Carbon emissions study in the European Straits of the PASSAGE project

Final Report

Prepared for Département du Pas-de-Calais and the partners of the PASSAGE Project

April 2018

Document information

CLIENT	Département du Pas-de-Calais - PASSAGE Project
REPORT TITLE	Final report
PROJECT NAME	Carbon emissions study in the European Straits of the PASSAGE project
DATE	April 2018
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DISCLAIMER	The project team does not accept any liability for any direct or indirect damage resulting from the use of this report or its content. This report contains the results of research by the authors and is not to be perceived as the opinion of the partners of the PASSAGE Project.
ACKNOWLEDGMENTS	We would like to thank all the partners of the PASSAGE Project that contributed to the carbon emissions study.

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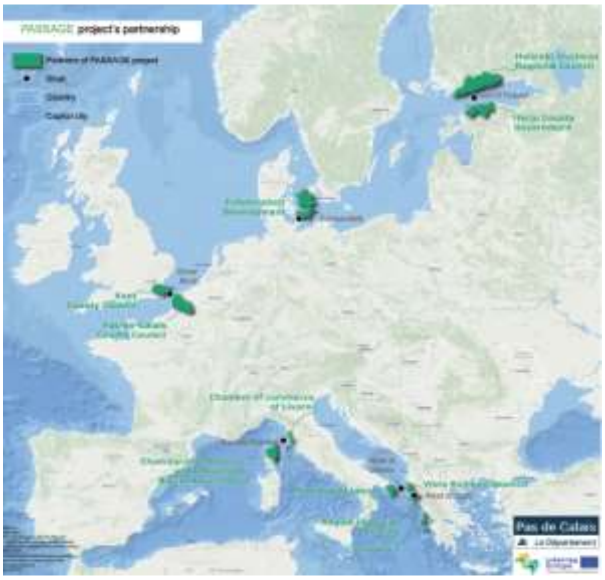
1. Context of this study

a) PASSAGE Project



The PASSAGE (*Public AuthoritieS Supporting low-cArbon Growth in European maritime border regions*) project[1] involves 6 straits, with 11 partners from 8 countries.

It emerged from the European Strait Initiative (ESI)[2] and is co-financed by the ERDF in the framework of the Interreg Europe programme. The European Straits Initiative was launched in 2009 by Pas-de-Calais County Council and Kent County Council and now includes 24 public authorities in Europe. Experiencing the features of a strait territory and the related human, social, economic and environmental challenges, their aim is to bring together strait territories and to structure projects along their common issues.

Even if straits have apparent basic similarities (a stretch of water that is surrounded by two coastal areas which are linked to their proper hinterlands), each side of a strait might have different carbon intensive economic activities and are often subject to different governance and laws as they are from different countries.

As a result of these area features, cross-border cooperation is required. Following the "*Network Of STRAits*" (NOSTRA) project, launched in 2012, which aimed to reinforce the governance tools supporting sustainable development, the 2016-2020 PASSAGE project is the second strait-related project to be supported by the INTERREG Europe programme (formerly Interreg IV C), and is dedicated to the development of low-carbon solutions in the straits areas.

At the request of the Pas-de-Calais County Council, a carbon study was launched in January 2017 in order to support the preparation of action plans at strait level by the partners of the PASSAGE Project.

b) Straits and climate change

Straits have unique geographies, and are characterised by diversified and specific economic activities, including transportation, industrial activities, tourism, services and manufacturing. Straits are important centres of communication, commerce and culture.

[1] www.interregeurope.eu/passage
[2] www.europeanstraits.eu

Straits include cities with an important population living on coastlines, and thus particularly vulnerable to global environmental change, such as rising sea levels and coastal storms. Additionally, all these economic activities may be a significant, and growing, sources of energy consumption and account for a significant percentage of greenhouse gas (GHG) emissions. This may include not only GHG emissions from "land based" activities (ports, industries, cities, tourism), but also "sea based" activities, such as domestic or international maritime transportation. Therefore, straits may play an important role in tackling climate change and responding to climate impacts, bringing an integrated management approach, considering marine areas and hinterlands, on both sides of the strait.

As for cities, strait's ability to take effective action on mitigating climate change and monitoring progress, begins with developing a GHG inventory; a "carbon study". Such an inventory will first enable straits to understand the main emissions contribution of different activities taking place at strait level. It may then allow straits to determine where to best direct mitigation efforts, where to best consolidate partnerships with key stakeholders, and finally create a strategy to reduce GHG emissions.

Nevertheless, it is worth noting that state, regional, city and company level inventories are mainly carried out because of legally binding obligations. Voluntary initiatives to account for and disclose GHG emissions are quite new practices, such as *The Covenant of Mayors for Climate and Energy* or the *World Port Climate Initiative* (WPCI). Very few studies have been carried out at strait level, and it is worth mentioning that the governance of these areas is often complex, because it involves multiple levels and responsibilities, as well as administrative and cultural divisions that may hinder the implementation of common action at a strait level.

2. Objectives

The aim of this "carbon study" is to provide a first review of knowledge, experience and requirements in terms of GHG emissions at a strait level, to enable partners of the PASSAGE project, as well as relevant stakeholders, to define the strategic direction for the better integration of "low carbon measures" in these straits.

In addition, to ensure credible reporting and good consistency in GHG accounting, this study proposes a framework on how emissions sources are defined and categorised, and a specific methodology for calculating and reporting GHG emissions and scientific studies (that are built on existing methodologies), related to the definition of a strait. A detailed methodology is provided in the Annexes.

In this study a total of 6 European straits have been involved: Dover / Pas de Calais Strait, Strait of Otranto, Strait of Corfu, Gulf of Finland's Strait, Fehmarn Belt, and Corsica Channel.

3. Overview of the general approach

This carbon study has been designed by the project team, in agreement with Pas de Calais County Council and all participating PASSAGE partners. The study was carried out with the following steps.

a) Step 1: Understanding of the local context

During the first step of this study, the project team carried out a review of all the documents and information provided by PASSAGE partners. This desk review helped the project team to better understand the various local situations and to start identifying the main characteristics of each strait. For instance, Pas-de-Calais County Council provided a report presenting the GHG inventory carried out by the "*Société d'exploitation des Ports du Détroit*", which is the unique operator for the ports of Calais and Boulogne-sur-Mer (see, for example, the charts below illustrating the GHG emissions in 2011 and 2014 for the port of Calais, in tons of CO_2 equivalent).

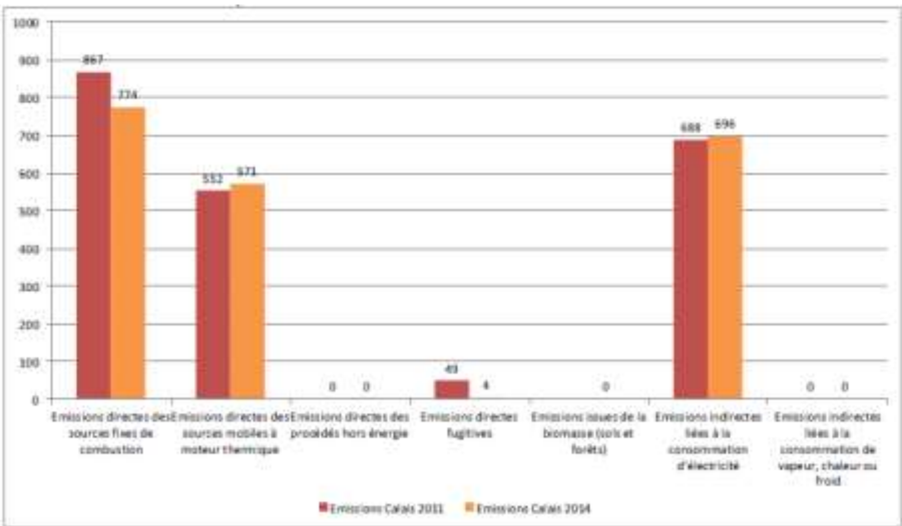


Figure 1 – Comparison of GHG emissions per sector in the Port of Calais, in 2011 and 2014 (Source: Bilan des émissions de gaz à effet de serre, Société d'exploitation des Ports du Détroit, 2016)

Other relevant reports reviewed by the project team are those prepared under the "NOSTRA" project, which were very useful in strengthening the general level of knowledge on each strait. Following this desk review, the project team organised telephone interviews with the PASSAGE partners, using a preliminary questionnaire intended to identify the primary stakeholders to involve at strait level, and to gather initial information regarding the analysis of the specificities of each strait. Additionally, the first theoretical concepts were presented to the local partners so that they could also better understand the need for additional information and prepare to send inquiries to other relevant agencies for data collection. The table below presents the members of the PASSAGE project that have been interviewed by the project team.

Table 1 - List of the PASSAGE project stakeholders interviewed

	Strait	Organisation
Liz FAGG Doug KEMPSTER	Dover / Pas de Calais strait	Port of Dover

Heidi SKINNER	Dover / Pas de Calais strait	Freight Transport Association - FTA
Antoine SURGET Colette MARIE	Dover / Pas de Calais strait	Pas-de-Calais County Council
Marc HAERINCK	Dover / Pas de Calais strait	Grand Port Maritime de Dunkerque
Mathieu SAMARCQ Karine SELLIER	Dover / Pas de Calais strait	Eurotunnel
Elina LOMPERI Kaarina RAUTIO	Gulf of Finland	Helsinki-Uusimaa Regional Council
Jesper BILLE Horst WEPPLER	Femharn Belt	Femern Belt Development Kreis Ostholstein
Anila HITAJ Mirela KOCI Nikolaos PETROPOULOS Ionnis PAPAGIANNOPOULOS	Otranto/Corfu	Regional Council of Vlora AULEDA Innopolis Innopolis

The interviews with each PASSAGE project partner increased understanding of the context and specificities of each strait. These exchanges mainly enabled additional local context information to be identified, and it was also an opportunity to briefly present the first methodological approach to calculate the GHG emissions at a strait level. The port authorities were also invited to participate to these discussions, when possible. This information served as the basis for the design of the methodological framework, and for the preparation of the data collection tool.

b) Step 2: Literature review and expert interviews

The second step of the study was mostly done in parallel with the first step: the project team carried out a literature review of relevant studies and scientific publications related to the definition of a strait, the GHG emissions methodologies and actions for specific sectors and activities taking place at strait level. This review has been consolidated through several interviews with researchers and representatives of key organisations working on these fields. The table below presents the organisations and representatives that have been interviewed.

Table 2 - List of the people interviewed by the project team

Name	Organisation	Expertise
Frédérique LOEW-TURBOUT	Université de Caen	Atlas Transmanche
Nora MAREI	CNRS (PRODIG)	Expertise on Gibraltar strait and regional economics
François LEVARLET	T33 SRL	Study cross border needs (EU, 2016)
Patrick RIGOT-MULLER	Mines PARISTECH	Low-carbon shipping

c) Step 3: Defining a methodological framework

The project team defined a common methodological framework for all the straits, based on the literature review and the interviews carried out in the previous steps. The framework includes a definition of the strait's boundary, a description of the activities accounted for in the inventory, the calculation methodologies and a categorization of the emissions by sectors and sub-sectors. The methodological framework follows the main accounting and reporting principles from the *GPC Protocol Standard*. A methodological note was written to ensure transparency and that stakeholders had a good comprehension of the calculations and methodologies used . The detailed methodological framework is described further below in this report.

d) Step 4: Data collection and complementary literature review

The data collection was led by the PASSAGE partners in each strait. To facilitate the data collection, the project team provided a draft letter to be sent to each type of stakeholder (port authority, coastguards), describing the data needed and the deadline, along with a data collection tool. However, the tool was just indicative, the cells were not expected to be filled in one by one, but the tool enabled the stakeholders to identify the data needed under the project. The stakeholders were encouraged to send any database containing the data listed, in order to facilitate the process for the data holders.

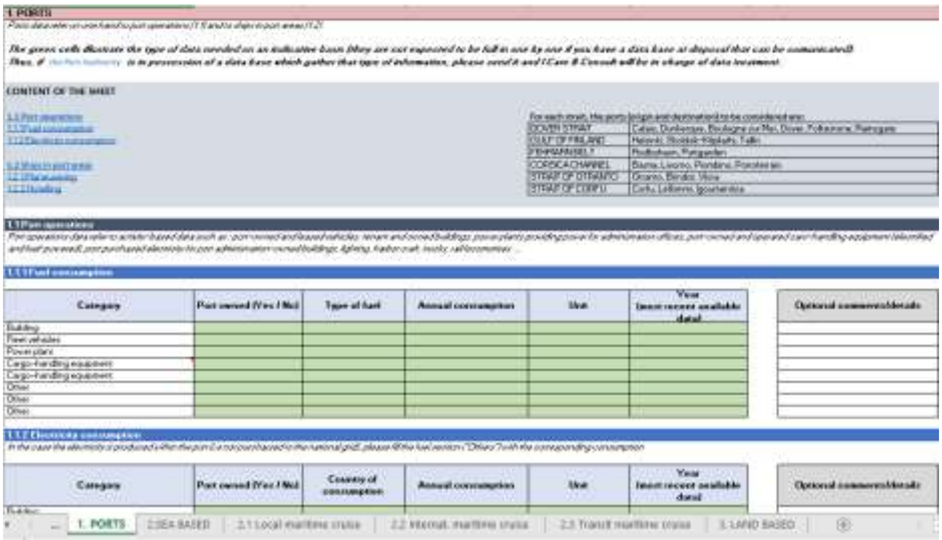


Figure 2 - Extract of the data collection tool sent to PASSAGE partners (Source: I Care & Consult)

To cope with the difficulties faced by partners to collect data and to inform the data collection tool, a complementary literature review was carried out by the project team. Based on the literature desk review, together with the information provided by PASSAGE partners, the project team was able to fill in some of the remaining data gaps in the data collection tool. Unfortunately, due to some data unavailability ("defence secret" classified data, for example), it was not possible to totally complete the GHG inventory for all the straits, and despite several hypothesis proposed by the project team, the required accuracy of the results could not be reached under this project. The main limitations of the study are presented further below in this report.

e) Step 5: Analysis at strait level and completion of individual monograph

During this step, the full information collected from both data collection tool and complementary literature review was documented in the form of an individual monograph dedicated to each PASSAGE straits. In each strait's monograph, the current GHG emissions due to each sector and sub-sector considered in the area were presented.

f) Step 6: Transversal analysis and completion of final report and recommendations

A transversal analysis was conducted to draw the main lessons and key findings from the carbon study in each strait. Recommendations and good practices were provided to the PASSAGE partners while they were preparing their action plan. Recommendations for further work on this subject and for further actions to reduce the emissions are also presented in this final report.

4. Focus on the key elements of the approach

This section provides a detailed explanation on the methodological approaches being defined and used in the development of the GHG inventories of the Straits during this study.

a) Defining a strait: perimeter, activities

Geographers describe straits as “narrow stretches of water between two land masses joining two marine expanses” as explained by Nathalie Fau, a well-known expert on straits[3]. They can connect two oceans, or an ocean to a sea (the Strait of Gibraltar), two continents (the strait of Gibraltar, the Bosphorus), an island and a continent (Dover / Pas de Calais Strait), or two islands (Bonifacio Strait). In a paper published in 2003, the geographer Jean-Pierre Renard defines the Strait of Dover as a “terraqué” or terraqueous space, trans-border area (from the Latin words terra and aqua). Indeed, as recalled by Fau in HyperGeo, this complex space forms a maritime and terrestrial interface, and to study a strait it is necessary to consider longitudinal flows, cross-flows and the maritime space per se, since it at once constitutes the dividing line and the zone of contact in either direction.

The strait also induces several discontinuities, notably legal ones, administrative ones with different systems and competences for the local authorities across the border and, sometimes, economic ones when the two regions facing each other do not have the same level of economic activity. Cooperation is notable for maritime security and risk minimisation. The straits and the cross-border regions show and benefit from regional economic integration as documented by several OECD studies in the Oresund or Helsinki-Tallinn regions (OECD, 2013[4]).

From a geographical point of view, a strait is a narrow stretch of water between two land-masses joining two marine expanses. Unlike cities, for which we can generally base studies on administratives boundaries, a strait is a complex area comprising a maritime space and a terrestrial interface, with a spatial dimension that can be subject to discussion and interpretation depending on the purpose of this definition. Moreover, there is no administrative boundary for a strait (although there are different administrative boundaries within a strait), and thus it is necessary to take into consideration functions and activities of a strait to be able to propose and justify a specific boundary.

From a functional point of view, a strait is the crossing-point where the crossing is the shortest possible. It is thus a core node of transport and communication, with a "bridge effect" stepping up maritime connections (ferries, container transport, ro-ro ferries etc.) or fixed links (bridges and tunnels). A strait can be seen as a transportation hub organized around the main ports on both side of the strait, involving longitudinal (between the main ports of the strait) and transit flows of goods and people

[3] http://www.hypergeo.eu/spip.php?article576

[4] Nauwelaers, C., K. Maguire and G. Ajmone Marsan (2013), “The Case of Helsinki-Tallinn (Finland-Estonia) – Regions and Innovation: Collaborating Across Borders”, OECD Regional Development Working Papers, 2013/19, OECD Publishing. http://dx.doi.org/10.1787/5k3xv0lrt1r6-en

through the maritime corridor. Economic activities, as well as in-land transportation are then induced by theses flows through the maritime corridor.

A strait is thus a maritime corridor through which there are longitudinal flows and transit flows. Chorems or ("chorèmes" in French) are proposed by Marei & Baron (2014[5]) to represent the spatial functions as well as to propose four possible different engines of the territorial development along a terraqueous frontier. This type of graphic representation identifies the main representative stakeholders (institutional, economic) of a strait activity ,as well as their operational competences. An example is the port authority, with operational competences directly linked with the strait activity (notably the maritime freight between the two sides of the strait).

Finally, based on the literature review, and interviews carried with key experts and PASSAGE partners, a first schematic representation named "*chorem*" has been proposed for each strait, which represent the spatial functions and boundaries, as well as the main flows and induced economic activities to be potentially included in a GHG inventory. At a later stage, the individual straits were requested to validate the specific activities that can be found in their strait, and provide associated data for identified sectors and activities.

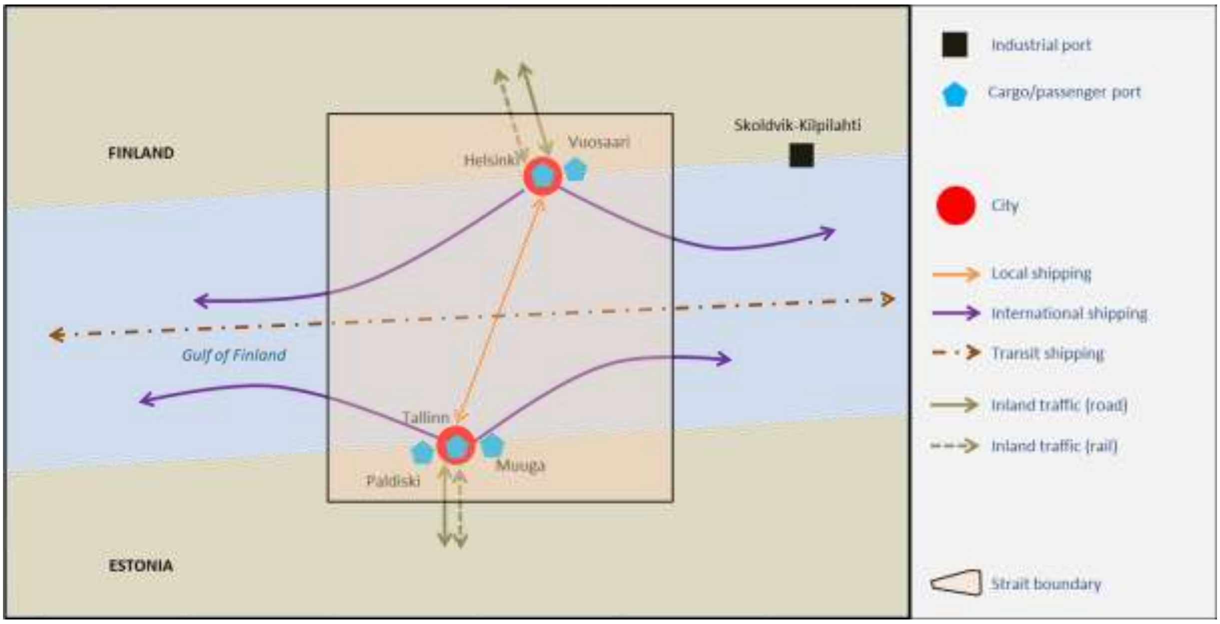


Figure 3 – Chorem representation for the Gulf of Finland (Source: I Care & Consult)

To clarify the geographic boundaries of the strait (including the hinterland distance and the maritime distance of the strait), the NUTS 3 regions corresponding to the ports taken into consideration in each strait, were considered for most of the straits (with some exceptions, described in the carbon study for each strait). The NUTS (Nomenclature of Territorial Units for Statistics) is a hierarchical system for dividing up the economic territory of the EU, for the purpose of socio-economic analysis of the regions. The NUTS 3 correspond to small regions, which allow a precise analysis.

