Assessment of Environmental Impact and Greenhouse Gas Emissions of Port of Tallinn based on 2019 Data

Final report

Abbreviated version

Name of the study client: AS Tallinna Sadam

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1. MISSION STATEMENT

The aim of this study was to assess the environmental impact of the activities of AS Tallinna Sadam (TS) (marine environment, ambient air, energy use, etc.) based on the strategy of the TS sustainable development goals[1] (achieving climate neutrality, circular economy, energy efficiency) and to develop indicators and target levels for achieving the environmental goals of the strategy.

The following tasks were solved in the course of the work:

1. Calculation of greenhouse gas (GHG - CO_2, N_2O and CH_4 reduced CO_2 equivalent) emissions in TS harbours (Old City Harbour, Muuga Harbour, Paljassaare Harbour, Paldiski South Harbor, Saaremaa Harbour) according to the following scope areas[2], based on the ownership or control of the pollution source:
    - ***Scope 1* - direct sources of pollution in the port.** These include TS-owned vessels, vehicles and other equipment, and boiler houses.
    - ***Scope 2* - indirect sources of pollution in the port.** These sources include purchased electricity and heat for TS-owned buildings and infrastructure. Electricity and heat in buildings owned by tenants and operators are not included in this scope.
    - ***Scope 3* - other indirect sources of pollution.** These sources are related to the activities of tenants and operators and the traffic in the port area and include ships calling at the port, ro-ro cargo, cargo handling equipment, railway locomotives, electricity and heat purchased by tenants and operators (excluding purchased from the port), means of transport originating from the port area (including taxis, pick-up and drop-off cars, regular buses, tourist buses and vehicles serving the port and ships, etc.), personal vehicles of port workers and all other sources of emissions from the port area. The calculation of GHGs from mobile sources (ships, vehicles and other means of transport and equipment) covered by Scope 3 was limited to activities in the port area.
2. The basic data for **Scope 1 and 2 is sufficient and their GHG emission calculations could be calculated more accurately. However, data for Scope 3 is insufficient,** and to obtain information, **automatic queries were made from different types of databases** and **a questionnaire was developed** to provide feedback on operators' activities.

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[1] https://sustainabledevelopment.un.org/?menu=1300

[2] Scope areas are based on the GloMEEP (Global Maritime Energy Efficiency Partnership Project) guidelines for assessing port air emissions: Port Emissions Toolkit, Guide No.1: Assessment of port emissions

3. **An optimized approach was used to map GHG emission sources**, i.e., for those for whom data or no survey results were available, analogues and best practices published in the scientific literature/reports were used to find the parameters.

4. **GHG emissions were mapped and calculated for 2019.**
5. The methodology for estimating GHG emissions, together with the basic data on TS, was compiled into a **single database**, on the basis of which, in the second phase of the project, it will be possible to create a web-based user interface for operational mapping of GHG emissions and for assessing the degree of achievement of various environmental targets.
6. **In the framework of this work, a simple web-based pilot application was created,** which sets out the indicators (on assessments of GHG emission reduction, circular economy rate, environmental status) characterizing the environmental, economic and social objectives of the port and shows the current levels of these values. During this work, the main key indicators were identified in cooperation with TS experts based on the environmental objectives of the TS sustainable development strategy and their target levels by 2030.
7. **In addition, the following questions were answered in the work:**
    - What are the recommendations for reducing GHG emissions by 2030? (Scope 1 and 2 propose measures to reduce air emissions. Scope 3 is not entirely covered in the action plan because TS does not control or influence the indirect sources covered by it and is not able to control the implementation of their emission reduction strategies).
    - In which areas does the greatest savings potential lie and what measures should be used to achieve it?
    - Recommendations-assumptions that TS should follow in order to achieve the target levels of environmental objectives.
    - How big is the carbon footprint of TS and what is the environmental impact of TS?

2. CLIMATE CHANGE

The acceleration of climate change is one of the most important environmental policy challenges in today's world. The essence of the problem is that too many greenhouse gases (GHGs) are released into the atmosphere during human activities, which causes temperatures to rise, increases the frequency of extreme weather events and storms, and has many other unpredictable consequences.

In order to limit further global warming, international agreements oblige all countries to implement ambitious targets for reducing GHG emissions. The most important GHGs are carbon dioxide, methane, nitrous oxide and fluorinated gases or freons.

The amount of greenhouse gases emitted into the atmosphere by human activities is usually converted into carbon dioxide, or CO_2 equivalent (eq) emissions, which is calculated using the relative greenhouse gas effects of different gases (Global Warming Potential - GWP).

GHG accounting only covers estimates of anthropogenic GHG emissions, taking into account the following gases per 100 years:

- **Carbon dioxide (CO_2)** released from the combustion of fossil fuels (coal, oil, oil shale, natural gas and peat). The GWP of CO_2 is 1.
- The GWP of **methane (CH_4)** is 25 times higher[3] than that of carbon dioxide. At the same time, CH_4 emissions are also an order of magnitude lower than for carbon dioxide.
- The GWP of **nitrous oxide (N_2O)** is 298 times higher than that of carbon dioxide, but nitrous oxide emissions are also several orders of magnitude lower than CO_2.
- **F-gases** are emitted when using aerosols (deodorants, various foams), refrigerators and freezing systems, air conditioners, fire extinguishers, chemical cleaners. While emissions of fluorinated gases are low, their potential to cause a greenhouse effect is several orders of magnitude higher than that of carbon dioxide.

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[3] IPCC's Fourth Assessment Report, p 212 https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf

3. METHODOLOGY FOR ASSESSING GHG EMISSIONS

AS Tallinna Sadam (TS) is the largest cargo and passenger port complex in Estonia, which plays an important role in the Estonian transport system and in the economy as a whole. **In order to assess TS GHG emissions, the existing data on direct and indirect sources of pollution in the port were compiled, a survey was conducted among TS operators to assess their GHG emissions, a query was made to the Estonian Road Administration regarding mobile vehicles, information on train traffic was collected from Operail, Go Rail, Skinest Rail and in addition, various maritime databases were queried to determine the emissions of ships visiting the TS in the port area.** The scope area of GHG emissions is defined in the mission statement. GHG emissions were mapped and calculated for 2019.

There are currently no precise standards for GHG mapping, and basic data for estimating GHG emissions may be collected in varying degrees of detail. The selected assumptions also significantly affect the results of GHG mapping. As a rule, basic data for the assessment of primary GHG emissions has been collected in a more general way, and in the coming years the details will be increased on those aspects that can most effectively reduce analytical uncertainty and/or provide recommendations for best practice. It is important to increase the mapping accuracy of those sources for which the emission rate is the predominant part of the total emissions. **Based on similar studies in other ports, most GHG emissions are related to shipping,** for example 87% of total GHG emissions in the port of Rotterdam[4] and 79% in the port of Helsinki[5]. Consequently, it is very important to assess GHG emissions from shipping as accurately as possible.

The GHG calculations related to the activities of the Port of Tallinn have been made using the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines[6]. The same methodology is used for the annual submission of the national anthropogenic greenhouse gas inventory to the United Nations (UN) Framework Convention on Climate Change and the European Commission.

The IPCC 2006 instruction allows emissions to be calculated using three methods: Tier 1, Tier 2 and Tier 3. Tier 1 is the basic method which uses the default value of the specific emission factor of the IPCC 2006 methodology in addition to the national basic data. Tier 2 is the medium method that uses national basic data and specific emission factors. Tier 3 is the most sophisticated method that requires accurate basic data on the pollution source. In the present work, a combined solution was used, in which the Tier 3 methodology was used for the most important emission source (i.e., shipping) and for

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[4] https://www.portofrotterdam.com/sites/default/files/port-of-rotterdam-co2-neutral.pdf

[5] https://www.portofhelsinki.fi/en/port-helsinki/environmental-responsibility/carbon-neutral-port-helsinki

[6] https://www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

other pollution sources, due to the lower level of detail of the basic data, the Tier 2 methodology was used. In the chapters on various topics below, we describe in more detail the methodological approach and the calculation formulas used.

GHG emissions were mapped by the following activities:

1. TS direct and indirect sources of pollution
2. Ro-ro traffic on TS territory
3. Traffic of other vehicles on TS territory
4. Pollution sources from operators/tenants
5. Pollution sources from ships visiting TS

3.1. BASIC DATA ON DIRECT AND INDIRECT SOURCES OF GHG POLLUTION IN THE PORT OF TALLINN

Based on the existing data sets of the Port of Tallinn, it was decided at the project meeting to assess TS GHG emissions by the following major pollution sources:

- Direct:
  - boiler houses;
  - auxiliary fleet;
  - vehicles and equipment.
- Indirect:
  - purchased electricity;
  - purchased heat.

Input data on TS heat production and consumption, electricity consumption and vehicle movement was obtained from TS experts. In the case of heat production, the type of fuel used in the boiler house (e.g., gas) and annual fuel consumption (m^3) were mapped; regarding the heat consumption, the heat consumed by all heat consuming companies (Port of Tallinn, tenant, operator) was mapped (MWh). Similarly, the annual electricity consumption (MWh) of all companies that are customers of TS network service was mapped. Fuel consumption information for the vehicles, equipment and auxiliary fleet of the Port of Tallinn was obtained based on accounting data.

In addition to calculating the GHG emissions of TS 's parent company, the GHG emissions of TS group have been calculated in the study, which also took into account the GHG emissions of the port's subsidiaries TS Laevad and TS Shipping.

3.2. BASIC DATA ON RO-RO TRAFFIC IN THE PORT OF TALLINN

Ships carrying ro-ro cargo (or rolling stock) are serviced in three different ports of the Port of Tallinn - Paldiski South Harbour, Muuga Harbour and the Old City Harbour. Information on ro-ro freight traffic on TS territory was obtained from TS experts. TS experts made a query from the Port of Tallinn's business analysis software Cognos to obtain detailed information on ro-ro cargo units.

3.3. BASIC DATA ON TRAFFIC OF OTHER VEHICLES IN THE PORT OF TALLINN

In the Old City Harbour, the automatic traffic management system of the Port of Tallinn (Smart Port) was used to map the pollution sources from the port area (taxis, buses, passenger escorts, guests, ship and port service). In other harbours, the automatic number recognition system Visy was used for this purpose. TS datasets make it possible to determine the total annual number of vehicles passing under barriers, and the registration number of each such vehicle is also stored in the databases. In order to assess which categories of vehicles visit different ports and what fuel these vehicles consume, a sample of collected registration numbers was sent to the Road Administration and, based on the vehicle category (e.g., M1, N2) and engine type (e.g., petrol, diesel) provided by the Road Administration, frequency distributions of different types of vehicles were found for each harbour. Based on this distribution and the total number of mobile vehicles, the total number of different types of vehicles visiting TS harbours was found. The typical distance that these vehicles could cover in each harbour was also taken into account (6 km in Muuga Harbour, 1.5 km in Paldiski South Harbour, 1 km in Paljassaare Harbour and 2 km in the Old City Harbour). The number of visits by regular buses and Hop-On/Hop-Off buses passing through the Old City Harbour port area was obtained from the bus schedules. Information on tourist buses moving in the port area was obtained from tourism companies. As the traffic in front of the Terminal D in the Old City Harbour was not mapped by the Smart Port, the total number of taxis and escort cars there was derived from the information of the Smart Port on the Terminal A, taking into account the elevated number of passengers and ships at Terminal D.

