Emissions from navigation and fishing including international bunkers

Quality assurance of emissions 1990-2010 for reporting to UNFCCC, NEC and CLRTAP

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Agreement: 309 1112

Commissioned by the Swedish Environmental Protection Agency
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Summary

In this study, bottom-up estimates of emissions from domestic navigation and fishing have been produced. Also, fuel data in the Monthly fuel, gas and inventory statistics, used as activity data for estimating emissions from national navigation and international maritime bunkers has been analyzed. Data from other sources relating to these emissions from international bunkers has been explored and analyzed.

Conclusions

National navigation, CRF 1A3d
Given the completely different approaches and uncertainties that are included in models and emission factors, bottom-up estimates using Shipair seem to correspond quite well with estimates produced using fuel data from energy statistics. Results do not imply that there is an obvious need for revision of emissions reported to the UNFCCC.

Fishing, CRF 1A4c
The current model used produces slightly higher estimates than if using fuel data for 2007 from Swedish Board of Fisheries. Compared to bottom-up estimates using Shipair, the current model gives much higher estimates, estimates from Shipair being approximately one third. Since smaller fishing vessels are not obliged by law to have AIS transponders, one should expect the coverage of Shipair to be somewhat limited. To give an estimate of how much the emissions are underestimated due to this fact, one would need to study the ship population more closely. It is also possible that the estimates for fishing based on fuel statistics are overestimated by the current model. However, since the only time series available is data on installed power for the Swedish fishing fleet used in the current model, we do not have enough information to judge whether the current time series is wrong. A revision of the time series is not possible with the current data situation. It is however clear that data should be updated and evaluated again coming years. Also, the estimates by the bottom-up approach will improve as the AIS-usage becomes more and more wide-spread, in time making it possible to perform a more complete independent validation.

International bunkers, CRF 1C1b
Data on international bunker fuel in the Monthly fuel, gas and inventory statistics has been found to be of excellent quality. As a consequence of that VAT is applied on national fuel consumption but not on international bunkers, all respondents to the survey are able to separate these fuel amounts with high accuracy. Fuels used for domestic and international navigation have been separated correctly and in line with IPCC Guidelines. Fluctuations in time series are to a large extent due to “spot sales”. Occasional fluctuations in time series for international maritime bunkers
should be expected. The increasing trend is, in addition to driving forces such as amount of goods or tonnage of the fleet, due to acquired international customers and an expansion in the fleet of lighters.

Various data from energy statistics, transport statistics, trade statistics and fuel price statistics have been found and could be used further if additional analysis is wanted.

**Recommendations**

**National navigation, CRF 1A3d**

The current methodology should be used for reporting to the UNFCCC also in the future. Estimates using Shipair should preferably be updated for 2008-2010 and also for coming years, thus producing a time series that in due time will provide more information and verification of emissions reported to the UNFCCC.

**Fishing, CRF 1A4c**

The current methodology should be used for reporting to the UNFCCC also in submission 2012. Estimates using Shipair should preferably be updated for 2008-2010 and also for coming years, thus producing a time series that in due time will provide more information and verification of emissions reported to the UNFCCC. The current methodology should be evaluated again when the next update of the national statistics on fishing is available.

**International bunkers, CRF 1C1b**

Current data is found to be of excellent quality and should be used also in the future for reporting to the UNFCCC.
Background

Time series from 1990 onwards reported in submission 2011 to UNFCCC, NEC and CLRTAP for domestic navigation, fishing and international marine bunkers, based on energy statistics from Statistics Sweden's, shows large fluctuations for which it has been difficult to find natural explanations. There is a need to verify the quality of the time series and the extent to which the division between national and international navigation has been made in accordance with IPCC guidelines and the guidelines for reporting under CLRTAP and NEC. Also, alternative data sources need to be explored.

SMHI and the National Maritime Administration have developed a system, Shipair, to make bottom-up emission estimates. Shipair is based on the vessels tracked continuously using location data from the AIS (Automatic Identification System), combined with ship-specific data from the National Maritime Administration databases. With the help of Shipair it is possible to calculate emissions from 2008 onwards. Such calculations can be used to verify emissions from fishing and domestic navigation reported to e.g. the UNFCCC. It is however more difficult to verify data on international marine bunkers, because there is no information on where the ships are refueled.

The purpose of this study is to:

- Propose a method that ensures that the allocation of fuel for estimation of emissions from shipping and fishing including international bunkers are in accordance with IPCC guidelines and the guidelines for reporting under CLRTAP and NEC for the years 1990 onwards.
- Provide a better understanding of the causes of variations over the years and also to the trend of emissions from international bunkers.
- Through comparison of bottom-up estimates clarify any issues with the current methodology for calculating emissions from domestic shipping and fishing.
Introduction

The energy use for national navigation; fishing and international maritime bunkers as reported in submission 2011 to the UNFCCC is shown in Figure 1 below.

![Energy consumption for navigation and fishing submission 2011, TJ](image)

**Figure 1. Energy use for national/international navigation and fishing according to submission 2011 to the UNFCCC.**

Most fuel is allocated to international maritime bunkers. The time series for national navigation and fishing are rather smooth. International bunkers on the other hand show large fluctuations. Also, there is a significant increasing trend that calls for explanations.

Emissions are currently estimated by using energy statistics from Statistics Sweden - Monthly fuel, gas and inventory statistics - together with national thermal values and emission factors. For fishing, data are also modeled using data on installed power for the Swedish fishing fleet.