[5] Penser le détroit de Gibraltar pour figurer l'entre-deux, Nora Mareï et Nacima Baron Yellès. https://belgeo.revues.org/10632

b) Selecting the main activities related to GHG emissions taking place in the Straits

From an economical point of view, most of the straits in Europe are characterised by **diverse economic activities**, ranging from fishery, tourism, services and manufacture to industry. According to NOSTRA[6], all these economic activities contribute directly to the local GDP and many provide essential employment opportunities for the local population as well as contributing to welfare. Additionally, as explained in the previous section, a strait can be seen as a **transportation hub** organized around the main ports on both side of the strait, involving longitudinal (between the main ports of the strait) and transit flows of goods and people through the maritime corridor. Economic activities, as well as in-land transportation are then induced by theses flows through the maritime corridor.

During this study, a focus was made on the activities that have a potential and relevant impact in terms of GHG emissions. Based on the literature review and current framework in terms of GHG calculation and reporting, a first distinction was made to distinguish three main sectors and type of activities at strait level: "port" activities, "land-based" activities, and "sea-based" activities.

A second distinction with several sub-sectors was also proposed, to enable a better understanding of what physically happens in terms of GHG emissions, especially regarding transportation activities, (considering that GHG emissions from strait activities are mainly driven by transportation activities). This distinction should also help to identify the main stakeholders involved in GHG emissions of specific sub sector. The table below presents an exhaustive list of activities taking place in all the European straits and that are considered in the scope of this study.

Figure 4 – Proposed categorization of GHG emissions at strait level (Source: I Care & Consult)

It is assumed in the present methodology that ports are able to influence strait's GHG emissions, and as a consequence, ports should be considered as an important component of a low carbon strategy at strait level. The proposed designation includes:

- **Sectors**: define the topmost categorization of the strait's GHG sources activities, mainly driven by flows of people and goods;

[6] Baseline study of the Nostra Project: Final report

- **Sub-sectors**: this additional level of categorization enables the use of disaggregated data, and helps identify mitigation actions by partners and stakeholders.

It is important to clarify here, that the availability of data is a key factor in deciding whether to include or exclude several sub-sectors proposed above. Indeed, the GHG inventories that were built under the PASSAGE project are based on recent and easily available data, because the data collection needed to be finalized under a tight timescale.

c) Setting a methodological framework

During this study, the main accounting and reporting principles for strait GHG emissions follow the main principles from the *GPC Protocol Standard*, which enables a fair and true account of emissions:

Relevance: The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities of a strait. The inventory can also serve the decision-making needs of the PASSAGE project members, taking into consideration relevant local, subnational, and national stakeholders and regulations. The principle of relevance applies when selecting data sources, and determining and prioritizing data collection improvements.

Completeness: Straits shall account for all required emissions sources within the inventory boundary. Any exclusion of emission sources should be justified and explained.

Consistency: Emissions calculations shall be consistent in approach, boundary, and methodology. Using consistent methodologies for calculating GHG emissions enables meaningful documentation of emission changes over time, trend analysis, and comparisons. Calculating emissions should follow the main methodological approaches available for GHG emissions inventory.

Transparency: Activity data, emission sources, emission factors, and accounting methodologies require adequate documentation and disclosure to enable verification. The information should be sufficient to allow individuals outside of the inventory process to use the same source data and derive the same results. All exclusions shall be clearly identified, disclosed and justified.

Accuracy: The calculation of GHG emissions shall not systematically overstate or understate actual GHG emissions. Accuracy should be sufficient to give decision makers and the public reasonable assurance of the integrity of the reported information. Uncertainties in the quantification process shall be reduced to the extent that it is possible and practical.

This methodology requires straits to measure and disclose a comprehensive inventory of GHG emissions and to total these emissions following a categorization of all emissions depending on where they physically occur.

Activities taking place within a strait can generate GHG emissions that occur inside the strait's boundary, as well as outside the strait's boundary (such as international maritime cruise for example). This methodological approach is based on an adapted application of the scopes framework used in the "*GPC Protocol Standard*", and takes into consideration the strait-induced activities and the different abilities of strait stakeholders to take effective action on mitigating climate change.

The figure below illustrates which emission sources occur solely within the geographic boundary of a strait, which occur outside the geographic boundary of a strait, and which may occur across the geographic boundary:

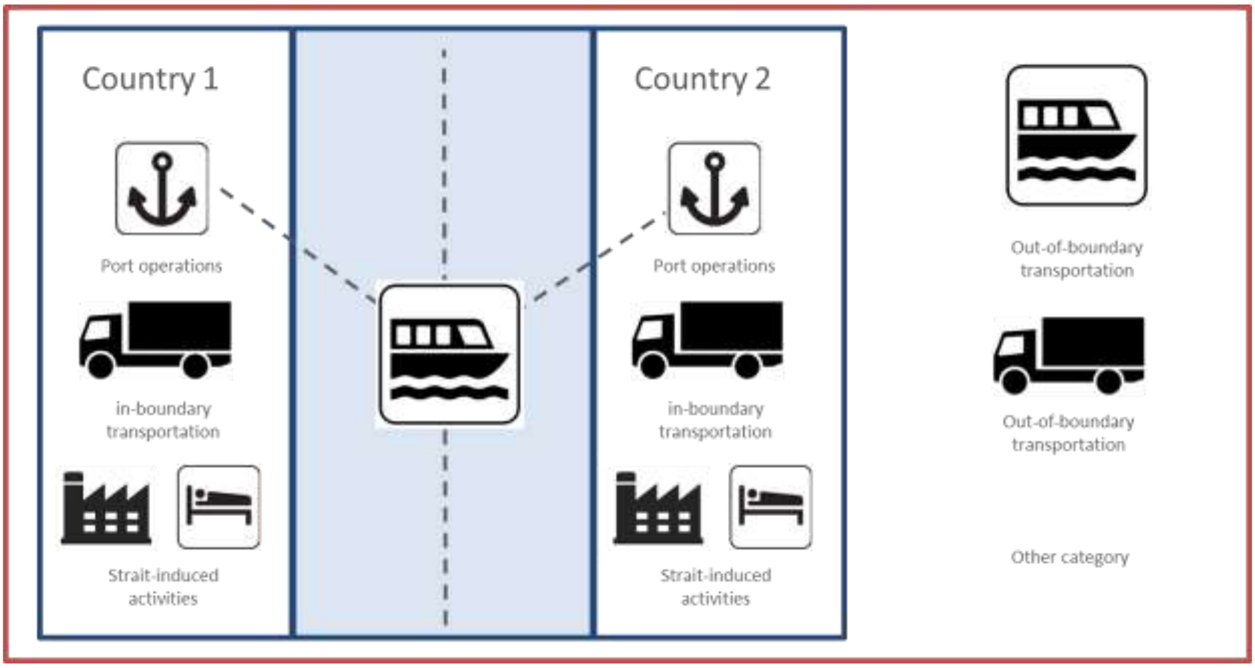


Figure 5 – Illustration of the emission sources within and outside the strait's boundary (Source: I Care & Consult)

This proposed methodological approach should enable strait inventories to be consolidated with existing available GHG inventories (for example the WPCI carbon footprint calculator[7] used by a Port Authority, the *Baseline Emission Inventory* carried out by a city involved in the Covenant of Mayors[8] or an industrial plant located inside the strait boundary that carried out a specific GHG inventory of its activity[9]), and to be compared with national GHG inventories, especially regarding international maritime traffic.

d) Calculation methodologies

The proposed methodology is based on the main purpose of a strait inventory, that is to say:

- Demonstrate leadership in climate change mitigation: stakeholders of PASSAGE project will propose a first GHG inventory of strait-induced activities, and try to engage the main relevant stakeholders, in order to promote and implement low-carbon operations and reduce GHG emissions at strait level;
- Estimate and understand the order of magnitude and the share of GHG emissions from straits activities in comparison to other territories in the European Union: this project will also enable stakeholders to estimate the consistency of the results with their country's national inventories;
- Compare with, learn from, and share best practice with other straits: the PASSAGE project brings together six straits and eleven partners in several countries, that will map and understand the emissions contribution from different activities at a strait level.

[7] http://wpci.iaphworldports.org/carbon-footprinting/
[8] http://www.covenantofmayors.eu
[9] National Emission Registry of industrial plant in France: www.georisques.gouv.fr

This approach does not require specific methodologies to be used to produce emissions data. Instead it is based on the most appropriate methodologies used by the main stakeholders involved in strait activities, and already carrying out inventories for those activities, that is to say:

- Port authorities, following the WPCI carbon footprint calculator;
- Transportation companies, following the GLEC framework;
- Cities, following the GPC Protocol Standard or the Covenant of Mayors.

For most emission sources, as for companies or cities, the strait's stakeholders will need to estimate GHG emissions by multiplying activity data by an emission factor associated with the activity being measured.

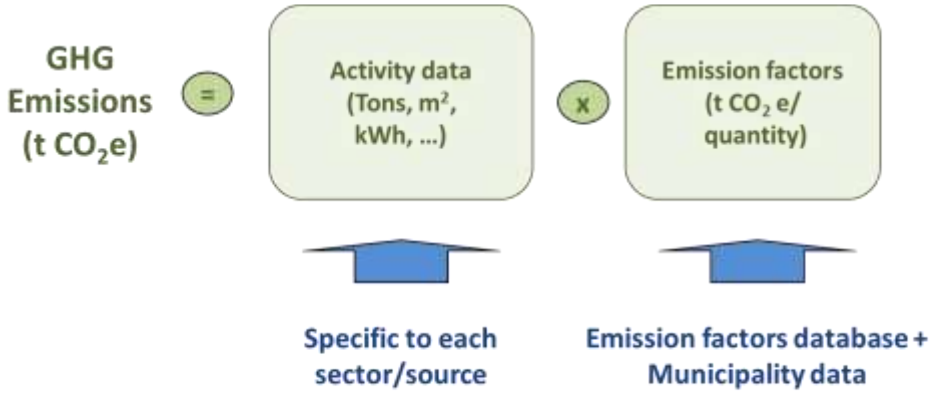


Figure 6 - Principles of calculations (Source: I Care & Consult)

- Activity data is a quantitative measure of a level of activity that results in GHG emissions taking place during a given period of time (2016 in the case of this study): For example, the electrical consumption due to port operations, or the ton-kilometers transported by trucks departing from a port, etc.
- Emission factor is a measure of the mass of GHG emissions relative to a unit of activity: For example, estimating CO_2 emissions from the use of electricity involves multiplying data on kilowatt-hours (kWh) of electricity used by the emission factor ($kgCO_2/kWh$) for electricity, which will depend on the technology and type of fuel used to generate the electricity.

Activity data will need to be gathered from a variety of sources, including national or local statistics, the country's national GHG inventory report, scientific and technical articles, or GHG emission reports carried out by a specific stakeholder (for example Eurotunnel).

The calculation methodologies per sub-sector are detailed in the annex.

5. Opportunities and benefits resulting from the carbon study

Following the NOSTRA project, the carbon study carried out for the European Straits of PASSAGE is one of the first studies on the carbon footprint at a strait level. Through the work that has been carried out, PASSAGE partners have had access to some key opportunities during the study:

- Opportunity to deepen the collaboration with the cross-border partners in each strait and with the stakeholders outside their structure;

- Opportunity to share good practices and collaborate with the PASSAGE partners.

The main benefits the PASSAGE partners could take advantage of as a result of the carbon study are:

- Awareness raising and capacity building of the PASSAGE partners on the mitigation of climate change issues;

- Analysis of the stakes at a strait level, in terms of GHG emissions, on which actions must be taken to reduce their impact on climate change;

- Awareness raising on the maritime emissions at a local level. This study aimed to allocate emissions at a local level and integrate them into the local stakeholders' responsibilities. This occurred in a favourable timing with the adoption of an MRV (Monitoring, Reporting, Verification) Shipping Regulation by the European Commission and the IMO DCS (Data Collection System). This led to a lobbying action at a European level, as well as a common answer to the European public consultation on the revision of the policy on monitoring, reporting and verification of CO_2 emissions from maritime transport.

- Completion of an original and innovative study, to increase the knowledge of the GHG impact of these specific territories, the straits, in the continuity of different studies led by universities. This study brought a global perspective of the situation and evolution of the strait, as well as the identification of some gaps in addressing key challenges for the strait. This could also lead to the publication of a scientific article.

6. Limitation of the carbon study

The main limitation was to juggle multiple straits with specific characteristics (geography, economy etc.) and the will to build a common and homogeneous methodological approach. The main limitations linked to the approach were:

- **Type of straits**: there were major differences between the straits studied, in terms of economic activities and maritime transport specifically. For example, the strait of Dover / Pas de Calais is a major hub of transport, with almost 20% of worldwide maritime traffic in 2006 and important industries, while the Strait of Corfu presents a very different economical context (mainly small-scale ports, few industries, tourism being the main economic activity).

- **Definition of the organizational perimeter**: contrary to the cities, there are no administrative boundaries to a strait. The definition of the boundaries of a strait is a research subject and there is no clear definition nowadays, specifically on the depth of the hinterland and the length of the maritime boundary. An arbitrary decision was made to consider the NUTS3[10] regions as the hinterland of the strait and as the limit of the maritime boundary. However, some boundaries differ due to local context. In some cases, there was already a defined maritime boundary (according to the IMO Separation Traffic Scheme, such as the Strait of Dover / Pas

[10] Nomenclature of territorial units for statistics (hierarchical system for dividing up the economic territory of the EU).

de Calais or the Corsica Channel). In some other cases, more relevant hinterland was considered (such as the consideration of the capital region in the Finnish shore of the Gulf of Finland's Strait, for the economical induced activities). This led to a heterogeneity in the boundaries, to align with the local context of the strait, with arbitrary decisions that are debatable and differences between the straits.

- **Definition of the operational perimeter**: this perimeter is mainly homogeneous for all the straits, except for the inclusion of tourism in the induced economical activities of the Strait of Dover / Pas de Calais, that was not included in the other straits. A functional approach around the strait was considered, which means that not all the emission sources within the boundary are considered (such as waste or resident's transport). Only the activities induced by the presence of the strait were considered, which led to a selection of representative activities (ports activities, in-land transport linked to the ports, maritime transport, industrial activities, residential and commercial activities). One of the limitation is that not all sources of emissions and activities are taken into account in the straits. Moreover, there might be some overlaps and double counting in the calculations of emissions from tourism in the Strait of Dover / Pas de Calais, as a part of these emissions might be included in the Residential and Commercial emissions from the cities.

- **Definition of a methodological approach**: the approach was built based on scientific works, without being able to evaluate the type of data available and needed. There was then an adjustment of the method depending on the available data, that led to some arbitrary decisions that could be debatable. For example, there is a difference in the emission factors for ferries considered in the local maritime cruise and the ferries considered in the maritime cruise with calls to the strait's ports, depending on the availability of data such as the number of ferries and the number of passengers transported.

- **Emission factors**: the emission factors for maritime transport considered in the study are taken from the DEFRA database mainly. However, there seems to be large differences between the emission factors in the different databases available at a European level (Base Carbone in France, DEFRA in the UK, LIPASTO in Finland…). It was decided to use only the DEFRA database in all the straits, in order to be consistent in the methodology, but this impacts largely the results in some of the straits (such as the Gulf of Finland's Strait).

- **Missing data**: due to difficulties accessing some information in the very restricted timeline, some data is missing for some of the straits. This is due to the technicality of the study and the lack of time to reinforce the capacity of the stakeholders and ensure a good comprehension of the stakes and the data to collect. Moreover, with the transit maritime transport, there is variation between the countries on the institutional cooperation and the governance, which led to data missing in some straits (Corsica Channel, Fehmarnbelt, Strait of Otranto). 95% of the data needed was not in direct possession of the PASSAGE partners, meaning that access to data depended on the connection of the partner to its stakeholders and their capacity to collect the data needed. The governance and the network of actors varied greatly between the straits and between the countries.

- **Results**: in some cases, due to missing data the GHG emissions inventories are not complete. In these cases, notation keys (NC – not communicated) were used to indicate that the source of emissions is not negligible, but that it was not accounted for as the data was not collected. This could lead to a misinterpretation of the results. Moreover, it was only possible to distinguish the emissions within and outside the strait's boundaries in two cases (Strait of Dover / Pas de Calais and Gulf of Finland's Strait). Finally, there was no inventory management plan implemented for the follow-up and the update of the inventories, even though a robust and transparent tool was provided with the calculations. Training could be provided to ensure a good comprehension of the tool and the calculations and the ability to update the inventory over time.

- **Action plans and decarbonization paths**: The action plans proposed are not always directly linked to the study due to the operational responsibilities of the partners (such as the CCI de Bastia, which has a direct operational responsibility with the Port of Bastia in the Corsica Channel, and the Pas-de-Calais County Council which doesn't have a direct link with the ports). Moreover, for the decarbonization paths, an indicative top-down logic was used, which means the trajectory was built from national and/or sectoral plans, and was not connected with the action plan.

7. Recommendations for further work

To continue the work, the main recommendations are the following:

- Ensure a translation of the deliverables in the native language of the PASSAGE partners and communicate the study to the stakeholders;

- Continue to build cooperation with the stakeholders, to sustain the data collection over time and to allow the inventories to be updated and the missing date to be obtained;

- Improve the emission factors used to reflect the local context and the specificities of each strait and actors (such as the maritime companies operating in the strait);

- Consolidate the data, specifically on transit maritime cruise, by working with the institutional organizations in charge of collecting the data and the coastguards;

- Expand the work through a university thesis or work.

1. Main GHG emission sources at strait level

As described earlier, there are 4 main emission source sectors considered in this study:

- **Ports operation**: including energy consumption of the buildings in the port and of the ships in the port areas. This emission source was included in the inventory when available (for the Strait of Dover/Pas-de-Calais). However, the information was not easily accessible in most cases and thus this emission source was incomplete in some cases (Gulf of Finland's Strait, missing the emissions from the ships in port areas in the Estonian shore, and Corsica Channel, missing the energy consumption in the port's buildings in the French shore and the emissions from the ships in port areas in the Italian shore) or not considered at all in other cases (Fehmarnbelt, Strait of Otranto and Strait of Corfu). However, the emissions are in most cases small, especially compared to the other sectors considered in this study (less than 2% in the case of the Strait of Dover / Pas-de-Calais and the Gulf of Finland's Strait).

- **Maritime transport**: including local, international (with calls to the strait's ports) and transit maritime cruise. This emission source was included in most of the inventories, depending on the local availability of data. The local maritime cruise data was collected from the ports and/or the local maritime companies. The international maritime cruise data was collected from the ports, and the transit maritime cruise was collected from the coastguards. This last one was harder to obtain due to the lack of monitoring of the ships passing through the straits in some cases (Strait of Corfu for example), or due to the difficultly accessing the data due to the institutional relationships and governance (Strait of Otranto for example). The inventory for the Strait of Otranto is incomplete on this sub-sector as no data could be collected. For the other straits, the missing data could be estimated thanks to data collected on the other shore or from publications. This emission source represents 10% to 30% of the emissions within the strait, and up to 64% of the emissions in the Strait of Corfu.