3.4. BASIC DATA ON GHG POLLUTION SOURCES FROM OPERATORS

In order to collect data for the assessment of GHG pollution from the activities of operators, a questionnaire was prepared to map the GHG emissions of the operators. The questionnaire was designed with a level of detail that allows for subsequent recommendations of the data analysis to reduce GHG emissions.

An invitation was sent to all TS operators to participate in the mapping of TS GHG emissions (https://www.ts.ee/terminalide-operaatoriai/). Operators were asked for information on heat production and consumption, electricity consumption, fuel and energy consumption of stationary equipment, and vehicle movements. Mapping of operators' vehicles was necessary because the mapping of vehicles based on barrier information described in the previous chapters does not provide a comprehensive overview of vehicles, as it does not include vehicles that only move in and never leave the territory of the TS.

In addition, we also made queries about the fuel consumption of locomotives operated by Operail, Go Rail and Skinest Rail in the territory of the Port of Tallinn in 2019. A separate query was also made from the ro-ro operators of the Old City Harbour about the fuel consumption of terminal's tractors in the territory of the Old City Harbour in 2019.

3.5. CALCULATION OF GHG EMISSIONS FROM THE PORT OF TALLINN AND OPERATORS

The calculation of greenhouse gas emissions (GHG - CO_2, N_2O and CH_4 as reduced CO_2 equivalent) in TS harbours was based on the following assumptions:

1. The specific heat emission factor is calculated based on Statistics Estonia (SA) and the national GHG inventory 2017 data (SA data in 2018 were incomplete, SA has been informed) (NIR, 2019; Statistics Estonia, 2020).
2. The specific electricity emission factor has been calculated based on Statistics Estonia (SA) and national GHG inventory 2018 data. It is based on national average values. (NIR, 2020).
3. According to the references below, the efficiency of electricity production in Estonia in 2018 is 40.68%. The calculation is made by the formula: electricity production divided by the amount of fuel needed for electricity production (incl. renewable energy). To simplify the calculations, the loss of the electricity network and import-export have not been taken into account (NIR, 2020).
4. The specific emission factor for natural gas has been calculated based on the national GHG inventory 2018 data and Elering's network gas quality data (Elering, 2020).
5. The specific emission factor for petrol and diesel has been calculated based on the 2018 national GHG inventory data. The calorific value of petrol is 31.82 MJ/L and that of diesel 35.69 MJ/L. Calorific value of petrol 31.82 MJ/L and of diesel fuel 35.69 MJ/L. The values of specific densities of fuels (as a basis for calculating the calorific value) have been transmitted by the EKUK Fuel Laboratory (NIR, 2020).

6. The specific emission factors and calculation methodology for greenhouse gas emissions from transport are based on the IPCC 2006 guidelines, which apply the Tier 2 and Tier 3 methodologies, which take into account vehicle mileage and technology in the calculation of greenhouse gas emissions in addition to fuel combustion.

For all mapped sources, generalized factors were defined that were used to convert measured quantities (e.g., MWh consumed, petrol or diesel consumed) into CO_2 emissions and CO_2 emissions as CO_2 equivalent (Annex 1).

The following formulas for different topics were used to calculate GHG pollution sources. The values of calorific values and specific emissions in the formulas depend on the type of fuel / energy and equipment and the corresponding constants are given in the annex (Annex 1). Calculations of GHG emissions from ships visiting TS are described in more detail in the next chapter.

Vehicles and mobile equipment (including auxiliary fleet, ferries, icebreakers and yachts):

Fuel consumption (TJ) = fuel consumption (liters) × calorific value (TJ L^{-1})

CO_2 emissions (tonnes) = fuel consumption (TJ) × specific emissions of CO_2 ($tCO_2\ TJ^{-1}$)

CO_2 emissions as CO_2 equivalent (tonnes) = CO_2 emissions (tonnes) + 25 × CH_4 (tonnes) + 298 × N_2O (tonnes)

CH_4 emissions = fuel consumption (TJ) × CH_4 specific emissions (t CH_4 TJ^{-1})

N_2O emissions = fuel consumption (TJ) × N_2O specific emissions (t N_2O TJ^{-1})

Electricity consumption:

Fuel consumption (TJ) = annual electricity consumption (MWh) × Calorific value (TJ MWh^{-1})

CO_2 emissions (tonnes) = fuel consumption (TJ) × CO_2 specific emissions ($tCO_2\ TJ^{-1}$)

CO_2 emissions as CO_2 equivalent (tonnes) = CO_2 emissions (tonnes) × specific emissions of CO_2 equivalent ($tCO_2\ TJ^{-1}$)

The GHG emissions of **stationary equipment** were calculated according to whether the unit consumed fuel (calculation as for vehicles) or electricity (calculation as for electricity consumption).

Heat production:

Fuel consumption (TJ) = fuel consumption (m^3) × calorific value (TJ m^{-3})

CO_2 emissions (tonnes) = fuel consumption (TJ) × CO_2 specific emissions ($tCO_2\ TJ^{-1}$)

CO_2 emissions as CO_2 equivalent (tonnes) = CO_2 emissions (tonnes) + 25 × CH_4 (tonnes) + 298 × N_2O (tonnes)

CH_4 emissions = fuel consumption (TJ) × CH_4 specific emissions (t CH_4 TJ^{-1})

N_2O emissions = fuel consumption (TJ) × N_2O specific emissions (t N_2O TJ^{-1})

Heat consumption:

Fuel consumption (TJ) = annual heat consumption (MWh) × Calorific value (TJ MWh^{-1})

CO_2 emissions (tonnes) = fuel consumption (TJ) × CO_2 specific emissions (tCO_2 TJ^{-1})

CO_2 emissions as CO_2 equivalent (tonnes) = CO_2 emissions (tonnes) × specific emissions of CO_2 equivalent (tCO_2 TJ^{-1})

3.6. BASIC DATA ON SHIPS VISITING THE PORT OF TALLINN AND IDENTIFICATION OF GHG POLLUTION SOURCES FROM VISITING SHIPS

The mapping of TS GHG emissions confirmed the assumption that shipping accounts for a very large share of TS GHG emissions. As a result, we paid great attention to being able to estimate GHG emissions from shipping as accurately as possible. **The developed methodology is based on the best available information, i.e. uses an automatic ship identification system (AIS)[7] and GHG emission values reported and verified for each vessel (EMSA/THETIS-MRV)[8].**

The advantages of the developed solution over previous practices are the automation and accuracy of calculations. Emission studies carried out by other ports (e.g. Port of Helsinki, Port of Stockholm) generally do not use actually measured emission values but are based on theoretical links between the nature of marine engines and GHG emissions. However, if specific measured emission rates are used, they are generally generalized to the type of ship (no ship specific parameters are used), e.g., the same conversion factor is used for all tankers to calculate GHG emissions when manoeuvring or standing at the quay (Entec, 2002; Starcrest Consulting Group, 2005, 2007; Denier van der Gon & Hulskotte, 2020). This situation is due to the fact that the annual obligation to report CO_2 emissions from ships to the European Commission only arose in 2019, when data for 2018 were submitted. Consequently, ship-based CO_2 emission parameters are only available in the EMSA/THETIS-MRV database for the last two years.

The methodology developed in the course of this work will enable the automation of similar calculations in the future, i.e., it will be possible to generate electronic reports on the rate of CO_2 equivalent emissions from ships present in the port aquatory, either in real time or

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[7] http://www.emsa.europa.eu/ssn-main.html

[8] http://www.emsa.europa.eu/ship-inspection-support/thetis-mrv.html

on the basis of certain time periods (for example a calendar month). We describe our approach in detail below.

In order to assess GHG emissions from ships, the following databases were consulted:

1. The database for the automatic identification system (AIS) of ships was first queried, to obtain information on vessels in the territory of the TS aquatory in 2019. For the current mapping, it was necessary to make an official request to the Maritime Administration, as this agency coordinates the sharing of AIS information in the Estonian maritime area. To date, a preliminary agreement has been made with the Maritime Administration, on the basis of which the Estonian Maritime Academy will be given access to the AIS database in the near future (ideally by the end of 2020), which enables to avoid manual data collection and make automated queries in real time.

The AIS basic data contains information on the period during which the different ships were in the TS territory and the navigational status of these ships at different times (e.g., underway using engines, at anchor, etc.). It is also possible to estimate the speed and voyage of ships based on coordinates and time stamp. The IMO code was used as the ship identifier (each vessel has a unique IMO number), which allows the next stage of analysis to calculate the total CO_2 emissions of ships in the port area based on their movements.

Next, by filtering the AIS data received from the Maritime Administration, we validated possible incorrect entries in the ship type, status, IMO number, time stamp and coordinates fields. For example, some of the data was located outside the aquatory and such data was removed from the database. In addition, for some records, the IMO number of the ship was missing from the AIS database, making it impossible to routinely calculate the location and time of the ships' stay at TS area. Surprisingly, several ship types (e.g., passenger ships and tankers) or different ship dimensions (vessel length, draft) were also given for the same IMO number.

To avoid such manual correction of the data in the future, the next-step scripts include command lines that allow the anomalies described above to be removed from the AIS database.

As a result of the first stage query, it was found out which vessels visited TS in 2019. This query also provided information on the distance travelled by each vessel in the TS aquatory and the total annual time for each vessel to maneuver and stand at the berth.

2. The EMSA / THETIS-MRV database aggregates reported and verified GHG emission values for ships. Annual reports are available at https://mrv.emsa.europa.eu/#public/emission-report. Following the verification of the AIS data in the previous stage, an automated query was generated based on the IMO code to collect information from the EMSA/THETIS-MRV database (http://www.emsa.europa.eu/ship-inspection-support/thetis-mrv.html) on the CO_2 emission parameters of ships visiting the TS harbours. **As a result of the second stage query, the following parameters were imported into the databases for each vessel which visited TS: the IMO number of the ship, the average annual fuel**

consumption and CO_2 emission rate reported for the vessel for the distance travelled (tonnes fuel consumption or kg CO_2 per nautical mile), the total annual CO_2 emissions at sea and at berth (tonnes) and time spent at sea and in port (hours).

Using the AIS/EMSA aggregate database, the CO_2 emissions from manoeuvring and standing at the berth are calculated separately for each vessel according to the following formulas:

Total annual CO_2 emissions during manoeuvring (tonnes) = distance travelled by the ship in the TS waters × CO_2 emission rate of the specific ship per distance travelled × emission parameter of the specific ship during manoeuvring

Total annual CO_2 emissions during standing at berth (tonnes) = time spent at berth × CO_2 emission rate of the specific ship per time at berth × emission parameter of the specific ship at berth

Total annual CO_2 emissions of the ship (tonnes) = total annual emissions during manoeuvring + total annual emissions during standing at berth

The CO_2 equivalent emission was obtained according to the following formula:

Total annual CO_2 emissions of the ship = total annual CO_2 emissions (tonnes) of the ship + 25 × CH_4 emissions (tonnes) + 298 × N_2O emissions (tonnes)

CH_4 emissions = fuel consumption (TJ) × CH_4 specific emissions ($t\ CH_4\ TJ^{-1}$)

N_2O emissions = fuel consumption (TJ) × N_2O specific emissions ($t\ N_2O\ TJ^{-1}$)

As pilot vessels are not classified (supervised by the Maritime Administration), they also do not have an IMO number. Information on the fuel consumption of pilot vessels was received from *Eesti Loots* (Estonian Pilot). Information on the fuel consumption of tugs was obtained from the towing company *Ålfons Hakans*.