Monthly fuel, gas and inventory statistics\(^1\) is a monthly survey produced by Statistics Sweden on commissioned services to the Swedish Energy Agency. Data are collected from oil companies and other sellers who have stocks of petroleum products and coal. The survey also collects stock data from companies with a large consumption of oil in the manufacturing industries and energy industries. All (approximately 70) companies in the population are included in the survey and are

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\(^1\) [http://www.scb.se/Pages/Product 6359.aspx (sv)](http://www.scb.se/Pages/Product 6359.aspx)  [http://www.scb.se/Pages/Product 6347.aspx (en)](http://www.scb.se/Pages/Product 6347.aspx)
obliged by law\textsuperscript{2} to respond. All figures are double-checked by both Statistics Sweden and all respondents. Data are available for each year at national level.

Solid fuels (coal, coke etc) and liquid fuels (various types of oil), FAME and ethanol are reported by fuel type and in physical units. Data on internal use of natural gas and biofuels are included. Deliveries of motor gasoline and diesel fuel are reported by environmental classes.

Fuel data is reported separately for following categories: Stocks and stock changes, imports, exports, production, internal use, \textit{bunkering for foreign shipping}, deliveries to consumers and retailers. Deliveries to consumers and retailers are separated on
\begin{itemize}
  \item Agriculture, forestry, fishing
  \item Mines and quarries, manufacturing
  \item Power works, gas works
  \item District heating plants
  \item Other public use
  \item Railway
  \item \textit{Shipping excl bunkering for foreign shipping}
  \item One- and two dwelling buildings
  \item Multi dwelling buildings
  \item Other buildings
  \item Other
\end{itemize}

As can be seen, fuels used for domestic and international navigation are separated in the survey, which facilitates the use of this data for estimating emissions from national navigation and international bunkers.

The overall reliability for this survey is according to published documentation very good. The largest source of uncertainty is measurement errors, which could have a significant impact since there are so few respondents. There is no over coverage. There is a minor delay until new companies entering the market are covered in the statistics. There are errors in classification of deliveries at different consumer categories; the group "others" is likely to be overestimated. The material is reviewed and if any problems are noted, respondents are contacted to obtain further information. For companies that fail to respond, imputations are made by using older data and other data collected elsewhere. For the 2010 survey, non-response (objects and partial) was limited to a few single objects.\textsuperscript{3}

\textsuperscript{2} SFS 2001:99, SFS 2001:100, STEMFS 2006:1
\textsuperscript{3} Statistics Sweden, Description of statistics, \url{http://www.scb.se/Pages/ProductDocumentations_18813.aspx}
In other words, total amounts of fuel (by fuel type) are very accurate, but we cannot assure that the amounts for each consumer category are accurate. If only distribution of national fuel consumption on consumer categories is affected, this affects emission estimates for different CRF categories, however national totals are accurate. These errors could be an explanation to the residual for diesel oil that needs to be distributed on different kinds of transports (see methodology description in section Analysis Fishing, CRF 1A4c). If also the distribution between national consumption and international bunkers is affected, national emission totals are inaccurate.

Data on national navigation and fishing are verified through bottom-up calculations of emissions; see section Bottom-up estimates 2010 for verification of domestic navigation and fishing. The analysis is provided in section Analysis National navigation, CRF 1A3d and section Analysis Fishing, CRF 1A4c.

Data on fuel consumption for international bunkers including distribution between national consumption and international bunkers is verified using other methods (since bottom-up estimates are not possible) as described and analyzed in section Analysis International bunkers, CRF 1C1b.
Bottom-up estimates 2011 for verification of domestic navigation and fishing

From the year 2008 and onwards it is possible to calculate emissions using the Shipair system. Before 2008 the AIS-system did not yet have sufficiently widespread use in order to provide a realistic picture of the traffic in the seas bordering Sweden. Calculations with Shipair can be used to verify emissions from fishing as well as domestic navigation. The discrimination of fishing vessels is done using the classification of the Swedish Maritime Administration (SMA). In those cases when this is not possible, the ship categories from the AIS system are used. The division of traffic into domestic and international is described in the next section.

Model calculations cannot be used to verify international bunkering, since there is no information on where the ships load their fuel. This means that international traffic where the ships bunker in countries other than Sweden cannot be separated from ships bunkering in Sweden. A reasonable estimate would be to assume that half of the ships refuel in the destination country and half in the origin country. However, the uncertainties in such an estimate are considered too large to make the results appropriate for verification of fuel statistics.

Calculations using the Shipair systems for this study have been performed using emissions from February – May 2011. These emissions have been extrapolated to represent the whole year. The variation between winter and summer month is at most 5%. The period February to May is expected to give an acceptable representation of the traffic during the whole year. It should be noted that the results from the beginning of 2011 are compared to emissions based on fuel statistics for 2010. The systematic differences, and sources of uncertainty, between estimations based on fuel statistics and bottom-up calculations are expected to be much larger than the differences in the real emissions between two consecutive years. Therefore, also this inconsistency in the comparisons is considered acceptable.

