combining diesel electric with wind or solar). However this will take time (undefined), and other systems may be needed in the short to midterm to reduce emissions.
- Propulsion systems in the future, should and most likely will, provide solutions to multiple problems (e.g. reducing emissions as well as minimising noise).
- There is an expected increase in container ship size and traffic.
- Economic drivers are not enough to achieve a shift in ship fuels or other environmental concerns. Additional drivers such as public concern over pollution or health are needed to create political will and momentum for policy changes.
  Timing of policies is a critical factor. It takes time to decide on policies, and ships require a lot of time to be built.
  Shipping can cope with NO_X, SO_X limits by applying current abatement technology or LNG, but those technologies cannot achieve great GHG emission reductions. When low CO_2 standards are introduced, renewable energy sources must be used.
- Noise – operational measures will need to play a key role when designing new ships. There currently exists many opportunities for propulsion.

2.4.2 Socio-economic development

For cruise shipping an attractive development is anticipated – globally and in the Baltic Sea. The need for modern ships within the cruise sector impacts decisions to invest in building of new, modern ships as well as a matching infrastructural development of port facilities.

Input for scenario building regarding merchant shipping is depending on an expected growth in container marked compared to liquid and bulk carriers. The pressure of intermodal shifts from road to sea within the EU is influencing road-, bridge-, and tunnel taxes as well as oil prices. The pricing for these shifts may cause conflicts and a counter shift back from sea to road.

Changes in shipping routes (north-west/north east passages, due to climate change) will change the traffic pattern, the use of feeder vessels in the Baltic and the need for infrastructure in ports. Possibly larger ships and more ConRo vessels are going directly to the Baltic without reloading in Le Havre, Antwerp, Rotterdam or Hamburg. Ports in the Baltic need to cope with this development since they are not equipped or financed to handle larger ships.

Regarding emissions current environmental best practice is slow steaming, which is favoured due to cost reduction. An increase in modernisation of and investments in new ships with lower emissions is likely.

By 2018 the Marine Strategy Framework Directive (MRV) is to be implemented, the EU Regulation 2015/757 on “monitoring”, “reporting”, and “verification” targets carbon dioxide emissions from maritime transport. Possible international social and economic changes on demand for freight in the Baltic depend on global economic growth (e.g. change in international trade due to change in global production patterns), freight rates, oil prices and a possibly increasing demand in LNG due to NECA (NO_X emission control area of the Baltic).

3 Business as usual scenario

The business as usual (BAU) scenario aims to calculate shipping activities in the Baltic Sea in 2030 and 2040 following current trends and taking into account already decided policy measures and regulations. This scenario is the one all other scenarios are compared with in order to assess the impact of different measures/policies or other developments.

In the BAU scenario developed here, a conservative development of shipping following recent trends is used. The forecasts are developed from data for shipping in the Baltic Sea for the period 2006 to 2014 from AIS data combined with an analysis from literature sources. The data is analysed so that the shipping activities are obtained for different ship types and sizes. In this way the change in transport work and trends in ship sizes are analysed.

3.1 Global development trends

The World Energy Council (WEC) has analysed the future relationship between energy and transport, building Global Transport Scenarios up to 2050. The scenarios reflect potential developments in transport fuels, technologies, and systems over the period 2016-2040. It gives an overview of the global transport sector, along with discussion of the related major driving forces, constraints, and uncertainties (WEC, 2011):

"Over the next four decades, the global transportation sector will face unprecedented challenges related to demographics, urbanization, pressure to minimize and dislocate emissions outside urban centres, congestion of aging transport infrastructure and growth in fuel demand. Regional and global cooperation, unstable global economic situations, and potential technological breakthroughs will all have a significant impact." The scenarios describe potential developments in transport fuels, technologies, and mobility systems.

For 2040 two distinct transport scenarios, "Freeway" and "Tollway", were developed. The main difference between these two scenarios is the degree and style of government intervention in regulating future transport markets.

- Total fuel demand in all transport modes will increase by 30% - 82% above the current level.
- The growth in fuel demand will be driven mainly by trucks buses, trains, ships, and airplanes.
- Transport sector fuel mix will still depend heavily on gasoline, diesel, fuel oil and jet fuel, as they all will constitute the bulk of transport market fuels
- Demand for major fuels will increase by between 10% (Tollway) to 68% (Freeway) over the scenario period.
- Demand for diesel and fuel oil will grow by between 46% (Tollway) to 200% (Freeway).
- Demand for jet fuel will grow by between 200% (Tollway) to 300% (Freeway).
- Demand for gasoline is expected to drop by between 16% (Freeway) to 63% (Tollway).
- Biofuels will also help to satisfy the demand for transport fuel as their use will increase almost fourfold in both scenarios. Other fuels including electricity, hydrogen, and natural gas will increase six- to sevenfold.

Significant changes generated as an effect of globalisation, progress in technology and engineering, new international legislation processes introducing various regulations in the field of safety and security of shipping, marine labour, principles of use of marine resources, etc. in the world maritime economy in the past 3-4 decades can be observed.

Apart from containerships and its LNG[2]-powered vessels, few shipping companies are investing in abatement technologies such as scrubbers or dual-fuel engines. Nevertheless in 2013 the first step was taken to establish a Europe-wide web of LNG bunkering facilities, preparing the EU for more ships propelled by gas. Two initiatives that are located in the Baltic Sea region – the LNG Rotterdam Gothenburg and the LNG bunkering infrastructure solution and pilot actions for ships operating on the Motorway of the Baltic Sea projects - aimed to set up a complete supply and fuel transport infrastructure from a terminal to a bunker vessel and then to an LNG-fuelled ship.

According to new estimates, maritime transport will remain the main mode for international freight transport in 2050 (EC, 2011; Enei, 2010). However, road freight is expected to grow significantly (40%) if no alternative infrastructure is introduced. The average haul distance will also increase by nearly 20% as a result of shifts in major trading partners.

3.2 Cargo transport volumes

In 2013, the volume of EU-28 international maritime freight was 3.7 billion tonnes, equivalent to an average of 7.3 tonnes per inhabitant[3]. Baltic Sea volumes in 2013 were over 0.6 billion tonnes of which around 25% was attributed to Russia (ESPO, 2015).

There is a global tendency to pack more types of cargo in containers. Nevertheless within the Baltic Sea there are still ports where a great deal of general cargo is served as break bulk. Moreover, for many ports, especially medium and small ones, the break bulk cargo is an important cargo. The most common subcategories existing in the ports figures referring to break bulk are: wood or forestry products, metals and steel. Other goods are often hidden behind the term 'other cargo' or 'mix cargo'. In 2012, Baltic ports handled nearly 73.7 million tonnes of break bulk cargo. Russia served nearly 70% of the total Baltic break bulk cargo market. Estimations show that break bulk cargo accounts for 8.7% of the total turnover of Baltic seaports (ESPO, 2015).

The main break bulk cargos handled in Baltic ports are various metal, forestry and steel products. In 2012 around 32 million tonnes of forestry products were loaded and unloaded. Total Baltic throughput of metals was estimated at 22 million tonnes (41% via Russian ports). The Port of St. Petersburg handled 2.5 million TEU in 2013 containerised cargo amounted to 23.18 million tonnes. Containerised goods were followed by oil products with 13.97 million tonnes throughput, metals 5.6 million tonne, reefer freight 2.2 million tonnes, scrap metal 1.41 million tonnes and ro-ro cargo 1.34 million tonnes, which marked the highest growth of 75.5% over the previous year.

The Baltic Sea region is becoming more and more significant in container traffic. In 2013, Maersk Line decided to deploy Triple-E, world's biggest container ships, on its AE-10 route. The Triple-E class is a family of 194 000 dwt and 14.5 m in draft container vessels with 18 340 TEU of capacity. The ships comply with the economy of scale, energy efficiency and environmentally improved. Thanks to vari-

[2] The project on Liquefied Natural Gas - the HELGA-LNG has investigated the regional market potential of LNG and carried out geographical analysis in order to point out the best location for LNG infrastructure, one of them being Helsingborg.
[3] EU 28 Maritime and Short Sea Shipping growth rate: 2005-2020-2030-2050 (billion tonne-km): 1. SSS 2020, 2030 2050 – accordingly 2223(+45.8%), 2645(+73,4%), 2949 (93,4%); 2. Sea freight outside Europe 2020, 2030 2050 – accordingly 52022(+44.8%), 75309(+76,5%), 129104 (148,2%);

ous eco-solutions, the Triple-E container ships are designed to reach 50% lower carbon dioxide emissions in comparison to other container carriers sailing on the Asia-Europe route as well as 20% lower CO_2 pollution than E-Class units.

Trade between EU and Russia has grown steadily since 2010, reaching a peak in 2012. The EU mainly imported raw materials, in particular crude and refined oil and gas. Baltic Sea waters are among the most intensely trafficked in the World. The Baltic Sea shipping routes are crossed monthly by 3500 to 5500 vessels. According to HELCOM's calculations, daily marine traffic in the Baltic Sea records around 2000 sizeable vessels daily. The densest traffic is in Danish Straits. Half of the all ships operating on the Baltic Sea waters are general cargo and dry bulk transport ships, while the share of tankers is around 17% and passenger ships 11%.

In 2013, 10 largest Baltic Sea ports jointly handled 7.8 million TEU, which accounts for a 3% growth compared to 2012. In 2010 the top 10 Baltic Sea ports handled nearly 2 million TEU less than in 2013. The container throughput growth in 2010-2013 was 32%. In 2013 the Top 10 Baltic container ports handled 7.82 million TEU, which was about 3.1% more than in 2012.

The total short sea shipping in the EU is estimated at 1.8 billion tonnes of goods in 2014, an increase of 2.4% from the previous year. The overall increase in short sea shipping recorded by the main EU ports consolidated the gradual recovery seen in EU short sea shipping in the years following the economic downturn in 2009.

Short sea shipping made up 59% of total maritime transport of goods to and from the main EU ports in 2014, about the same as in 2013. The predominance of short sea shipping of goods over deep sea shipping was particularly pronounced (close to 70% or more) in Denmark, Estonia, Ireland, Greece, Croatia, Italy, Cyprus, Latvia, Lithuania, Malta, Poland, Romania, Finland, Sweden and the UK.

Liquid bulk was the dominant type of cargo in EU short sea shipping in 2014. In total, liquid bulk accounted for close to 43% of total short sea shipping of goods to and from EU ports in 2014 (781million tonnes), followed by dry bulk at 20% (366 million tonnes), containers at 15% (268 million tonnes) and Roll on - roll off (Ro-Ro) units at 13.5% (243 million tonnes). Liquid bulk also remained the dominant cargo type in all sea regions in 2014.