The emission of yachts was assessed based on the number of visits by small boats to the Old City Harbour marina and the distance each vessel travels to and from the port (3.4 km in total). Based on the profile of yachts / small boats that have visited the port, a typical yacht was a diesel-powered vessel (16-40 hp), with a fuel consumption at low revs (2-4 knots) estimated at 1 liter per hour. According to these assumptions, each vessel consumes 0.47 l of diesel per visit. GHG emission calculations for pilot ships, tugs and yachts / small boats were performed based on the calculation rules described in the chapter "Calculation of GHG emissions of the Port of Tallinn and operators."

4. RESULTS

4.1. SUMMARY OF GHG EMISSIONS MAPPING

Mapping and calculation of the GHG emissions in the TS harbours (Old City Harbour, Muuga Harbour, Paljassaare Harbour, Paldiski South Harbour, Saaremaa Harbour) were carried out based on the ownership or control of the pollution sources:

- **Scope 1 – direct sources of pollution in TS harbours** (TS-owned vessels, vehicles, other equipment and boiler houses).
- **Scope 2 – indirect sources of pollution in TS harbours** (electricity and heat purchased for TS-owned buildings and infrastructure).
- **Scope 3 – other indirect sources of pollution** (tenants, operators, ships calling at the port, traffic through the ports and ro-ro cargo, cargo handling equipment, railway traffic).

Below, a summary of the results of mapping the GHG emissions in the TS parent company and the TS group is provided by sources and by different scopes. The following chapters describe in more detail the division of the GHG emissions in the TS group, separately by TS, TS Laevad and TS Shipping companies, and in the TS parent company.

The GHG emissions as CO_2 equivalent in the TS harbours (Old City Harbour, Muuga Harbour, Paljassaare Harbour, Paldiski South Harbour, Saaremaa Harbour) **in 2019 amounted in total to 97,426 tons as CO_2 equivalent (scope 1, 2 and 3)** (Table 1). **The corresponding figure of the TS group** (TS, TS Laevad, TS Shipping) **amounted in total to 27,069 tons as CO_2 equivalent (scope 1 and 2)** (Table 2).

Table 1. Greenhouse gases emissions as CO_2 equivalent in tons in TS harbours (Old City Harbour, Muuga Harbour, Paljassaare Harbour, Paldiski South Harbour, Saaremaa Harbour) by sources (scope 1, 2 and 3) [9]

Pollution sources / harbours	**Scope 1**	**Scope 2**	**Scope 3**	**Total**
Electricity consumption	**0**	**3957**	**18032**	**21989**
Muuga Harbour	0	1192	13366	14558
Paldiski South Harbour	0	335	1167	1502
Paljassaare Harbour	0	121	2263	2384
Saaremaa Harbour	0	28	4	33
Old City Harbour	0	2281	1231	3512
Ships	**41**	**0**	**52084**	**52125**
Muuga Harbour	33	0	29005	29038
Paldiski South Harbour	0	0	7132	7133
Paljassaare Harbour	0	0	1151	1151
Saaremaa Harbour	0	0	513	513
Old City Harbour	7	0	14283	14290
Mobile equipment	**496**	**0**	**10142**	**10638**
Muuga Harbour	154	0	6015	6170
Paldiski South Harbour	28	0	2096	2125
Paljassaare Harbour	0	0	61	61
Old City Harbour	313	0	1970	2283
Heat consumption	**684**	**261**	**8518**	**9462**
Muuga Harbour	514	0	7548	8062
Paldiski South Harbour	0	0	902	902
Paljassaare Harbour	110	0	0	110
Old City Harbour	60	261	67	388
Stationary equipment	**0**	**0**	**3212**	**3212**
Muuga Harbour	0	0	2851	2851
Paldiski South Harbour	0	0	361	361
Paljassaare Harbour	0	0	0	0
Total	**1220**	**4218**	**91988**	**97426**

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[9] Scope 1 – direct sources of pollution in TS harbours (TS-owned vessels, vehicles, other equipment and boiler houses). Scope 2 – indirect sources of pollution in TS harbours (electricity and heat purchased for TS-owned buildings and infrastructure). Scope 3 – other indirect sources of pollution (tenants, operators, ships calling at the ports, traffic through the ports and ro-ro cargo, cargo handling equipment, railway traffic).

Table 2. Greenhouse gases emission as CO_2 equivalent in TS group (TS, TS Laevad, TS Shipping) in total (scope 1 and 2) by sources [10]

Pollution source / companies	Scope 1	Scope 2	Total
Electricity consumption	**0**	**5066**	**5066**
incl. TS	0	3957	3957
Ships	**20563**	**0**	**20563**
incl. TS	41	0	41
Mobile equipment	**496**	**0**	**496**
TS	496	0	496
Heat consumption	**684**	**261**	**945**
TS	684	261	945
Total	**21743**	**5326**	**27069**

The GHG emissions of the TS group companies, incl. parent company's tenants, operators and ships calling at the port (scope 1,2,3) in 2019 amounted in total to 119,057 tons as CO_2 equivalent.

4.3. GHG EMISSIONS IN TS GROUP (TS, TS SHIPPING AND TS LAEVAD)

The GHG emissions in the TS group in total amounted to 27,069 tons as CO_2 equivalent (scope 1 and 2), and the traffic of the ships owned by the TS group accounted for a significant majority thereof (76%) (Figure 1, Figure 2, Figure 3, Figure 4).

The business activities of TS Laevad mainly produced the emissions relating to shipping. TS Laevad provide shipping services between the Estonian largest islands and the mainland using the ferries Tõll, Tiiu, Leiger, Piret, Mercandia (chartered vessel for summer peak time) and Regula for this purpose. The next biggest source of the GHG emissions of the group was electricity consumption (19%). TS was the biggest consumer of electricity in the TS group (78% of the total electricity consumption), particularly in the Old City Harbour (45% of the total electricity consumption).

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[10] Scope 1 – direct sources of pollution in the ports of TS, TS Laevad and TS Shipping (owned vessels, vehicles, other equipment and boiler houses). Scope 2 – indirect sources of pollution in the TS harbours, TS Laevad and TS Shipping (electricity and heat purchased for TS-owned buildings and infrastructure).

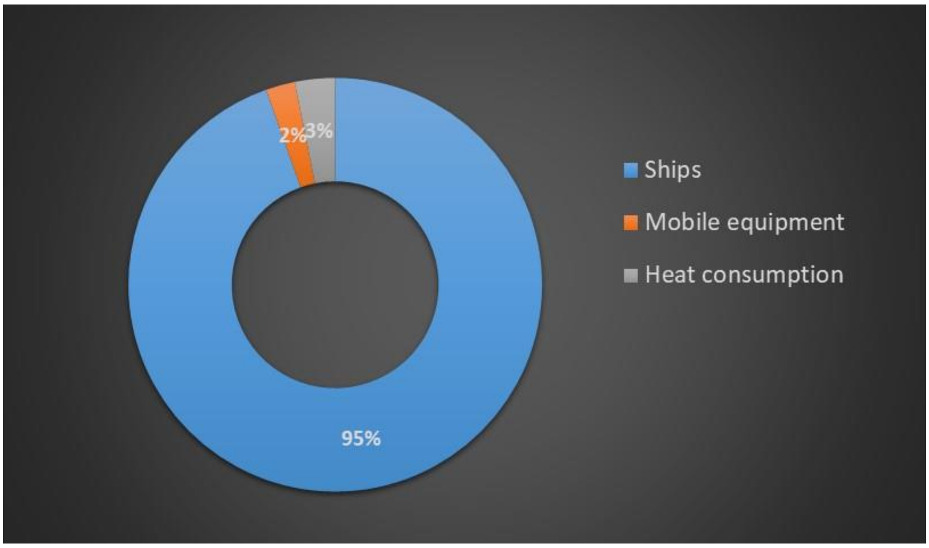

Figure 1. Total GHG emissions of TS group in scope 1 by sources in 2019. The total GHG emissions (100%) amounted to 21,743 tons as CO_2 equivalent [11]

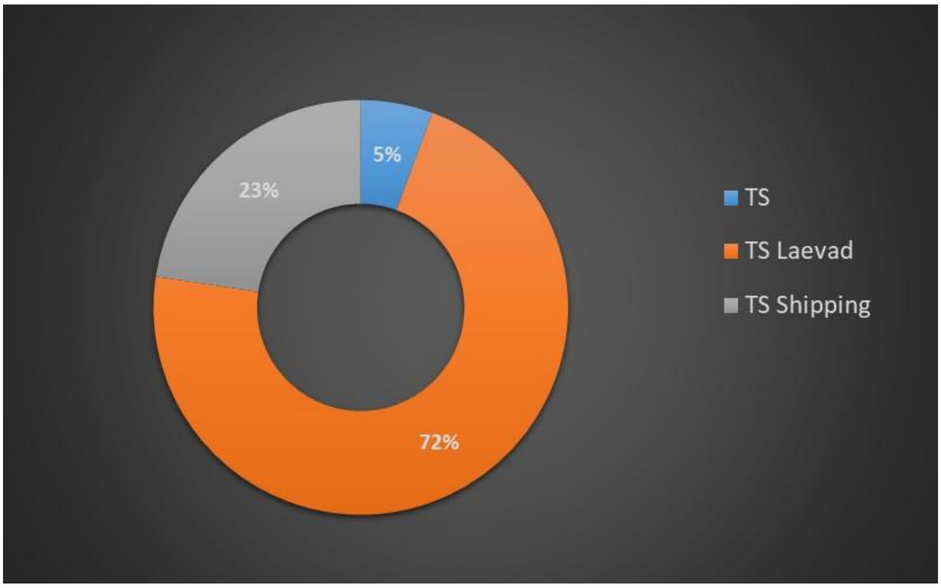

Figure 2. Total GHG emissions in TS group based on sources of scope 1 by companies in 2019 [12]

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[11] Scope 1 – direct sources of pollution in the harbours of TS, TS Laevad and TS Shipping (owned vessels, vehicles, other equipment and boiler houses). Mobile equipment includes cars, buses, freight vehicles, lifting equipment.

[12] Scope 1 – direct sources of pollution in the harbours of TS, TS Laevad and TS Shipping (owned vessels, vehicles, other equipment and boiler houses).