Description of the Shipair system

SMHI and the SMA have developed a system that can calculate shipping emissions using a bottom-up methodology. This system is based on automatic tracking of ships using position data from the AIS (Automatic Identification System). The AIS is a complement for RADAR and is today a global standard for positioning of ships. In the Baltic Sea the Helsinki Commission (HELCOM) has created a common positioning database for its member states. This database covers the whole Baltic Sea, Kattegat, Skagerrak and the North Sea just to the west of Denmark. Ships are tracked with a time resolution as high as a few seconds. These tracks are processed to decrease the large amounts of data and for the calculations of emissions the time resolution for positioning is 5 minutes. The movement between these
points is then interpolated. The velocities of the ships can be calculated from the positioning data, and in combination with known ship data the power output can be obtained. The ship-specific properties are downloaded from the SMA ship database. The logic for emission factors and the transfer of data from SMA to Shipair is done using the SMA service called SEI (Ship-Emission-Information). The SEI service also contains additional ship data.

The uncertainties in emission factors for ships are large. This is due to few measurements of emissions from ships, as well as lacking information about some of the ships moving in the Baltic Sea region. In the SMA databases there is fairly complete information mainly for ships calling at Swedish ports, which in the context of this project should be sufficient. In the case when data is missing, default values for the actual ship category will be used.

At the moment the ship database contains about 27000 unique MMSI (AIS transponder id’s), but the number is growing constantly as new ships enter the HELCOM area. The actual number of ships should be expected to be lower since ships are changing transponders, and some of the MMSI represent very little actual ship movements. Out of these 27000 ships, about 2700 MMSI representing fishing vessels have been extracted. The calculations were then made using two different sets of ships, all ships and fishing vessels. In both cases the calculations were limited to domestic traffic, i.e. ship routes having both origin and destination in Sweden.

An overview of the data sources and the systems used to calculate the emissions from shipping are given in Figure 2. For a more complete description of the Shipair system we refer to Segersson et al. (2010).\(^4\)

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Distinguishing domestic shipping

In Shipair the ship movements are divided into routes. A route is defined as the movement between departure and arrival. The time in port is evenly divided between the routes before and after. Each route is classified by the country of origin and the destination country. A route where both the origin and destination is Sweden is classified as domestic. This is a quite precise definition, since one could expect a ship travelling between Swedish destinations to also refuel in Sweden. There is probably a slight over-estimation of the domestic traffic due to the possibility that ships that are arriving from other countries continue to travel between Swedish ports without refueling first.

All calculations made in this study are limited to only include domestic traffic. This means that also the fishing vessels are required to depart and arrive at a Swedish port to be included in the calculations. An alternative method would be to limit the calculations using the flag of the ships. This is considered a more uncertain method since ships might still be operating in other countries, and was therefore not used in this study.

Ship properties

Two ship databases were created in the study. One database including all ships found in the AIS signal and one only including fishing vessels. Below some statistics are presented over the most important properties for the population of fishing vessels. No statistics are presented for ship properties representing the domestic traffic. The reason is that the ship database used for these calculations contains all ships and the domestic traffic is filtered out at run-time. Statistics produced from the ship database would therefore represent the entire fleet of the Baltic Sea. Smaller changes to Shipair would be necessary to allow a more representative description of the ships contributing to the results.

Using this database, certain statistical information can be extracted. Figure 3 shows the number of ships with different engine power. This graph shows two distinct peaks, indicating that to a large extent the ships have been assigned default values. This suggests a lack of information for each individual ship. Still, it does not necessarily mean that the data is of poor quality, since it may well be representative on the average. A strong advantage of Shipair is that it allows for handling of many ship sources simultaneously, and in such cases the use of default values will have a smaller impact. It should be noted that all the fishing vessels are not part of the Swedish fishing fleet. If the data sets would have been limited to ships in the Swedish fleet, it is likely that the use of default ships would not be as common.
Next we turn to Figure 4, where the number of ships with a certain emission factor for specific fuel consumption (SFC) is shown. A few (6) ships have zero SFC factor for the main engine, which is most likely an error. Still this should be acceptable since these 6 ships constitute about 0.2% of the ship database in question. A few different values for the SFC factor are used in the database. Notice though that the emission factors are not expected to vary in the same way as installed power does. Emission factors are expected to vary mainly with ship category and less with different engine sizes.

Figure 3 and Figure 4 represent the properties used for cruising ships. Cruising is the status when a ship is travelling between ports. Shipair uses separate emission factors when the ship is maneuvering and when it is hoteling. While the AIS system can register the current status of a ship, it is up to the ship crew to correctly set this status. Since the data quality for this is low, the Shipair system instead calculates the status from the position and speed of the ship. Figure 5 shows the emission factors for maneuvering and hoteling.
Figure 4. Number of ships as a function of SFC (Specific Fuel Consumption). Left panel show the main engines, while the right hand panel shows auxiliary engines. Average values are shown by red lines.

Figure 5. Number of ships as functions of emission factors. Left panel shows emission factor for maneuvering of the main engines, while the middle panel shows the same emission factor for the auxiliary engines. The right hand panel shows the emission factor for hoteling. Average values are shown by red lines. The unit for the emission factors is g/kWh.

**Results from the bottom-up calculations**

Bottom-up calculations have been made with Shipair for consumed amounts of fuel and for emissions of CO₂. The results are given in Table 1 and also as bar charts in Error! Reference source not found. and Error! Reference source not found.. In Figure 8 the results are shown on a map over the Baltic Sea.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Fuel [kton/year]</th>
<th>CO₂ [kton/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing</td>
<td>14</td>
<td>45</td>
</tr>
<tr>
<td>Domestic</td>
<td>244</td>
<td>767</td>
</tr>
</tbody>
</table>
Figure 8. Emissions of CO₂ from domestic shipping during 2011, extrapolated from bottom-up calculations during Feb-May. The inclusion of some trajectories calling at Finnish or Danish ports is caused by the port register not being complete.
Analysis National navigation, CRF 1A3d

Comparing emissions from domestic navigation according to data reported to the UNFCCC versus bottom-up estimates using data Shipair is easiest if CO₂ emissions are compared (Figure 9).