In 2013 in the Baltic Sea area about 840 million tonnes of cargo was transported by sea, which was by 18% more than in 2004 and 305 million tonnes was transport of liquid cargo, of which 280 million tonnes consisted crude oil and oil refinery products. Within the decade of 2004-2013 the total seaborne transported cargo in the Baltic Sea waters increased by around 18%, mainly due to increased demand for general cargo and increased supply of liquid cargo from eastern Baltic Sea ports (EC, 2012, p. 41). The contribution of western Baltic ports to general cargo transport was 60% in 2004 and decreased to 47% in 2013. The reason behind such decrease was among others the development and increased activity of Russian ports, including the fuel transhipment ports in the Gulf of Finland. Oil transport in the region rose from 40 million tonne to over 240 million tonnes after completing the construction of deep water oil terminals in Primorsk and Ust-Luga (total cargo turnover of Ust-ługa in 2015 was 87.9 million and Primorsk 59.6 million tonnes, which was an increase by 19% and 11% accordingly over the previous year; the cargo was mainly crude oil and oil products). The coming years will probably entail a steady growth of crude oil and oil refinery products in the Baltic Sea area. However there will still remain an option of transporting oil and products via pipeline for technical and geopolitical reason resulting from increased transport in the Baltic Sea to Central and Eastern Europe. There are estimated around 40 fuel terminals in the Baltic Sea area. Some of them are aimed for expansion, which in turn will lead to further increase of tanker traffic in the Baltic Sea area. There was recently a tendency towards substantial increase of transport of crude oil and fuels in total cargo volumes. Since mid of 90 the oil transport grew more than twofold.

In 2013-2014, the worldwide ocean transport of refrigerated fresh products continued the trends shaped in previous years. Amongst others, reefer container capacity continued to grow, while conventional reefer space is gradually shrinking. In addition, the shift from conventional to container carriers is becoming even more vivid, as several dedicated specialised operators decided to shift some of their businesses into boxes. The traditional sector continues to lose cargo in worldwide reefer trades. Even some specialised operators made a whole or partial switch to containers.

3.3 Maritime fleet development

Between 2005 and 2014, the EU-controlled fleet (including Norway) expanded by more than 70% (both GT and DWT). At the end of 2013, the EU controlled 40% of the world's GT and 39% of the world's DWT (see Table 3).

During this time period the total number of vessels has decreased by 31%, reflecting the trend towards deploying larger ships, which offer greater economies of scale. In 2013 the EU governed 26% of the world's vessels, whilst its share of tonnage has slightly reduced reflects that increase elsewhere has been especially concentrated on very large vessels.

The EU-controlled fleet (including Norway) is dominated by three types of vessels: bulkers with 28% of GT, oil tankers 25% and container ships 25%. Under the EU control is 60% of the world's container vessels. The strongest growth rate during the past decade was recorded amongst offshore vessels. The EU governed fleet of container ships, LNG & LPG tankers and cruise ships also recorded high increase of around 100% or more for each of these types of vessels.

Table 3 - World fleet[a] by country of domicile in 2014

Country of domicile	Total			Of which cargo carrying ships			
	Number of ships	capacity thousand GT	average age, years	number of ships	capacity thousand GT	thousand DWT	average age, years
Denmark	904	284 455	11	777	27 501	34 399	10
Estonia	78	8 446	22	71	827	299	18
Finland	112	2 160	99	99	2 095	1798	18
Germany	3 128	82 153	10	3 039	81 850	109 244	10
Latvia	51	649	20	39	604	1 006	16
Lithuania	46	211	23	35	153	207	21
Norway	2 110	36 496	13	1334	30 704	37 097	15
Poland	108	1 730	15	101	1 719	2 435	15
Russia	1 626	14 192	26	1131	12 268	18 967	24
Sweden	311	6 985	15	288	6 580	6 432	15
World Total	50 500	1 191 003	19	41 804	1 141 230	1 708 545	18

a) Ships of 1 000 GT and above.

Source: World Fleet Statistics 2015 IHS

Year 2013 and 2014 did not bring any major breakthroughs across the Baltic Sea region. Shipping lines are adjusting their networks practically on a monthly basis, while “bigger & more efficient” are the terminals’ catchwords, as a natural consequence of the ever larger vessel cascading process (Myszka, 2014).

The size of the reefer container fleet determines refrigerated carrying capacity. Currently the amount of installed plugs is increasing at a much faster pace than the quantity of reefer boxes. For every 40’ reefer box there are currently more than three plugs available. Thus, for every reefer container on board, there will be another unit onshore, so that the availability will in practice be seven plugs per 40’ reefer box. In practice each reefer TEU will make no more than five full voyages a year on inter-continental liner services.

By mid-2013, the number of container ships operating on the popular reefer south-north routes had increased to nearly 780 vessels with an average capacity for 4100 TEU, compared with 3800 TEU in 2012.

Considering both, the last five years’ pace of scrapping and the age of reefer fleet, there are estimations that the conventional reefer capacity will come down to around 100 mill CFT in 10 years’ time, provided that no new significant orders will take place. This is less than half of the present capacity and equal to some 320 conventional reefer ships by 2023 (Visser, 2014).

Currently, the largest deployed reefer-heavy container ships of 9800 TEU with no less than 2 100 reefer plugs, operated by Hamburg Süd on the east coast South America-Far East route. The company will operate even larger units in late 2015 with 10 500 TEU and 2 100 plugs.

In January 2013 the first LNG-fuelled cruise ferry (worth EUR 240 mln ro-pax) in the Baltic the Viking Grace of Viking Line, entered into service Turku-Mariehamn/Langnäs-Stockholm route. It is an important step towards LNG shipping in the Baltic Sea (Containerships, 2014; Tallink Silja Group, 2015; Schuler, 2016; ESL Shipping, 2015). Apart from gas carriers, it is the biggest ship running on LNG. The ship complies with the stricter sulphur standards

3.4 Passenger traffic, passenger/cargo ferries

The total number of maritime passengers that embarked or disembarked in EU-28 ports in 2013 was almost 400 million of which over 50 million are attributed to the Baltic Sea (excluding Rostock) (see Table 4). Aside from the Mediterranean, there were two other areas that accounted for a high share of passenger traffic. These included the port regions of Kent (the United Kingdom) and the Nord - Pas-de-Calais (France) on either side of the English Channel which both maintained almost 13 million passengers. The remaining regions were, to some extent, all interconnected as there was a considerable flow of maritime passenger transport between the Nordic and Baltic Member States in the Baltic Sea and neighbouring areas (such as the Gulfs of Finland and Bothnia). In particular, there were large passenger flows in the ports located within the capital regions of Denmark, Finland and Sweden, Estonia (a single region at this level of analysis), the Danish region of Sjælland and the southern Swedish region (which includes the ports of Malmö and Helsingborg)[4].

Table 4 - Number of seaborne passengers embarked and disembarked in Baltic countries ports (in thousand)

Country	2002	2007	2012	2013	2014			
					Total	Inwards	Outwards	Cruise
Denmark	48 178	48 409	40 955	40 958	41353	20 733	20 619	417
Estonia	5 136	8 665	12 654	13 146	13 654	5 799	6 855	16
Finland	16 557	16 450	18 254	18 524	18 487	9 277	9 209	0
Germany	33 222	30 200	29 481	29 848	30 780	15 134	15 645	1 104
Latvia	23	362	825	872	802	393	409	0
Lithuania	107	212	286	280	280	136	144	0
Poland	3 304	2 456	2 358	2 201	2 204	1 111	1 113	0
Sweden	32 112	32 662	29 471	29 146	29 258	14841	14 416	71
Norway	6 077	6 447	6 003	7 998	7 908	4 207	3 700	122
EU-28 Total	**439 556**	**438 843**	**398 146**	**399 674**	**401 973**	**201 155**	**200 818**	**390 618**

Source: Eurostat

3.5 Cruisers

Europe is a key market for the global cruise industry and the sector growth rate the last 5 years has been 12.3% (European Cruise Council, 2012). During 2014 there were 42 cruise lines domiciled in Europe, operating 123 cruise ships with a capacity of around 146 000 lower berths. Another 60 vessels with a capacity of around 89 000 lower berths were deployed in Europe by 18 non-European lines. An estimated 6.4 million European residents booked cruises, a 0.5% increase over 2013, representing about 30% of all cruise passengers worldwide.

An estimated 5.85 million passengers embarked on cruises from a European port. The vast majority of these cruises visited ports in the Mediterranean, the Baltic and other European regions, generating 29 million passenger visits at a total of around 250 European port cities. In addition, an estimated 14.4 million crew also arrived at European ports (European Cruise Council, 2012).Since 2009 European-sourced passengers have grown by 29% from 4.94 million in 2009 to 6.39 million in 2014. Embarkations at European ports have grown at a more moderate pace of 21% over the 5-year period, increasing from 4.83 million in 2009 to 5.85 million in 2014. Port-of-call passenger visits have risen by 22% over the 2009–2014 period, growing from 23.76 million to 28.96 million.

Over the period from 2015 to 2018, 31 cruise vessels have been scheduled for delivery for worldwide trading with capacity for 93 300 passengers. In addition a further four ships are already on order for

[4] EUROSTAT

2019–2020, all in European yards. Thus, from the beginning of 2015 through 2021, Europe will account for 34 of the 36 new cruise ships to be constructed.

Out of the total 18 ships in the order book at the end of 2015, 10 ships with 30,375 berths (30.0%) will primarily serve the European source market, representing an investment of €5.2 billion. Many of the others will visit European destinations. This new investment underlines the cruise industry's continuing commitment to the future of its business both in Europe and elsewhere in the world.

Table 5 – Development of cruise passenger market - million passengers (©Statista, 2016)

Region	2004	2009	2010	2011	2012	2013	2014
North America	9.14	10.40	11.00	11.44	11.64	11.82	12.16
Europe	2.80	5.04	5.67	6.15	6.23	6.39	6.39
Sub-total	11.94	15.44	16.67	17.58	17.87	18.21	18.55
Other		1.13	2.15	2.40	2.91	3.03	3.09
Total		13.07	17.59	19.07	20.49	20.90	21.30
% NA		69.9	59.1	57.7	55.8	55.7	55.5

Six new ships were added in 2015 with a gain in passenger capacity of 18 813. Further, 15 more new cruise ships will add 39637 or 8.1% to passenger capacity by the end of 2017. By 2019, 25.3 million cruise passengers are expected to be carried worldwide of which 25.1% will originate from Europe.

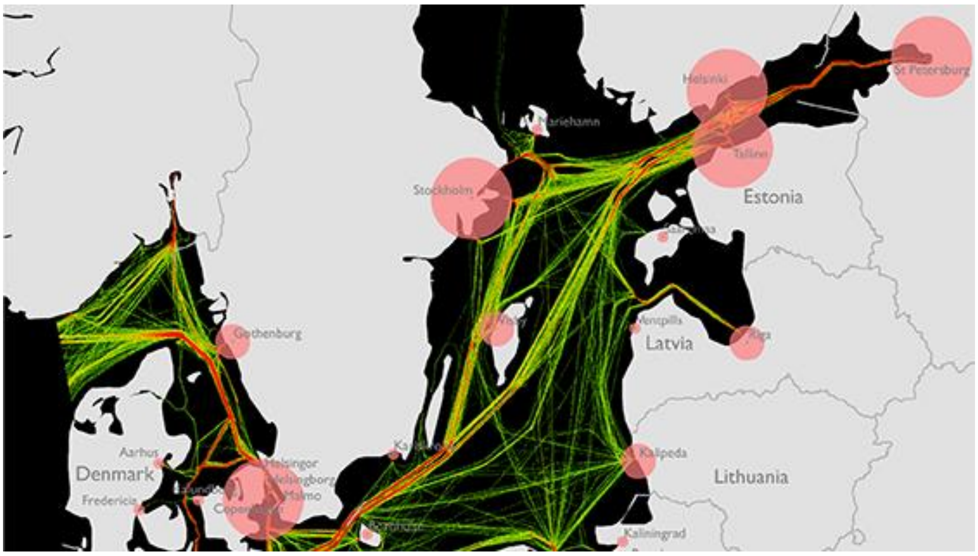

Figure 1 - Cruise ship visits per city and traffic density (Laurila, 2015; HELCOM, 2015)

Around 77 different cruise ships owned by 37 operators sailed in the Baltic Sea during the cruising season 2014. Half of these were smaller vessels with a maximum capacity of 1 500 persons or less, including staff and passengers. Eight vessels, or 10%, were large vessels with a maximum capacity of 4 000 persons or more.