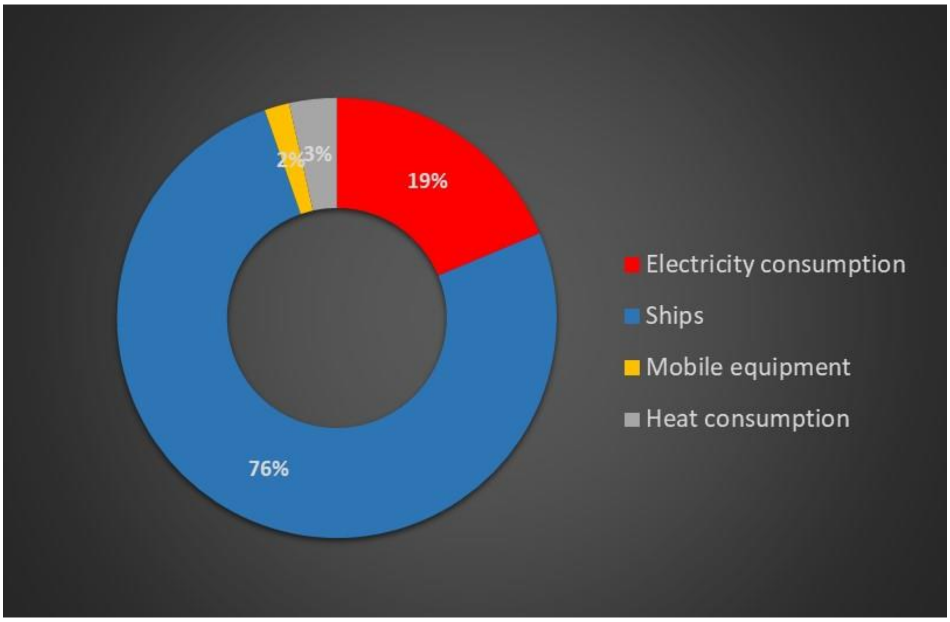

Figure 3. Total GHG emissions in TS group in scope 1 and 2 by sources in 2019. Total GHG emissions (100%) amounted to 27,069 tons as CO_2 equivalent [13]

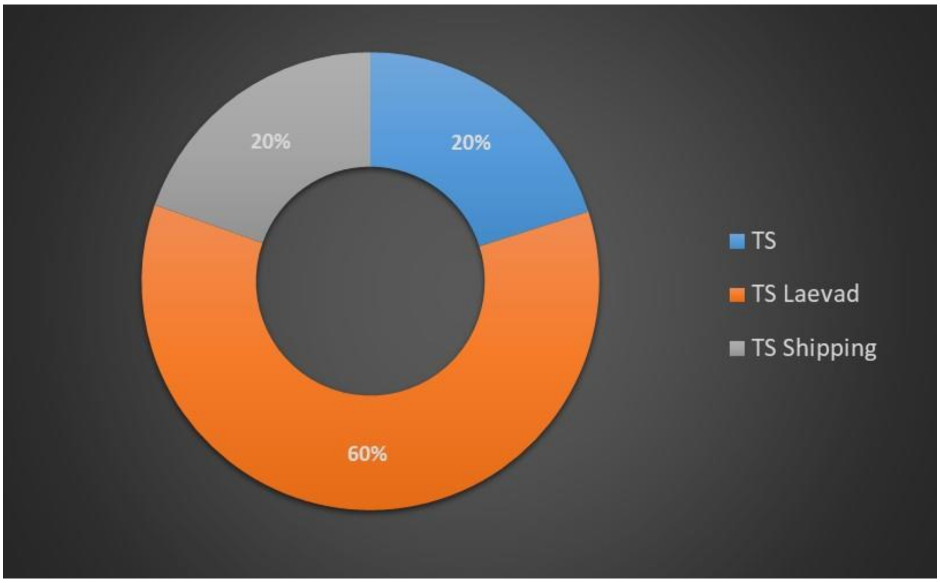

Figure 4. Total GHG emissions in TS group based on sources of scope 1 and 2 by companies in 2019 [14]

Total emissions in TS Laevad amounted to 16,330 tons as CO_2 equivalent (scope 1 and 2) and the shipping services accounted for the major part of the GHG emissions. The electricity consumption of TS Laevad was mainly related to consumption of electricity

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[13] Scope 1 – direct sources of pollution in the harbours of TS, TS Laevad and TS Shipping (owned vessels, vehicles, other equipment and boiler houses). Scope 2 – indirect sources of pollution in the TS harbours, TS Laevad and TS Shipping (electricity and heat purchased for TS-owned ships, buildings and infrastructure). Mobile equipment includes cars, buses, freight vehicles, lifting equipment.

[14] Scope 1 – direct sources of pollution in the harbours of TS, TS Laevad and TS Shipping (owned vessels, vehicles, other equipment and boiler houses). Scope 2 – indirect sources of pollution in the TS harbours, TS Laevad and TS Shipping (electricity and heat purchased for TS-owned ships, buildings and infrastructure).

by ferries at the berth (93% of the electricity consumption of TS Laevad), and the remaining part was related to the electricity consumption at leased spaces.

Total emissions in TS Shipping amounted to 5301 tons as CO_2 equivalent (scope 1 and 2) and the shipping services also accounted for the major part of the GHG emissions (93%). TS Shipping has the icebreaker Botnica and the shipping emissions are related to the fuel consumption of this vessel. The electricity consumption in TS Shipping is mainly related to the consumption of shore power in the Paljassaare Harbour.

To summarize, the mapping of the TS group's GHG emissions shows that 95% of the group's GHG emissions come from shipping and electricity consumption, and in order to reduce the GHG emissions in the TS group, it is necessary to focus on the measures that ensure reduction of emissions by their sources.

4.3. GHG EMISSIONS IN TS PARENT COMPANY

The total emissions of TS in the TS harbours (Old City Harbour, Muuga Harbour, Paljassaare Harbour, Paldiski South Harbour, Saaremaa Harbour) **amounted to 5438 tons as CO_2 equivalent** (scope 1 and 2), and the **electricity consumption accounted for the major part of the GHG emissions (73%)**. The next major sources of the GHG emissions in TS include heat consumption (17%) and emissions from mobile equipment (9%) (Figure 5, Figure 6).

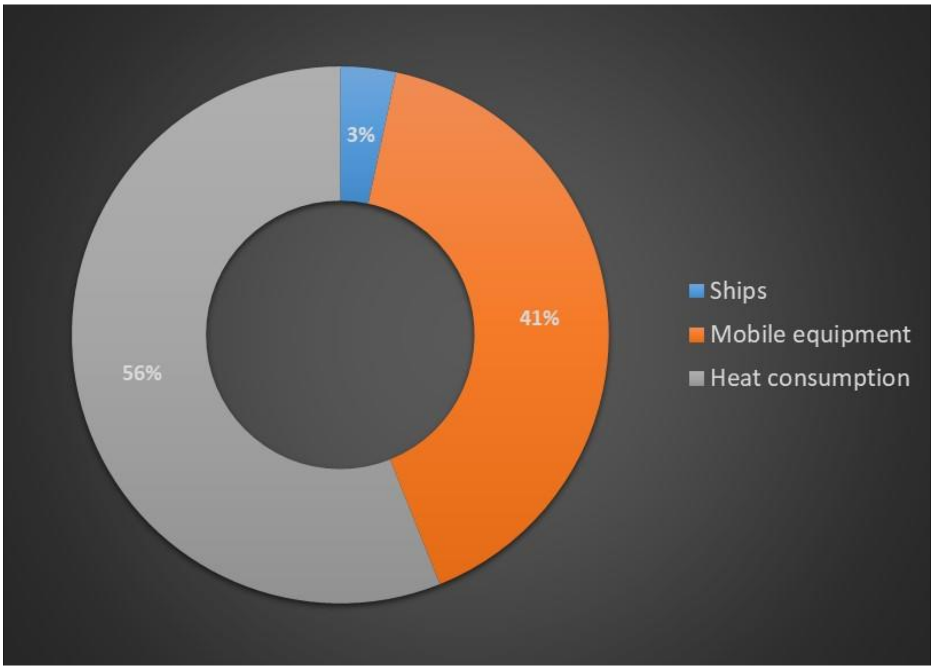

Figure 5. Total GHG emissions in TS parent company by sources of scope 1 in 2019. Total GHG emissions (100%) amounted to 1220 tons as CO_2 equivalent [15]

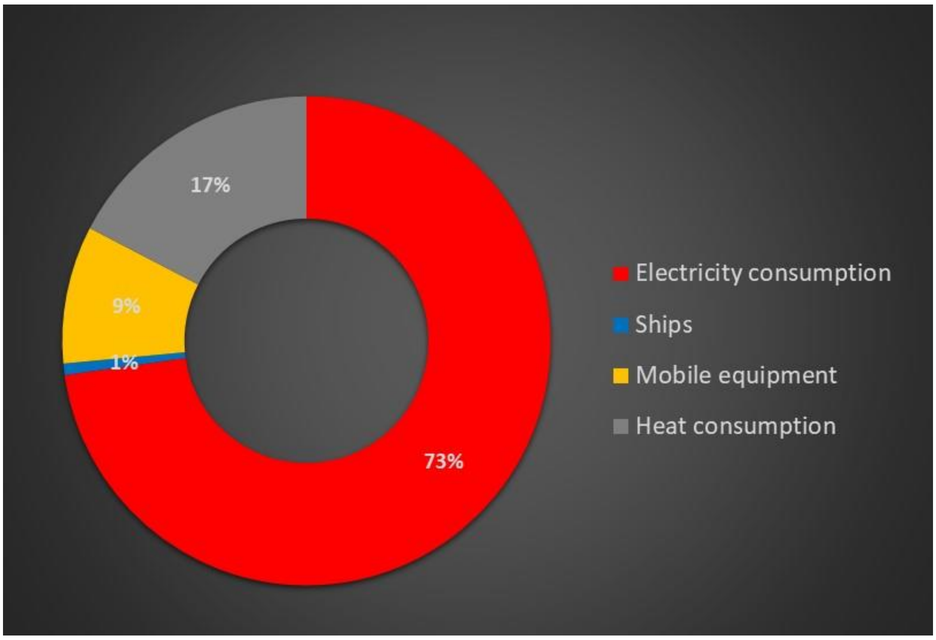

Figure 6. Total GHG emissions in TS parent company in scope 1 and 2 by sources in 2019. Total GHG emissions (100%) amounted to 5438 tons as CO_2 equivalent [16]

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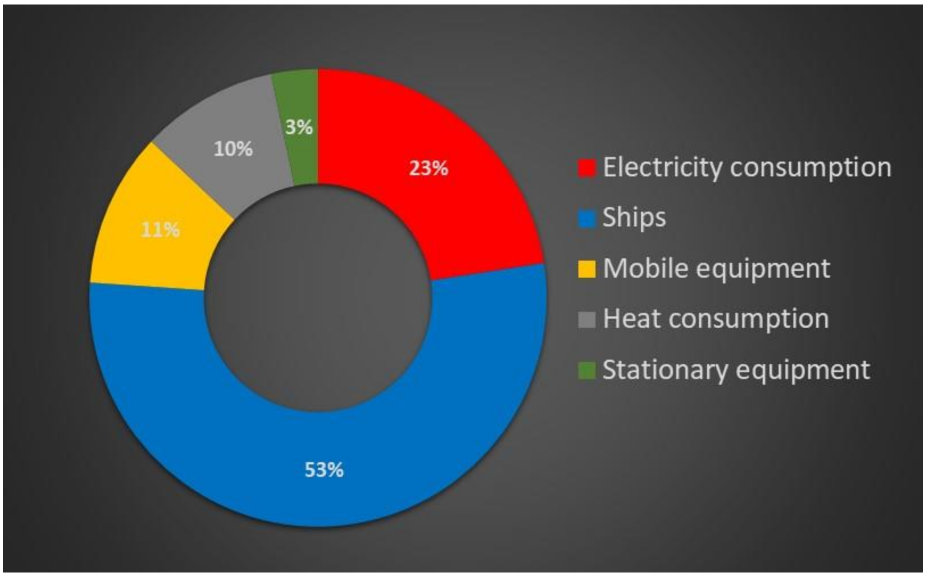
[15] Scope 1 – direct sources of pollution in TS harbours (TS-owned vessels, vehicles, other equipment and boiler houses). Mobile equipment includes passenger cars. The ships include TS-owned vessels.