Figure 9. CO₂ emissions in Gg from national navigation according to submission 2011 to the UNFCCC and according to bottom-up estimates using Shipair.

The estimate of emissions from domestic shipping based on a bottom-up approach gives higher emissions than the estimates based on fuel statistics. Since there will always be some sources missing in a bottom-up inventory, it should normally be expected to show lower emission compared to a top-down approach. The higher emissions given by Shipair can to some extent be explained by systematic differences:

- Uncertainties in models, emission factors etc.
- Some of the international traffic is possibly classified as domestic in Shipair. In the map showing the estimated ship emissions from fishing and domestic shipping, it can be seen that a few ship trajectories call at ports in Finland and Denmark. This is caused by an incomplete register of all ports in Shipair. Differences due to this should however be much smaller than the difference seen in Figure 9.
- Ships travelling between Swedish ports, but using foreign bunker fuel. This traffic will be classified as domestic by Shipair and might cause a slight overestimation.
- Domestic navigation as reported to the UNFCCC based on fuel statistics could be underestimated. As discussed in Introduction, fuel used domestic
is not always separated on a specific consumer category but simply reported as “other”. It should be noted that if this is the reason behind the observed discrepancy, emissions from domestic navigation are still accounted for in other domestic categories and thus included in the national total reported to the UNFCCC. See also section Analysis Fishing, CRF 1A4c.

Conclusions and recommendations

Given the completely different approaches and uncertainties that are included in models and emission factors, we find bottom-up estimates using Shipair to correspond quite well with estimates produced using fuel data from energy statistics. Results do not imply that there is an obvious need for revision of emissions reported to the UNFCCC. A revision is not even possible with the current data situation.

Current methodology should be used for reporting to the UNFCCC also in the future. Estimates using Shipair should preferably be updated for 2008-2010 and also for coming years, thus producing a time series that in due time will yield more information and verification of emissions reported to the UNFCCC.
Analysis Fishing, CRF 1A4c

Emissions from fishing are currently estimated using a methodology described in Cooper et. al. (2005)\textsuperscript{5}:

1. Installed power (kW) in the fishing fleet according to Swedish Board of Fisheries (data available for 1996 and later years, 1990-1995 extrapolated).
2. Diesel consumption in the fishing fleet 2005 according to Statistics Sweden.\textsuperscript{6}
3. For 2005, consumption of diesel/installed kWh can be calculated. This ratio is applied for all years. Using the data on installed power for each year, an estimate of diesel consumption for fishing is given for each year.
4. When diesel consumption is distributed on all kinds of transports, the remaining residual is distributed proportionally on fishing, road traffic and navigation.
5. Energy amounts and emissions are calculated using national thermal values and emission factors.

The model needs data on installed power in the Swedish fishing fleet. Updated data 2008-2010 has been collected from Swedish Board of Fisheries within this study. A time series on CO\textsubscript{2} emissions according to the model is provided in Figure 10 (the parameter CO\textsubscript{2} is chosen to facilitate comparison with bottom-up estimates using Shipair).

The model of course includes uncertainties. When distributing the remaining residual (see bullet point 4 above and Figure 10), amounts exceed 10\% for 1990, 1991, 1998, 2004, 2005 and 2006. However, there seems to be no systematic over- or underestimation in the model. It should be noted that these differences do not necessarily imply that data for fishing is wrong. The residual might as well originate from uncertainties in other models used for diesel-related emissions from mobile combustion, for example emissions from road traffic or navigation.

For energy consumption within fisheries, currently only data according to Table 2 exists. The survey on energy consumption within fishing (ER 2006:35) is planned to be updated in the coming years.\textsuperscript{7} Data on gasoline and domestic heating oil are excluded in the model used. This is a simplification. Given the small amounts, errors introduced into the model could be considered negligible. Data on fuel consumption 2007 according to Swedish Board of Fisheries is produced with a sample survey. The amounts are 14\% lower than modeled data for 2007 currently used in the model, see Figure 10.

\textsuperscript{6} Statistics Sweden (2006) Energianvändning inom fiskesektorn 2005
\textsuperscript{7} Swedish Energy Agency, Niklas Notstrand, personal communication 2011-05-18
Table 2. Available data on energy use within fisheries

<table>
<thead>
<tr>
<th>Year</th>
<th>Sub-sector</th>
<th>Diesel m$^3$</th>
<th>Gasoline m$^3$</th>
<th>Domestic heating oil m$^3$</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>more active part of fleet</td>
<td>57980</td>
<td></td>
<td></td>
<td>Swedish Board of Fisheries according to ER 2010:12 Uppdrag energikartläggning av de areella näringarna, table 12</td>
</tr>
<tr>
<td>2006</td>
<td>more active part of fleet</td>
<td>58817</td>
<td></td>
<td></td>
<td>Swedish Board of Fisheries according to ER 2010:12 Uppdrag energikartläggning av de areella näringarna, table 12</td>
</tr>
<tr>
<td>2007</td>
<td>more active part of fleet</td>
<td>46985</td>
<td></td>
<td></td>
<td>Swedish Board of Fisheries according to ER 2010:12 Uppdrag energikartläggning av de areella näringarna, table 12</td>
</tr>
<tr>
<td>2007</td>
<td>all fleet</td>
<td>49093</td>
<td></td>
<td></td>
<td>Swedish Board of Fisheries 2010: Kartläggning av energianvändning och energieffektiviserande åtgärder inom svensk fiskesektor 2007</td>
</tr>
</tbody>
</table>
Figure 10. CO$_2$ emissions in Gg from fishing according to submission 2011 to the UNFCCC, to model with AD 2008-2010 updated, using data from Swedish Board of Fisheries and according to bottom-up estimates using Shipair.