- **In-land traffic**: including road, railway, waterways transport from and to the ports and tunnel transport if appropriate. This emission source was included in all the inventories based on local and national statistics on the quantity of merchandise transported, the number of passengers passing through the ports, the mode of transport and the distance travelled. This emission source represents between 3% and 20% of the emissions within the strait. In the Gulf of Finland's Strait, the in-land traffic represents only 3%, which can be explained by the characteristics of the strait, which links two capitals with a large alternative transport offer and lower distances travelled. In Fehmarnbelt, the in-land traffic represents almost 20% of the emissions, which can also be explained by the characteristics of the strait which is far from the main cities in both countries, implying higher distances travelled.

- **Induced economical activities**: including industries and residential and commercial activities. This emission source was included in all the inventories based on European data on the emissions from industries (in the EU-ETS database), and on the emissions from residential and commercial activities per capita in each country (as reported to the UNFCCC). This is a major source of emissions representing between 20% and more than 80% of the emissions in the strait. In the straits of Dover / Pas de Calais, Corsica Channel, Gulf of Finland and Otranto, this is mainly due to the many industries in the strait region.

2. Significance of GHG emissions in straits

The emissions of the PASSAGE straits were 44.0 $MtCO_2e$ in 2016, mostly emitted by the Strait of Dover / Pas de Calais (33%). This is equivalent to the emissions of 6.5 million inhabitants in Europe[11] and to 1.1% of the European Union emissions[12].

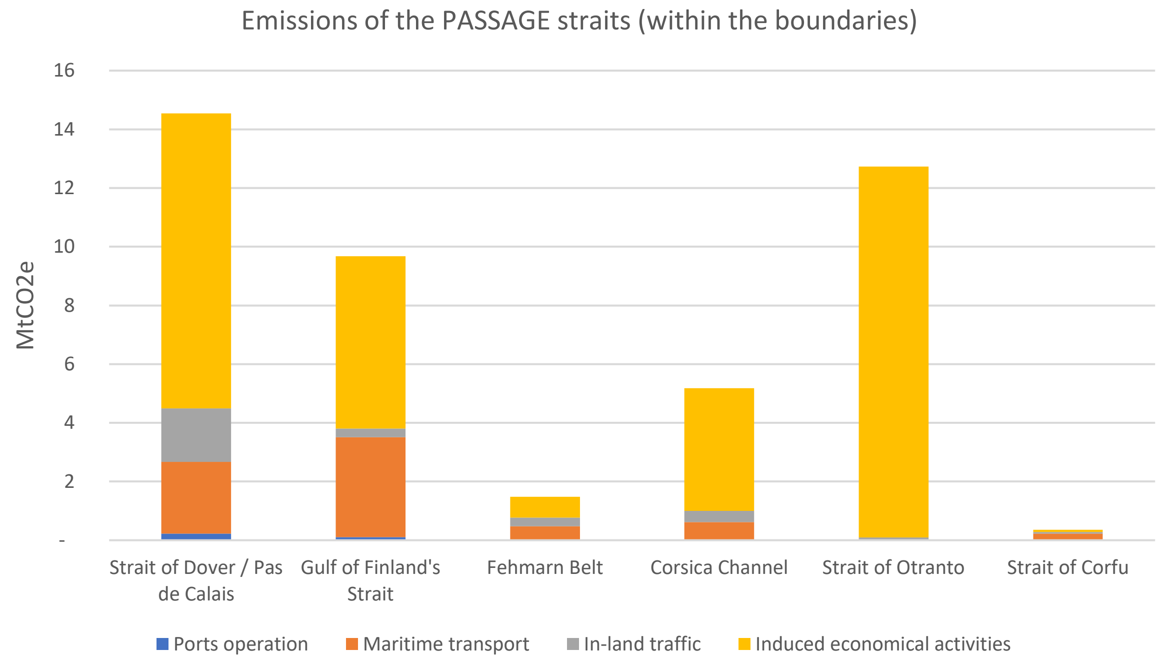


Figure 7 - Emissions of the PASSAGE straits (within the boundaries) (Source: I Care & Consult)

In most of the straits, the induced economical activities (industries & cities) represent a significative part of the GHG emissions within the strait's boundaries. This is mainly the case in the Strait of Dover / Pas de Calais, the Gulf of Finland's Strait, Corsica Channel and the Strait of Otranto, where there are many industries that influence the emissions. The cities (residential and commercial activities) are also a main source of emissions in the straits.

The maritime cruise, and specifically the transit maritime cruise, is an important source of emissions for the straits occurring mainly in the Strait of Dover / Pas de Calais and the Gulf of Finland's Strait. The maritime cruise (local, international and transit maritime cruise) represents 16% of the global emissions of the PASSAGE straits.

Finally, the on-road transportation is also an important source of emissions in the majority of the straits.

However, it's important to note that, due to data missing, some inventories are not complete (specifically concerning the ports operation and the transit maritime cruise, such as in the straits of Corfu and Otranto).

[11] Considering 6.8 tCO_2e/capita. Source: Service of Observation and Statistics in France, based on data by EDGAR, World Bank, 2015
[12] Considering emissions of 4 054 MtCO2e in the European Union in 2014. Source: CAIT Climate Data Explorer, World Resources Institute

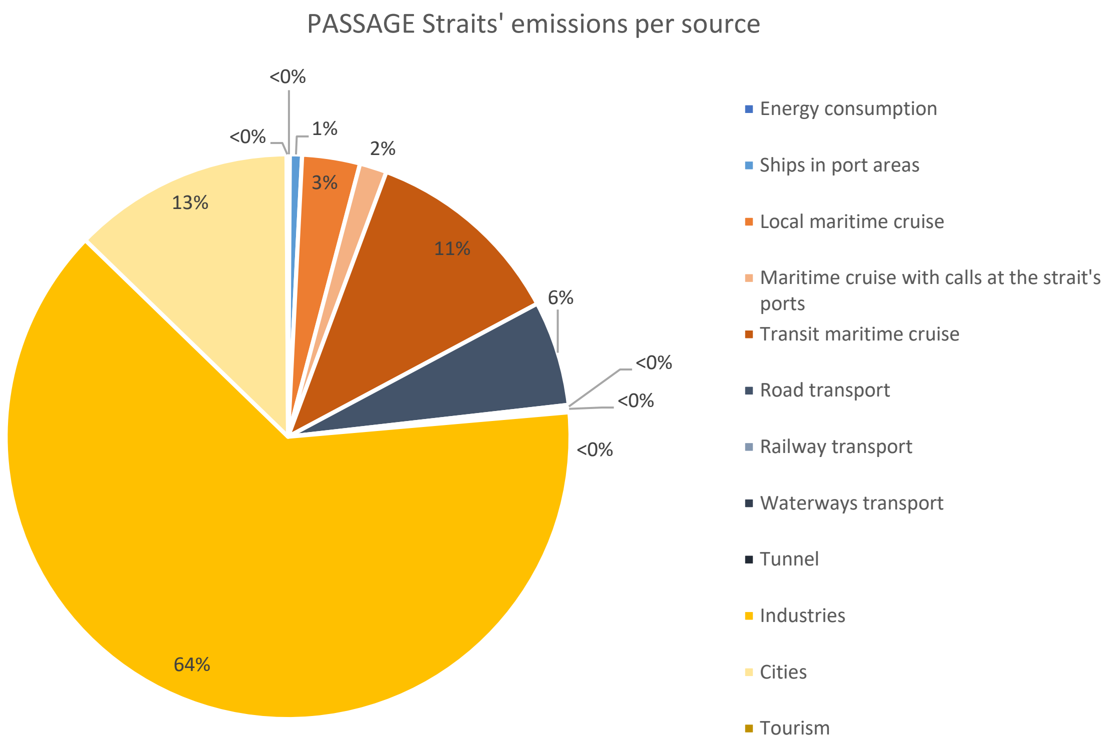


Figure 8 - Breakdown of the PASSAGE straits' emissions per sub-sector (Source: I Care & Consult)

3. Comparative table between straits

The following table show the emissions per source of each of the straits. It is important to note that the results cannot be compared between the straits, as they are influenced by the specificities of each strait and the availability of data (as not all the inventories are complete).

But, it is still interesting to note that the emissions mainly reflect the specificities of the straits. The straits with significant levels of traffic (such as the straits of Dover / Pas de Calais, Gulf of Finland or Otranto) also have significant emissions due to the industries, as well as significant road transport. This can be explained by the influence of the traffic and the main ports on the supply of materials to the industries for example.

The straits with a less significant traffic (such as Fehmarnbelt and the strait of Corfu) are mostly impacted by the emissions from the local maritime cruise, the residential and commercial activities in the cities and the in-land transport. The transit maritime cruise and maritime cruise with calls at the strait's ports are of less importance compared to the other straits.

Table 3 - Comparative table of the emissions of each strait

Emission source (within the strait's boundary) *in tCO2e*		Strait of Dover / Pas de Calais	Gulf of Finland's Strait	Fehmarnbelt	Corsica Channel	Strait of Otranto	Strait of Corfu
Port operations	Energy consumption	16 205	26 437	NC	694	NC	NC
	Ships in port areas	206 868	75 590	NC	23 138	NC	NC
Maritime transport	Local maritime cruise	725 457	190 435	248 571	73 117	55	214 443
	Maritime cruise with calls to the strait's ports	21 834	383 583	NC	229 978	31 377	16 435
	Transit maritime cruise	1 702 548	2 839 190	231 081	289 993	NC	/
In-land traffic	Road transport	1 688 671	262 653	289 190	367 205	61 466	50 308
	Railway transport	32 951	22 431	3 086	21 415	2 691	/
	Waterways transport	36 345	/	/	/	/	/
	Tunnel	64 899	/	/	/	/	/
Induced economical activities	Industries	8 346 854	4 849 287	0	3 570 531	11 163 390	1 556
	Cities & Towns	1 667 014	1 028 048	710 864	606 029	1 468 585	75 469
	Tourism	37 896	NC	NC	NC	NC	NC
TOTAL		**14 547 543**	**9 677 653**	**1 482 791**	**5 182 101**	**12 727 564**	**358 210**

4. Responses addressing key challenges for low carbon development of straits: EU policies and governance practices

The European Union emissions represent about 10% of total global emissions. Its Member States have ratified the UNFCCC's Kyoto Protocol in 1997 and the Paris Agreement in 2015, setting emission targets to limit the global emissions and keep global warming below 2°C.

In its 2050 Low-Carbon Economy Roadmap, the EU aims to cut greenhouse gas emissions to 80% below 1990 levels (with milestones to 40% by 2030 and 60% by 2040), with a contribution from all sectors (power sector, residential and tertiary, industry, transport, agriculture). The Effort Sharing Decision establishes binding annual greenhouse gas emission targets for Member States for the period 2013-2020. These targets concern emissions from most sectors not included in the EU Emissions Trading System (EU-ETS), such as transport, buildings, agriculture and waste. The national emission targets for 2020 have been agreed unanimously and are based on the relative wealth of each Member States (GDP per capita).

The international maritime transport is not included in the national inventories and the Paris Agreement. However, it represents about 2.5% of global greenhouse gas emissions according to the 3rd IMO GHG Study. Moreover, they are predicted to increase between 50% and 250% by 2050, depending on future economic and energy development, which is not compatible with the goal of keeping global temperature increase to below 2°C compared to pre-industrial levels. In order to promote the reduction of emissions by the maritime companies, the European Commission set out a strategy in 2013 to include maritime transport emissions into the EU's policy for reducing its domestic GHG emissions. The strategy consists in 3 steps:

- Monitoring, reporting and verification of CO_2 emissions from large ships using EU ports
- Greenhouse gas reduction targets for the maritime transport sector
- Further measures including market-based measures in the medium to long term

From 2018, the MRV companies (ships over 5000 gross tonnes loading/unloading cargo/passengers at EU maritime ports) are to monitor and report their related CO_2 emissions, submit to an accredited MRV shipping verifier a monitoring plan and submit the verified emissions through THETIS MRV (a dedicated European Union Information system currently under development by the European Maritime Safety Agency). In parallel, the IMO is implementing a Data Collection System. This system requires every ship of 5000 gross tonnage and above to collect consumption data for each type of fuel oil they use. The aggregated data is reported to the flag State each year and then transferred to an IMO Ship Fuel Oil Consumption Database. An annual report will then be produced by the IMO.

All these initiatives, combined with the national and sectoral plans in each country aiming to reduce greenhouse gas emissions, will impact the straits and lead them into low-carbon development.

5. Recommendations for future actions

a) At the level of the partnership

The carbon study has resulted in several key recommendations for the PASSAGE partners:

- Capitalise on this first work by deepening the knowledge of the strait's carbon footprint through academic research;
- Consider monitoring the emissions over time, through the update of the inventories;
- Consolidate the governance at a strait level;
- Bring the key findings to the attention of the European Commission.

b) At strait level

The carbon study has resulted in key recommendations that are generic at a strait level:

- **Port Authorities**: it would be interesting for all the ports of the straits to adhere to the WPCI (World Ports Climate Initiative), an initiative launched by the International Association of Ports and Harbors (IAPH) under the auspices of the C40 Cities to reduce the greenhouse gas emissions in the ports. Moreover, the Port Authorities should ask the European Commission for the MRV Shipping Regulation data for all the ships calling at their ports. This would improve and facilitate the data collection for the future update of the inventories and allow the ports to better understand their impact on climate change and their role as transportation and economic centers.

- **Port towns**: it would also be interesting for the cities and towns with a port to include the maritime transport and the port's emissions in their inventories to have a better understanding of the impact of these activities on the territory and the emissions and to ensure an inclusion of actions linked to these activities in the strategies and action plans to tackle climate change.

- **PASSAGE partners**: it is important to continue and improve the working cooperation with the different stakeholders within the strait (port authorities, coastguards, cities etc.), to facilitate the data collection and the implementation of the action plan to reduce the GHG emissions. Moreover, it is also important to continue and improve the cooperation between the two shores of the strait and between the local and regional institutions in charge of specific topics, to ensure compatible and shared strategies and actions within the strait.

Overview of the baseline study at strait level: Fehmarn Belt

This chapter presents the main conclusions of the analysis carried out for Fehmarn Belt.

IDENTITY OF THE STRAIT

The strait in a nutshell

The Strait of Fehmarn Belt is an 18 km width passage area where the Bay of Kiel and the Bay of Mecklenburg meet the German island of Fehmarn and the Danish island of Lolland.

The strait specificities

- Most of the maritime traffic is transit shipping, without any stop on the two shores of the strait.
- Both Puttgarden (DE) and Rodby (DK) ferry harbours are small town/villages.
- A binational institution The Fehmarnbelt Committee
- A tunnel project across the strait of Fehmarn Belt: “The Fehmarn Belt Fixed Link”

Main findings

- 1.5 $MtCO_2e$ were emitted within Fehmarnbelt’s boundary in 2016, equivalent to the average emissions of about 217 000 inhabitants in Europe[13], which is 0.2% of German emissions and 3.0% of Danish emissions in 2014[14].
- The local maritime cruise (Scandlines) represents an important part of the emissions, with 17% of the emissions.
- The residential and commercial activities of the regions are the main emitters of the strait.
- The road transport linked to the goods and passengers passing by the strait’s ports (Puttgarden and Rodby) is also an important emitter of the strait.

Decarbonization paths

- Denmark and Germany have ambitious targets of reduction of GHG emissions implemented in national strategies:
    - Reduction of emissions by 55% by 2030 compared to 1990 and greenhouse gas-neutral by 2050 in Germany
    - Reduction of emissions by 40% by 2020 and 80-95% by 2050 compared to 1990 in Denmark
- The decarbonization path, based on the national targets applied to the strait’s emissions, results in a reduction of the GHG emissions by 17% by 2030 compared to 2016.

[13] Considering 6.8 tCO_2e/capita. Source: Service of Observation and Statistics in France, based on data by EDGAR, World Bank, 2015

[14] Considering emissions of 854 MtCO2e in Germany and 49 MtCO2e in Denmark in 2014. Source: CAIT Climate Data Explorer, World Resources Institute

1. Analysis of the situation at the strait level

Organizational perimeter

The Region Zealand and the County of Ostholstein are the PASSAGE administrative authorities. The table below presents their main respective features.

The Fehmarnbelt	DENMARK	GERMANY
The PASSAGE administrative authorities	Region Zealand	County of Ostholstein
Inhabitants (million)	0,83	0,20
Area (km²)	7 273	1 392
Density (inhab./km²)	110	140
Number of district authorities	17	12
Coastline (km)	208	185
Main city	Roskilde	Eutin

The boundaries of the strait were determined as following:

- The maritime boundary is set according to the boundaries of the NUTS 3 [15] region (Zealand and Ostholstein);
- The Danish border boundary is the Zealand region (NUTS 3);
- The German border boundary is the Ostholstein region (NUTS 3).

The following map shows the boundaries of the strait considered here:

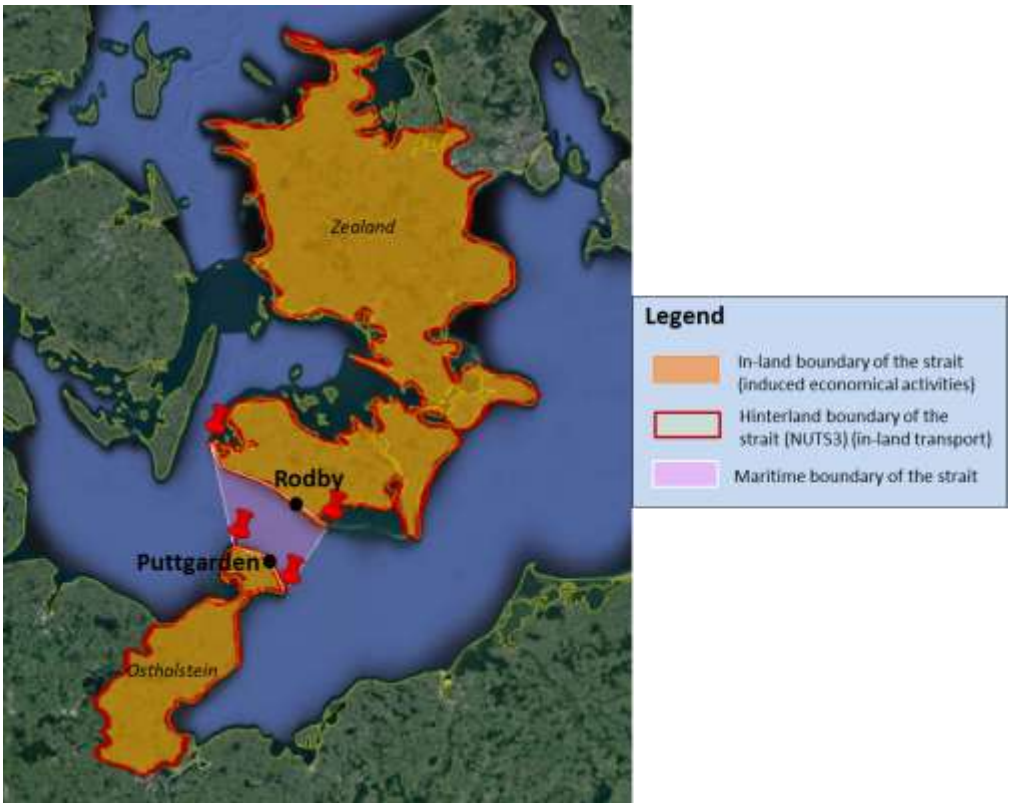


Figure 9 - Geographical boundary of the strait of Fehmarnbelt (Source: I Care & Consult)

[15] Nomenclature of territorial units for statistics (hierarchical system for dividing up the economic territory of the EU).