[16] Scope 1 – direct sources of pollution in TS harbours (TS-owned vessels, vehicles, other equipment and boiler houses). Scope 2 – indirect sources of pollution in TS harbours (electricity and heat purchased for TS-owned buildings and infrastructure). Mobile equipment includes passenger cars. The ships include TS-owned vessels.

The GHG emissions as CO_2 equivalent in the TS parent company in 2019 amounted in total to 97,426 tons as CO_2 equivalent (scope 1, 2 and 3). **The major part of the GHG emissions of scope 1–3 came from shipping (53%),** followed by electricity consumption (23%), emissions from mobile devices (11%), heat consumption (10%), and stationary equipment (3%) (Figure 7). Taking into consideration the GHG emissions of the TS parent company in scope 3, the total emissions amounted to 91,988 tons as CO_2 equivalent, and the major part thereof came from shipping (57%) and electricity consumption (20%) (Figure 8).



Source of emissions Electricity consumption Ships Mobile equipment Heat consumption Stationary equipment

Figure 7. Total GHG emissions in TS parent company in scope 1, 2 and 3 by sources in 2019. The total GHG emissions (100%) amounted to 97,426 tons as CO_2 equivalent [17]

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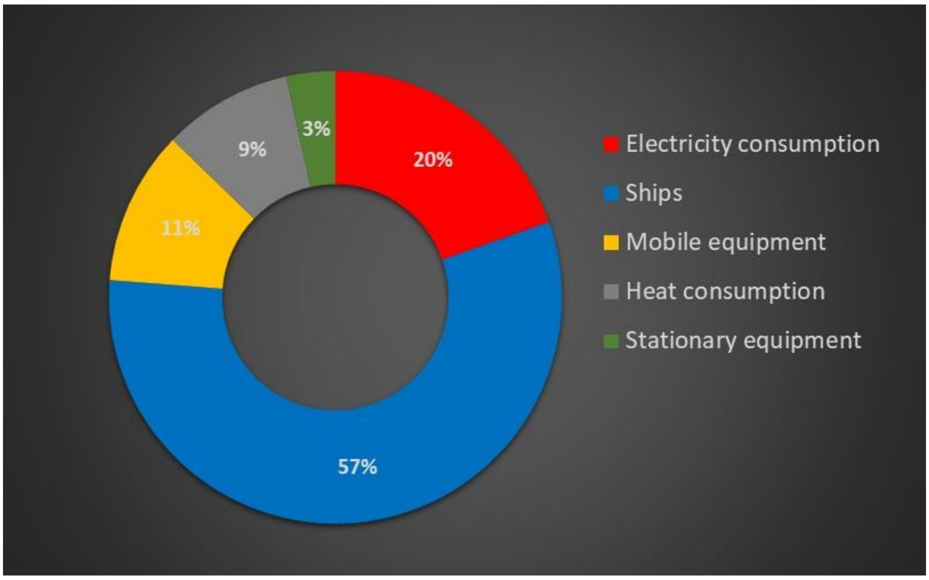
[17] Scope 1 – direct sources of pollution in TS ports (TS-owned vessels, vehicles, other equipment and boiler houses). Scope 2 – indirect sources of pollution in TS ports (electricity and heat purchased for TS-owned buildings and infrastructure). Scope 3 – other indirect sources of pollution (tenants, operators, ships calling at the ports, traffic through the ports and ro-ro cargo, cargo handling equipment, railway traffic). Mobile equipment includes locomotives end other rolling stock, passenger cars, buses, freight vehicles, lifting equipment, tractors, loaders, mobile cranes and other loading and unloading equipment. Ships include TS-owned vessels, auxiliary fleet (pilot boats / tugboats) and ships calling at ports.



Source of emission Electricity consumption Ships Mobile equipment Heat consumption Stationary equipment

Figure 8. Total GHG emissions in TS parent company by sources of scope 3 in 2019. The total GHG emissions (100%) amounted to 91,988 tons as CO_2 equivalent [18]

The share of shipping in the GHG emissions of the TS harbours is significantly lower (53%) **than that of the other ports located in the region.** For example, the share of shipping in the Port of Rotterdam is 87% of the total GHG emissions[4], and the respective figure of the Port of Helsinki is 79% respectively[5]. **The current situation is caused to a large extent by different methodological approaches of different ports when defining the shipping GHG**. Our methodology allows to determine the emissions of each vessel based on validated and audited basic data, both during manoeuvring operations and when standing at the berth. The basic ship-based data were obtained from the EMSA/THETIS-MRV database, which contains the reports relating to the GHG emissions of the European Union shipping[8]. Emission rates generalised to the type of ship are used for assessing the GHG emissions from shipping in the Port of Helsinki, e.g. one coefficient is used for assessment of standing at berth in the case of all passenger ships. However, in reality passenger ships are so different that using such generalization poses a high risk for overestimation of the GHG emissions rate. In addition, even the technical characteristics of the ships have significantly changed over the time, and the use of relatively old coefficients in the methodological approaches of the Port of Helsinki and other ports has a significant impact on the GHG mapping results (Entec, 2002; Starcrest Consulting Group, 2005, 2007). The same coefficients (Starcrest Consulting Group, 2005, 2007) were also used in the Transport and Mobility Development Plan for 2021+ ordered by the Ministry of Economics and Communication for assessment of the contribution of shipping to the GHG emissionsl[19, 20]. Consequently, the results of the research of the

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[18] Scope 3 – other indirect pollution sources (tenants, operators, ships calling at ports, traffic through the ports and ro-ro cargo, cargo handling equipment, railway traffic). Mobile equipment includes locomotives end other rolling stock, passenger cars, buses, freight vehicles, lifting equipment, tractors, loaders, mobile cranes and other loading and unloading equipment.

[19] https://www.mkm.ee/et/uudised/transpordi-ja-liikuvuse-visioon-inimkesksem-rohelisem-ja-nutikam-taristu

[20] https://www.itf-oecd.org/sites/default/files/docs/dp201420.pdf

Ministry of Economics and Communication also significantly differ from the results of the current mapping.

In general, the GHG mapping methods of ports are extremely diverse and comparison of the GHG emissions in different ports do not give a full picture of the current situation. The main objective of the ports GHG emissions mapping is to compare the results within the same port in time, incl. in order to assess the efficiency of any measures implemented in the ports to reduce GHG emissions. Therefore, the ports located in our region use such GHG emissions mapping methodologies which gave the best possible result in their time (i.e. when these ports commenced with GHG emissions mapping). The annual obligation to report the CO2 emissions from ships to the European Commission only arose in 2019, when the data for 2018 were submitted. Consequently, ship-based CO_2 emission parameters are only available for the last two years in the EMSA/THETIS-MRV database.

The GHG emissions relating to the Muuga Harbour (56%), the Old City Harbour (28%) and Paldiski South Harbour (13%) account for the major part of the shipping GHG emissions in TS-owned ports. The major part (93%) of the total shipping emissions come from the emissions of ships standing at berth. The emissions of ships standing at berth depend on the time spent in the port (Figure 9) and the emissions rate of each ship[8]. From among the types of ships, the biggest contributors to the GHG emissions are cargo vessels (43%), passenger ships (30%) and tankers (17%) (Figure 10). However, the emissions of TS-owned ships in the TS ports are marginal. The emissions of the ships of TS Laevad and TS Shipping are described in the previous chapter.

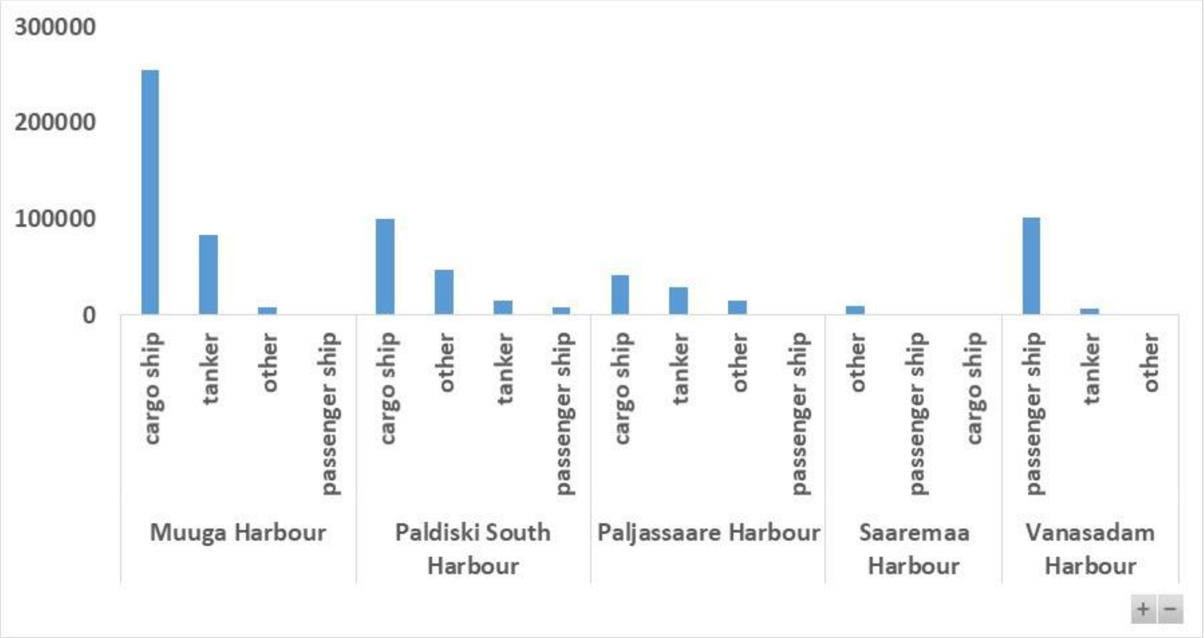

Figure 9. Total time of standing at berth of different types of ships that called at TS parent company (in hours) at different ports in 2019

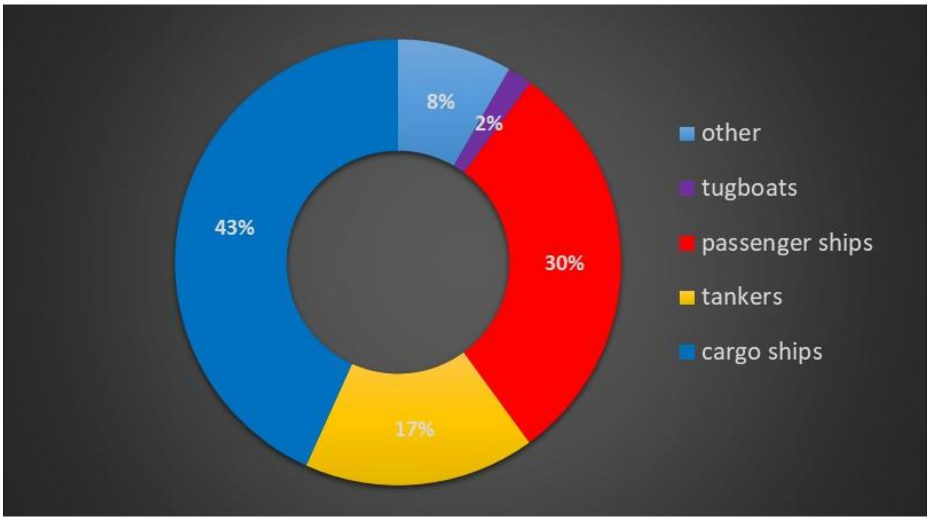

Figure 10. Shipping related GHG emissions in TS parent company (scope 3) by types of ships in 2019. The total GHG emissions (100%) amounted to 52084 tons as CO_2 equivalent [21]

The largest electricity consumption was in the Muuga Harbour (65% of the total electricity consumption), followed by the Old City Harbour (16%) and the Paljassaare Harbour (12%). The electricity consumption of operators (81%) significantly exceeded the TS electricity consumption (19%); only in the Old City Harbour and the Saaremaa Harbour the TS electricity consumption exceeded that of the operators. The electricity consumption of six operators (Liwathon E.O.S. AS, Vesta Terminal Tallinn OÜ, HHLA TK Estonia AS, DBT AS, MGT Muuga Grain Terminaal AS and Nynas AS) accounted for 44% of the entire GHG emissions caused by the electricity consumption in the TS parent company.