In Figure 10, also CO$_2$ emission according to bottom-up estimates using Shipair is shown. Estimated emissions are approximately one third of emissions estimated using the current model.

To put things into perspective, total national CO$_2$ emissions from domestic navigation and fishing are shown in Figure 11. Emissions 1990-2009 are according to current data and models, as reported to the UNFCCC. Emissions 2011 are according to bottom-up estimates using Shipair.
Data on fishing is shown in green, national navigation in blue and total domestic emissions in black. Total emissions according to Shipair is somewhat higher, but still, given uncertainties and the completely different approaches, well in line with emissions as reported to the UNFCCC. One reason for the differences on subsectors might be that some fuel used for fishing is reported as used for national navigation in the Monthly fuel, gas and inventory statistics.

Conclusions and recommendations

The current model used yields slightly higher estimates than when using fuel data for 2007 from Swedish Board of Fisheries. Compared to bottom-up estimates using Shipair, the current model yields much higher estimates. Data for fishing could be overestimated by the current model. However, since the only time series available is data on installed power for the Swedish fishing fleet used in the current model, we do not have enough information to prove that the current time series is wrong. A revision of the time series is not possible with the current data situation. It is however clear that data should be updated and evaluated again coming years.

- Current methodology should be used for reporting to the UNFCCC also in submission 2012.
- Estimates using Shipair should preferably be updated for 2008-2010 and also for coming years, thus producing a time series that in due time will yield more information and verification of emissions reported to the UNFCCC.
- Current methodology should be evaluated again when an update on ER 2006:35 is available.
Analysis of International bunkers, CRF 1C1b

Definitions on domestic and international consumption

When using IPCC guidelines for reporting to the UNFCCC, domestic emissions from fuel consumption are defined as emissions within the country originating from fuel sold within the country. International bunkers are defined as fuel sold within the country but used abroad. Imports of fuels are on the other hand not to be reported (amounts are reported by countries exporting the fuel). It is not important who uses the fuel.

For the Swedish Energy Agency, the aim is to be able to show how much energy is used for each sector in Sweden. For navigation this means knowledge is needed about exact amounts of imported fuel used within Swedish borders as well as exact amount of international bunkers (that is fuel exported and used outside Swedish borders). Some work in this direction regarding energy consumption for navigation has been done. Parts of results from the further work of Swedish Energy Agency can be implemented in this study. See section on Swedish Energy Agency below and section Bottom-up estimates 2010 for verification of domestic navigation and fishing.

A third definition of domestic consumption is used by the System of Environmental and Economic Accounts at Statistics Sweden. Here, the aim is to show emissions originating from fuel consumption by Swedish residents, no matter where in the world the fuel is bought or used.

Differences in definitions have to be kept in mind when discussing energy statistics for domestic and international navigation. Current energy statistics are (as shown below) well adapted for reporting of international bunkers according to IPCC guidelines, but more difficult to use for the purposes for the Swedish Energy Agency or the System of Environmental and Economic Accounts at Statistics Sweden.

Verification of survey data

As noted in Introduction, Monthly fuel, gas and inventory statistics is a monthly survey produced by Statistics Sweden on commissioned services to the Swedish

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8 Swedish Energy Agency 2009: Utveckling av statistikunderlaget avseende transportsektorns energianvändning
9 http://www.scb.se/Pages/Product___38175.aspx
10 http://www.scb.se/Pages/Product___6359.aspx (sv) http://www.scb.se/Pages/Product___6347.aspx (en)
Energy Agency. Data are collected from oil companies and other sellers who have stocks of petroleum products and coal. The survey also collects stock data from companies with a large consumption of oil in the manufacturing industries and energy industries. The population consists of approximately 70 companies, and all of them are included in the survey.

Background data for all companies have been studied for the years 1993-2010 (data 1990-1992 was (in 2011) not available on this detailed level). For each company, time series was produced for fuel amounts reported as domestic navigation (“Shipping excl bunkering for foreign shipping”) and as international maritime bunkers (“bunkering for foreign shipping”). The time series for domestic navigation and international maritime bunkers consists of data from quite few companies (Table 3):

**Table 3: Number of companies reporting fuel data for domestic navigation and international bunkers**

<table>
<thead>
<tr>
<th>Total number of companies reporting fuel data 1993-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic navigation</td>
</tr>
<tr>
<td>International maritime bunkers</td>
</tr>
<tr>
<td>Domestic navigation AND International maritime bunkers</td>
</tr>
<tr>
<td>Domestic navigation OR International maritime bunkers</td>
</tr>
</tbody>
</table>

In 1993, 24 companies reported fuel amounts for domestic navigation and 15 companies reported amounts for international maritime bunkers. During the period, many companies have disappeared or been taken over by larger companies. In 2010, very few companies remained – only eight companies reported fuel amounts for Domestic navigation or International maritime bunkers. With few companies in the population, it is possible to study each company carefully.