Five main destinations (according to HELCOM), St. Petersburg, Copenhagen, Tallinn, Helsinki and Stockholm, account for 67% of the total cruise ship traffic over the Baltic Sea Region in terms of calls. In total, cruise ships visited 31 different ports during 2014. Half of the 31 ports had eleven or fewer visits, six only one visit. In three ports, including Visby, large ships anchor outside the port and use shuttle boat transportation to the shore.

80% of the international cruise ship calls were intra-Baltic travels, or calls where both the previous port visited and the current port are in the Baltic Sea Region. There were 2 252 international cruise ship calls in total. In a small fraction of visits the ships travelled a long time at sea from previous port, stopped for a short time and had a high maximum number of persons on board. Such visits create challenges for ports if the assumption is that all sewage is to be delivered in ports between voyages.

3.6 IHS Global Insight Scenario until 2030

The macro economic and trade forecasts have also been elaborated by IHS Global Insight**.** The scenario time perspective is 2030. For the purpose of this report, the forecasts have been extended up to 2040. The European trade forecasts are derived from the GDP forecasts in the Global Redesign scenario. The baseline trade is from Eurostat. Europe has passed a peak in the energy consumption in this scenario. As a consequence of the deteriorating oil fields in the North Sea, imports of LNG are expected to increase, primarily to the UK. Total trade grew 2% per year between 1995 and 2008. Between 2011 and 2029 growth is projected to 3%, after that growth is projected to slow down to 2%. Exports grew by 3% between 1995 and 2008. The forecast between 2011 and 2029 is 3% per year. After that growth the forecast will slow down to 2%. Dry bulk and container show the highest average increase. Still, the container growth is a lot lower than in the past. Imports increased by 1.8% between 1995 and 2008. The forecast for 2011-2029 is higher with an expected growth rate of 2.3%. After 2030 growth is projected to decrease to 1.7%. Imports of containers show the highest increase.

3.6.1 Dry bulk trade 2011-2029

BIMCO forecasts[5] a dry bulk import growth of 171 million tonnes, from 357 million tonnes in 2011 to 528 million tonnes in 2029, which is a compound annual growth rate of 2.3%. The average annual growth in tonnes is 9 million tonnes for the entire European Union. The dry bulk export growth forecast shows a growth of 92 million tonnes over the same period, from 127 to 219 million tonnes - 3.0% increase per year.

3.6.2 Dry bulk imports

Close to half of the import growth is from ores, scrap and coal. These are commodities that feed into the steel industries in the EU. Steel is produced in most member states, but the large production countries are Germany, Italy, France, Spain, the UK, Poland, Belgium, Austria, the Netherlands, the Czech Republic, Sweden, Slovakia and Finland. The forecast of the imports of coal, ores & scrap to the EU points at a growth by 84 million tonnes, from 120 million tonnes in 2011 to 204 million tonnes in 2029. The main providers are exporters in Brazil, Colombia, South Africa, USA and Canada. Most of the imports are destined for Germany, the UK and the Netherlands. Coal imports to Germany are expected to increase by about 16 million tonnes. Much of it will be sourced from Colombia and South Africa. Sweden is the largest iron ore producer in the EU with a production of 28 million tonnes in 2010. Current investments will increase the production capacity of the mines in Lousavaara and Kiru-

[5] https:// www.bimco. org/~/media/Products/BIMCO.../pdf100.ashx

na to 37 million tonnes by 2015. Further investments are to be expected following the move of the entire city of Kiruna to allow for continued production.

3.6.3 Dry bulk exports

Sweden and the Netherlands are the biggest iron ore exporters in the EU. Sweden exported close to 23 million tonnes (source Statistics Sweden) in 2010 of which 13.7 million tonnes to the EU. Steel exports from EU member states in 2010 went according to Eurostat to Turkey, India, USA, Algeria, Egypt, China, Morocco, Russia and a large number of other countries, of which many in Asia, Middle East and Africa. The largest export commodities in the WTS forecast are ores & scrap, scrap, iron and steel. These commodities are forecasted to grow with 119% until 2029 from 29.8 million tonnes to 65.2 million tonnes. This increase represents a share of 39% of the total dry bulk export increase over the period. The total Swedish extra-EU exports of ores & scrap is projected to increase with 11.3 million tonnes or 91% (2011-2029) from 12.4 million tonnes to 23.8 million tonnes (Ricardo-AEA, 2013).

3.6.4 Trends in vessel sizes

Increasing vessel sizes have increased the efficiency of seaborne transport over time. The trend for larger vessels, as noticed in particular for container vessels in recent years during times of economic expansion, achieves economies of scale for shipping companies. Larger ships are not efficient if not enough cargo is available and they have to sail only partly loaded.

3.6.5 Transport of passengers

Two competing trends have been observed in the maritime passenger transport sector within the past two decades. On the one hand, some ferry services have declined or ceased over time on routes where inexpensive commercial flights or high speed rail links have competed directly against the ferries. On the other hand, the cruise sector has seen significant growth in the last decade. These competing trends suggest where possible for passenger ferries to be treated separately from cruise vessels.

3.6.6 Fuel trends

The coming into force of MARPOL Annex VI regarding fuel sulphur content limits in the sulphur emission control areas of the North Sea and Baltic Sea, together with the Sulphur Content of Marine Fuels Directive, has led to a partial switch from residual to distillate fuels.

3.6.7 NO_X technical code

The NO_X technical code adopted as part of the MARPOL Annex VI set NO_X emission limits for new marine engines produced from the year 2000. There was a shift from fuel-optimised engines to NO_X optimised engines.

3.6.8 Slow steaming

Slow steaming was adopted by the industry as a response to high fuel costs and an oversupply of container fleet capacity arising from the economic recession. Slow steaming is a measure that reduces fuel consumption (and costs) and therefore CO_2 emissions of ships.

3.7 The BAU scenario in SHEBA

Following the analysis above the development of the fleet in the SHEBA BAU scenario is as described in Table 6. The estimation is based on analysis of available trends and forecasts of economic development including freight and passenger transport and maritime fleet. From the methodological point of view, the main indicators including external drivers, internal and impact drivers as well as policy factors which affect transport have been examined (based on EU, IMF, OECD and WORLD BANK data). The scenario follows the general assumptions of the EU's transport policies and priorities e.g. opportunities for marine and maritime sustainable growth (EC, 2012) and Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system (EC, 2011).

Table 6 - SHEBA's BAU scenario for Baltic Sea Region

SPECIFICATION	Unit	2010 base	2015	2015-2020	2020-2030	2030-2040
		% growth av. Year				
Baltic Sea cargo volume						
total	Mtonne	800	950	2.2	2.0	1.8
liquid	Mtonne	350	380	2.4	2.2	2.1
bulk cargo	Mtonne	200	220	2.2	2.1	2.0
containers	Mtonne	120	150	3.0	2.2	2.0
general cargo	Mtonne	130	200	1.1	0.9	0.7
Passenger traffic total	thousand pas.	420 000	400 000	0	0	0
cruise	thousand pas.	100 000	100 000	1.0	1.0	1.2
Fleet deployment						
total	no of ships	360 000	380 000	0.3	0.2	0.1
	capacity thousand dwt	120 000	120 500	1.1	1.0	0.9
Tankers	no of ships	60 000	64 000	1.2	1.2	1.2
	capacity thousand dwt	40 000	42 000	2.1	2.0	2.0
Bulkers	no of ships	40 000	42 000	0.2	0.2	0.2
	capacity thousand dwt	50 000	53000	0.5	0.5	0.5
Container ships	no of ships	40 000	45 000	1.0	1.0	1.0
	capacity thousand dwt	60 000	65 000	1.3	1.2	1.1
General cargo	no of ships	50 000	50 000	0	0	0
	capacity thousand dwt	40 000	42 000	0.1	0	0
Ro-pax	no of ships	90 000	90 000	1.2	1.1	1.0
	capacity thousand dwt	40 000	45 000	1.3	1.3	1.1
Other	no of ships	80 000	86 500	0.5	0.4	0.3
	capacity thousand dwt	70 000	75 000	0.5	0.4	0.3
Cruisers	no of ships	1330	1330	1.0	1.0	1.0

	capacity thousand GT	65 000	65 000	0.5	0.4	0.3

Further, legislation and other regulations already decided upon are assumed being enforced while other probable policy measures are not. Table 7 shows a list of potential regulations indicating if they are included in the BAU scenario or not. Several of the regulations not included are topics of other scenarios in this report as indicated in the table.

Table 7 - Included potential regulations in BAU scenarios

Topic	Included in BAU	Technologies	Comment
SO_X emissions	SECA limit (0.1%) from 2015, global limit (0.5%) from 2020. Following current trends in fuel mixture.	There will be an assumed fraction of scrubbers (open and closed) as well as a mixture of low-sulphur fuels.	The change of the global limit have no direct impact on BS but may influence technology choices
NO_X emissions	Up to Tier II but with SCR and LNG following current trends	For Tier II basically engine modifications and tuning	
Emission of greenhouse gases	The decided EEDI limits	Described as EEDI	
Ballast water	No ballast water regulation assumed.		
Use of LNG	Follow current trends taking into account the EU fuel directive.	Dual fuel mainly	
Hull paint	Following current trends		

In order to calculate for example emissions projections, the age distribution of the ships is an important parameter. Table 8 gives the average expected lifetimes of different ship types.

Table 8 - Average expected lifetime for different ship types

	Average lifetimes of ships (Kalli et al., 2013)	Values calculated from linear fit of population age (IHS, 2015); half of population remaining gives average lifetime
Bulk carrier	19	25
Chemical tanker	26	28
Container ship	25	38
General Cargo	26	21
LG tanker	28	29
Oil tanker	26	25
RoRo cargo	27	38
Ferry	27	38
Cruise	27	35
Vehicle carrier	27	20

4 Single scenarios

4.1 Slow steaming scenario

Slow steaming is an operational measure for shipping to reduce fuel consumption, exhaust emissions and underwater noise. However, it is not certain how much reduction in noise, fuel consumption and emissions that can be achieved with slow steaming. Work was initiated in Johansson et al. (2013), which investigated how much impact speed reduction had on exhaust emission. Noise scenarios have not been run earlier, neither has emissions to water been analysed.

The analysis of noise will only concern commercial ship traffic since leisure boat activity is not fully included in AIS activity data. Other anthropogenic sound sources than continuous shipping noise are neglected. Impulsive sounds (explosions, construction work) are beyond the scope of the project as well as the natural background noises (seismic activity, wind, waves, rain, sea ice cover). Noise concerning icebreaking against vessel hull is excluded. However, speed reduction impact on engine loads, emission factors and specific fuel consumption are included.