Functional & operational perimeter

Within the strait area, the main activity with possible significant GHG emissions is the sea-based traffic, and more precisely the transit shipping traffic. In comparison, as there are no major local economic activities (urban areas, industries), and even if there is a ferry route carrying passengers, the local traffic between the two shores of the strait is of much less magnitude. The two major large cities on each side of the strait are quite far, respectively 160 km and 150 km for Copenhagen (DK) and Hamburg (DE).

PORTS

Both Puttgarden (DE) and Rodby (DK) ferry harbours are dedicated to ferries (see Puttgarden photo opposite). Scandlines is operating the main Rodby port. This private company is currently operating 6 ferries across these two ports. A secondary port (Rodbyhavn Traffic harbour) is partly owned by the Rødbyhavn Lolland Municipality and has a small traffic of about 100 ships a year. They mainly carry fertilizer and grain for agriculture.

Figure 10 - Puttgarden (Source: Wikimedia Commons)

MARITIME TRAFFIC

As suggested by the literature review, the sea-based activity must be the main GHG source of emissions within a strait. The key figures of the **main maritime traffic** occurring in the Fehmarn Belt Strait are reported below:

- **The local maritime traffic** concerns the trips, by ferries, between Rodby and Puttgarden. This traffic represents around 35 500 trips in 2016, according to Scandlines, the main ferry operator. About 6 million passengers were transported across the strait, as well as more than 1.5 million cars, 472 700 lorries, 31 100 busses and 13 400 passenger trains. Scandlines are engaged in reducing their GHG emissions with the implementation of large scale Hybrid technology and fuel efficiency programs. The next aim is to operate "zero emission" ferries by 2020-2025 (operating on electricity from neighbouring windmill farms).

Figure 11 - Prinsesse Benedikte hybrid ferry operating on the Rodby-Puttgarden line (Source: Scandlines)

- **The maritime traffic with calls at the strait's ports** (Rodby and Puttgarden) is almost non-existent.

- **The transit maritime cruise** concerns the vessels passing through the Fehmarnbelt without any calls to the strait's ports. This represents more than 38 000 ships in 2016, mainly General Dry Cargo ships and Tankers.

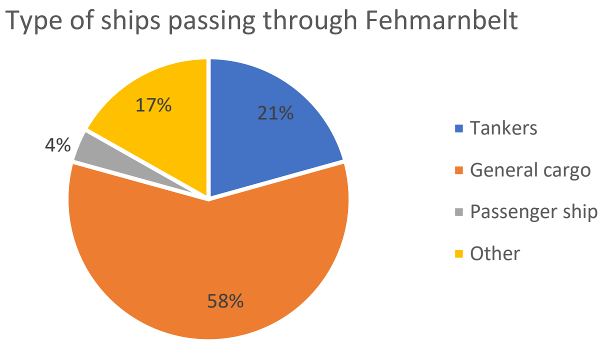


Figure 12 - Type of ships passing through the Fehmarnbelt (Source: I Care & Consult, based on data provided by Femern A/S)

Femern A/S provided AIS data for the ships passing through the Fehmarnbelt. It is required by IMO, Regulation 19 of SOLAS Chapter V, that AIS is fitted aboard all ships of 300 gross tonnage and upwards engaged on international trips, as well as the cargo ships of 500 gross tonnage and upwards not engaged on international trips and all passenger ships irrespective of size.

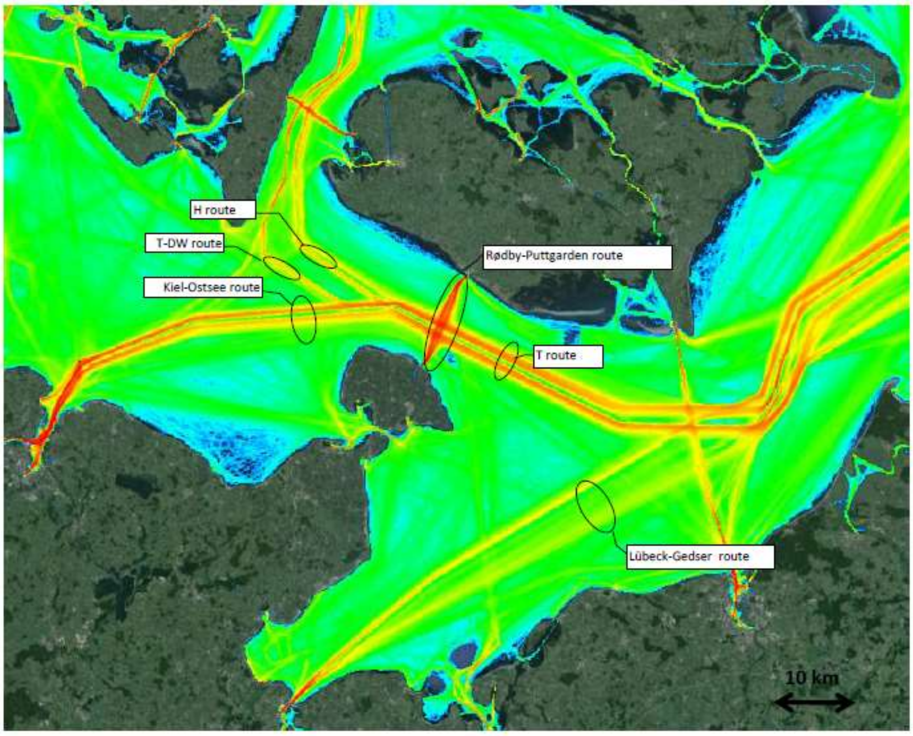


Figure 13 - Intensity plot of the Fehmarnbelt area based on AIS registrations in 2013 with main navigational routes marked (Source: Femern A/S)

According to the AIS data studied by Femern A/S, the main route through Fehmarnbelt (T route) has approximately 20 200 westbound ship movements and 17 300 eastbound ship movements in 2013.

IN-LAND TRAFFIC

The in-land traffic related to the ferry service activity is dominated by passengers travelling by cars (80 %) and trailers (18 %). Buses and railway wagons traffics are of much less magnitude, buses concentrating almost the remaining 2% of the overall traffic[16].

In 2016, 6 008 187 passengers crossed the strait with the ferries, including 1 529 649 cars, 31 113 buses (driving an estimated distance of 160 km in Denmark and 400 km in Germany) as well as 13 414 passenger train wagons (travelling an estimated distance of 32 km in Denmark and 34 km in Germany). The ferries also transported 472 725 lorries, which are considered to be driving a distance of 129 km in Denmark and 107 km in Germany.

Figure 14 - Scandlines traffic (Source: Scandlines)

CITIES & TOWNS

The regions Zealand (Denmark) and Ostholstein (Germany) also present emissions due to the energy consumption in the residential and commercial sectors. Those emissions are estimated based on the population of the strait's main regions and the national GHG inventory.

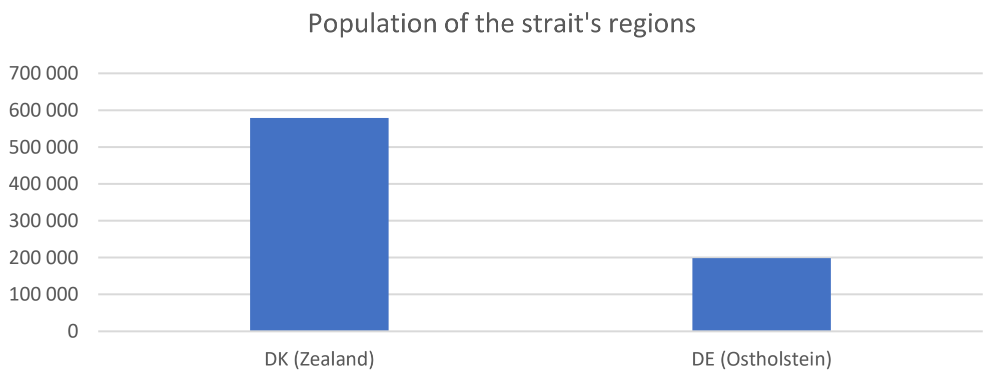


Figure 15 - Population of the main regions of the Fehmarnbelt (Source: I Care & Consult from data by Eurostat – NUTS 3)

[16] Ibid. and NOSTRA project figures.

Schematic representation of the strait

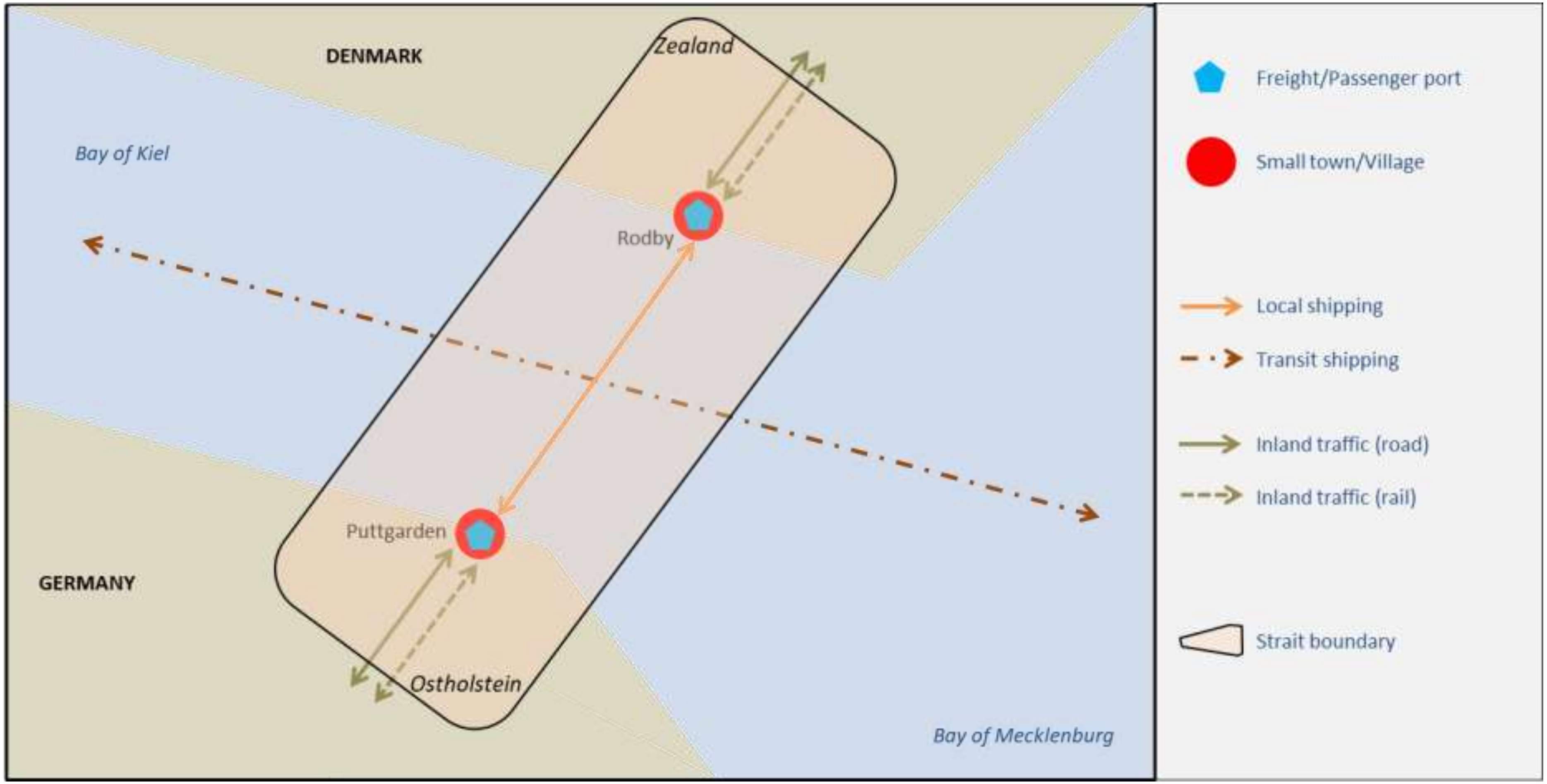


Figure 16 - Schematic “choreme” representation of the Fehmarnbelt (Source: I Care & Consult)

Geographic representation of the strait

This map presents the main distances considered within the boundary based on the geographic boundary of the strait, as defined in the methodological note. The NUTS3 regions were considered to delimit the maritime boundary of the strait.

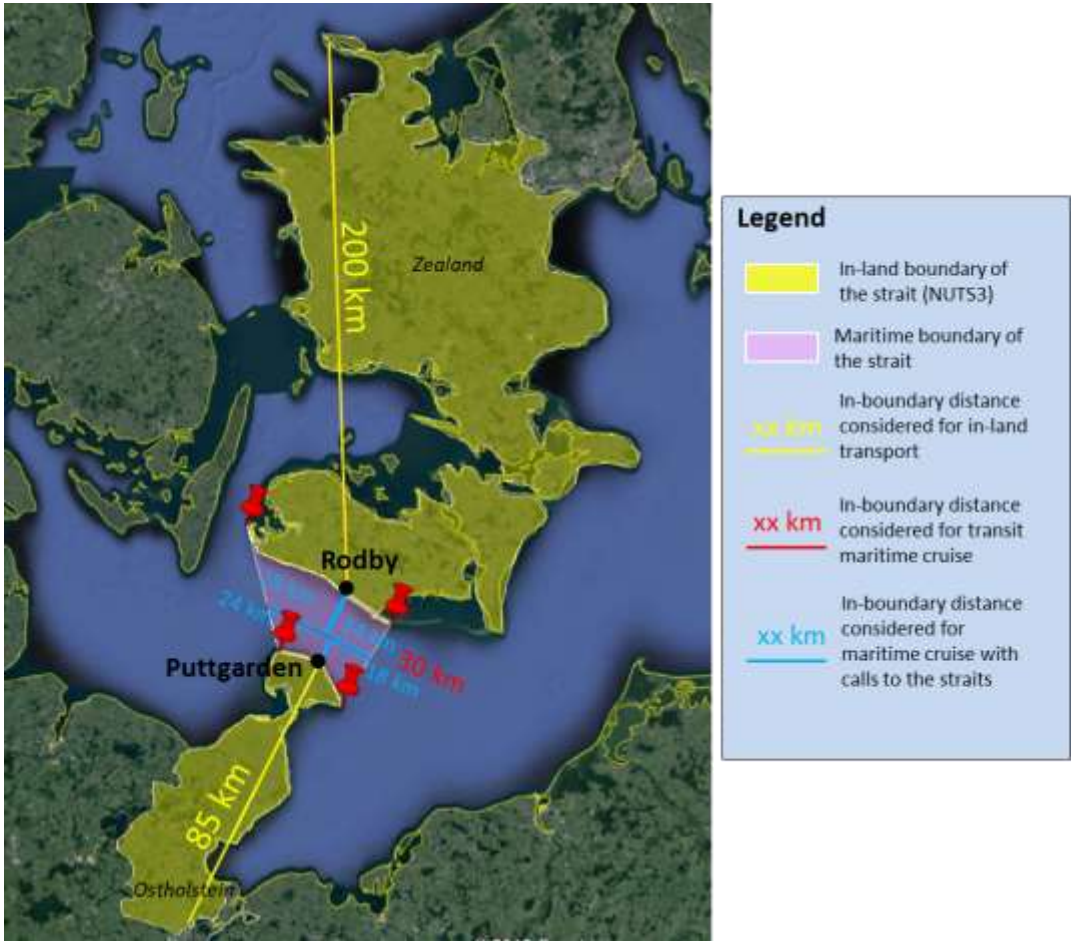


Figure 17 - Representation of the geographical boundary of the Fehmarnbelt (Source: I Care & Consult)

2. GHG emissions and key priorities for future actions

This section aims to gather the main GHG emissions sources within the strait perimeter.

The latter are calculated thanks to the data collected from existing studies carried out by the PASSAGE administrative authorities, the local stakeholders, the literature reviews, and processed by I Care & Consult.

The Fehmarnbelt emitted **1.5 $MtCO_{2}e$** in 2016. The main source of emission is the induced economical activities with 48% of the total emissions, followed by the maritime transport representing 32% of the total emissions and the in-land traffic with 20% of the emissions. The emissions are mainly impacted by the emissions from the residential and economical activities in the regions. It is important to note that some emission sources were not estimated based on a lack of data (such as the emissions from the energy consumption in ports and the ships in port areas).

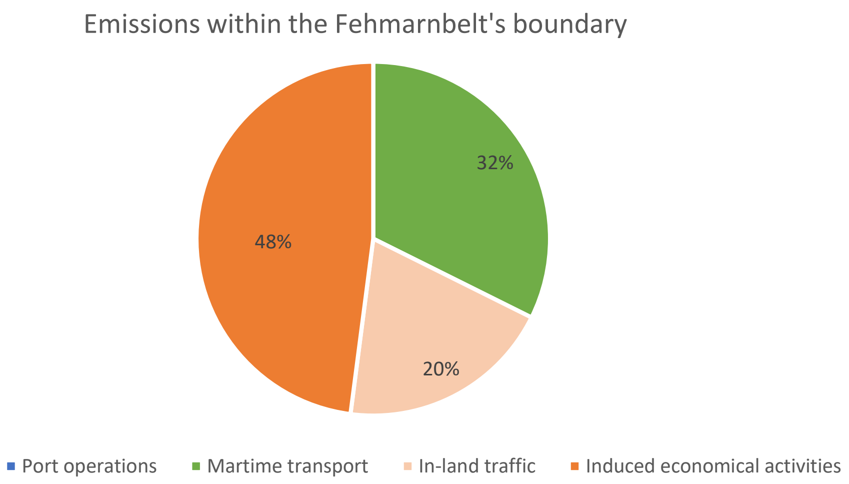


Figure 18 - Repartition of emissions from the Fehmarnbelt (Source: I Care & Consult)

Table 4 - Repartition of emissions from the Fehmarnbelt, per source

Emission source (within the strait's boundary) *in tCO2e*		Denmark	Cross-border	Germany
Port operations	Energy consumption	NC		NC
	Ships in port areas	NC		NC
Maritime transport	Local maritime cruise		248 571	
	Maritime cruise with calls to the strait's ports		0	
	Transit maritime cruise		231 081	
In-land traffic	Road transport	182 340		106 849
	Railway transport	1 997		1 088
Induced economical activities	Industries	0		0
	Cities	412 319		298 545

TOTAL	**596 657**	**479 652**	**406 483**

The emissions due to the strait's activity but emitted outside of the boundary (due to in-land and maritime transport outside of the boundary) were also estimated. Considering these indirect emissions, the strait is responsible for the emissions of 1.7 $MtCO_2e$, from which 86% are emitted within the boundary. It is important to note that some of the indirect emission sources could not be estimated due to lack of information (such as the out-boundary maritime transport from the transit maritime cruise).

PORTS

These emissions concern the emissions from the energy consumption of the ports and from the ships in port areas (manoeuvring and at berth, consuming energy for the main and auxiliary engines). Due to the lack of information on the ports, the emissions were not estimated.

MARITIME TRAFFIC

These emissions concern the emissions from the maritime transport within the strait's boundary. They represent 33% of the total emissions.

- **Local maritime cruise**

This source of emissions concerns the ferries navigating between Rodby and Puttgarden (with the company Scandlines) and occurs only within the strait's boundary. It represents **249 $ktCO_2e$**, 17% of the total emissions and more than 50% of the emissions from maritime transport.

In 2016, more than 6 million passengers travelled between the ports of Rodby and Puttgarden, as well as more than 470 000 lorries.

- **Maritime cruise with ships calling at the strait's ports**

This source of emissions concerns all the ships calling at each of the strait's ports (Rodby and Puttgarden) travelling to a port outside of the strait. Due to a lack of information, this emission source was not estimated in this study. However, due to the relatively small size of the ports, it is likely that these emissions would be negligible.