Suppliers of significant quantities of bunker oil (~100 000 m³ – 2 000 000 m³) have been examined more closely. First, an email was sent to the persons noted as responsible for responding to the survey. In the email, time series with data from the company on Domestic navigation and International maritime bunkers 1993-2010 was enclosed to facilitate their response. The purpose of this study was explained, and the respondents were asked if they could provide some additional information on reported data:

- Please double-check outliers in the time series - years when they had reported very low or high fuel amounts. They were asked if the given data was correct and, if so, what had caused changes in deliveries of oil for domestic navigation or bunker oil.
- How are data on international bunkers defined and separated from domestic use?
- What kinds of deliveries occur – to ships or to pumping stations or other?
• Are fuel delivered to Swedish and/or foreign companies?
• What kind of ships are fuels delivered to – passenger ships or cargo vessels?

Companies that were late at responding or provided especially interesting answers were also contacted by telephone to ensure a complete response and that all details in the response were understood correctly. In some cases, when companies had been taken over by other companies, several persons were contacted until the accurate respondents were located. We were able to track down all respondents that have reported amounts of fuel that significantly affects the time series – at least for the later part of the time series when amounts are higher. We were not able to get hold of some of the suppliers for years back, since they had either been taken over by other companies or had moved their business abroad.

The response was very good, producing reliable information regarding the amounts and fluctuation of fuel deliveries for national navigation and international maritime bunkers over the years:

• The suppliers’ billing- and accounting systems clearly separate the sales of domestic and international bunker oils, since this is a requirement from the Swedish tax authorities (VAT is not applied on international bunkers). Thus, we can be sure that reported data on international maritime bunkers are truly international and that data on international bunker oils are of high quality. **Fuels used for domestic and international navigation have been separated correctly and in line with IPCC Guidelines.**
• Fuel is sold to ships, to depots or picked up by customers directly at the stocks. Customers that pick up fuel themselves are responsible for reporting and paying correct taxes and VAT to the Swedish Tax Agency. This implies that these customers are included in the population for the Monthly fuel, gas and inventory statistics and that this fuel, if used for international bunkers, is reported correctly.
• Sudden increases of fuel amounts for international bunkers occur when occasional customers buy shiploads of bunker fuels, so called “spot sale”. These buyers are not on the “ordinary supply list”. According to the respondents, this phenomenon is quite common and amounts may be significant. Thus, **occasional fluctuations in time series for international maritime bunkers should be expected.**
• During the period, merging of companies and take-over of companies is a frequent phenomenon. This results in sudden increases in the supply of bunkers for the company taking over, whilst the company that had been taken over disappears from the population. National totals are however not affected.
• Bunker fuels are by nature an international market, and if customers choose suppliers from other countries, national time series on international bunkers will be affected. This happened for instance in 2001, when one
major supplier of bunker oil acquired additional international customers, which led to a noticeable increase in their amount of sold fuel. Customers stayed with the company, *thus levels are higher also for years after 2001.*

- To be able to sell bunker oil directly to ships, supplier needs so called lighters. A lighter is a ship that delivers oil to the customers, e.g. ships which most of the time are anchored right outside the harbor. In 2005, one major supplier of bunker oils expanded their fleet of lighters, which made it possible for them to increase their sale of bunker oils. *This is the major cause for the increase in amounts of sold fuel for 2005 onwards.*

**Additional explanations of time series**

There are some other sources providing data that gives a better understanding of the driving forces behind the development of international bunkers. Sources found are discussed below.

**Energy statistics**

Energy consumption for transportation as reported by Statistics Sweden has been analyzed by The Swedish Energy Agency. Variations in the time series are discussed. It is concluded that allocation on consumer categories has uncertainties, as noted above.

The Energy Agency concludes that one reason for the decrease in use of heating oil for domestic navigation might be that diesel oil (that has increased) is used instead. Also for international bunkers, one reason for shifts in consumption of different fuel types might be substitution of residual oil with diesel oil.11

**PASSENGER TRAFFIC AND FREIGHT TRAFFIC**

In “Transportsektorns energianvändning”12, estimates on fuel consumption for passenger traffic versus freight traffic are shown. It is stated that the distribution includes uncertainties, but is still informative when trying to understand what the driving forces behind the fuel consumption and related emissions are. Background data for calculating ratios on domestic navigation are taken from ER2007:2613, a study covering professional traffic (no private traffic) in Swedish territorial water. It is stated in the report that there are major uncertainties in results. Respondents were obliged to respond only for 2006, thus results 2002-2005 became even more uncertain. The overcoverage was according to the report significant. Results do not match data in official energy statistics or data reported to UNFCCC very well.

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11 ES 2011:05 Transportsektorns Energianvåndning 2010
If using published results in ER2007:26 the following ratios can be estimated (Table 4):

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Transport</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel oil + domestic heating oil</td>
<td>Freight</td>
<td>11%</td>
<td>9%</td>
<td>8%</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>Diesel oil + domestic heating oil</td>
<td>Passenger</td>
<td>87%</td>
<td>90%</td>
<td>91%</td>
<td>91%</td>
<td>93%</td>
</tr>
<tr>
<td>Diesel oil + domestic heating oil</td>
<td>Other</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Residual oil</td>
<td>Freight</td>
<td>23%</td>
<td>23%</td>
<td>23%</td>
<td>22%</td>
<td>99%</td>
</tr>
<tr>
<td>Residual oil</td>
<td>Passenger</td>
<td>77%</td>
<td>77%</td>
<td>77%</td>
<td>78%</td>
<td>1%</td>
</tr>
<tr>
<td>Residual oil</td>
<td>Other</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Source: ER2007:26 (processed).