Current knowledge of underwater sound and its impact is limited. This is an emerging topic and basic data needs to be collected in order to assess whether underwater noise presents a problem and if so, how great that problem is. Stakeholders are clearly not familiar with underwater noise. This was evident in the stakeholder conference in Hamburg. Slow steaming was considered as a temporary solution to fuel consumption reduction.

The physical size of the ship has an impact on noise emissions. Larger engines produce more noise. The percentages need to be evaluated against the design changes of future vessels. Vessels will be designed to meet stricter EEDI rules for better fuel efficiency.

If noise is demonstrated to be a serious issue, there can be mandatory design changes for new vessels. Old ones have to rely on changes of operational profile. It is expected that shipping activity will increase in the future, which means more and larger vessels than in the existing fleet. Port quay size limits the growth of vessel size.

If slow steaming will continue in large scale and there is an increase in trade, more vessels are needed to maintain the flow of cargo. However, vessel speed is likely the first step to increase capacity to handle the demand.

It has been observed that the average ship speed in the Baltic Sea decreased after the financial crisis in 2008 and has maintained at a low level. The reason is likely an overcapacity on the marked. However, in this scenario we assume a further reduction in speed; on average we assume a reduction with 10% beyond the situation in 2014.

Table 9 - Summary table of slow steaming

Name	Slow steaming
Purpose	To investigate changes in emissions to air and water and noise that comes from a general reduction in speed.
Changes vs. BAU	Vessels will run 10% slower. More vessels are required in the transport system in order to perform the same transport work.
Main results	Reduction in noise, fuel consumption and emissions to air. Increase in emissions to water.

4.2 Modal Shift from land to sea

The European Commission aims at making transport in the European Union more resource efficient. This has been laid down in the White Paper "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" of the European Commission from March (2011). The goal is to reduce greenhouse gas emissions from the transport sector by 60% in 2050 (compared to 1990) and by 20% in 2030 (compared to 2008). The latter will still be 8% above the 1990 levels.

In the White Paper, several measures to reach this goal are described. Among them are:

- use more inherently resource efficient transport modes for long distance freight
- more long haul transport should be done on rail and by waterborne transport
- use of more sea ports as entry points to the European Union
- improvements of the hinterland connections from sea ports, in particular those with inland waterway connections

Among the 10 goals, for a competitive and resource efficient transport system, are:

- to move 30% of road freight over 300 km to other modes (rail and waterborne) by 2030 and more than 50% by 2050

Short Sea Shipping is explicitly mentioned twice in the document but no quantitative goals are given for this sector.

Modal Shift from land to sea is of high interest because of the EU policies mentioned above. The Baltic Sea Region is particularly suited for short sea shipping. Therefore it might develop into a model area for bringing more freight from road to ship. It is of high interest to evaluate if this development will produce less emissions of air pollutants and less eutrophication in the Baltic Sea Region. Ship owners often mention the reverse scenario (modal shift from sea to road) that might play a role if shipping becomes more expensive due to stricter regulations.

Relevant publications were evaluated to develop a meaningful quantitative scenario.

Tavasszy & van Meijeren (2011) analyse the current situation for distribution of goods among the transport modes in Europe. Since 1995, the transport volume has increased by about 20% in the EU27, however, the modal split has not changed much. About 80% of all tonne km is done on road and sea. The fraction of these two modes in the total transport work has increased slightly with a slightly larger increase for road compared to sea. About 11% of the mass is transported over distances above 300 km. However, this amounts to 56% of the mass distance (tonne km). There are differences between the distances over which goods of certain types are transported in the EU27. Crude oil, solid mineral fuel, ores and metal products have a relatively high share in long distance transport. Solid mineral fuels and petroleum products have the highest share in non-road transport. According to the numbers given in the EU's White paper, the share of the volume on roads needs to decrease from 75% to 52% until 2030. Rail will therefore increase from 21% to 39% and inland shipping from 4% to 8%. The authors do not focus on the potential of short sea shipping and they are very sceptical that this shift can be realised. They argue that time has become a very relevant factor in the logistics networks and rail transport and shipping takes more time. In many cases, the last kilometres need to be done by truck anyway; therefore a change in transport mode is inefficient if the distances are short. Another reason for being sceptical about the possibilities to reach the goals of the White Paper is that a doubling of the volumes transported by rail or inland ship may need significant investments in the associated infrastructure. This will be expensive and take time. On the other hand, EU has invested a lot more resources in roads compared to rail networks and ports.

The Baltic Sea Region has a large potential for short sea shipping, because many harbours already exist and connections between economic centres in the Baltic Sea area can be connected on shorter distances by ship compared to rail and road.

ISL Logistics studied the potential for short sea shipping in the Baltic Sea (ISL Logistics, 2010; ISL Logistics, 2014). The study from 2014 describes the current situation for the container market in the Baltic Sea region and gives scenarios for 2020 and 2030. They also investigate the potential of several measures to bring more freight from road to sea. The analysis of the containerised traffic flow shows that 1.3 million TEU were transported in 2012, 1.1 million of those between the North Sea ("North Range") and the Baltic Sea and 0.2 million within the Baltic Sea. The traffic between the North Range and Russia amounts to 0.6 million TEU. The intra-Baltic traffic of containers is dominated by RoRo traffic because container handling is expensive and the fuel savings in ship transport are too low on short distances. 28% (3.8 mill tonnes) of the traffic between the North Range and Russia is by ship, 72% on land. Similar fractions of the total transported volume go by ship to Sweden, Norway, Finland, but much less to the Baltic States (14%) and Poland (1%). Finland (container ships) and Sweden (RoRo ships) are mostly served by ship from the South Baltic (mainly from Lübeck), while the Baltic States and Norway have low fractions of ship transport from there.

In ISL's analysis, it is considered that SECA rules, which implies a maximum of 0.1% sulphur content in ship fuels, will be implemented which leads to a shift of freight from sea to road (ISL Logistics, 2010). Based on fuel prices in 2010, it was estimated that about 25% of the container transport (1.2 million TEU) will go from sea to land in the BSR in 2015. Most likely this did not happen. One reason could be that the fuel prices dropped significantly the last two years. Looking at current fuel prices, it must be put in question if this needs to be considered for future scenarios.

The forecast for 2020, including stricter SECA regulations, implied a 1.1% per annum increase in trade volume on average, which resulted in an increase of 22% in 2030 and 36% in 2040, compared to the transport volume in 2012. They estimate no increase in the volume transported by ship until 2030 (and 10% reduction in 2020). An increase in transported volume by 14% in 2030 can be deduced from this (ISL Logistics, 2010; ISL Logistics, 2014).

The study investigates incentive systems to bring more freight from road to sea. These are mainly financial subsidies. If fuel costs would be subsidized by 30% container traffic could increase by 18% compared to BAU. This will be most efficient for the transport from the large North Sea harbours or the South Baltic area to Russia because of the long distance and the high share of fuel costs in the total costs. Subsidizing container handling fees by 10€ per movement would increase the volume transported by short sea shipping by 8% compared to the base case.

Other measures discussed but difficult to quantify are the introduction of “grey boxes” and marketing efforts to reduce the transport of empty containers. Short sea cargo transport could also be increased if feeder ships would also be more used for short sea shipping.

The effects of the SECA fuel sulphur regulations were studied in several papers:

- Polish ports showed a decrease in containerized cargo in 2015 compared to 2014 by -12.9%. However, in the Port Monitor Matczak viewpoint is that trade restriction with Russia and the shrinking economy in Russia are the main explanations for that decrease (Matczak, 2016). The total cargo turnover increased by 3% in the ports of Gdynia, Gdansk and Szczecin.
- Odegaard et al (2013) suggest that only RoRo and container traffic may be affected by modal shifts from sea to road. They find that the effects of a SECA dominate the total effects. However, they are most likely small, less than 1% shift of cargo from sea to road.

Conclusions and recommendations for the SHEBA scenarios

- SECA and NECA will have only minor effects for a shift from sea to road. This will be neglected in the SHEBA scenarios.
- Container and RoRo transport are the main areas affected by modal shifts. We do not consider other types of transports.
- Incentive measures might increase the transported volume by ship (only containers and RoRo) by 30% compared to the BAU.
- The additional volume transported by ship will mainly affect routes between the North Sea and Poland, the Baltic States and Russia. This is because most of the transport between these regions is on road.
- Russia and the Baltic States are most attractive for short sea shipping between the North Range and the South Baltic because of the long distances.
- For every two 20‘ containers (or one 40’/45’ container) transported by ship one truck is removed from the same route on land.
- We assume that 30% of the containerized land based traffic will be on sea by 2030, 40% by 2040. We consider only routes longer than 300 km between the North Range/South Baltic and Poland, the Baltic States and Russia.
- We do not consider changes in the routes to Sweden and Finland. Ship traffic to Finland is already on a high level. Road traffic to Sweden might increase when the Fehmarn Belt tunnel will be built in 2030 (or earlier).

Table 10 - Summary table of modal shift from land to sea

Name	Modal shift from land to sea
Purpose	To investigate changes in emissions to air and water and noise that comes from a significant modal transfer of transport work from land to sea.
Changes vs. BAU	More RoRo and container traffic from the North Sea to Poland, Russia and the Baltic States
Main results	General increase of impact from shipping. Decrease in impact (mainly air pollution) from road.

4.3 NECA 2021

Joint political efforts are made in Northern European states to make the Baltic Sea and the North Sea so called Nitrogen Emission Control Areas (NECAs), according to existing IMO regulations. The process of having the regulations imposed has come far enough that enforcement is likely, although not yet decided. The investigated scenario considers changes in emissions to air (mainly of NO_X) from an introduction of a NECA in the Baltic and North Seas by 2021.

4.3.1 Background

The NO_X regulation of MARPOL is constructed with three Tiers, and each Tier requires further reductions of emissions compared to the previous Tier. Tier III regulations are not planned for global enforcement but can be applied in special areas, NECAs. Currently, the only NECAs that exist are the North American ECA and the United States Caribbean Sea NECA. All NO_X regulations in MARPOL primarily apply to new built ships only.

Tier II levels accomplish approximately 15% to 20% reductions in NO_X emissions compared to a Tier I engine. These reductions can often be accomplished by adjustments of combustion parameters on existing engine models. Fulfilling requirements of Tier III yields reductions of NO_X emissions by 80% compared to the Tier I levels. Reduction to the significantly lower Tier III levels of NO_X emissions can be achieved by installation of abatement technology. Many options exist; the so far most widely used technology is a catalytic converter for aftertreatment of the exhaust gases, SCR. Another option is exhaust gas recirculation (EGR), a technology widely used on diesel engines on land. A third option is to use a fuel that causes less NO_X emissions when combusted. Liquefied natural gas (LNG) is one, and also methanol is a potential choice, although rarely tested as a marine fuel.

The regulation is constructed so that only new vessels will need to comply with the Tier III emission limits. No actions need to be taken to reduce emissions from ships constructed before 2021. As a consequence the emissions will not be reduced at an instant. Instead, total emission levels will be reduced only slowly and could even increase if the ship traffic increases.