- **Transit maritime cruise**

The transit maritime cruise represents the vessels passing through the Fehmarnbelt without any call to the strait's ports (Rodby and Puttgarden). It represents **231 $ktCO_2e$** in 2016, which is 48% of the total maritime emissions and 16% of the total emissions. It is important to note that, due to lack of information, the out-boundary emissions from transit maritime cruise could not be estimated.
Most of the emissions come from the general cargo ships, the tankers and the passenger ships representing more than 80% of the transit maritime cruise.

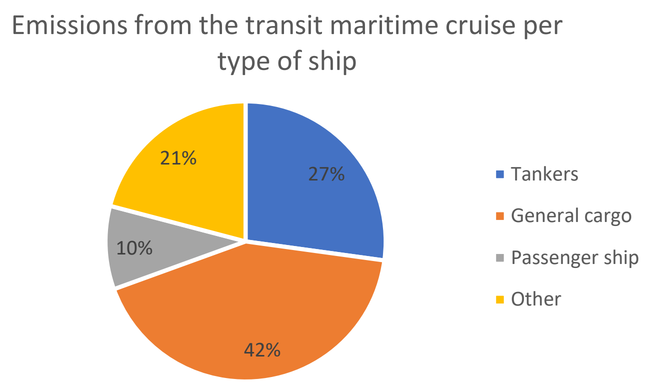


Figure 19 - Repartition of emissions from transit maritime transport per type of ship (Source: I Care & Consult, from data provided by the Femern A/S)

The main ports of destination for westbound traffic on the route are Rotterdam (Netherlands), Hamburg and Kiel (Germany), while the main ports of destination for eastbound traffic are St Petersburg (Russia) and Klaipeda (Lithuania).

IN-LAND TRAFFIC

These emissions concern the in-land transport (road and railway transport) within the strait's boundary. They represent 32% of the total emissions.

Road transport is the most important source of in-land traffic emissions and represents about **289 ktCO$_2$e**. Road transport represents more than 99% of the emissions from in-land traffic.

Railway transport is the second source of in-land traffic emissions and represents **3 ktCO$_2$e**. Railway transport represents less than 1% of the emissions from in-land traffic.

Concerning freight traffic, even though both ports handled the same amount of goods, the emissions are higher in Denmark, because of the longer distance travelled. Road transport is the most important source of emissions and most of the emissions occur within the strait's boundary. There are no freight trains transported by ferry. The freight trains take a 160km detour across the Great Belt Bridge.

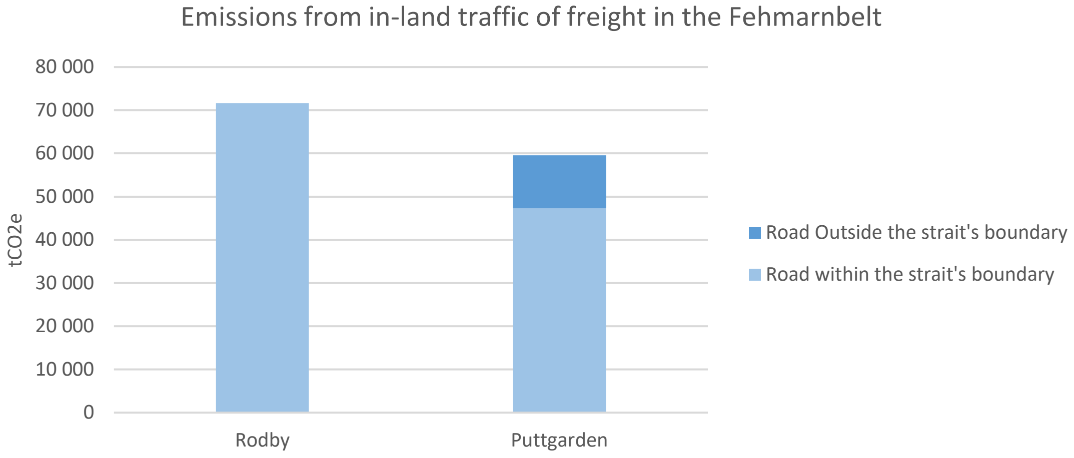


Figure 20 - Emissions from in-land traffic of freight in the Fehmarnbelt (Source: I Care & Consult)

Concerning the passenger traffic, even though both ports welcomed the same number of passengers, the emissions of the port of Puttgarden are higher due to a longer distance travelled. The road transport is still the most important source of emissions.

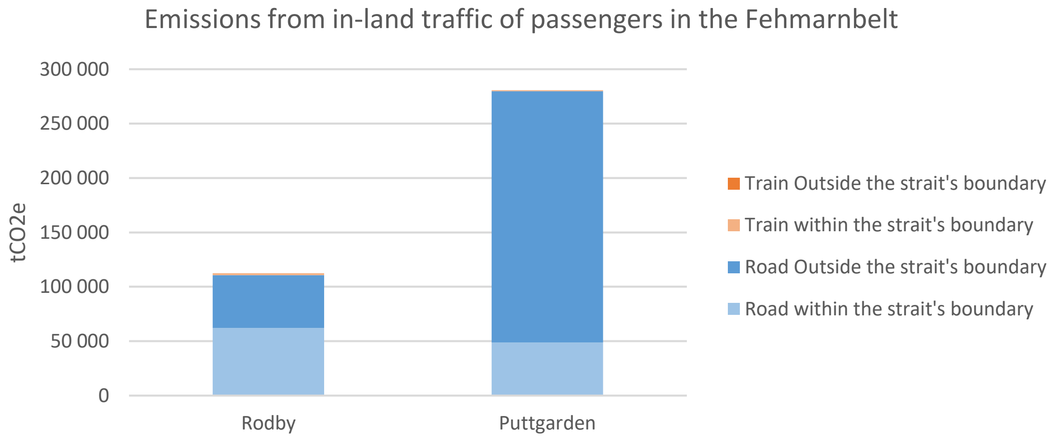


Figure 21 - Emissions from in-land traffic of passengers in the Fehmarnbelt (Source: I Care & Consult)

INDUCED ECONOMICAL ACTIVITIES

This source concerns the emissions from the industries and from the cities (residential and commercial emissions from energy consumption) which occur only within the strait's boundary. It represents **711 ktCO_2e**, which represents 48% of the total emissions.

- **Industries**

No industries were identified near Rodby and Puttgarden.

- **Cities**

The emissions from the cities were estimated based on the number of inhabitants in the NUTS 3 region which shore correspond to the strait (Region Zealand and Ostholstein). They emitted about **711 ktCO_2e** in 2016.

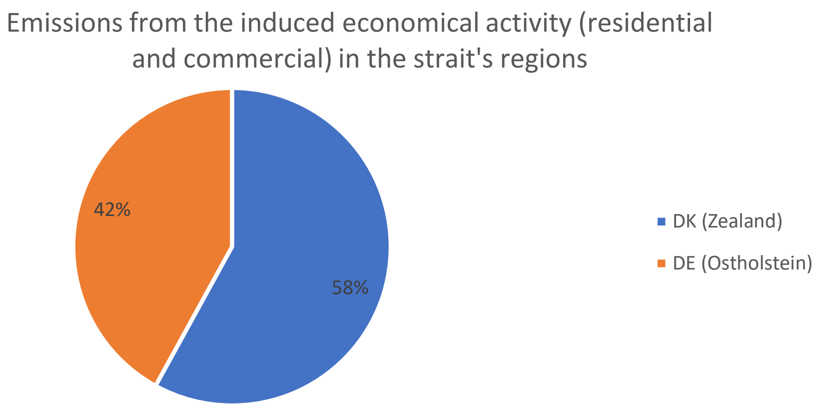


Figure 22 - Emissions from the Fehmarnbelt's regions (Source: I Care & Consult)

3. Decarbonization paths

In the last years, the threat of climate change is being addressed globally by the United Nations Framework Convention on Climate Change (UNFCCC). The EU emissions represent about 10% of total global emissions and its Member States have ratified the UNFCCC's Kyoto Protocol in 1997 and the Paris Agreement in 2015, setting emission targets to limit the global emissions and keep global warming below 2°C. The EU aims to decarbonize its energy system and cut its greenhouse gas emissions by 80% to 95% by 2050. To achieve this goal, it has set a binding target of reducing emissions by at least 40% compared to 1990 levels by 2030. Many European countries have adopted national programs aimed at reducing emissions.

DENMARK

The Danish government set ambitious targets through its Climate Policy Plan, published in 2013. The aim is to reduce greenhouse gas emissions by 40% by 2020 compared with the 1990 levels, and by 80-95% by 2050, in compliance with the EU target and the recommendations from climate scientists. The Danish government wants all sectors, including non-ETS sectors, to contribute with concrete and documented reductions up to 2020 and beyond. Within the EU, Denmark has an obligation to reduce non-ETS emissions in the period 2013-2020, increasing to a total reduction of 20% in 2020 compared with 2005. All of Denmark's energy supply, including transport energy consumption, shall be based on renewable energy by 2050. As part of this, oil for heating purposes and coal are to be phased out by 2030 and electricity and heating supply is to be 100% covered by renewable energy by 2035.

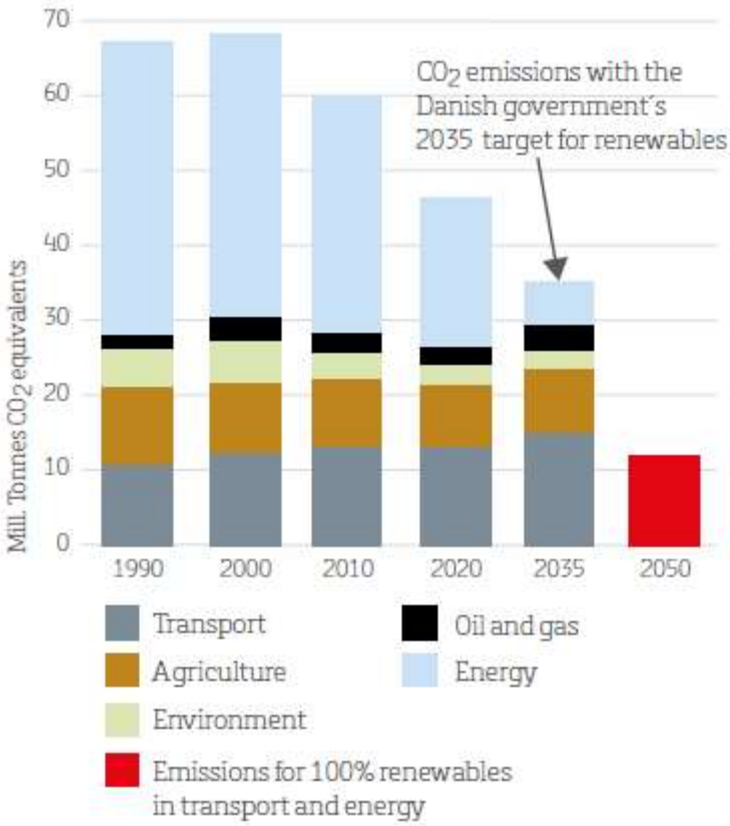


Figure 23 - Historical and projected Danish greenhouse gas emissions without policy changes up to 2020 (Source: Danish Climate Policy Plan, 2013)

In 2014, the parliament passed the Danish climate law. The law is supposed to ensure a stable direction and framework around the Danish climate policies. The goal is to transform the Danish economy into a low-emission society by 2050, resulting in a resource efficient society where energy supply is based on renewable energy resources and where the greenhouse gas emissions from other sectors is significantly lower, while at the same time leaving room for economic growth and development.

In compliance with the EU policy Denmark must reduce its non-ETS emissions by 39% by 2030 relative to 2005.

In 2015, total Danish greenhouse gas emissions had fallen by about 27% compared with 1990. Basic scenario projections, according to the Danish Energy and Climate Outlook 2017, show a fall in total emissions up to 2020, mainly due to the deployment of and conversion to renewables as well as decreased energy consumption as a consequence of energy efficiency improvements. After 2020, and with the assumption of no new policy, the schemes for renewable energy capacity installation and energy saving efforts will not be replaced by new ones, which will lead to an increase in emissions. Considering the realization of the announced phase-out of coal by 2023, emissions are expected to drop in a period up to 2025, and after which they will slowly begin to rise again. A reduction of emissions by 39% by 2030 compared to 1990 is then projected.

- Energy: reduction by 15% by 2030 compared to 2015 (considering the alternative scenario)
- Transport: stabilization of the emissions by 2030 compared to 2015
- Agriculture: stabilization of the emissions by 2030 compared to 2015
- Other: reduction by 15% by 2030 compared to 2015

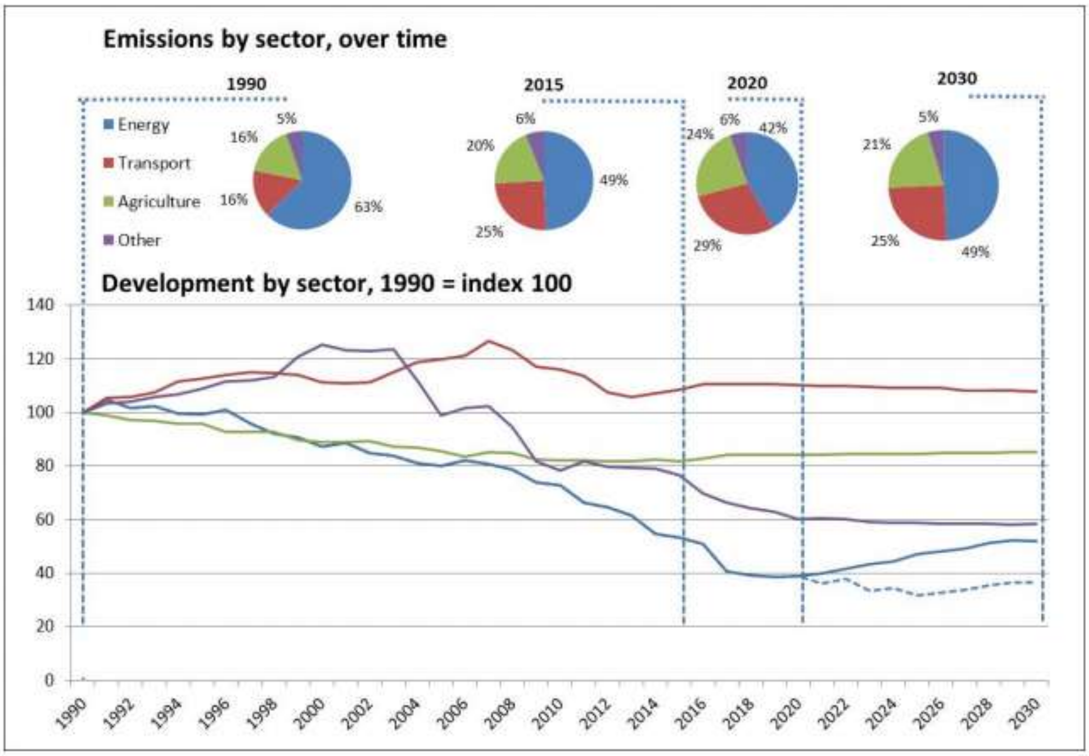


Figure 24 - Development in emissions and share of total emissions by sector (Source: Denmark's Energy and Climate Outlook, 2017)

It should be noted that the Danish Energy and Climate Outlook is published each year and take into account only the policies now implemented. After 2020, a new Energy Policy will be elaborated and according to the Danish Climate Law, new national climate targets are to be proposed every fifth year by the minister for energy, utilities and climate.

GERMANY

In November 2016, the German government adopted the Climate Action Plan 2050. The long-term goal is to become extensively greenhouse gas-neutral by 2050 and the medium-term target is to cut greenhouse gas emissions in Germany by at least 55% by 2030 compared to 1990 levels. A broad dialogue process was implemented to elaborate the action plan, with suggestions for strategic climate measures up to 2030. In its Climate Action Plan 2050, the German government also lays down 2030 targets for individual sectors:

- Energy sector: reduction by 49% by 2030 compared to 2014
- Industry: reduction by 21% by 2030 compared to 2014
- Buildings: reduction by 39% by 2030 compared to 2014
- Transport: reduction by 39% by 2030 compared to 2014
- Agriculture: reduction by 15% by 2030 compared to 2014

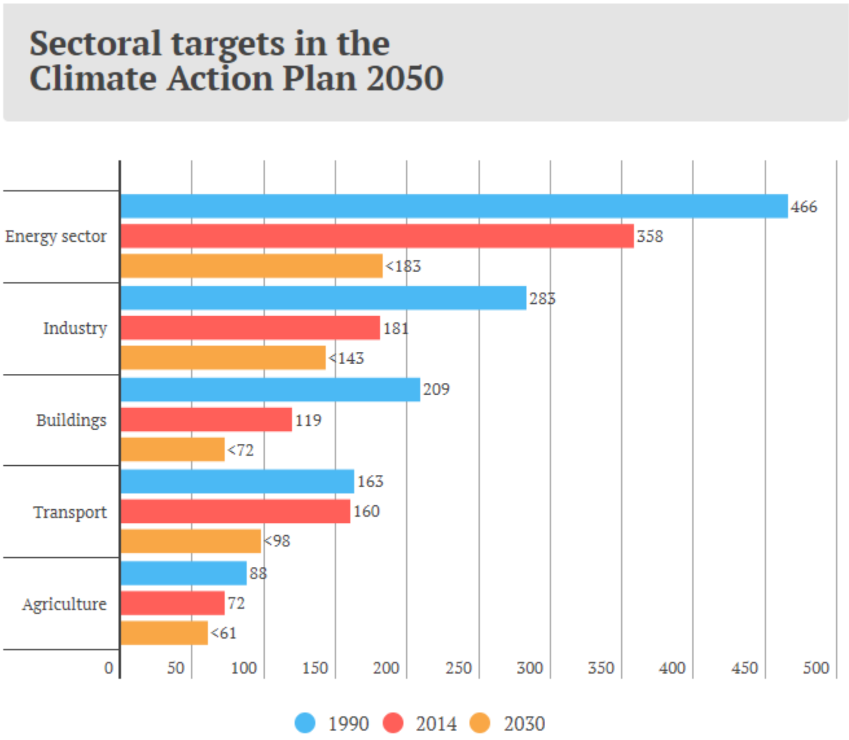


Figure 25 - Sectoral historical and target emissions (Source: Federal Ministry for the Environment, Nature Conservation, Construction and Reactor Safety, 2017)

To ensure the 2030 targets are achieved, in 2018 the Climate Action Plan 2050 will be underpinned with a programme of measures with quantifiable effects on reductions. An evaluation will be carried out for each programme of measures prior to its implementation to assess its possible ecological, social and economic impacts.

Furthermore, the regions, districts and cities also implement climate action plan on their territory. The district of Ostholstein has fixed climate protection goals in 2016 in its “Integriertes Klimaschutskonzept” to reduce the CO_2 emissions by 30% by 2030 compared to 2013 and by 85% by 2050 compared to 2013.

INTERNATIONAL SHIPPING SECTOR

Maritime transport emits around 1 000 MtCO_2e annually and is responsible for about 2.5% of global greenhouse gas emissions (3rd IMO GHG Study). Shipping emissions are predicted to increase between 50% and 250% by 2050, depending on future economic and energy developments. According to the 2nd IMO GHG Study, ship's energy consumption and CO_2 emissions could be reduced by up to 75% by applying operational measures and implementing existing technologies. The EU and its Member States have a strong preference for a global approach led by the International Maritime Organization (IMO) to reduce the energy consumption and GHG emissions of the shipping sector[17]. The European Commission's 2011 White Paper on transport suggests that the EU's CO_2 emissions from maritime transport should be cut by at least 40% from 2005 levels by 2050, and if feasible by 50%. However international shipping is not covered by the EU's current emissions reduction targets.

In 2013, a strategy was set out by the Commission to include maritime emissions into the EU's policy for reducing its domestic GHG emissions. The strategy consists in three steps:

- Monitoring, reporting and verification of CO_2 emissions from large ships using EU ports
- Greenhouse gas reduction targets for the maritime transport sector
- Further measures including market-based measures in the medium to long term

From 2018, the MRV companies (ships over 5000 gross tonnes loading/unloading cargo/passengers at EU maritime ports) are to monitor and report their related CO_2 emissions, submit to an accredited MRV shipping verifier a monitoring plan and submit the verified emissions through THETIS MRV (a dedicated European Union Information system currently under development by the European Maritime Safety Agency).