Because of the uncertainties and the short time series, these ratios cannot be used for explaining trends in domestic navigation. We do however agree with the Swedish Energy Agency that this information might be informative when trying to understand the driving forces behind emissions /fuel consumption for navigation. If using ratios, preferably the ratio for 2006 should be used since this ratio is based on more data.

Data on gasoline consumption is not included above. If using SMED data on gasoline consumption referring to leisure boats it is reasonable to assume that this mostly refers to passenger traffic.

**Transport statistics**

Background information on navigation can be found from Transport Analysis, a Swedish government agency responsible for statistics on transports in Sweden.

Statistics on ships, passenger traffic and goods handled in Swedish harbors and wharfs has been published since the beginning of the twentieth century. As from 1996, the statistics on international and domestic shipping has been adapted to EU legislation and is collected every three months. Before 1996 similar surveys were only implemented on a yearly basis. The purpose with the statistics is to illustrate domestic and international shipping regarding both cargo and passengers. Statistics are produced by Statistics Sweden on commissioned services to Transport Analysis.

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15 [http://www.trafa.se/Statistik/Sjofart/](http://www.trafa.se/Statistik/Sjofart/)
In this section, the most relevant statistics is presented. If further analysis is needed, there is a wide range of reports and statistics available at the Transport Analysis website.

Since there is an upward trend for the supply of bunker fuel Sweden, it’s relevant to compare it with the trend for international shipping; both of passenger and cargo. International shipping applies to both Swedish vessels leaving Sweden and international vessels entering Sweden.

During 2010 a total amount of 84.4 million tons of goods were either shipped to Sweden or exported to other countries. This is an increase with 13 % since 2009 and as Figure 12 shows it has been an upward trend since 1996 with only a few exceptions. Between 2008 and 2009 there was a sharp decrease in export and import due to the recession, but in 2010 the upward trend continued.

The amount of cargo in tons has been compared with data on bunker fuels according to submission 2011. To make the datasets comparable, an index has been developed with 1996 as base year, since data on loaded and unloaded cargo in Swedish harbors is not available for 1990-1995. It is reasonable to assume that ships that are unloading and loading cargo in Swedish harbors also refuel in these harbors.

Figure 12. Statistics on loaded and loaded cargo in Swedish harbors indexed to be compared with energy amounts for international bunkers 1996-2010 (processed)¹⁶

Please note that passenger traffic is not included in the cargo data, however fuel consumption for international passenger traffic is included in the data on fuel consumption. Time series are clearly correlated until approximately 2003, however fluctuations diverge. Cargo freight explains a large part of the fuel consumption for international bunkers. For later years, the increase in international bunkers exceeds the increase for shipping goods. This is mainly due to the expanded fleet of lighters as discussed above. Ships may, more frequently, refuel in Sweden when passing by (for example on the west coast), without loading or unloading any goods.

The number of passengers ships and ferries arriving and departing from Sweden during 2009 amounted to 1 926 739, which is a decrease of 5% since 2008. This has been a decreasing trend since 1991, with only a few deviations. However, the tonnage of both the passenger-ships and ferries has increased during the same time span just as for cargo vessels. In other words, ships have become much larger since 1991.

There has also been a decrease in the number of passengers; from 32 350 thousands in 2001 to 30 171 thousand in 2010. The trend seems to be a decrease in the number of passengers as well as the amount of passenger ships and ferries, whilst the volume of the passenger ships and ferries increase. But according to experts at Statistics Sweden’s transport statistics, numerous ferries don’t carry passengers but only cargo-trucks and their drivers. This means that this category of ships also carries a lot of cargo and not only passengers, despite being referred to as ferries and not cargo vessels.

When finding explanations for trends in fuel consumption, tonnage is maybe a more valid measure than the number of ships. Tonnage for cargo vessels, passenger vessels and ferries is shown in Figure 13. The same pattern as in Figure 12 is shown here, with the trend for bunker fuels exceeding the trend for the tonnage of ships.

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17 The measurement called gross tonnage refers to the volume of the interior of the ship, but it’s a type loose kind of measurement and doesn’t have a unit.

18 Margareta Södergren, Statistics Sweden, personal communication 2011-06-09
Figure 13 Indexed statistics on gross tonnage of ships arriving and departing Sweden compared with indexed energy amounts for international bunkers 1990-2010\(^{19}\)

**National Accounts**

Swedish National Accounts at Statistics Sweden (producing among other things the Swedish GDP) includes information on exports of fuel to foreign ships. This information is based upon energy data in Monthly fuel, gas and inventory statistics, which is the same source that is verified in this study.

**Trade statistics**

In Statistics Sweden trade statistics\(^{20}\), information on amount of bunker fuels sold to foreign registered aircrafts and ships can be found from 2004 onwards. (N.B that Swedish registered ships buying bunker oils are not included in their statistics, as in the bunker data reported to UNFCCC). Unfortunately, aviation fuel and maritime fuel cannot be separated. If adding aviation bunkers according to the UNFCCC reporting, data can be compared and we get information on what share of the bunker fuel is used by domestic actors or foreign actors, see Figure 14 below.