The GHG emissions of the mobile equipment in TS-owned harbours (locomotives and other rolling stock, passenger cars, buses, cargo vehicles, lifting equipment, loaders, mobile cranes and other loading and unloading equipment) **were the largest in the Muuga Harbour (58% of the total emissions of the mobile equipment of the TS parent company), followed by the Old City Harbour (21%) and the Paldiski South Harbour (20%).** The share of the mobile equipment of the operators in the emissions was significantly higher in all TS-owned ports (95%) than in TS (5%). Due to the nature of the available data (the total annual number of mobile equipment that passed under the barriers and the registration number of each vehicle), it is not possible to distinguish accurately between different operators' share in the emissions of mobile equipment and point out the more important GHG emissions generated by operators' mobile vehicles.

The largest heat consumption among TS-owned harbours was in the Muuga Harbour (85%), followed by the Paldiski South Harbour (10%) and the Old City Harbour (4%). The share of the heat consumption of the operators in the emissions was significantly higher in all TS-owned harbours (90%) than in TS (10%). The heat

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[21] Scope 3 – other indirect pollution sources (ships of tenants and operators, ships calling at the ports). Yachts and pilot boats were left out of the Figure since their total emissions only amount to 0.036% of the emissions of all the ships.

consumption of six operators (Liwathon E.O.S. AS, Olerex Terminal AS and Vesta Terminal Tallinn OÜ) accounted for 67% of the total GHG emissions arising from the heat consumption in the TS parent company.

In conclusion, the GHG emissions mapping in the TS parent company showed that the major part of the emissions comes from shipping and economic activities relating to operators. Consequently, the TS parent company needs to focus on the measures that allow to reduce the GHG emissions relating to shipping and operators' electricity consumption. In the case of TS (scope 1 and 2), electricity and heat consumption account for the major part of the GHG emissions (90%), and in order to reduce the environmental impact of TS, it is necessary to focus on the activities that ensure reduction of the emissions particularly by their sources.

5. RECOMMENDATIONS TO REDUCE CO_2 EMISSIONS IN TS

The greatest potential of the TS group and parent company in reduction of the GHG emissions is outlined below by different scopes. The share of the specified measures in reduction of the GHG emissions in the TS group and parent company are illustrated in the figures (Figure 11, Figure 12, Figure 13). Implementability of the measures in the short or long term with explanations are provided in the table (Annex 2).

Shipping accounted for 95% GHG emissions in the TS Group, related to the business activities of TS Laevad and TS Shipping.

Measure 1: By transferring the vessels of TS Laevad and TS Shipping to alternative fuels (e.g. green electricity or hydrogen), it is possible to reduce the GHG emissions **by 20,522 tons** as CO_2 equivalent (**75.8%** of the TS group's emissions, scope 1).

Measure 2: By transferring the shore power of TS Laevad to (either produced or purchased) green electricity, it is possible to additionally reduce the GHG emissions by **677 tons** as CO_2 equivalent (**2.5%** of the TS group's emissions, scope 1 and 2).

Measure 3: By transferring the TS vehicles to green electricity, green gas or hydrogen, it is possible to reduce the GHG emissions by **496 tons** as CO_2 equivalent (**9.1%** of the emissions of the TS parent company, scope 1 and 2).

Measure 4: By transferring the TS auxiliary fleet to alternative fuels (e.g. green electricity or hydrogen), it is possible to reduce the GHG emissions by **41 tons** as CO_2 equivalent (**0.8%** of the emissions of the TS parent company, scope 1 and 2).

Measure 5: By transferring the TS boiler houses to green gas, it is possible to reduce the GHG emissions by 684 tons as CO_2 equivalent. In the case production of heat energy is commenced even for the Old City Harbour (currently the heat energy is purchased there), it is possible to additionally reduce the GHG emissions by **261 tons** as CO_2 equivalent (**17.4%** of the emissions of the TS parent company, scope 1 and 2).

Electricity consumption accounted for 73% of the GHG emissions of the TS parent company. At present, the price of the conventional and green electricity does not differ significantly.

Measure 6: In the case the TS parent company transfers to a green electricity package, it is possible to reduce the GHG emissions by **3957 tons** as CO_2 equivalent (**72.8%** of the emissions in the TS parent company, scope 1 and 2). As an alternative, it is possible to produce electric energy either in part or in full by TS, for example in the solar parks built on the port territory, and/or to participate in the construction of land and offshore wind farms.

The largest part of the scope 3 emissions come from the emissions relating to shipping in the total quantity of 51,137 tons as CO_2 equivalent. Of this quantity, 3491 tons as CO_2 equivalent are the emissions relating to manoeuvring operations, and 47,646 tons as CO_2 equivalent are the emissions from ships standing at berth (from passenger ships 12,884, from cargo vessels 22,045, and from tankers 8486 tons as CO_2 equivalent).

Measure 7: Hence, one of the biggest measure for TS GHG reduction is to redirect the ships to use shore power. When (either produced or purchased) green electricity is used for electricity production, it is possible to reduce the GHG emissions by **47,646 tons** as CO_2 equivalent (**48.9%** of the emissions of the TS parent company, scope 1, 2 and 3).

Measure 8: By transferring pilot boats and tugboats to alternative fuels (e.g. hydrogen or green electricity), it is possible to reduce the GHG emissions by **941 tons** as CO_2 equivalent (**1.0%** of the emissions of the TS parent company, scope 1, 2 and 3).

Measure 9: Giving priority to such vessels which GHG emissions are lower (e.g. those using alternative fuels, e.g. LNG or hydrogen), it is possible to reduce in the long term even this part of the GHG emissions of the vessels which is related to manoeuvring operations in the port water area in total by **3491 tons** as CO_2 equivalent (**3.6%** of the emissions of the TS parent company, scope 1, 2 and 3).

The electricity consumption accounts for 20% in the GHG emissions of the operators of the TS parent company.

Measure 10: In the case TS redirects operators to consume green energy and/or produces green energy itself to its operators, it is possible to reduce the GHG emissions **by 18,032 tons** as CO_2 equivalent (**18.5%** of the emissions of the TS parent company, scope 1, 2 and 3).

Measure 11: By transferring the boiler houses of the TS operators to green gas, it is possible to reduce the GHG emissions of the entire TS parent company by **9462 tons** as CO_2 equivalent (**9.7%** of the emissions of the TS parent company, scope 1, 2 and 3).

Measure 12: In the case TS redirects its operators' stationary equipment running on diesel and natural gas to consume green energy, it is possible to reduce the GHG emissions by **1482 tons** as CO_2 equivalent (**1.5%** of the emissions of the TS parent company, scope 1, 2 and 3).

In addition, it is possible to reduce the GHG emissions in the TS group and parent company by activities which allow energy / fuel consumption saving, e.g. development of sustainable behaviour in the port area (engines of cars standing in parking lots switched off, use of air-conditioning devices only in cruise buses en route), development of digital solutions with the aim to reduce waiting lines of cars in port area, optimization of traffic in road junctions, improving energy efficiency of buildings, hydrogen technology, creating opportunities for use of seawater for heating/cooling on the TS territory. However, it is impossible to define in this report the precise impact of such activities to the GHG reduction rate as we do not have any detailed basic data for carrying out such analyses.

In addition to the above suggested solutions, it is possible to also contribute to **different types of compensatory measures, e.g. to consider participation in construction of offshore wind farms and use of energy produced by wind farms to reduce GHG emissions of the TS operations. It is also possible to consciously contribute to the improvement activities of the natural environment in order to facilitate CO_2 capture from atmosphere. These activities include, for example, construction of a small shellfish farm**. The conditions at the Küdema Bay are ideal for shellfish farms, e.g. harvesting of one crop in a 5 hectare farm allows to compensate for 15 tons of GHG emissions as CO_2 equivalent, which accounts for 53% of the GHG emissions generated by TS in the Saaremaa Harbour (GHG emissions generated in electricity consumption, scope 2, in 2019 amounted to 28.1 tons as CO_2 equivalent). In addition to reduction of the GHG emissions, such farm is also able to significantly improve the state of coastal ecosystems by removing excess nutrients (deposited in the previous decades) from there.

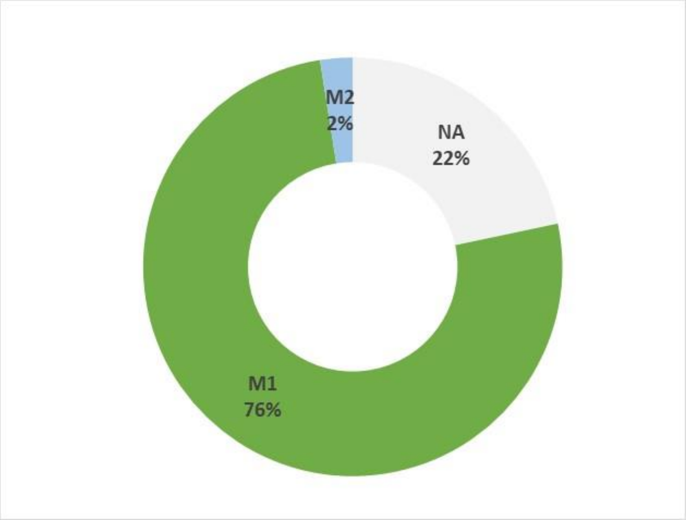

Figure 11. Potential of different measures (M1, M2) (%) to allow to reduce GHG emissions of TS group based on results of GHG emissions mapping in 2019 (scope 1–2). GHG emissions of TS group (scope 1–2) amounted in 2019 to 27069 tons as CO_2 equivalent [22]

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[22] The measures are described in more detail in the text. NA includes the measures concerning TS which are outlined below in the figures of TS and TS parent company.