[17] Reducing emissions from the shipping sector, European Commission https://ec.europa.eu/clima/policies/transport/shipping_en

At the strait level, the application of the national objectives (disaggregated by sector) results in a reduction of the emissions **by 17% by 2030**, compared to 2016. The following table presents the main hypothesis made to estimate the decarbonization path of the Fehmarnbelt.

Table 5 - Hypothesis for the estimation of the decarbonization path of the Fehmarnbelt

Emission source (within the strait's boundary)	Source of hypothesis	% of reduction	Emissions 2016 (tCO_2e)	Emissions 2030 (tCO_2e)
Port operations	European Commission's target on CO2 emissions from maritime transport	-40% between 2005 and 2050 (corresponding to -12.3% between 2016 and 2030)	NC	NC
Maritime transport	European Commission's target on CO2 emissions from maritime transport	-40% between 2005 and 2050 (corresponding to -12.3% between 2016 and 2030)	479 652	420 655
In-land traffic	Transport target in Danish Energy and Climate Outlook 2017 and German Climate Action Plan 2050	DK: stabilization between 2015 and 2030 (corresponding to -0% between 2016 and 2030) DE: -39% between 2014 and 2030 (corresponding to -33.3% between 2016 and 2030)	292 275	256 332
Industries	Energy target in Danish Energy and Climate Outlook 2017 and Industry target in German Climate Action Plan 2050	DK: -15% between 2015 and 2030 (corresponding to -13.9% between 2016 and 2030) DE: -21% between 2014 and 2030 (corresponding to -18.1% between 2016 and 2030)	0	0
Buildings	Energy target in Danish Energy and Climate Outlook 2017 and Building target in German Climate Action Plan 2050	DK: -15% between 2015 and 2030 (corresponding to -13.9% between 2016 and 2030) DE: -39% between 2014 and 2030 (corresponding to -33.3% between 2016 and 2030)	710 864	554 136
TOTAL			**1 482 791**	**1 231 123**

This reduction is due to the actions implemented at all the levels (national, regional, local) and corresponds to the path that is being taken with the actual strategies. The emissions can also be reduced by implementing new actions specifically on the strait's boundary.

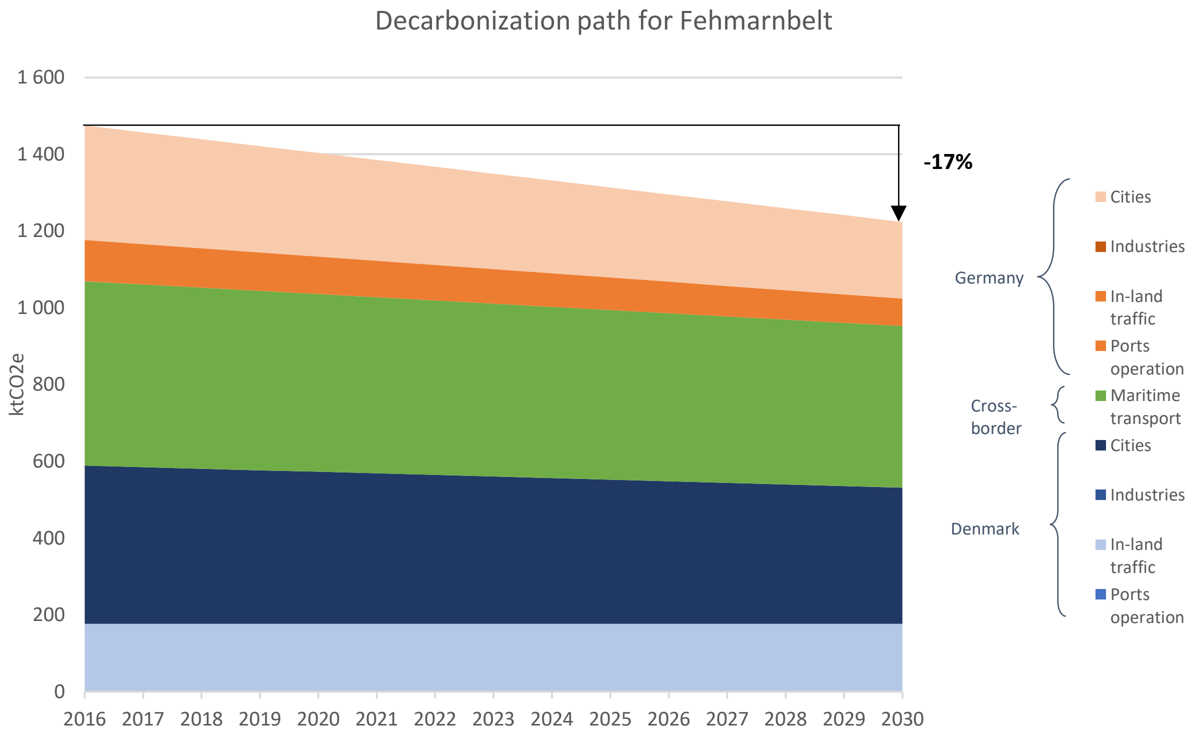


Figure 26 - Decarbonization path for the Fehmarnbelt, based on the national sectorial targets (Source: I Care & Consult)

Furthermore, it is important to note that the new Fehmarnbelt tunnel will also help to reduce the emissions of the traffic between the two countries. The Fehmarnbelt link is part of the European TEN-T network whose objective is to enhance the efficiency of the infrastructure to have less environmental impact. Therefore, one of the objective is to transfer more freight from the roads to the railway, to reduce energy consumption and to ease congestion on local roads and in cities. With the fixed link, the rail freight journey will be shortened by 160 km between Scandinavia and Europe.

Indeed, even though the construction of the fixed link will be a source of greenhouse gas emissions (about 2 000 $ktCO_2e$) and the operation will also emit greenhouse gases (about 5.9 $ktCO_2e$), according to the Greenhouse Gas Emission Inventory of the Fehmarnbelt Fixed Link, published in 2013, there will still be reduction in the emissions due to the traffic. Once built, the Fehmarnbelt project will result in a reduction of 43 to 198 ktCO2e per year, depending on the traffic scenario (all the traffic goes through the tunnel and the ferries stop operating or half the passenger cars continue to take the ferries), compared to a "zero-alternative" (without fixed link).

Scandlines aims to implement zero-emission ferries around 2020 between Rodby and Puttgarden, operating on electricity from neighboring windmill farms. This will impact the estimation of emissions reduced by the operation of the fixed link, however, according to the report on amended emissions published in 2015, a significant reduction of emissions will still be achieved. Furthermore, considering a more global scale, the implementation of the fixed link will not only allow a reduction of the emissions linked to the road transport in the strait, but will also impact emissions from transport in the two countries. A reduction of the flights between Hamburg and Copenhagen is expected, as happened with the construction of a railway between Hamburg and Berlin, due to the presence of a fast train between those two cities.

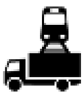
4. Towards the implementation of action plans

Fehmarnbelt developed an action plan contributing to the reduction of the strait's emissions. The action plan has 5 main actions about "People meet across the Fehmarnbelt and generate less CO_2". These actions are mainly cross-border actions to strengthen the cooperation between the two regions:

- "New stations": this action consists of ensuring that the new stations are equipped to service the costumers expected to use the trains.
- "Types of traffic and the new stations on the upgraded railway": this action consists of ensuring that a number of trains stop at the stations in the Fehmarnbelt Region to improve the accessibility to the region.
- "Connection between new station and town": this action consists of establishing public transport between the towns and the new stations.
- "Get more people to use the train, new mobility in the Fehmarnbelt Region": this action consists in encouraging the transport by train instead of cars in the region.
- "Reintroduction of the Fehmarnbelt Ticket": this action consists of promoting the use of public transports by proposing an affordable ticket to use on both sides of the strait.

All these actions should mainly impact on the in-land traffic emissions by promoting the use of public transport and electric vehicles.

Table 6 - Impact of the actions of Fehmarnbelt on each source of emissions

Thematic axes	Cross-border
In-land traffic 	• New stations • Types of traffic and the new stations on the upgraded railway • Connection between new station and town • Get more people to use the train, new mobility in the Fehmarnbelt Region • Reintroduction of the Fehmarnbelt Ticket

1. Carbon footprint methodologies and key studies

a) Port level

The WPCI[18] (World Ports Climate Initiative) developed a free on-line carbon footprinting calculator (scope 1, 2 and 3), that gave the ports guidance and an operational calculating tool to start developing a GHG inventory[19].

The WPCI has been launched in 2008 under the initiative of the *International Association of Ports and Harbors* (IAPH) and gathers 55 of the world's key ports. They all adopted the "C40[20] *World Ports Climate Declaration*", to mitigate the GHG emissions related to ports and port operations, while maintaining their roles as transportation and economic hubs.

Amongst the PASSAGE project stakeholders, the ports of Tallinn and Dunkirk are members of the WPCI. The Finnish Port Association was also one of the participating ports to the WPCI project "Carbon Footprinting Guidance Document", which is led by the port of Los Angeles.

As transportation hubs for sea-based and land-based activities, ports are crucial stakeholders within a strait. The GHG emissions assessment generated in their operational perimeter has been the subject of some scientific works. Two of them are briefly presented below.

At a port activity level, Winnes H. et al. has carried out *Reducing GHG emissions from ships in port areas;* a case study of the Port of Gothenburg in 2010. Five different operational modes have been identified and considered to calculate the port GHG emissions (see graph opposite).

The study provides quantification of the potential reduction in ships' GHG emissions that ports might implement, as well as projections and scenarios.

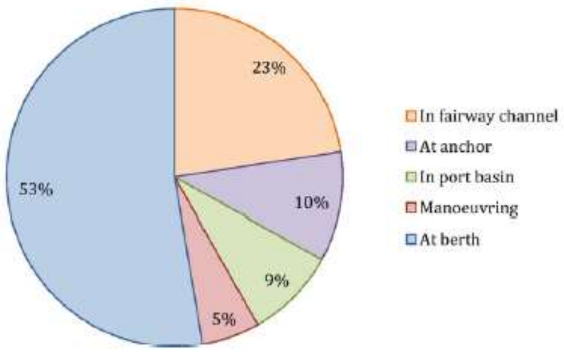


Figure 27 - GHG emissions divided in five different operational modes, from ships to and from Port of Gothenburg in 2010 (Source: Winnes H. et al.)

In *Estimating GHG emissions of marine ports – The case of Barcelona* (2011), Villalba and Gemechu asked different stakeholders to collect data and to assess land-based and vessel movement emissions in the port area. For example, a collaborative work with the port authority enabled reliable data on vessel operations to be collected. It is calculated that half of the 331 390 tonnes of CO_2 equivalents of the Port of Barcelona in 2008 are due to land-based activities, namely energy consumption. The vessel

[18] http://wpci.iaphworldports.org/
[19] http://wpci.iaphworldports.org/carbon-footprinting/
[20] C40 is mainly known as the "C40 cities" network, which is a climate leadership group. See following section.

movement emissions in the port limits (ships arriving/departing into/from the port, manoeuvring, hotelling) reached 175 184 tonnes of CO_2 equivalents.

b) Logistics and maritime traffic

As straits are significant maritime and in-land transportation hubs, the GLEC framework [21] (Global Logistics Emissions Council Framework) is a relevant tool to assess the related GHG emissions. Indeed, as stated by Blanco [22] and reminded in the GLEC framework, "there are inherent differences in both the amount and the detail of the data available to the different stakeholders throughout the transport chain".

The methodology has been designed as a company-specific guidance to join forces with the *GHG Protocol Corporate Standard*. For each mode of transportation, it provides a synthetic analysis namely similarities, differences, uncertainties etc. of the main base methodologies identified.

Figure 28 - Principle of the GLEC Framework (Source: Smart Freight Centre)

Among the rich bibliography dealing with maritime traffic related GHG emissions (some are also dealing in parallel with the port area ones) one of the most relevant scientific paper that has been identified is *A comprehensive inventory of ship traffic exhaust emissions in the European sea areas in 2011*. AIS[23] data and the STEAM[24] emission model have been used to model emissions (CO_2, NOx, SOx, CO, and PM2.5) induced by ship traffic in European sea areas. The figure below presents the geographic distribution of shipping emissions of CO_2. Among the 30 "hotspots" identified in terms of ship emissions in 2011, some are part of the PASSAGE project area: English Channel, Gulf of Fehmarn, Tallinn harbour, Livorno harbour.

[21] http://www.smartfreightcentre.org/glec/glec-framework
[22] Blanco, E. E. (2013). Assessing Global Freight Emission Methodologies
[23] Automatic Identification System
[24] Ship Traffic Emission Assessment Model

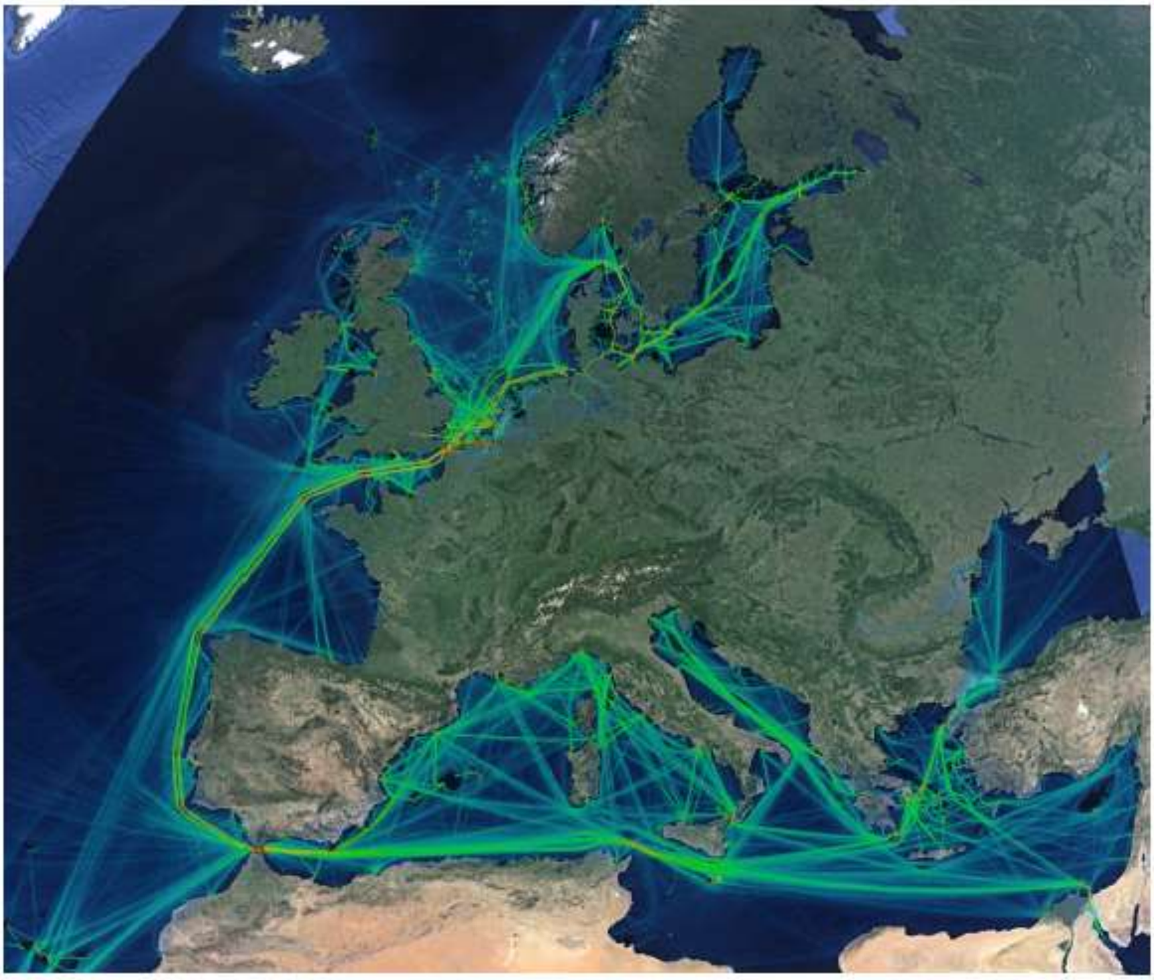


Figure 29 - Geographic distribution of shipping CO_2 emissions in Europe in 2011 (Source: Finnish Meteorological Institute)

Another relevant methodological approach using AIS data to calculate maritime traffic CO_2 emissions in a strait was proposed in 2010 by See Chuan Leong and al.: *Estimation of CO_2 Emission from Marine Traffic in Singapore Straits Using AIS Data*. By assessing the GHG emissions by ship type daily, it has been demonstrated that such a tool is vital for port authorities to manage their emissions, and that quite simple solutions like reducing operational speed and increasing gross tonnage could lead to compliance with IMO (International Maritime Organization) GHG target. During the monitoring period (January to June 2014), they estimated that on average, each ship emitted 14 432 tons of CO_2 daily.

AIS[25] data and the STEAM[26] emission model have also been used by Tichavska and Tovar in *Port-city Exhaust Emission Model: an approach to Cruise and Ferry operations in Las Palmas Port*. This methodology enables both CO_2 and air pollutant emissions (NOx, SOx, PM, CO) to be assessed and classified in four mains classes: hotelling, manoeuvring, cruising operations and weight.

In *The role of sea ports in end-to end maritime transport chain emissions* (2014), Gibbs et al. use the UK – Department for Transport (DfT) Maritime Statistics Data to assess some Great British port GHG emissions.

[25]Ibid.
[26]Ibid.

c) Cities and hinterland activities

The GHG protocol for Cities[27] (Global Protocol for Community-Scale GHG Emission Inventories – GPC) has similar strait hinterland issues, as these territories have different types of economic activities (cities, industries, transportation, etc.) and possibly different ways to account their GHG emissions.

It provides reporting and accounting principles at a territorial scale, for instance, to define the inventory boundary. It also brings global and sector-specific accounting and reporting guidance. Furthermore, the methodology enables stakeholders to understand how a GHG inventory can be used to set mitigation goals and track performance over time. The "GPC protocol" is an accounting-reporting standard for cities, which has been developed by World Resources Institute, C40 Cities Climate Leadership Group and ICLEI – Local Governments for Sustainability (ICLEI). It is one of the standard coming from the GHG Protocol Initiative, a partnership launched at the end of 1990's between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD).

In *The role of sea ports in end-to end maritime transport chain emissions* (Gibbs and al. 2014), the road traffic emissions, which might be considered as hinterland activities, are assessed.

It is demonstrated that the road GHG annual emissions (138 kt of CO_2) of the UK's busiest container port of Felixstowe are twice higher than the port ones (71.5 kt of CO_2).

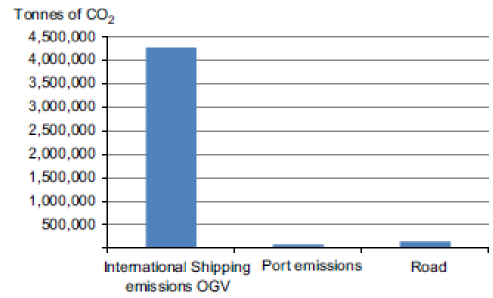


Fig. 1. Comparison of CO_2 emission sources at Felixstowe port (tonnes of CO_2).

Figure 30 - Comparison of CO2 emission sources at Felixstowe port (Source: Gibbs and al. 2014)

In comparison, the International Shipping OGV (Ocean Going Vessels) emissions seem to be huge, but it is worth noting that they are assessed for the overall origin-destination distance of the journey.

Other in-land activities are also generating GHG emissions within a strait area, like cities, industries or companies. These stakeholders carry out GHG inventories due to legal obligation or on voluntary bases.