The deviation for later years that could also be seen in earlier figures with data on international bunkers increasing rapidly in later years appears also in Figure 14. Keeping in mind that the proportion of Swedish/foreign actors is not necessarily the same for aviation as for navigation, it could be noted that the share of foreign ships/planes are 50%-60% for most years. The 2008-2009 recession seems to have

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\(^{19}\) Statistics Sweden, Statistical Yearbook of Sweden 2011 and 2010

\(^{20}\) Statistics Sweden, http://www.scb.se/Pages/Product____7232.aspx
affected foreign registered ships/planes more, the share of bunker fuels to foreign registered ships and planes being 39% and 35% these years.

Figure 14. Bunker fuels according to UNFCCC reporting, covering Swedish as well as foreign ships and aircrafts compared with bunker fuels to foreign ships and aircrafts according to Trade statistics.

Fuel prices, taxes and VAT


According to SPI, crude oil and oil products of equivalent quality are traded at approximately the same price for each product all over the world if shipping costs excluded. The global price of crude oil and petroleum products is controlled by supply and demand, economic forecasts, conflicts, production forecasts, stocks, season, weather forecasts, accidents and many other factors. As a result of this, almost all trade is on shorter contracts, and prices are set by day.

Prices of oil products in Sweden are according to SPI determined by

- Market conditions
- International product prices in U.S. dollars
- Exchange rate SEK/U.S. dollars
- Taxes and VAT

http://spi.se/var-bransch/marknadssituationen/oljepris
As can be seen from Figure 15 and Figure 16 below, prices have increased since 2001; the most significant change being within production costs, including large fluctuations during the 2008-2009 recession. VAT is 20% of sales prices all years. Taxes have according to SPI actually decreased during the period, being 40% - 45% in the beginning of the period and 30% - 35% at the end of the period. Prices as seen in these time series do not seem to have any significant influence on increases or decreases in fuel consumption as reported to Monthly fuel, gas and inventory statistics used for reporting to UNFCCC.

![Figure 15. Sales prices (bulk) for diesel oil in Sweden, SEK/l. Average price for diesel fuel for stocks selling via truck directly to large customer’s facilities.](image)

www.spi.se
Figure 16. Average selling price of heating oil in Sweden, SEK/m3.\(^{23}\)

According to information from Swedish Tax Agency\(^{24}\), energy taxes, sulphur taxes and tax for CO\(_2\) are applied on fuels for private consumption but not for professional use. This means that international bunkers as well as national navigation and fishing are excluded from this taxation.

Also according to information from Swedish Tax Agency, VAT is applied for fuel used within Sweden but not applied for bunker fuels\(^{25}\). This has been confirmed by respondents to Statistics Sweden’s energy surveys. As a consequence of this taxation, fuel suppliers need to separate data on sold quantities for national use from data on sold quantities for international bunkers. It has been confirmed by respondents to Statistics Sweden’s energy surveys that billing systems are organized this way.

**International Maritime Organization**

International Maritime Organization (IMO) has developed Global Integrated Shipping Information System (GISIS) that offers, among many other shipping data, a module used as an interim monitoring index for energy efficiency of a ship in operation, limited to efficiency expressed as CO\(_2\) emitted per unit of transport work\(^{26}\). The data on ship efficiency can be accessed using a public web application. Currently only 19 ships were found in the database accessible using the web application.

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\(^{23}\) www.spi.se

\(^{24}\) Swedish tax agency; personal communication with Ulf Arenlind 2011-06-14


(http://www.skatteverket.se/rattsinformation/handledningar/handbocker/mervardesskatt/2011.4.70ac421612e2a997f85800033032.html); “Handledning för mervärdesskatt 2011 (2‘nd part; 23.5)

\(^{26}\) http://gisis.imo.org/Public/GHG/Default.aspx
tion, suggesting that the database is not yet usable for global purposes. The data is presented as a table with efficiency described as emitted CO₂ per transported unit of goods. One purpose of the system could be to compare different ships, in order to select the most efficient one for transport services.
Conclusions and recommendations

Data on international bunker fuel in Monthly fuel, gas and inventory statistics have been found to be of excellent quality. As a consequence of that VAT is applied on national fuel consumption but not on international bunkers, all respondents to the survey are able to separate these fuel amounts with high accuracy. Fuels used for domestic and international navigation have been separated correctly and in line with IPCC Guidelines. Fluctuations in time series are to a large extent due to “spot sales”. Occasional fluctuations in time series for international maritime bunkers should be expected. The increasing trend is, in addition to driving forces such as amount of goods or tonnage of the fleet, due to acquired international customers and an expansion in the fleet of lighters.

Various data from energy statistics, transport statistics, trade statistics and fuel price statistics have been found and could be used further if additional analysis is wanted.

Current data should be used also in the future for reporting to the UNFCCC.
References

Data and websites
Data from Statistics Sweden Monthly fuel, gas and inventory statistics
Results from and documentation on this survey is available online at
http://www.scb.se/Pages/Product____6359.aspx (sv)
http://www.scb.se/Pages/Product____6347.aspx (en)
http://www.scb.se/Pages/ProductDocumentations____18813.aspx

Transport statistics: http://www.trafa.se/Statistik/Sjofart/

Trade statistics: http://www.scb.se/Pages/Product____7232.aspx

Swedish Petroleum Institute:
www.spi.se,
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