4.3.2 Scenario construction

The NECA 2021 scenario is built on the assumption that emissions of NO_X are significantly reduced in relation to traffic as old ships are replaced by new after 2021. There are four aspects that are central in order to make a forecast for the scenario that are included in the scenario modelling:

- Changes in traffic
- Changes in average ship efficiency
- Turnover time of fleet
- Which technological solutions are chosen to reduce NO_X emissions

The changes in traffic and the average ship efficiency are used to estimate the fuel use of future Baltic Sea shipping. These are important parameters also in the BAU scenario, and the BAU forecasts on these parameters are used also for the NECA 2021 scenario.

The turnover time of the fleet is of high importance in this scenario since it determines the rate at which old ships with high NO_X emissions are replaced by new ships that comply with the Tier III requirements. Different segments of the fleet have different turnover times. In BAU scenario, the average lifetime of ships of different types is used as a proxy to calculate turnover time of ships in the Baltic Sea.

There are a handful of technological solutions available that reduce NO_X emissions to the levels required by the Tier III regulation. In addition to their reduction of NO_X they also cause reductions, and sometimes elevations, of the levels of other pollutants in the exhausts. It is therefore necessary to make assumptions on which technologies the ship owners will choose for their ships in order to make a more comprehensive environmental assessment of the NECA 2021 scenario. We have selected the three most mature technologies, and considered costs and technological maturity to determine their share of implementation. We have also considered how well they function together with technologies to fulfil the SECA requirements. A brief overview of the considered technologies will be given in the following. A more complete description of technologies, their benefits and disadvantages can be found in IMO (2013a; 2013b).

The technologies that are thought to be relevant for the scenario building are Selective Catalytic Reduction (SCR), Exhaust Gas Recirculation (EGR), and Liquefied Natural Gas (LNG). These technologies are also pointed out in the (IMO, 2013a).

SCR is a well proven technology that has been used for many years both in marine and other applications. The IMO report from 2013 lists over 500 ships equipped with SCR. In the SCR, urea is added to the exhausts and a catalytic reaction occurs where nitrogen oxides are reduced to nitrogen gas by urea. The SCR functions only at high exhaust gas temperatures that are seldom reached at low loads of an engine, a typical situation when a ship manoeuvres in and out of ports. The SCR system sometimes causes an ammonia slip to air. The slip is typically below 20 ppm.

In a study for Transport and Environment it was estimated that the total costs for installing and running an SCR are in a range of 150 to 2000 € per tonne abated NO_X (Winnes, et al., 2016) Only installations in new built ships are included.

EGR is not fully verified in marine applications but available by marine engine manufacturers. Still, EGR is a well proven technology in land based transport. High concentrations of SO_2 and PM in the marine engine exhausts are lowered with a scrubber system fitted to the EGR. Similar to SCR, the technology functions at high engine loads. An EGR requires little extra space in the engine room. Abatement costs for an EGR have been estimated to be between 210 and 1200 € per tonne NO_X (T&E study). The maximum investment costs are lower than those for SCR, although the expected abatement costs of the two technologies are fairly similar.

LNG has been used as a fuel in gas carriers for decades. Due to regulations on sulphur levels of marine fuels and political incentive schemes, the use of LNG engines is increasing also in other segments of the fleet. LNG has thus the benefit of fulfilling requirements of both SECAs and NECAs. Any sulphur dioxide from the LNG engine can be attributed to a small amount of marine gasoil used for ignition. Compared to a diesel engine, the emissions are typically reduced by 95% or more. Also particle emissions are to a large extent due to the ignition fuel. A negative effect is the methane slip from the engine that contributes to atmospheric warming. The slip has been measured to around 7 g per kg LNG at higher engine loads, rising to 23–36 g at lower loads, on one ship (Anderson, Salo, & Fridell, 2015). The cost difference between LNG and conventional marine fuels determines if there are economic benefits of using LNG from a long term perspective (Nielsen & Stenersen, 2010). However, short pay back times are used in the ship owner sector and high investment costs are a significant share of the costs. Many LNG driven ships are fitted with engines that can run on both LNG and MGO in which case the cheapest fuel can be chosen whenever operating outside an emission control area. In the study for T&E referred to above the span for costs for using LNG to 100% is between -2200 and 12000 €/tonne NO_X compared to operations in marine gasoil. Potential alternatives are also methanol fuel, and fuel reduction measures in general. Methanol is a fuel alternative that currently is used for generation of propulsion- and electric energy on board one ship. With little experience of its suitability in marine operations, its full potential remains to be demonstrated. An overview of the costs, benefits and disadvantages with the technologies are given in

Table 11.

Table 11 - Overview of SCR, EGR and LNG abatement costs, benefits and drawbacks

	SCR	EGR	LNG
Technology maturity in marine application	High	Low	High
Costs	0.15 to 2.0 €/kg NO_X	0.21 to 1.2 €/kg NO_X	-2.2 to 12 €/kg NO_X
Major benefits	Proven technology	Relatively compact design	Potential to negative costs
Major disadvantages (ship owner perspec-tive)	High space demand. Uncertain function at low engine loads (manoeuvring). Operational costs for urea consumption.	Only little proven in ships. Uncertain function at low engine loads (manoeuvring).	High space demand. Uncertainties about infrastructure develop-ments for fuel supply in ports (EU, 2014)). Uncertain pay back
Side effects	Ammonia slip	Sludge from EGR-scrubber	Reduces SO_X and parti-cles Emissions of unburnt methane.

For the NECA 2021 scenario we have assumed that the implementation rate of SCR, EGR and LNG in new ships does not depend on ship category, size of ship, or time in the NECA. Based on the available information it is likely that SCR will dominate the installations on new ships that aim to oprate in the NECA. The main reason is that compared to EGR it is a proven technology, and compared to LNG it has low investment costs. Returned investment costs for LNG require high availability of LNG at low prices. For the scenario calculations, we assume that 70% of all fuel used on new ships in Baltic Sea shipping will be used on ships fitted with an SCR after 2021. It can however be assumed that for ships in particular trades and of particular designs will find either LNG or EGR to be the preferred solution. The benefit of EGR compared to LNG propulsion is the relatively low investment costs. EGR could be a beneficial solution to ships with little time in the emission control area. LNG has the benefit over EGR to be well-proven for marine use. Further, for ships with a lot of time in the region, the LNG op-tion will potentially be beneficial for their owners; these ships will not need additional installations to comply with sulphur regulations, and the LNG price is often expected to be less than the price for MGO. For the scenario calculations, we assume that 15% of the fuel used on new ships in Baltic Sea shipping will be used on ships fitted with an EGR, and 15% will be LNG after 2021.

Table 12 - Expected results

Name	NECA 2021
Purpose	To investigate changes in emissions to air (main-ly of NO_X) from a introduction of a NECAs in the Baltic and North Sea by 2021.
Changes vs. BAU	New vessels from 2021 will follow the Tier III NO_X emission regulations.

Main results	Reduction in emissions of NO_X as old vessels are replaced by new ones after 2021. A mix of SCR, EGR and LNG is used to meet the standard.

4.4 Zero emissions into water

Currently (2016) it is allowed to discharge untreated black water and ground food waste beyond 12 NM from the nearest coast in the Baltic Sea. Greywater is not regulated by the international law. One step towards the zero-emission scenario is the revised MARPOL 73/78 Annex IV Sewage which prohibits discharging untreated black water from the passenger ships (MARPOL 73/78, 2005). The entry into force has been preliminary set to 2016 for the new ships and 2018 for the older passenger ships however these dates have been postponed. The new dates discussed are 1 June 2019 and 1 June 2021, respectively. One important issue in case of the zero-emission scenario is that the adequate port reception facilities are in place to be able to receive the waste from ships.

There is currently no regulation for discharge of food waste, and therefore will this source of nutrient contribution have a relatively high impact when nutrient-release from sewage becomes regulated (Wilewska-Bien, Granhag, & Andersson, 2016).

There are now ongoing discussions in several EU countries if discharges of open-loop scrubbers are in compliance with the marine strategy framework directive (MSFD). For example, the Swedish Agency for Marine and Water Management is of the opinion that the discharge is unacceptable in an environmental point since the water is acidic and many discharge water have shown to contain elevated concentrations of PAHs and heavy metals. Hence, one legislative scenario could be that no discharge is allowed in the Baltic Sea.

The Ballast Water Management Convention (BWMC) was adopted in 2004 and to get into force ratification by 35% of the world fleet tonnage is needed. In March 2016 34.82% of the world tonnage had ratified and the convention is therefore likely to get into force in the coming year/s. (The criteria for number of countries is already fulfilled as 49 countries have signed and 30 is needed, however both criteria: 1) number of countries (least 30) and 2) 35% of world tonnage has to be fulfilled before convention gets into force). When into force approximately 70 000 ships worldwide will need to have a way to treat their Ballast Water where installation of Ballast Water Treatment Systems (BWTS) is expected to be used for the major part of the ships. For the Baltic Sea the option for certain ships to apply for exemption from treating the Ballast Water have been discussed and a 'Joint Harmonized Procedure' for this has been developed under HELCOM and OSPAR. This alternative is most relevant for ferries on route between two ports (in traffic between two countries but short distances, like for example Helsingborg, Sweden and Helsingør, Denmark). The BWMC is when in force expected to greatly reduce the spread of invasive species. However, biofouling on ship hulls is also a significant vector for spread of invasive species and today not regulated (but as Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species, IMO 2011). The use of BWST can be expected to increase the ships' fuel consumption.

Table 13 - Zero emissions into water

Name	Zero emissions into water

Purpose	To investigate the changes in impact on the Baltic Sea from a number of regulations limiting emissions to water from shipping.
Changes vs. BAU	Emission of black water prohibited, no discharge of greywater or bilge water, no open-loop scrubbers, BWMC in place, only biocide-free paint.
Main results	Lower emissions of nutrients, less transport of invasive species.

4.5 LNG

Using liquefied Natural Gas (LNG) as fuel in ships lowers emissions of sulphur dioxide (SO_2), particles and nitrogen oxide (NO_X) to air compared to operations on marine gasoil or heavy fuel oil. A negative effect is a slip of methane (CH_4) from the engines, which contributes to atmospheric warming. This scenario aims at describing consequences of a high rate introduction of LNG as a marine fuel for ships in the Baltic Sea.

4.5.1 Background

International regulations on sulphur content in marine fuels have been in force since 2010. The Baltic Sea, the North Sea and the English Channel are appointed Sulphur Emission Control Areas (SECAs), where the maximum allowed sulphur content of fuels are 0.1%, since 2015. It is also allowed to use exhaust gas after treatment equipment that reduces the SO_2 content in the exhaust to levels equivalent to those from use of low sulphur fuel. The technical responses to the SECA regulation include use of low sulphur oils, installing SO_2-scrubbers, or running engines on LNG. Further incentives for LNG exist for ship owners operating in Norwegian waters, who benefit of the possibility to apply for funding from the Norwegian NO_X-fund. The NO_X fund gives financial support to ship owners that invest in low-NO_X technologies on their ships. LNG engines will in addition to the low SO_2 emissions reduce NO_X to approximately Tier III levels.

The political incentives have caused LNG engines on ships to become more used. The engines can either use only gas in a spark ignition engine, or use a combination of LNG and fuel oil (dual fuel engine) in a compression ignition engine. Both new engines and rebuilt existing diesel engines are being used. The barrier for a large technology breakthrough is mainly an often low availability of LNG for bunkering. Further, the LNG needs specially designed tanks to keep the fuel cold. These cryo-tanks require extra space on board compared to conventional fuel tanks. Another often discussed downside with the use of LNG engines is the slip of methane, which is a very potent greenhouse gas, a problem that must be addressed.