For instance, through the Covenant of Mayors for Climate & Energy and the setting of its Sustainable Energy Action Plan (SEAP), the Livorno municipality (Corsica Channel) has carried a GHG inventory.

In the industry sector, company emissions could be registered in on-line data base, like in France in the IREP data base which collect pollutant emissions from the main industrial companies.

[27] http://www.ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities

Other types of companies operating at a strait level might also achieve out GHG inventory, like the Getlink Group (formerly Eurotunnel Group) Eurotunnel Group. At cross-border scale (UK + France) and every two years, Carbon Trust Standard realizes a GHG inventory audit, and the Getlink Group also discloses for the same perimeter the GHG emissions in the yearly registration document. The Port of Dover is also a Carbon Trust Standard holder and aims to become a carbone neutral port.

On the French shore, Eurotunnel has achieved a legally obligated carbone footprint in 2012 and 2015. Since the first GHG inventory has been carried out at cross-border scale (2006, sea breakdown in the chart opposite), Eurotunnel has set several measures to reduce their GHG emissions.

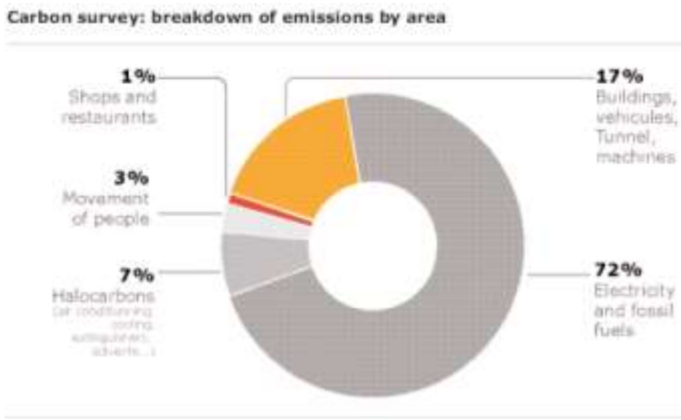


Figure 31 - Eurotunnel GHG emissions (Source: Eurotunnel, Environmental Report 2007)

2. Calculation methodologies

a) Port operations

i. Energy consumptions

The energy consumptions (such as electricity, natural gas, diesel, petrol, propane…) are provided by the Port Authority. The emission factors are taken from the national databases when available:

- France: ADEME Base Carbone[28] (Environment and Energy Management Agency), last updated in 2016, except for the electricity emission factor which was updated in 2014.
- UK: DEFRA / DECC[29] (Department for Environment Food & Rural Affairs and Department of Energy & Climate Change), last updated in 2016.
- Finland: Motiva[30], last updated in 2017 and Helsinki-Uusimaa Regional Council[31], last updated in 2015.

[28] www.bilans-ges.ademe.fr
[29] https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting
[30] https://www.motiva.fi/ratkaisut/energiankaytto_suomessa/co2-laskentaohje_energiankulutuksen_hiilidioksidipaastojen_laskentaan/co2-paastokertoimet
[31] https://www.uudenmaanliitto.fi/tietopalvelut/uusimaa-tietopankki/aineistot/alue_ja_ymparisto

For the other countries, where no national database was found, the IEA (International Energy Agency) factors specific to the country are used for electricity consumption and the DEFRA or IPCC (Intergovernmental Panel on Climate Change) standard factors are used for fuel consumption.

ii. Ships in port areas

To estimate the annual emissions from the ships in port areas (manoeuvring, at berth, etc.), the following equation is used (from the publication "*Estimating GHG emissions of marine ports – the case of Barcelona*" by Gara Villalba and Eskinder Demisse Gemechu):

$$Emission\ (tCO2e) = N\ \times PO\ (kW) \times t\ (hours) \times LF\ (\%) \times EF\ (tCO2e/kWh)$$

With:
N = Number of ships calling to the port
PO = power output in KW
t = time spent in the port in the mode considered in hours
LF = load factor
EF = emission factor in tCO_2e/kWh

This equation is used to estimate the emissions from the main engine and the auxiliary engine in the different modes (manoeuvring, at berth, etc.).

- **Number of ships per type**

The number of ships calling to the port for 2016 is provided by the Port Authority, per type of ship if available.

- **Power output**

The power output of each engine depends on the type of ship and the size (gross tonnage). When local data is available, it is directly used to estimate the emissions. When no local data is available, the European Environment Agency (EEA) provides, in the "*EMEP/EEA air pollutant emission inventory guidebook"* from 2002, a table with the estimated main engine power and auxiliary engine power by ship type and gross tonnage. As the gross tonnage is not always known, the average for all ships is taken into account, as indicated in the table below:

Table 7 - Estimated power of engines per ship type (Source: European Environment Agency, 2002)

Ship type	Estimated main engine power (kW) – total power of all engines	Estimated auxiliary power kW (medium speed)
Liquefied gas tanker	5 900	300
Chemical tanker	5 700	300
Other tanker	7 900	300
Bulk dry cargo	9 100	380
General cargo	3 300	175
Container	16 300	1 400
Passenger/ Ro-ro	12 800	1 000

➢ **Time spent in port areas**

This data is provided by the Port Authority, per type of ship when available.

➢ **Load factor**

As engines are not operating at their maximum tested power, the load factor needs to be considered. When local data is available, it is used directly to estimate the emissions. However, when no data is available, two modes are considered: manoeuvring and in port (including the un-loading, loading and hoteling phases). The following hypothesis, from the report "*Quantification of emissions from ships associated with ship movements between ports in the European Community*" by the European Commission (2002), are taken into consideration:

Table 8 - Load factor per engine and mode (Source: European Commission, 2002)

Mode	% load of MCR for Main Engine operation	% load of MCR for Auxiliary Engine operation
Manoeuvring	20%	50%
In port	20%	40%
At sea	80%	30%

➢ **Emission factors**

As recommended in the publication "*Estimating GHG emissions of marine ports – the case of Barcelona*" by Gara Villalba and Eskinder Demisse Gemechu, the following emission factors are considered (taken from ICF International, 2009[32]):

- For primary engine at intermediate speed: 677.91 gCO_2/kWh and 0.004 gCH_4/kWh, corresponding to 678 gCO_2e/kWh;
- For auxiliary engine: 722.54 gCO_2/kWh and 0.004 gCH_4/kWh corresponding to 722.6 gCO_2e/kWh.

b) Maritime transport

i. Local maritime cruise

The number of trips by ferries between the two shores in 2016 is provided by the Port Authorities or the Maritime Companies. The distance travelled is estimated with the websites "searoutes.com" and "sea-distances.org".

The emission factor used is taken from the Base Carbone (ADEME, France): 419 kgCO2e/km for Ro-Pax cargoes – passengers.

[32] ICF International, 2009. *Current methodologies in preparing mobile source port related emission inventories*. US EPA

ii. Maritime cruise with calls to the strait's ports

The Port Call Statistics in 2016 are provided by the Port Authorities, containing if possible the type of ship, the weight transported by each ship and the origin/destination. When all the information is available, the following equation is used to estimate the emissions:

$$Emissions\ of\ one\ ship\ (tCO2e) = d(km) \times w\ (tonnes) \times EF\ (tCO2e/t.km)$$

With:
d = distance travelled by the ship. This distance is disaggregated between the distance within the strait's boundary and outside the strait's boundary.
w = weight transported by the ship.
EF = emission factor

- **Distance**

The distance is estimated based on the country of origin/destination following "*the CERDI-seadistance database*" (by Bertoli S., Goujon M. and Santoni O. in 2016).

The distance within the strait's boundary is determined with Google Earth, based on the distance of the strait (see figures in the preceding chapter), the location of the port within the strait and the direction of the vessels. The distance was determined as showed in the following figure (in blue), with the distance from the port (here Tallinn) to the centre of the strait added to the distance from the centre to the limits of the boundary:

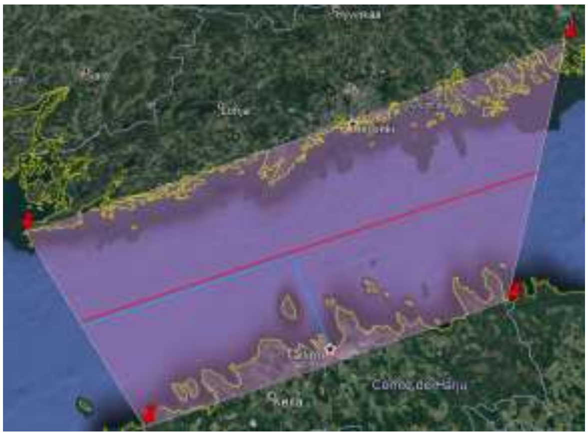


Figure 32 - Example of the determination of the distance within the strait's boundary (Source: I Care & Consult)

The following table presents the distances for each port, depending on the direction of the vessel. Those distances can also be seen in the figures of the geographic strait boundary.

Table 9 - Distances within the strait's boundary for each port (Source: I Care & Consult)

Strait	Ports	Distance from North / East (km)	Distance from South / West (km)
Dover / Pas de Calais Strait	Calais	47	78
	Boulogne-sur-Mer	87	50
	Dunkirk	45	122
	Dover	62	81
Gulf of Finland	Helsinki	94	144
	Tallinn	123	105
Corsica Channel	Bastia	79	40
	Livorno	63	114
Strait of Otranto	Vlorë	150	75
	Durres	95	200
	Brindisi	94	130
Strait of Corfu	Sarandë	50	/
	Igoumenitsa	/	26
	Corfu	/	43

The distance outside the strait's boundary is determined by subtracting the distance within the strait's boundary to the total distance between the two ports (on within the strait and the other anywhere in the world).

- In the case of the strait of Corfu, given the geography of the strait, almost no ships travel towards the north/east side of the strait, from the ports of Corfu or Igoumenitsa and no ships travel towards the south/west side of the strait from the port of Sarandë. Therefore, the distances linked to those sides are not considered here.**Emissions factors**

The following emission factors are used (from DEFRA/DECC, updated in 2016):

Table 10 - Emission factors per type of ship (Source: DEFRA/DECC, 2016)

Type of vessel	Emission factor (in $kgCO_2e/t.km$)
Bulk carriers	0.0042
Container	0.0190
Gas carriers	0.0136
General dry cargo	0.0156
Passengers ships	0.4581
Roro	0.0607
Tankers	0.0106
Other (average emission factor)	0.0123

The weight is usually provided in the Port Call Statistics, however if this information is missing the weight can be estimated in some cases (based on information provided by the Port Authority or based on the average weight of the other ships of the same type). In other cases (for passenger ships), the weight transported is not known but the number of passengers is provided. In this case, the emission factor (in $kgCO_2e$/pass.km) is taken from the Base Carbone (ADEME), updated in 2016:

Table 11 - Emission factor for passenger ship (Source: ADEME, 2016)

Type of vessel	Emission factor (in $kgCO_2e$/pass.km)
Ferries / Cruise ships	0.468

iii. Transit maritime cruise

The Ships databases in 2016 are provided by the Coastguard Agencies (where existing). They contain, when available, the type of ship, the weight transported by each ship and the previous port of call and the next port of call. When all the information is available, the following equation is used to estimate the emissions:

$$Emissions\ of\ one\ ship\ (tCO2e) = d(km) \times w\ (tonnes) \times EF\ (tCO2e/t.km)$$

With:
d = distance travelled by the ship. This distance is disaggregated between the distance within the strait's boundary and outside the strait's boundary.
w = weight transported by the ship.
EF = emission factor

- **Distance**

The distance is estimated based on the country of origin/destination following "*the CERDI-seadistance database*" (by Bertoli S., Goujon M. and Santoni O. in 2016).

The distance within the strait's boundary is determined with Google Earth, based on the limits of the strait (as defined in the previous chapters), including the main ports identified:

Table 12 - Distance within the strait's boundary (Source: I Care & Consult)

Strait	Distance of the strait (km)
Dover / Pas de Calais Strait	100
Gulf of Finland	164
Fehmarnbelt	30
Corsica Channel	55
Strait of Otranto	130
Strait of Corfu	102

The distance outside the strait's boundary is determined by subtracting the distance within the strait's boundary to the total distance between the two ports.

➢ Emissions factors

The following emission factors are used (from DEFRA/DECC, updated in 2016):

Table 13 - Emission factors per type of ship (Source: DEFRA/DECC, 2016)

Type of vessel	Emission factor (in $kgCO_2e/t.km$)
Bulk carriers	0.0042
Container	0.0190
Gas carriers	0.0136
General dry cargo	0.0156
Passengers ships	0.4581
Roro	0.0607
Tankers	0.0106
Other (average emission factor)	0.0123

When no information is available on the weight transported, an emission factor in $kgCO_2e/veh.km$ can be used (from the Base Carbone, ADEME, updated in 2016):

Table 14 - Emission factors per type of ship (Source: ADEME, 2016)

Type of vessel	Emission factor (in $kgCO_2e/veh.km$)
Tankers	264
General cargo	145
Passenger ship	495
Other (average)	250

c) Induced economical activities

i. Industry

To calculate the GHG emissions due to industry in each strait, the following methodology is used.

Only the industries participating to the EU emissions trading systems are considered. These industries are identified by cities of the straits on the EU emission trading system website[33]. All the industries with an address in a city of the straits are taken into account.

For each industry identified, the "verified emissions" stated on the EU emission market for 2016, in tons of CO_2 are used. This data is available on the EU emission trading system website. If no emission is stated for 2016 for an industry, emissions for the most recent year are considered.

The emissions of all the industries identified are then summed by strait.

[33] http://ec.europa.eu/environment/ets/napMgt.do;EUROPA_JSESSIONID=g-XI_tEdLcXzpzAnMq_2ayWUZgqc7WTsxueOiGYcOiCF6INAaes1!1777535239?languageCode=en

ii. Cities

To estimate the annual GHG emissions due to the residential and economical activities in the cities of the strait, the following methodology is used:

$$Emissions\ (tCO2e) = \frac{Emissions_{National}}{Population_{National}} \times Population_{Local}$$

The national emissions from residential and economical activities are taken from the national inventories submitted to the United Nations Framework Convention on Climate Change (UNFCCC)[34] (1.A.4 Energy - Fuel combustion - Other sectors, including commercial/institutional, residential and agriculture/forestry/fishing). Most of the European countries are included in the Annex I Parties and need to report their emissions every year. The latest reporting year is 2014. For the countries (such as Albania) that are not part of the Annex I Parties, the inventory need to be submitted every four years. The latest submission was taken into account (2009 for Albania). However, it is considered that it is still representative for the year of reporting (2016).

The emissions (in tCO_2e) are then divided by the population of the country, in the reporting year when available (if the population in the reporting year is not available, the closest available year is taken into account). The population number are taken from the national statistics institute of each country:

- France: INSEE[35] (2014)
- UK: Office for National Statistics[36] (2014)
- Estonia: Statistics Estonia – Eesti Statistika[37] (2017)
- Finland: Statistics Finland – Tilastokeskus[38] (2016)
- Denmark: Statistics Denmark / Statbank Denmark – Danmarks Statistik / Statistikbanken[39] (2014)
- Germany: Statistische Ämter des bundes und der länder[40] (2014)
- Italy: Istat – Instituto nazionale di Statistica[41] (2014)
- Albania: Instat – Instituti i Statistikave[42] (2009)
- Greece: Hellenic Statistical Authority[43] (2011)

Finally, the regions considered for the residential and commercial activities are the NUTS 3 regions which shore correspond to the strait. The information on the population in the NUTS 3 regions is given in Eurostat[44], last updated in 2015.

Exceptions:

[34] http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php
[35] https://www.insee.fr/fr/accueil
[36] https://www.ons.gov.uk/
[37] https://www.stat.ee/en
[38] http://tilastokeskus.fi/index_en.html
[39] http://www.statbank.dk/statbank5a/default.asp?w=1366
[40] http://www.statistik-portal.de/Statistik-Portal/
[41] http://www.istat.it/en/
[42] http://www.instat.gov.al/al/home.aspx
[43] http://www.statistics.gr/en/greece-in-figures
[44] http://ec.europa.eu/eurostat/cache/RCI/#?vis=nuts3.population&lang=en

- For Dover / Pas de Calais Strait, the NUTS3 areas Pas-de-Calais and Nord include the Lille Metropolis and the Mining Basin, which are not linked to the strait's activities. It was then decided to include only the population of the "Pôle Métropolitain Côte d'Opale"[45].
- For the Gulf of Finland's Strait, the Helsinki-Uusimaa Region is much larger than the area of the Port of Helsinki, it was then decided to consider only the capital region (i.e. Helsinki, Espoo, Vantaa and Kauniainen)[46].
- For Albania, as it is not part of EU, there are no NUTS 3 regions. Then, it was decided to take into account only the main cities on the shore[47] (Vlora and Durres for the strait of Otranto and Saranda, Konispol, Himarë and Delvinë for the strait of Corfu).

iii. Tourism

To estimate the GHG emissions due to the tourism activities in the cities of the strait, the following methodology is used:

$$Emissions\ (tCO2e) = N \times EF\ (tCO2e/night)$$

with:
N = Number of tourist nights in the areas
EF = emission factor for a hotel night (in tCO_2e/night)

The number of tourist nights in the areas is provided by the stakeholders.

The emission factor is estimated based on an average energy consumption for one hotel night, multiplied by the country's emission factors for energy consumption (for example: Base Carbone, 2016 for France and DEFRA, 2016 for the UK). The average energy consumption is taken from a study by ADEME, EU Ecolabel and AFNOR, which give the following data for a two stars hotel: an electricity consumption of 74.8 kWh/night and a water consumption of 335 l/night (last update in 2012).

d) Inland transport

i. Passengers transport

This paragraph presents the methodology used to quantify the annual GHG emissions due to the transport of the passengers that land and board in the ports of the studied straits in 2016. Two different transport modes are considered: rail and road.

For these two modes, the data needed for the calculation are the following:
- Number of passengers who travel by the transport mode
- Average distance achieved with this transport mode
- Emission factor to convert the distance in GHG emission

The following equation is then used to calculate the GHG emission by port:

$$Emissions\ (tCO2e) = N\ \times d\ (km) \times EF\ (tCO2e/km)$$

with:

[45] http://www.pm-cote-opale.fr/
[46] http://pxnet2.stat.fi/PXWeb/pxweb/en/StatFin/StatFin__vrm__vaerak/statfin_vaerak_pxt_028.px/?rxid=30517e03-c548-45ac-a2d7-6ec0fa5cabe9
[47] http://pop-stat.mashke.org/albania-cities.htm

N = Number of passengers landing and boarding in the studied port
d = Average distance
EF = Emission factor (tCO_2e/pass.km)

For each mode of transport, assumptions used to obtain the necessary data are presented below.

Road

- **Number of passengers who travel by road**

To obtain the number of passengers who land or board in the studied port and travel by road, the total number of passengers who land and board in the ports and the modal share of the port is used:

$$N = Np \times MS$$

with:
N = Number of passengers travelling by road and landing or boarding in the port (and Channel Tunnel in the case of the Dover / Pas de Calais Strait)
Np = Number of passengers landing or boarding in the port (in total)
MS = Modal share for road (in %)

The number of passengers who land or board in the ports in total is given by the port's authorities, as well as the modal share, if available.

If no information is available on the real modal share in the studied ports, the average national modal shares for 2015 are used. They are obtained on the Eurostat website[48] for all the European countries.

- **Average distance**

The average distance is considered equal to the distance between the port and the capital of the port's country. The average distance is then different for all the cities, even in the same strait. This distance is estimated thanks to Google Maps and the shortest itinerary is chosen.

Exception: the islands
For islands (ports of Bastia, Corfu and Lefkimi), the distance to the capital is not relevant.
Therefore, the average distance arbitrary chosen is the distance between the port and the furthest cost of the island, divided by 2.

This distance is disaggregated between the distance within the strait's boundary and outside the strait's boundary, in order to provide a complete picture of the emissions directly emitted in the strait's boundary, and the emissions induced by the strait but emitted outside of the boundary.
The strait's boundaries that are considered are the ones of the port region (NUTS3) and the distance between the port and the region boundary is estimated (named "NUTS3 Distance") (see schema below). To know the boundary of the region (NUTS3), the Eurostat website[49] is used and GoogleMaps is then used to estimate the distance. The disaggregation is then done as presented in the schema below, depending on the comparison between the average distance and the NUTS3 distance.