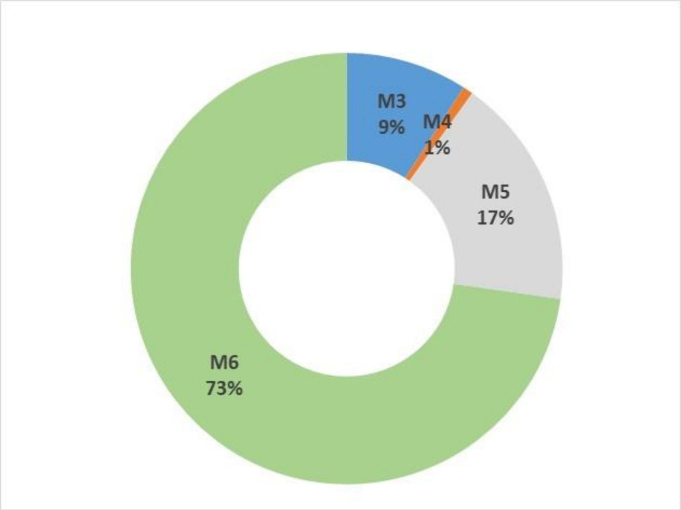

Figure 12. Potential of different measures (M3, M4, etc.) (%) to allow to reduce <u>GHG emissions of TS</u> based on results of GHG emissions mapping in 2019 (scope 1–2). TS GHG emissions (scope 1–2) amounted in 2019 to 5438 tons as CO_2 equivalent [23]

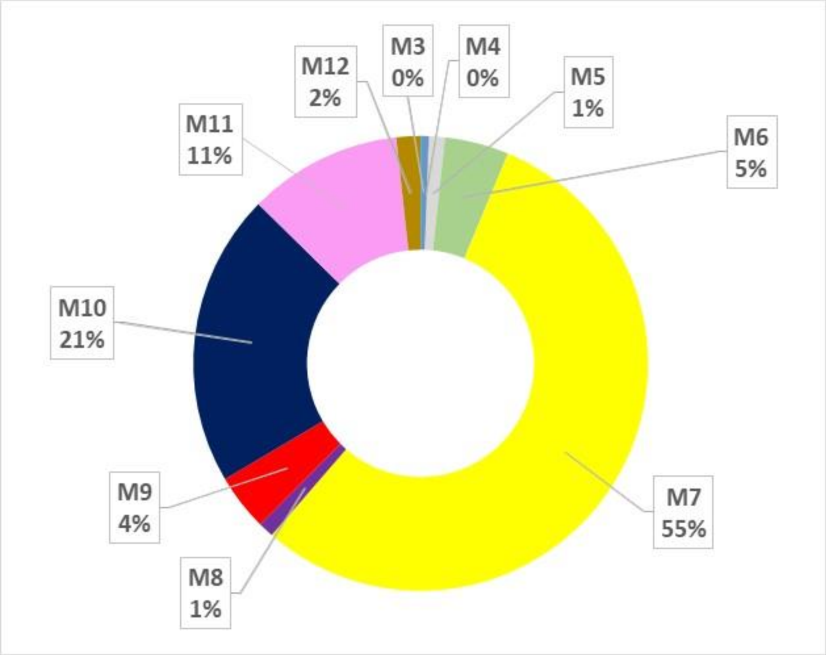

Figure 63. Potential of different measures (M3, M4, etc.) (%) to allow to reduce <u>GHG emissions of TS parent company</u> based on results of GHG emissions mapping in 2019 (scope 1–3). GHG emissions of the TS parent company (scope 1–2) amounted in 2019 to 97426 tons as CO_2 equivalent [24]

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[23] The measures are described in more detail in the text.

[24] The measures are described in more detail in the text.

To conclude, such activities should be regarded as the most efficient measures in the reduction of the GHG emissions which bring about the largest reduction in the emission rate. In the TS group, such activity is unquestionably the transfer of ferries to alternative fuels and the use of (either purchased or produced) green shore power. For the TS parent company, the largest effect comes from transfer of calling vessels to (preferably green) shore power (will reduce the total emissions of the TS parent company by 55%). Importantly, the transfer of the operators' electricity and heat consumption to green energy is extremely important (will reduce the total emission of the TS parent company by 32%).

5.1. OTHER RECOMMENDATIONS

One of the biggest challenges of the GHG emissions mapping in 2019 was to obtain timely feedback from operators. Consequently, it is reasonable to simplify the questionnaire sent to the operators for the following years. **One opportunity would be to send the questionnaire in the form of a web-based application** where the operators can give feedback only on those issues that directly affect their operations. All the fields that do not concern the given operator can be left out from such dynamic questionnaire. A web-based application also allows to immediately validate the basic data. In the case an operator enters any incorrect data, the operator can be immediately notified of the problem fields by error messages and representative basic data can be generated by means of such quality control. As the TS mobile equipment mapping is done automatically at the barriers, the mapping of operators' mobile equipment which move out from the port territory is not necessary in the subsequent years.

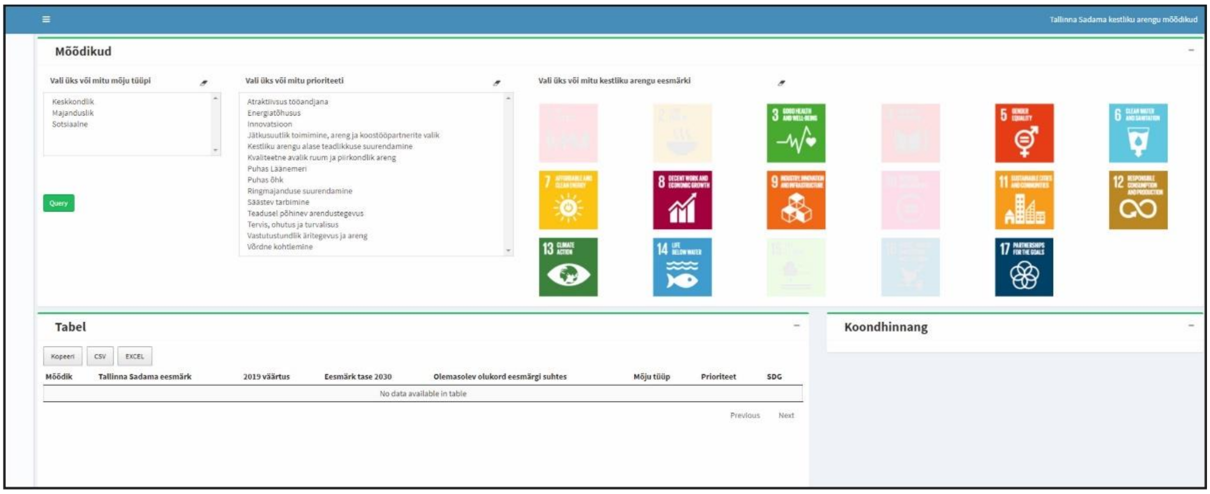
6. PILOT WEB-BASED DATA DISPLAY APPLICATION

In the framework of this work, a simple pilot web-based application was created, which sets out the indicators (incl. from assessments of GHG emissions reduction, rate of circular economy, environmental status), which characterize the environmental, economic and social sustainable development objectives of the port and show the current levels of these values. Possible preliminary key indicators were developed by the TS experts and supplemented by the authors of this work as regards the environmental objectives based on the objectives of the TS sustainable development strategy.

When the final analysis (table) is completed about the current and target levels of the indicators of the TS sustainable development objectives, it is possible to immediately import this table into the application and use the created functionality to analyse the current situations of sustainable development with respect to different TS objectives.

In the future, it is possible to integrate the basic data of the application (table of indicators) with the created SQL database of GHG emissions mapping owned by TS. In principle, the sustainable development application can be transferred to the Power BI platform, and it allows TS to display the results of the GHG emissions analysis and sustainable development indicators on the TS web site.

The home page of the web application displays three general systems based on which it is possible to classify the created TS indicators: types of impact, TS priorities and the United Nations Sustainable Development Goals (Figure 14).



Mõõdik	Tallinna Sadama eesmärk	2019 väärtus	Eesmärk tase 2030	Olemasolev olukord eesmärgi suhtes	Mõju tüüp	Prioriteet	SDG

No data available in table

Figure 74. Application's opening page. The application allows its user to collect information about the targets and current levels of the indicators characterizing the TS environmental, economic and social sustainable development goals

In addition, a table is displayed in the lower part of the application which contains the TS indicators used for types of impact / priorities / sustainable development goals. The following columns are displayed in the table: exact name of the indicator, TS objective corresponding to the specific indicator, indicator’s value for 2019, indicator's goal level for 2030, current situation with respect to the goal (percentage of the goal), type of impact characterizing the indicator, priority and sustainable development goal.

7. SUMMARY

The purpose of this study was to calculate the greenhouse gases (GHG) emissions and define the level on environmental indicators in the harbours of the Port of Tallinn (TS) for 2019. In order to assess TS GHG emissions, the existing data on direct and indirect sources of pollution in the port were compiled, a survey was conducted among TS operators to assess their GHG emissions, a query was made to the Estonian Road Administration regarding mobile vehicles, information on train traffic was collected from Operail, Go Rail, Skinest Rail, and in addition, various maritime databases were queried to determine the emissions of ships visiting the TS aquatory.

Mapping and calculation of the GHG emissions in the TS harbours (Old City Harbour, Muuga Harbour, Paljassaare Harbour, Paldiski South Harbour, Saaremaa Harbour) were carried out based on the ownership or control of the pollution sources:

- **Scope 1 – direct sources of pollution in TS harbours** (TS-owned vessels, vehicles, other equipment and boiler houses).
- **Scope 2 – indirect sources of pollution in TS harbours** (electricity and heat purchased for TS-owned buildings and infrastructure).
- **Scope 3 – other indirect sources of pollution** (tenants, operators, ships calling at the TS harbours, traffic through the port and ro-ro cargo, cargo handling equipment, railway traffic).

The GHG emissions as CO_2 equivalent amounted in the TS parent company (Old City Harbour, Muuga Harbour, Paljassaare Harbour, Paldiski South Harbour, Saaremaa Harbour) **in 2019 in total to 97,426 tons as CO_2 equivalent** (scope 1, 2 and 3). **In the TS group** (TS, TS Laevad, TS Shipping), **the respective total figure was 27,069 tons as CO_2 equivalent** (scope 1 and 2), **the major part of which was generated by the traffic of the ships owned by the group**. **The major part of the GHG emissions of the TS parent company (scope 1–3) came from shipping (53%)**, followed by electricity consumption (23%), emissions from mobile devices (11%), heat consumption (10%), and stationary equipment (3%). **The GHG emissions of the TS group companies, incl. parent company's tenants, operators and ships calling at the port (scope 1,2,3) in 2019 amounted in total to 119,057 tons as CO_2 equivalent.**

In the TS group, transfer of ferries to alternative fuels and the use of (either purchased or produced) green shore power **are the most effective measures**. **For the TS parent company, the largest effect comes from transfer of the calling ships to (preferably green) shore power.** Smililarly, the transfer of the operators' electricity and heat consumption to green energy is extremely important.

In addition, in the framework of this work, a simple pilot web-based application was created, which sets out the indicators (incl. from assessments of GHG emissions reduction, rate of circular economy, environmental status), which characterize the environmental, economic and social sustainable development objectives of the port and show the current levels of these values.

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ANNEXES

ANNEX 1. AVERAGE FUEL CONSUMPTION OF MOTOR VEHICLES, CALORIFIC VALUES AND SPECIFIC EMISSIONS FACTORS USED IN GHG CALCULATIONS.