The technology may be attractive to ship owners from an economic perspective, which will be a significant force to a wide technology spread if the fuel is made more accessible. The fuel prices of LNG are fluctuating and predictions of future prices include high uncertainties. Historical prices of LNG indicate large differences between regions and prices more comparable to heavy fuel oil (average 2.4% S in fuel) than to marine gasoil (average 0.1% S in fuel).

A directive from the EU on the deployment of alternative fuels infrastructure, points out LNG as an attractive marine fuel for ships sailing in the emission control areas. The directive states that a core network of refuelling points for LNG at maritime ports should be available at least by the end of 2025 (European Union, 2015). The supply of LNG as marine fuels can be expected to rapidly increase following the directive, which also emphasises that the network in the long term might well be expanded to ports outside the core network.

4.5.2 Scenario construction

The scenario is constructed on the assumption that LNG engines are the preferred alternative to diesel engines, for a significant share of ship owners from an economic point of view. It is expected that the technology is mature and that the installation cost of an LNG engine in a new vessel is only slightly higher than an installation of a diesel engine. Fuel costs during operations are expected to be lower than operations with MGO. Further, it is expected that the directive on deployment of alternative fuels infrastructure is in full effect by 2025. Then LNG supply would not be a barrier for technology adoption.

The parameters determining which ships that are expected to be LNG ships in the scenario are mainly their trade patterns and their ages.

A ship's trade patterns determine the time the ship spends in a specific area. The time in the area will give an indication of potential return on investment for extra costs for LNG equipment on board. The time in an area is often related to whether a ship sails in liner services between defined ports, typical for RoRo ships, and RoPax ships. Also vehicle carriers and container ships typically have planned routes although, as opposed to RoRo and RoPax, their lines often include transocean service. Large ships that stay a long time in an area can be assumed to be exclusively RoRo and RoPax vessels. Other large ships cannot be expected to make more than a few calls per year in the Baltic Sea. Also many small sized vessels have most of their operations in the area. Small vessels predominantly operate in coastal service and will not move as long distances between port calls as larger ships. Definite size limits for small and large ships are not possible to establish but need to be estimated. Average times in the Baltic Sea for different ship types and sizes are illustrated in Figure 2 and Figure 3 respectively (FMI, 2015).

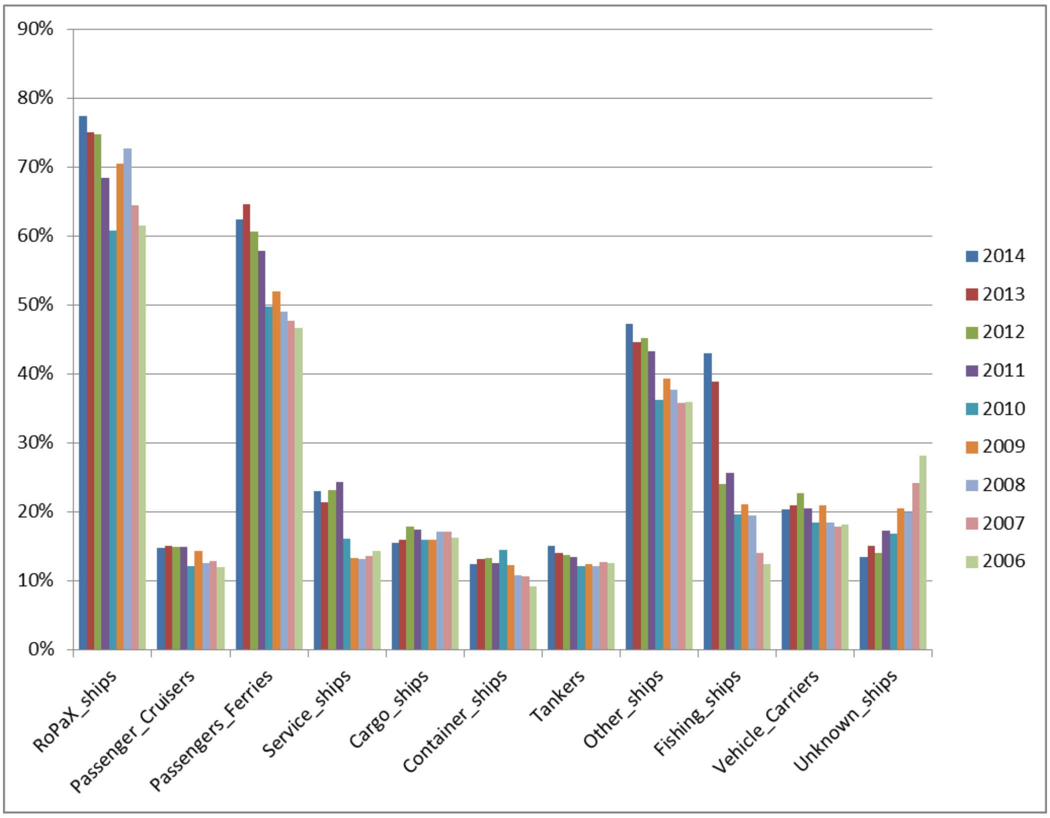

Figure 2 - Average share of full year that ships of different types spends in the Baltic Sea (data from FMI, 2015)

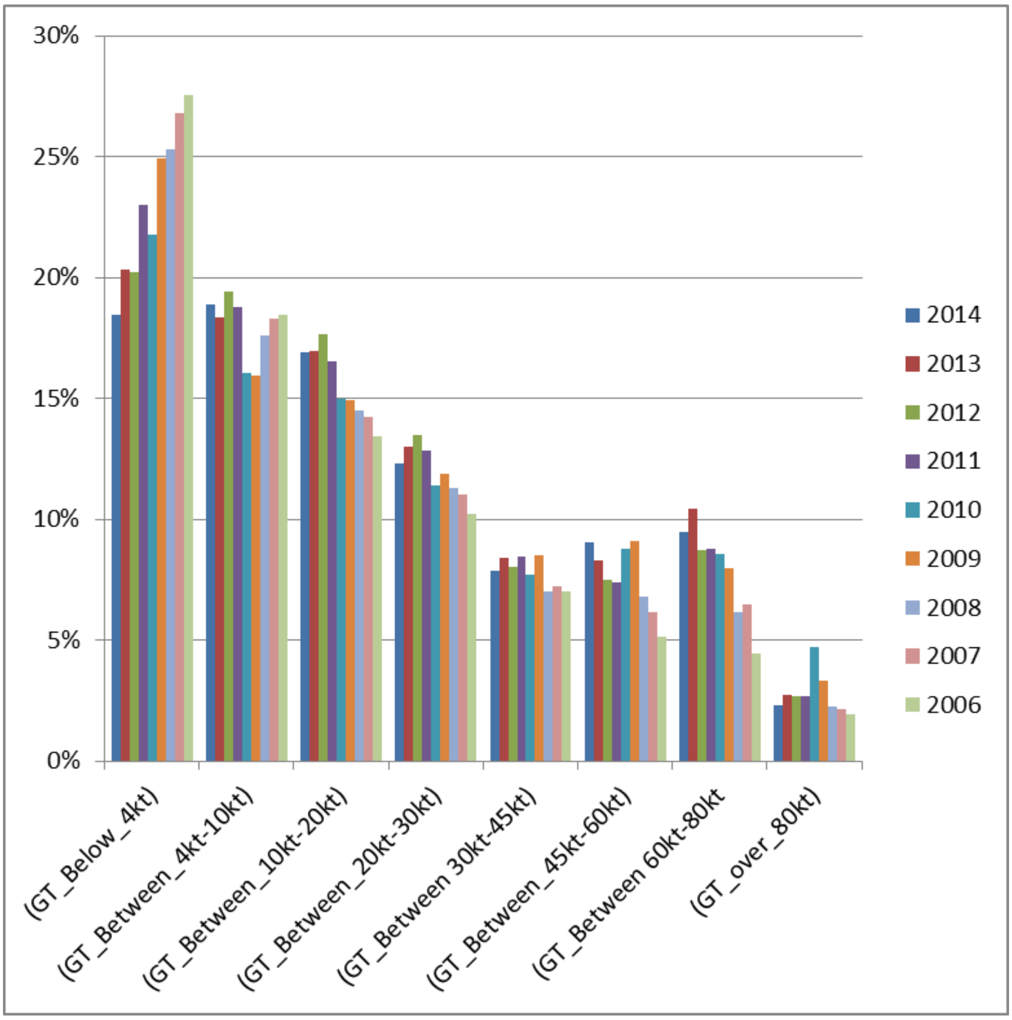

Figure 3 - Average share of a full year that ships in different size categories spends in the Baltic Sea (data from FMI, 2015).

The scenario forecast includes an assumption that all fuel used in new RoRo and RoPax ships is LNG from 2016 and forward. Further, for other ship types, it is expected that half of the fuel used in new built ships with a gross tonnage below 30,000 is LNG. No retrofit installations are assumed, since the return of investments on these is very uncertain.

The emission factors of CO_2, NO_X, SO_2, PM and CH_4 are different for an LNG engine compared to a diesel engine. Also the energy content is different in the two fuels.

Name	LNG
Purpose	To investigate changes in emissions to air and water from a strongly increased use of LNG in the Baltic and North Sea up to 2040.
Changes vs. BAU	New RoRo and RoPax ships use LNG from 2016 and forward. Further, for other ship types, it is expected that half of the fuel used in new built ships with a gross tonnage below 30,000 are LNG fuelled. No retrofit installations are assumed.

Main results	Reduction in emissions of PM, SO_2 and NO_X as old vessels are replaced by new ones. Increased CH_4 emissions.

4.6 Regulations for leisure boats

In EU, antifouling paints have to pass an environmental risk assessment (ERA) prior being put out on the market. However, in the Baltic Sea no harmonized risk assessment is in use. For example, Sweden has stricter regulation, allowing a release rate of copper of around 1 µg/cm^2/d while Finland, Denmark and Germany tolerate paints with a release rate of 6 µg/cm^2/d. What reduction in copper loads we will have in the coastal areas of the Baltic Sea if only 1 µg/cm^2/d is acceptable in the whole Baltic Sea and what concentrations of copper we will have in marinas and coastal areas due to leaching from AF paints depend on how active the regulatory bodies in i.e. Finland, Sweden, Denmark and Germany are in supporting of such legislation. There are currently ongoing discussions in the CHANGE project with the responsible agencies. One scenario could be that only 1 µg/cm^2/d of copper is allowed to be released from antifouling paints by year 2018.

In Sweden, several boat clubs especially in the Stockholm area have agreed to phase out the use of toxic AF paints. Instead they are using mechanical methods only. Hence, one “green/sustainable” scenario could be – no release of biocides from leisure boats to the Baltic Sea. Such scenario would gradually take place, i.e. only few percentages now and almost 100% by the year 2030/2040.

The emissions to air for 2030 and 2040 are calculated under the assumption that all leisure boat engines follow the latest regulations as described in the EU directive 2013/53/EU.

Table 14 - Regulations for leisure boats

Name	Regulations for leisure boats
Purpose	To investigate the changes in impact on the Baltic Sea from a number of regulations limiting emissions to water and air from leisure boats.
Changes vs. BAU	Stricter regulations for hull paint, stricter regulations for air emissions.
Main results	Lower emissions of toxic paint, lower emissions to air.