[48] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tran_hv_psmod&lang=fr
[49] http://ec.europa.eu/eurostat/cache/RCI/#?vis=nuts3.population&lang=en

If Average distance > NUTS3 Distance
Distance within the strait = NUTS3 Distance
Distance outside the strait = Average distance – Distance within the strait

If Average distance < NUTS3 Distance
Distance within the strait = Average distance
Distance outside the strait = 0 km

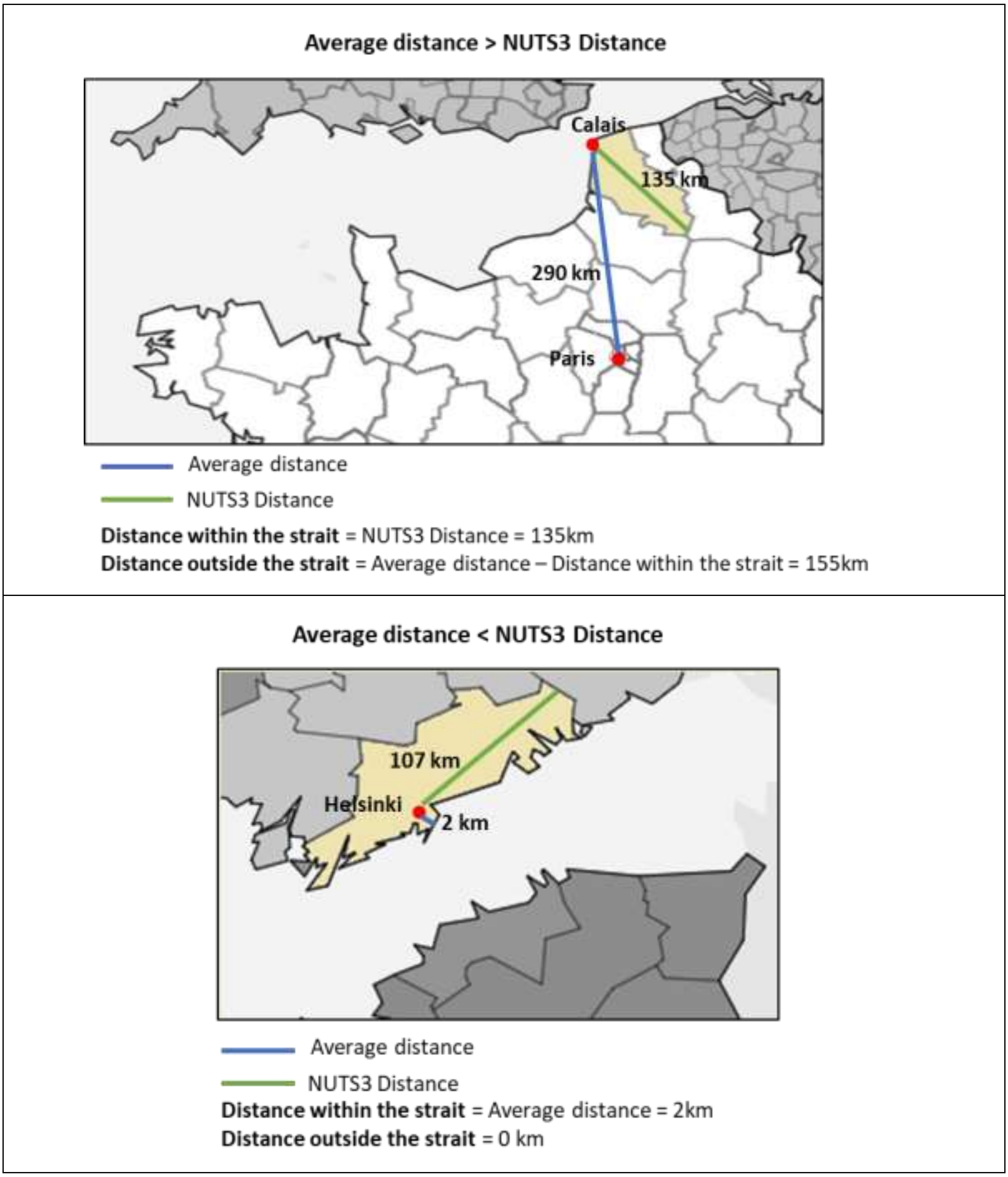


Figure 33 - Examples of estimation of the distance travelled (Source: I Care & Consult)

➢ **Emission factor**

The emission factor used is "Voiture particulière – Puissance fiscale moyenne, motorisation moyenne" ("Private car, Average fiscal power, Average motorization"), from the ADEME database "Base Carbone"[50] (updated in 2016). It is considered to be the same for all the countries.

The average load factor considered is two persons per car, considering the higher value of the European Environment Agency for travel and leisure[51].

As the unit of the emission factor is $kgCO_2e/km$, it is divided by two to take into account the load factor.

Table 15 - Example of calculations for on-road passenger transport

Example: Gulf of Finland – Passenger transport - Road

The steps for the calculation of the GHG emissions due to transport passenger by cars in Gulf of Finland are presented below:

➢ **Number of passenger for each port (landing and boarding):**

Port	Passengers
Helsinki	11 974 000
Tallinn	10 173 300

Pieces of data obtained through port authorities.

➢ **Modal share:**

National data used.

Country	Modal share
Finland	0.95
Estonia	0.98

Pieces of data available on Eurostat.

➢ **Average distance**

Country	Average distance (km) = distance to capital
Helsinki	2
Tallinn	2

Results are rounded to the nearest km.

➢ **Emission factor**

The emission factor used is 0.127 $kgCO_2$/pass.km

➢ **Results**

$$\frac{\text{Number of passengers } \times \text{Modal share } \times \text{Average distance (km)} \times \text{Emission factor (kg}CO_2\text{ /pass.km)}}{1000} = \text{Emissions (t}CO_2\text{)}$$

Port	Passengers	Modal share	Average distance (km)	Emission factor ($kgCO_2$/pass.km)	Emissions (tCO_2)
Helsinki	11 974 000	0.95	2	0.127	2 878
Tallinn	10 173 300	0.98	2	0.127	2 522

[50] http://www.bilans-ges.ademe.fr/fr/basecarbone/donnees-consulter/liste-element/categorie/151
[51] https://www.eea.europa.eu/publications/ENVISSUENo12/page029.html

Rail

- **Number of passengers who travel by train**

To obtain the number of passengers who land or board in the port and travel by train, the same equation than for road is used.

$$N = Np \times MS$$

with:
N = Number of passengers who travel by train and landing or boarding in the port (or travelling through the Channel Tunnel in the case of the Dover / Pas de Calais Strait)
Np = Number of passengers landing or boarding in the port (in total)
MS = Modal share for train (in %)

The number of passengers who land or board in the ports in total are given by the port's authorities, as well as the modal share, if available.

If no information is available on the real modal share in the studied ports, the average national modal shares for 2015 are used. They are obtained on the Eurostat website[52] for all the European countries.

- **Average distance**

The distance travelled in average by the passengers is calculated by country. Thus, the distance is the same for all the ports in a same country (for example Dunkirk, Calais and Boulogne-sur-Mer in France).

To obtain it, a ratio between passengers.km completed in 2015 in the whole country and the number of passengers who travelled in the whole country is calculated. These pieces of data are available on Eurostat[53] for the European countries.

Exception: the islands
For islands (ports of Bastia, Corfu and Lefkimi), the national average distance can be irrelevant. That is why, specific assumptions are used:

- For Bastia, as the national average distance seems relevant as it is almost entirely included in the NUTS 3 region, this data is then used.
- For Corfu and Lefkimi, it is considered that there are no railways on the island.

In the same way as road transport, this distance is disaggregated between the distance within the strait's boundary and outside the strait's boundary, in order to provide a complete picture of the emissions directly emitted in the strait's boundary, and the emissions induced by the strait but emitted outside of the boundary. The strait's boundaries that are considered are the ones of the port region (NUTS3) and the distance between the port and the region boundary is estimated (named "NUTS3 Distance"). The disaggregation is done depending on the comparison between the average distance and the NUTS3 distance.
If Average distance > NUTS3 Distance
Distance within the strait = NUTS3 Distance
Distance outside the strait = Average distance – Distance within the strait

[52] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tran_hv_psmod&lang=fr
[53] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rail_pa_total&lang=fr

If Average distance < NUTS3 Distance
Distance within the strait = Average distance
Distance outside the strait = 0 km

- **Emission factor**

Emission factors used are those from the ADEME database "Base Carbone"[54] (last update in 2016).
If the emission factor is available for the port's country, this factor is used.
If the emission factor is not available for the country of the port, an average factor is used, based on all the emission factors available (0,0629 $kgCO_2$/km.pass)[55].

For France, numerous factors are available, thus the emission factor "Train Grandes Lignes" is used.

Table 16 - Example of calculations for rail passenger transport

Example: Gulf of Finland – Passenger transport - Rail

The steps for the calculation of the GHG emissions due to transport passenger by train in the Gulf of Finland are presented below:

- **Number of passenger for each port (landing and boarding):**

Port	Passengers
Helsinki	11 974 000
Tallinn	10 173 300

Pieces of data obtained through port authorities.

- **Modal share:**

National data used.

Country	Modal share
Finland	0.05
Estonia	0.02

Pieces of data available on Eurostat.

- **Average distance**

National data used.

Country	Thousands pass.km	Thousands pass.	Average distance (km)
Finland	4 114 000	75 952	54.2
Estonia	286 000	6 659	43.9

Pieces of data available on Eurostat.

[54] http://www.bilans-ges.ademe.fr/fr/basecarbone/donnees-consulter/choix-categorie/categorie/176
[55] Average emission factor used for Albania and Estonia

➢ **Emission factor**

Country	Emission factor ($kgCO_2$/pass.km)
Finland	0.0452
Estonia	0.0629

National emission factor available for Finland on the ADEME's database. Average emission factor used for Estonia.

➢ **Results**

$$\frac{\text{Number of passengers } \times \text{Modal share } \times \text{Average distance (km)} \times \text{Emission factor (kg}CO_2\text{ /pass. km)}}{1000} = \text{Emissions (t}CO_2\text{)}$$

Port	Passengers	Modal share	Average distance (km)	Emission factor ($kgCO_2$/pass.km)	Emissions (tCO_2)
Helsinki	11 974 000	0,05	54	0.0452	1467
Tallinn	10 173 300	0,02	43	0.0629	549

ii. Freight transport

This paragraph presents the methodology used to quantify the annual GHG emissions due to freight transport (loaded and unloaded goods in the ports of the strait in 2016). Two different modes of transport are considered: rail and road[56].

For these two modes, data needed for the calculation is the following:
- Tonnage of goods transported by the transport mode
- Average distance achieved with this transport mode
- Emission factor to convert the distance in GHG emissions

The following equation is then used to calculate the GHG emissions by port:

$$Emissions\ (tCO2e) = T\ (t)\ \times d\ (km) \times EF\ (tCO2e/t.km)$$

with:
T = Tonnage of goods going transporting by the transport mode
d = average distance
EF = Emission factor (tCO_2e/t.km)

For each mode of transport, assumptions used to obtain these pieces of data are presented below.

[56] Except for the port for which data on waterway transport is available (case of Dunkirk)

Road

- **Tonnage of good transported by road**

To obtain the tonnage of goods passing through studied ports and transported by road, the total tonnage of goods passing through studied ports and the modal share of the port is used:

$$T = Tp \times MS$$

with:
T = Tonnage of good passing through the port and transported by road
Tp = Total tonnage of good passing through the port (and in the Channel Tunnel, in the case of the Dover / Pas de Calais Strait)
MS = Modal share for road (in %)

The tonnage of good passing through the port in total is given by the port's authorities, as well as the modal share, if available.

If no information is available on the real modal share in studied ports, the average national modal shares for 2015 are used. They are obtained on the Eurostat website[57] for all the European countries.

- **Average distance**

The average distance is calculated by country.

For each European country, the breakdown of tonnage by range of distance is available on Eurostat for national and international traffic. Data for 2016 are used.

The ranges considered are:
- Range 1: <50km
- Range 2: 50-149km
- Range 3: 150-499km
- Range 4: >500km

These pieces of data are available in tonnage and are then converted in percentage.

The average distance is calculated by using the middle mileage for each range with the following equation:

M (km) = 25km x %Range1 + 100km x %Range2 + 325km x %Range3 + 600km x %Range4

These calculated average distances are also used for islands.

As for passenger's transport, this distance is disaggregated between the distance within the strait's boundary and outside the strait's boundary, in order to provide a complete picture of the emissions directly emitted in the strait's boundary, and the emissions induced by the strait but emitted outside of the boundary. The strait's boundaries that are considered are the ones of the port region (NUTS3) and the distance between the port and the region boundary is estimated (named "NUTS3 Distance").

[57] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tran_hv_frmod&lang=fr

The disaggregation is done depending on the comparison between the average distance and the NUTS3 distance.

If Average distance > NUTS3 Distance
Distance within the strait = NUTS3 Distance
Distance outside the strait = Average distance – Distance within the strait

If Average distance < NUTS3 Distance
Distance within the strait = Average distance
Distance outside the strait = 0 km

- **Emission factor**

The emission factor used is "Ensemble articulé – marchandises diverses – PTRA 40T" ("Articulated 40T, Diverse goods"), from the ADEME database "Base Carbone"[58] (updated in 2016). It is considered to be the same for all the countries

Table 17 - Example of calculations for on-road freight transport

Example: Gulf of Finland – Freight transport - Road

The steps for the calculation of the GHG emissions due to freight transport by road in Gulf of Finland are presented below:

- **Tonnage for each port:**

Port	Tonnes
Helsinki	11 621 000
Tallinn	20 118 500

Pieces of data obtained through port authorities.

- **Modal share:**

National data used.

Country	Real modal share
Finland	0.74
Estonia	0.67

Pieces of data available on Eurostat.

- **Average distance**

National data used.

Finland				
Range	<50km	50-149km	150-499km	>500km
Middle km	25	100	325	600
thousands tonnes	146936	67290	49541	1060
%	53.6 %	24.5%	18.1%	3.9%
Average distance (km) = 25 x 53.6% + 100 x 24.5% + 325 x 18.1% + 600 x 3.9% = **119.8 km**				

[58] http://www.bilans-ges.ademe.fr/fr/basecarbone/donnees-consulter/liste-element/categorie/104

Estonia				
Range	<50km	50-149km	150-499km	>500km
Middle km	25	100	325	600
thousands tonnes	15738	7903	3989	6
%	57.0%	28.6%	14.4%	0.02%
Average distance (km) = 25 x 57% + 100 x 28.6% + 325 x 14.4% + 600 x 0.02% = **89.9 km**				

Pieces of data available on Eurostat.

- **Emission factor**

Country	Emission factor ($kgCO_2/t.km$)
Finland	0,0946
Estonia	0,0946

- **Results**

$$\frac{\text{Tonnage transported (t)} \times \text{Modal share} \times \text{Average distance (km)} \times \text{Emission factor (kg}CO_2/\text{t.km)}}{1000} = \text{Emissions (t}CO_2)$$

Port	Tonnage	Modal share	Average distance (km)	Emission factor ($kgCO_2/t.km$)	Emissions (tCO_2)
Helsinki	11 621 000	0.74	119.8	0,0946	97 459
Tallinn	20 118 500	0.67	89.9	0,0946	114 636

Rail

- **Tonnage of good transported by rail**

To obtain the tonnage of goods passing through the ports and transported by rail, the same equation than for road is used.

$$T = Tp \times MS$$

with:
T = Tonnage of goods passing through the port and transporting by train
Tp = Total tonnage of goods passing through the port (and the Channel Tunnel in the case of the Dover / Pas de Calais Strait)
MS = Modal share for train (in %)

The tonnage of goods passing through the port in total is given by the port's authorities, as well as the modal share, if available.

If no information is available on the real modal share in the ports, the average national modal shares for 2015 are used. They are obtained on the Eurostat website[59] for all the European countries.

[59] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tran_hv_frmod&lang=fr

Average distance

The average distance is calculated by country.

To obtain it, a ratio between the tonnes.km completed in 2015 in the whole country and the tonnage transported in the whole country is calculated. These pieces of data are available on Eurostat[60] for the European countries.

Exception: the islands
For the islands (ports of Bastia, Corfu and Lefkimi), the national average distance is not relevant. Therefore, the national average for road freight transport is used.

This distance is disaggregated between the distance within the strait's boundary and outside the strait's boundary, in order to provide a complete picture of the emissions directly emitted in the strait's boundary, and the emissions induced by the strait but emitted outside of the boundary. The strait's boundaries that are considered are the ones of the port region (NUTS3) and the distance between the port and the region boundary is estimated (named "NUTS3 Distance"). The disaggregation is done depending on the comparison between the average distance and the NUTS3 distance.

If Average distance > NUTS3 Distance
Distance within the strait = NUTS3 Distance
Distance outside the strait = Average distance – Distance within the strait

If Average distance < NUTS3 Distance
Distance within the strait = Average distance
Distance outside the strait = 0 km

Emission factor

Emission factors used are those from the ADEME database "Base Carbone"[61] (updated in 2016).

If the emission factor is available for the country of the port, this factor is used.
If the emission factor is not available for the country of the port the average factor for Europe (available on the data base) is used[62].

For France, numerous factors are available, the emission factor "Train de marchandises - motorisation mixte électricité / gazole - marchandises denses" ("Freight train – mixed power – dense goods") is used.

[60] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rail_go_grpgood&lang=fr
[61] http://www.bilans-ges.ademe.fr/fr/basecarbone/donnees-consulter/liste-element/categorie/127
[62] Average emission factor used for Albania and Estonia

Table 18 - Example of calculations for rail freight transport

Example: Gulf of Finland – Freight transport - Rail

The steps for the calculation of the GHG emissions due to freight passenger by rail in Gulf of Finland are presented below:

- **Tonnage for each port (landing and boarding):**

Port	Tonnes
Helsinki	11 621 000
Tallinn	20 118 500

Pieces of data obtained through port authorities.

- **Modal share:**

National data used.

Country	Modal share
Finland	0.26
Estonia	0.33

Pieces of data available on Eurostat.

- **Average distance**

National data used.

Country	Thousand tonnes	Thousand tonnes.km	Average distance (km)
Finland	33 392	8 468 000	253.6
Estonia	286 000	3 117 000	111.2

Pieces of data available on Eurostat.

- **Emission factor**

Country	Emission factor ($kgCO_2/t.km$)
Finland	0.0201
Estonia	0.0226

National emission factor available for Finland on the ADEME's database. Average European emission factor used for Estonia.

- **Results**

$$\frac{\text{Tonnage transported (t)} \times \text{Modal share} \times \text{Average distance (km)} \times \text{Emission factor } (\text{kg}CO_2/\text{t.km})}{1000} = \text{Emissions } (\text{t}CO_2)$$

Port	Tonnage	Modal share	Average distance (km)	Emission factor ($kgCO_2/t.km$)	Emissions (tCO_2)
Helsinki	11 621 000	0.26	253.6	0.0201	15 401
Tallinn	20 118 500	0.33	111.2	0.0226	16 685

Exception: Waterways transport

In cases where national modal share's data is available for other transport modes, such as waterway transport, it is considered to be non-material, because the modal share is negligible (mostly inferior to 1%). As such, only the modal shares of road and rail transport are taken into account to breakdown tonnages data.

However, if the real modal share of the ports is known and if the share of waterways transport mode is important, this transport mode is considered[63].The methodology used is exactly the same than for rail mode (same pieces of data are available on Eurostat for waterways).

Exception: Airports

It was considered that airports are not influenced by the presence of the strait. As such, the airports are not taken into account in the in-land transport or in the induced economical activities.

[63] Case of Dunkirk port