4.7 Port measures

Concerns about air and water quality in port cities as well as policies, for example on green-house gas emissions, have led to measures being imposed in several ports. These measures usually aim at reducing the use of engines for ships at berth and thereby reducing emissions of air pollutants and green-house gases as well as noise.

A measure used in several Baltic Sea ports is shore-side electricity where a ship uses power from land and thereby can turn off its auxiliary engines while at berth. A standard has recently been developed and it is possible that the usage will increase in the future. However, working against such a development is the low prices of fuel oil and the requirements for significant investments in electricity infrastructure in the ports and onboard the ships. Another possibility is to place LNG-fuelled generators on a barge and provide electricity to ships from these.

These measures will improve the air quality in the port and reduce the noise. Depending on the electricity source there may also be reductions in green-house gas emissions.

In this scenario it is assumed that RoRo, RoPax, Cruise ships all use shore-side electricity as well as 50% of the other ship types.

Table 15. Port measures.

Name	Port measures
Purpose	To investigate the changes in impact on air and water quality from measures in port, mainly shore-side electricity and other measures to replace the ship engines while at berth.
Changes vs. BAU	Auxiliary engines not used while at berth.
Main results	Lower fuel consumption, lower emissions to air, less noise compared to BAU.

5 Cumulative scenarios

In order to illustrate the shipping volumes in the Baltic Sea following more general developments cumulative scenarios were constructed. These follow the so-called Shared Socioeconomic Pathways described by O'Neill et al. (2014). These SSPs were developed mainly for the use in climate research to study mitigation of and adaption to climate change in different socioeconomic futures. These scenarios are also used by other BONUS projects (e.g. BalticApp) to construct scenarios and look at the state of the Baltic Sea in the future. The SSPs are global scenarios and they were adjusted to specific outcomes in the Baltic Sea region and for the shipping sector. These scenarios were chosen since they can be expected to be widely used and accepted in the climate community and also in other BONUS projects and thus it can be expected that they will be developed further and also that the SHEBA results can be used by other researchers, policy makers and stakeholders after the project. Further, they provide the comprehensive types of scenario required for the cumulative scenarios in SHEBA. Three of the SSPs are chosen here for further development. These were chosen since they are expected to give a strong variation in the output for shipping in the Baltic Sea when it comes to volumes and implementation of environmental technologies. Extensive descriptions of the narratives can be found in O'Neill (2014) and in IIASA (2016b).

5.1.1 SSP1 – Sustainability

SSP1 is named Sustainability and thus includes a sustainable development with high concern for the environment and good technology development with focus on renewables and efficiency. It is a global open economy with development of environmental technology and increase in trade. Stringent environmental policies are in place. There is a relatively low growth in global population with an increase up to 2050 to 8 461 million and then a decrease to 6 881 by 2100 (Samir & Lutz, 2014). There is a strong growth in global GDP up to 2100 – 2.2% globally, 3% to 2040 (Leimbach et al 2015). For the Baltic Sea region there is a moderate decline in population but with an increase for some countries (Sweden, Finland, Denmark). There is also a strong trend of urbanization in the region. The GDP growth in the region is strong. For shipping this means increased volumes, more stringent environmental regulations and use of clean fuels and abatement technologies. Table 16 summarises the policy instruments and other developments we are assumed are in place within SSP1.

5.1.2 SSP2 – Middle of the Road

Middle of the Road is a scenario where recent trends continue. This means a reduction in resource and energy use and slowly decreasing use of fossil fuel. The global economy is stable with functioning markets. The global development of the population and the GDP follows the similar trends as for SSP1, with 2% increases for GDP to 2100 and 2.7% to 2040 (Leimbach et al 2015). Population reaches 9,166 million in 2050 and drops to 9,000 million in 2100 (Samir & Lutz, 2014). For the Baltic Sea area there modest decline in population up to 2100 and there is a medium growth in the economy, somewhat lower than for SSP1. For shipping, this scenario is here interpreted as the same as the BAU scenario described above.

5.1.3 SSP3 – Fragmentation

Fragmentation is a scenario with a development in some regions and poverty in others. There is continued fossil fuel dependency and failure to meet environmental goals. Further there are barriers to trade and low investments in technology. There is a strong global population growth and slow economic growth in developing countries. For the Baltic Sea region there is population decrease, in contrast to the global trend which grows to 9 951 million in 2050 and 12 627 million in 2100 (Samir &

Lutz, 2014). The economic development is slow with a low increase, 1% to 2100 and 1.9% to 2040 (Leimbach et al 2015). Consequently, the SSP3 scenario includes slower development of marine transport of freight and passengers than the BAU scenario. However, there might be an increase in marine military activities. There is no development towards new fuels or abatement measures and environmental policy work is weak.

5.1.4 Summary of shipping developments in the SSPs

In order to model the impact of shipping on the Baltic Sea in the scenarios detailed assumptions need to be made as described in Table 16. In this table the assumptions made for each SSP are described as well as links to the single scenarios.

For air pollution it is assumed that for SSP1 a NECA will be introduced in 2021 which is not included in the BAU scenario or in SSP3. The discussion of a NECA is already advanced and it seems likely that it is in place by 2021; however, since it is not decided it is not included in SSP2.

For fuel efficiency the BAU scenario is assumed to follow the decided EEDI regulation. For SSP1 improved fuel efficiency with 1.5% per year beyond BAU is assumed. The objectives of the EU White Paper on Transport (about 40% reduction for European shipping by 2050 relative to 2005) means an annual reduction beyond EEDI of about 2.5%. We have here assumed that shipping in SSP1 meets this goal and that 1.5% annually is due to energy efficiency measures and that 1.0% comes from increased use of renewable fuels. For SSP3 it is assumed that the EEDI regulations are not met. These regulations give a fuel efficiency increase of about 1.2% annually compared with if they were not introduced (Bazari 2011). For SSP3 we assume that only half of this expected potential is realised, i.e. a fuel efficiency increase 0.6% worse than BAU.

For emissions to water SSP1 is essentially the same as the single scenario Zero emissions into water. For SSP3 it is assumed that a large fraction of the ships use open loop scrubbers to meet the SECA fuel sulphur requirements. Following the results in Johansson et al. (2013) it is assumed that 21% of the fuel used in the Baltic Sea is used in ships with open loop scrubbers.

The shipping volumes calculated for SSP2 are described in Section 3. To obtain the development of shipping volumes in SSP1 and SSP3 the difference in expected growth in GDP for the region was used as calculated for the SSPs (IIASA, 2015). Up to 2040 the annual average growth in GDP for the Baltic Sea region for SSP1, SSP2 and SSP3 are 1.8%, 1.6% and 1.1%, respectively. The use of the differences in GDP as an indicator of changes in shipping volume is motivated by the close connection historically between these parameters (see Boteler et al. 2015).

In SSP1 the average ship speed is assumed to reach design speed, up from the present situation with slow steaming. The reason for this assumption is the expected increase in trade in SSP1 together with more strict environmental regulation leading to scrapping of old tonnage. This will mean that ships will need to operate faster than today in order to manage a specific trade increase. For SSP3 we assume that the present situation continues.

The only waste that can be thrown overboard in the Baltic Sea is food waste. For SSP1 we assume that this will be prohibited by 2020.

In SSP1 there will be an introduction of renewable fuels such as electricity, hydrogen and biofuels. It is assumed that this introduction will be large enough to cover an annual reduction of fossil CO_2

emissions by 1%. This means that for SSP1 introduction of renewable fuels in combination with fuel efficiency measures will ensure that shipping meets the White Book objective.

In port measures and leisure boat measures in SSP1 are assumed to follow the single scenarios Port measures and Stricter regulations for leisure boats, respectively, while there is no difference between SSP3 and BAU.

Table 16 – The development of shipping assumed in this report

Scenario	SSP1	SSP2 = BAU	SSP3	Interlinked single scenarios
Emissions to air	NECA from 2021	No Tier III ships	No Tier III ships,	• 2021 NECA • LNG
Fuel efficiency	1.5% beyond EEDI regulation.	Development according to decided EEDI	Slower development by 0.6% annually than according to decided EEDI	• Slow steaming
Emissions to water	Ballast water directive effective from 2018. Only biocide free paint. No emissions of scrubber water, grey water, black water or bilge water.	Current trends with scrubbers	Open loop scrubbers used (21% of fuel). Bilge water only partly delivered in ports.	• Zero-emission into water
Shipping volume	0.2% per year over BAU	BAU	0.5% per year below BAU	• Modal shift from land to sea
Speed	Design speed	Existing slow steaming	Same as BAU	• Slow steaming scenario
Waste	Minimised waste into the sea (no food)	As now	As now	• Zero emissions into water
Fuel	1.0% reduction in CO_2 emissions through use of	Current trends	Only fossil fuel oil	• LNG

	renewable fuels.			
In port	RoRo, RoPax, Cruise ships all use shoreside electricity. 50% of other ship types.	Current trend for shoreside electricity	No use of shoreside-electricity	• Port measures
Leisure boats	Increase in volume. Only most recent air emissions standard. No release of biocides from paint.	Increase in volume	Increase in volume	• Stricter regulations for leisure boat emissions

6 Bibliography

©Statista. (2016). *Number of cruise passengers worldwide by source market from 2005 to 2014 (in millions)*. Retrieved from http://www.statista.com/statistics/272421/source-market-for-cruise-passengers-worldwide/

Alcamo, J. (2001). *Scenarios as Tools for International Environmental Assessment.* Copenhagen: Environmental issue report No 24. Retrieved May 5, 2016, from www.eea.europa.eu/publications/environmental_issue_report_2001_24

Anderson, M., Salo, K., & Fridell, E. (2015). Particle- and Gaseous Emissions from an LNG Powered Ship DOI: 10.1021/acs.est.5b02678. *Environmental Science & Technology, 49 (20)*, 12568-12575.

Bazari, Z., & Longva, T. (2011). *Assessment of IMO mandated energy efficiency measures for international shipping.* London/Oslo: MEPC 63/inf.2.

Boteler, B., Tröltzsch, J., Abhold, K., Lago, M., Nguyen, T., Roth, R., . . . Raudsepp, U. (2015). *Deliverable 1.1 - Drivers for the shipping sector* . SHEBA - Sustainable Shipping and Environment of the Baltic Sea region, BONUS Research Project.

Clarksons Research. (2014). *Shipping Review and Outlook.* London: Clarkson Research Services Limited .

Containerships. (2014, September 25). *Finnish Cargo Company to be the first LNG Shortsea Container Operator*. Retrieved from containershipsgroup.com: http://www.containershipsgroup.com/images/LNG/CSPR092014.pdf

DNV. (2012). *Shipping 2020.* Oslo: Det Norske Veritas.

EC. (2011). *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system.* Brussels: European Commission.

EC. (2012). *Blue Growth - Scenarios and drivers for Sustainable Growth from the Oceans, Seas and Coasts - Third Interim Report.* Rotterdam/Brussels: European Commission, Ecorys, Deltares, Oceanic Development.

EEA. (2011). *Knowledge base for Forward - Looking Information and Services. Catalogue of scenario studies. Technical report No 1/2011.* Copenhagen: EEA.

EEA. (2015). *SOER 2015 - The European environment — state and outlook 2015. A comprehensive assessment of the European environment's state, trends and prospects, in a global context. .* Retrieved May 6, 2016, from eea.europa.eu: http://www.eea.europa.eu/soer

Enei, R. (2010, January - Draft). *EU Transport GHG: Routes to 2050? - Annex to Task III Paper on the EU transport demand: Freight trends and forecasts* . Retrieved from eutransportghg2050.eu: http://www.eutransportghg2050.eu/cms/assets/EU-Transport-GHG-Routes-to-2050-Annex-to-Task-III-Report-on-drivers-on-transport-demand.pdf

ESL Shipping. (2015, November 26). *ESL Shipping has signed a long-term agreement for raw material sea transport with SSAB and orders the world's first large LNG-fueled bulk carriers*. Retrieved from eslshipping.com: http://www.eslshipping.com/en/news/news/-/news/974/ESL+Shipping+has+signed+a+long-term+agreement+for+raw+material+sea+transport++with+SSAB+and+orders+the+world%E2%80%99s+first+large+LNG-fueled+bulk+carriers+

ESPO. (2015). *ESPO Annual Report, 2014-2015 - Data of ports and web pages.* Brussels: European Sea Ports Organisation.

EU. (2014). Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure. *Official Journal of the European Union L307, Vol 57*. Retrieved May 6, 2016, from http://eur-lex.europa.eu: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0094

European Cruise Council. (2012). *Contribution of Cruise Tourism to the Economies of Europe 2012.* Brussels: European Cruise Council. Retrieved from http://www.nee.gr/downloads/175ec%20cruise%20report%202012.pdf

FMI. (2015). *Yearly statistics from AIS data 2006-2014, unpublished statistics.* Helsinki: Finnish Meteorological Institute.

HELCOM. (2015). *Baltic Sea Sewage Port Reception Facilities*. Retrieved from http://www.helcom.fi/Lists/Publications/Baltic%20Sea%20Sewage%20Port%20Reception%20Facilities.%20HELCOM%20overview%202014.pdf

Holmberg, J., & Robért, K.-H. (2000). Backcasting from non-overlapping sustainability principles – a framework for strategic planning. *International Journal of Sustainable Development and World Ecology 7*, 291-308.

ICIS. (2000). *Cloudy crystal balls - An assessment of recent European and global scenario studies and models. Experts' corner report: Prospects and Scenarios No 4. Enviromental issues series No 17.* European Environment Agency (EEA).

IHS. (2015). *World Fleet Statistics 2015.* Bracknell: IHS.

IIASA. (2015). *SSP Database (Shared Socioeconomic Pathways) - Version 1.0*. Retrieved from https://secure.iiasa.ac.at/web-apps/ene/SspDb

IIASA. (2016a). *SSP Database (Shared Socioeconomic Pathways)*. Retrieved May 3, 2016, from https://tntcat.iiasa.ac.at: https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about

IIASA. (2016b). *Supplementary note for the SSP data sets*. Retrieved 3 2016, May, from https://secure.iiasa.ac.at/web-apps/ene/SspDb/static/download/ssp_suplementary%20text.pdf

IMO. (2013a). *Final report of the Correspondence Group on Assessment of Technological Developments to Implement the Tier III NOx Emission Standards under MARPOL Annex VI.* London: International Maritime Administration.

IMO. (2013b). *Supplementary Information to the final report of the Correspondence Group on Assessment of Technological Developments to Implement the Tier III NOx Emission Standards under MARPOL Annex VI.* London: International Maritime Administration.

ISL Logistics. (2010). *Reducing the sulphur content of shipping fuels further to 0.1 % in the North Sea and Baltic Sea in 2015: Consequences for shipping in this shipping area.* Bremen: Verband Deutscher Reeder.

ISL Logistics. (2014). *Short Sea Shipping in the Baltic Sea Region - Results from the TransBaltic Extension Project.* Hamburg: Port of Hamburg Marketing.

ITF. (2014). Transport Outlook: Scenarios to 2050. *Transport for a Changing World.* Leipzig: International Transport Forum.

Jalkanen, J. P., Johansson, L., Kukkonen, J., Brink, A., Kalli, J., & Stipa, T. (2012). Extension of an assessment model of ship traffic exhaust emissions for particulate matter and carbon monoxide DOI:10.5194/acp-12-2641-2012. *Atmospheric Chemistry and Physics 12*, 2641–2659,.

Johansson, L., Jalkanen, J.-P., Kalli, J., & Kukkonen, J. (2013). The evolution of shipping emissions and the costs of regulation changes in the northern EU area; DOI:10.5194/acp-13-11375-2013. *Atmospheric Chemistry and Physic 12* , 11375–11389.

Jäger, J., Rothman, D., Anastasi, C., Kartha, S., & van Notten, P. (2007). Training Module 6 - Scenario development and analysis. In *GEO Resource Book - A training manual on integrated environmental assessment and reporting.* Nairobi/Winnipeg: UNEP and IISD (Ed.).

Kalli, J., Jalkanen, J. P., Johansson, L., & Repka, S. (2013). Atmospheric emissions of European SECA shipping: long-term projections. *Journal of Maritime Affairs*, 129-145.

Kok, K., ., Gramberger, M., Simon, K.-H., Jäger, J., & Omann, I. (2011). *Report on the new methodology for scenario analysis, including guidelines for its implementation, and based on an analysis of past scenario exercises. Report prepared in the CLIMSAVE-project*. Retrieved from climsave.eu: http://www.climsave.eu/climsave/doc/Report_on_the_Scenario_Methodology.pdf

Kosow, H., & Gaßner, R. (2008). *Methods of Future and Scenario Analysis - Overview, and Selection Criteria.* Bonn: Deutsches Institut für Entwicklungspolitik gGmbH.

Langmead, O., McQuatters-Gollop, A., & Mee, L. (2007). *European Lifestyles and Marine Eco-systems: Exploring challenges for managing Europe's seas. 43pp.* Plymouth, UK.: University of Plymouth Marine Institute.

Laurila, J. (2015, February 4). *Visits Per City and Density.* Retrieved from helcom.fi: http://helcom.fi/PublishingImages/action-areas/shipping/VisitsPerCityAndDensity_PRFreport.png

Leimbach, M., Kriegler, E., Roming, N., & Schwanitz, J. (2015). Future growth patterns of world regions – a GDP scenario approach. *Global Environmental Change; DOI:10.1016/j.gloenvcha*, 1-11.

Loyds Register Marine. (2014). *Global Marine Trends 2030.* Retrieved from http://www.lr.org/en/marine/projects/global-marine-trends-2030.aspx

MARPOL 73/78. (2005). *Annex IV of MARPOL 73/78 - Regulations for the Prevention of Pollution by Sewagefrom Ships.* Retrieved May 5, 2016, from mpa.gov.sg/: http://www.mpa.gov.sg/web/wcm/connect/www/690430f1-654d-491c-9c3e-4194a36eae73/mc03-18a.pdf?MOD=AJPERES

Matczak, M. (2016). *Polish seaports in year 2015.* Gdynia: Actia Forum, Port Monitor.

Myszka, P. (2014). Baltic container affairs 2013-2014. Living through the night. *Baltic Transport Journal 3*.

Nielsen, J. B., & Stenersen, D. (2010). *Emission factors for CH4, NOx, particulates and black carbon for domestic shipping in Norway, revision 1.* Trondheim: Klima og forurensningsdirektoratet.

Notten, P. v. (2006). *Chapter 4 - Scenario development: a typology of approaches.* Retrieved May 6, 2016, from oecd.org: http://www.oecd.org/site/schoolingfortomorrowknowledgebase/futuresthinking/scenarios/37246431.pdf

Notten, P. v., ., ., Rotmans, J., Asselt van, M., & Rothman, D. (2001). An updated scenario typology. *Futures 35(5)*, 423-443.

O'Neill, B. C., Kriegler, E., Riahi, K., Ebi, K. L., Hallegatte, S., Carter, T. R., . . . van Vuuren, D. P. (2014). A new scenario framework for climate change research: the concept of shared socioeconomic pathways. *Climatic Change, Volume 122, Issue 3, DOI: 10.1007/s10584-013-0905-2*, 387-400.

Odgaard, T., Frank, C., Henrigues, M., & Bøge, M. (2013). *The impact on short sea shipping and the risk of modal shift from the establishment of a NOX emission control area.* Holte: North Sea Consultation Group.

OECD. (2008). *2008. OECD Environmental Outlook to 2030. ISBN: 978-92-64-04048-9.* Paris: OECD Publishing.

OECD. (2012). *OECD environmental outlook to 2050: the Consequences of Inaction. DOI:10.1787/9789264122246-en.* Paris: OECD Publishing.

Pinnegar, J., Viner, D., Hadley, D., Dye, S., Harris, M., Berkout, F., & Simpson, M. (2006). *Alternative Future Scenarios for Marine Ecosystems, Technical Report.* Retrieved May 6, 2016, from meece.eu: http://www.meece.eu/meetings/bologna/documents/AFMEC%20technical%20report.pdf

Ricardo-AEA. (2013). *Technical annex: support for the impact assessment of a proposal to address maritime transport greenhouse gas emissions (EU-Comission Report).* Didcot: Ricardo-AEA Ltd, European Commission.

Samir, K., & Lutz, W. (2014). The human core of the shared socioeconomic pathways: Popula-tion scenarios by age, sex and level of education for all countries to 2100. *Global Environmental Change DOI:10.1016/j.gloenvcha.2014.06.004*.

Schuler, M. (2016, May 12). *Ship Photos of the Day – World's First LNG-Powered Icebreaker 'Polaris'*. Retrieved from gcaptain.com: http://gcaptain.com/photos-worlds-first-lng-powered-icebreaker-polaris/

Tallink Silja Group. (2015). *Name contest for the new LNG shuttle vessel*. Retrieved from tallinksilja.com: http://www.tallinksilja.com/en/web/int/newship

Tavasszy, L. A., & van Meijeren, J. (2011). *Discussion Paper – 17th ACEA SAG Meeting – October 2011 - Modal Shift Target for Freight Transport Above 300km:An Assessment.* Retrieved May 6, 2016, from acea.be: https://www.acea.be/uploads/publications/SAG_17.pdf

UNCTAD. (2012-2014). *Review of Maritime Transport.* New York/Geneva: United Nations Publications.

UNEP. (2007). *Global Environment Outlook-4: GEO 4 Environment for Development. ISBN 978-92-807-2836-1.* Nirobi: United Nations Environment Programme (UNEP).

WEC. (2011). Global Transport Scenarios 2050. In *ISBN: 978-0-946121-14-4* (pp. 4-5). London: World Energy Counsil.

Wilewska-Bien, M., Granhag, L., & Andersson, K. (2016). Wilewska-Bien, M., Granhag, L. och Andersson, K. The nutrient load from food waste generated onboard ships in the Baltic Sea. DOI:10.1016/j.marpolbul.2016.03.002. *Marine Pollution Bulletin Volume 105, Issue 1*, 359-366.

Visser, D. (2014). Report on Worldwide reefer trade. *Baltic Transport Journal*.

WWF. (2010). *2010 Future Trends in the Baltic. WWF Baltic Ecoregion Programme 2010.* Retrieved May 5, 2016, from http://awsassets.panda.org/downloads/wwf_future_trends_in_the_baltic_sea_2010_1.pdf