Calorific values and conversion factors	Value	Unit	Note
Petrol	31.82	MJ/L	The average calorific value 43 MJ/kg was obtained from Statistics Estonia[25]. The specific density 0.74kg/L was obtained from the fuel lab of the Estonian Environmental Research Centre.
Diesel	35.69	MJ/L	The average calorific value 43MJ/kg was obtained from Statistics Estonia[25]. The specific density 0.83 kg/L was obtained from the fuel lab of the Estonian Environmental Research Centre.
Diesel	43	MJ/kg	The calorific value 43MJ/kg was obtained from Statistics Estonia[25].
Diesel (B10)	35.97	MJ/L	The average calorific value 43.3 MJ/kg was obtained from Statistics Estonia[25]. The specific density 0.83 kg/L was obtained from the fuel lab of the Estonian Environmental Research Centre.
LPG	46	MJ/kg	The calorific value 46MJ/kg was obtained

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[25] http://pub.stat.ee/px-web.2001/dialog/statfile2.asp

			from Statistics Estonia[25].
Electricity	3.6	MJ/kWh	Energy unit conversion.
Natural gas	34	MJ/m^3	The average calorific value was obtained from Elering[26]
Shale oil	39.24	MJ/kg	The calorific value 39.24 MJ/kg was obtained from Statistics Estonia[25].

Average fuel consumption of motor vehicles	**Fuel type**	**Value**	**Unit**	**Note**
PC - passenger car	Petrol	11	L/100 km	The average fuel consumption of the type of vehicle was obtained from the Copert model of the Republic of Estonia Environment Agency. In addition, it was taken into consideration that urban driving (incl. short trips) increase the average fuel consumption by about 30%.
	Diesel	9.4	L/100 km	
LDV - Cargo van	Diesel	11.5	L/100 km	
HDV - Heavy-duty vehicle	Diesel	33	L/100 km	
HDV - Bus	Diesel	44.75	L/100 km	
MC - Motorcycles	Petrol	4.46	L/100 km	

Specific emission factors				
CO_2 specific emission factors by types of fuel	*Fuel*	*Value*	*Unit*	*Note*
	Petrol	71.0100	tCO_2/TJ	Formula for calculation of CO_2 specific emission factor: specific carbon emission (tC/TJ) x 44/12. The specific carbon emission
	Diesel	73.1778	tCO_2/TJ	
	LPG	63.6434	tCO_2/TJ	
	Diesel (B10)	65.8600	tCO_2/TJ	
	Shale oil	77.3667	tCO_2/TJ	
	Natural gas	65.8600	tCO_2/TJ	

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[26] https://elering.ee/vorgugaasi-kvaliteet

				was obtained from NIR2020[27] (p. 106 table 3.27)
Specific emission factors of petrol by types	*Type*	*Value*	*Unit*	*Note*
	PC	0.0091	tCH$_4$/TJ	Total annual CH$_4$ emission of types of vehicles were obtained from the Copert model of the Republic of Estonia Environment Agency, and it was divided by the total annual quantity of fuel consumed by the vehicle type (TJ).
	LDV	0.0078	tCH$_4$/TJ	
	HDV	0.0163	tCH$_4$/TJ	
	MC	0.0654	tCH$_4$/TJ	

Specific emission factors				
Specific emission factors of petrol by types	*Type*	*Value*	*Unit*	*Note*
	Equipment	0.0800	tCH$_4$/TJ	The specific emission was obtained from NIR2020[27] (p. 119 table 3.34)
	Ship	0.0070	tCH$_4$/TJ	The specific emission was obtained from IPCC2006[28] (p. 3.50 table 3.5.3)
	PC	0.0009	tN$_2$O/TJ	Total annual N$_2$O emission of types of vehicles were obtained from the Copert model of the Republic of Estonia Environment Agency, and it was divided by the total annual quantity of fuel consumed by the vehicle type (TJ).
	LDV	0.0012	tN$_2$O/TJ	
	HDV	0.0009	tN$_2$O/TJ	
	MC	0.0012	tN$_2$O/TJ	

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[27] https://www.envir.ee/sites/default/files/nir_est_1990-2018_15.03.2020.pdf

[28] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

	Equipment	0.0020	tN_2O/TJ	The specific emission was obtained from NIR2020[27] (p. 119 table 3.34)
	Ship	0.0020	tN_2O/TJ	The specific emission was obtained from IPCC2006[28] (p. 3.50 table 3.5.3)
Specific emission factors of diesel by types	*Type*	*Value*	*Unit*	*Note*
	PC	0.0005	tCH_4/TJ	Total annual CH_4 emission of types of vehicles were obtained from the Copert model of the Republic of Estonia Environment Agency, and it was divided by the total annual quantity of fuel consumed by the vehicle type (TJ).
	LDV	0.0003	tCH_4/TJ	
	HDV	0.0025	tCH_4/TJ	

Specific emission factors				
Specific emission factors of diesel by types	*Type*	*Value*	*Unit*	*Note*
	Equipment	0.0042	tCH_4/TJ	The specific emission was obtained from NIR2020[27] (p. 109 table 3.30)
	Train	0.0042	tCH_4/TJ	The specific emission was obtained from NIR2020[27] (p. 119 table 3.34)
	Ships	0.0070	tCH_4/TJ	The specific emission was obtained from NIR2020[27] (p. 111 table 3.31)
	PC	0.0030	tN_2O/TJ	Total annual N_2O emission of types of vehicles were obtained from the
	LDV	0.0024	tN_2O/TJ	
	HDV	0.0027	tN_2O/TJ	

				Copert model of the Republic of Estonia Environment Agency, and it was divided by the total annual quantity of fuel consumed by the vehicle type (TJ).
	Equipment	0.0286	tN_2O/TJ	The specific emission was obtained from NIR2020[27] (p. 119 table 3.34)
	Train	0.0286	tN_2O/TJ	The specific emission was obtained from NIR2020[27] (p. 109 table 3.30)
	Ships	0.0020	tN_2O/TJ	The specific emission was obtained from NIR2020[27] (p. 111 table 3.31)
LPG specific emission factors by categories	*Type*	*Value*	*Unit*	*Note*
	PC	0.0010	tCH_4/TJ	The specific emission was obtained from NIR2020[27] (p. 106 table 3.27)
	Equipment	0.0050	tCH_4/TJ	The specific emission was obtained from NIR2020[27] (p. 119 table 3.33)

Specific emission factors				
LPG specific emission factors by categories	*Type*	*Value*	*Unit*	*Note*
	PC	0.0001	tN_2O/TJ	The specific emission was obtained from NIR2020[27] (p. 106 table 3.27)

	Equipment	0.0001	tN_2O/TJ	The specific emission was obtained from NIR2020[27] (p. 119 table 3.33)
Natural gas specific emission factors by categories	*Type*	*Value*	*Unit*	*Note*
	Equipment	0.0010	tCH_4/TJ	Specific emissions obtained from NIR2020[27]: (p. 85 table 3.10)
	Heat production	0.0010	tCH_4/TJ	
	Equipment	0.0001	tN_2O/TJ	
	Heat production	0.0001	tN_2O/TJ	
Shale oil specific emission factors by categories	*Type*	*Value*	*Unit*	*Note*
	Heat production	0.0030	tCH_4/TJ	Specific emissions obtained from NIR2020[27] (p. (p. 85 table 3.10)
	Heat production	0.0006	tN_2O/TJ	
Electricity consumption specific emission factors	*Type*	*Value*	*Unit*	*Note*
	Electricity	96.0326	tCO_2/TJ	Calculated by an energy expert of the Estonian Environmental Research Centre
	Electricity	96.2293	tCO_2 ekv/TJ	

ANNEX 2. POTENTIAL OF DIFFERENT MEASURES (IN ABSOLUTE TERMS AND AS PERCENTAGE) TO ALLOW TO REDUCE GHG EMISSIONS OF TS GROUP AND PARENT COMPANY

Based on the results of the GHG emissions mapping of 2019 (perspectives of scope 1–2 and scope 1–3 are shown separately). In addition, implementability of the measures in the short and long term was also assessed.

Measure	**Organization**	**Quantity of GHG reduced by measure (tons as CO_2 equivalent)**	**Organization's total emissions (tons as CO_2 equivalent)**	**GHG emissions (%) subject to reduction in organization's total emissions**	**Scope**	**Time perspective of implementability of measures**	
						Short	**Long**
Measure 1: By transferring the vessels of TS Laevad and TS Shipping to alternative fuels (e.g. green electricity or hydrogen), it is possible to reduce the GHG emissions by 20,522 tons as CO_2 equivalent.	TS group	20522	27069	75.8	1.2	green electricity	hydrogen
Measure 2: By transferring shore power of TS Laevad to (either produced or purchased) green electricity, it is possible to additionally reduce the GHG emissions by 677 tons as CO_2 equivalent.	TS group	677	27069	2.5	1.2	purchased green electricity	produced green electricity
Measure 3: By transferring the TS vehicles to green electricity, it is possible to reduce the GHG emissions by 496 tons as CO_2 equivalent.	TS parent company	496	5438	9.1	1.2	green electricity, green gas	hydrogen

Measure	**Organization**	**Quantity of GHG reduced by measure (tons as CO_2 equivalent)**	**Organization's total emissions (tons as CO_2 equivalent)**	**GHG emissions (%) subject to reduction in organization's total emissions**	**Scope**	**Time perspective of implementability of measures**	
						Short	**Long**
Measure 3: By transferring the TS vehicles to green electricity, it is possible to reduce the GHG emissions by 496 tons as CO_2 equivalent.	TS parent company	496	97426	0.5	1, 2, 3	green electricity, green gas	hydrogen
Measure 4: By transferring the TS auxiliary fleet to alternative fuels (e.g. green electricity or hydrogen), it is possible to reduce the GHG emissions by 41 tons as CO_2 equivalent.	TS parent company	41	5438	0.8	1.2	green electricity	hydrogen
Measure 4: By transferring the TS auxiliary fleet to alternative fuels (e.g. green electricity or hydrogen), it is possible to reduce the GHG emissions by 41 tons as CO_2 equivalent.	TS parent company	41	97426	0.0	1, 2, 3	green electricity	hydrogen
Measure 5: By transferring the TS boiler houses to green gas, it is possible to reduce the GHG emissions by 684 tons as CO_2 equivalent.	TS parent company	945	5438	17.4	1.2	green gas	

Measure	**Organization**	**Quantity of GHG reduced by measure (tons as CO_2 equivalent)**	**Organization's total emissions (tons as CO_2 equivalent)**	**GHG emissions (%) subject to reduction in organization's total emissions**	**Scope**	**Time perspective of implementability of measures**	
						Short	**Long**
Measure 5: By transferring the TS boiler houses to green gas, it is possible to reduce the GHG emissions by 684 tons as CO_2 equivalent.	TS parent company	945	97426	1.0	1, 2, 3	green gas	
Measure 6: In the case the TS parent company is transferred to a green electricity package, it is possible to reduce the GHG emissions by 3957 tons as CO_2 equivalent.	TS parent company	3957	5438	72.8	1.2	purchased green electricity	produced green electricity
Measure 6: In the case the TS parent company is transferred to a green electricity package, it is possible to reduce the GHG emissions by 3957 tons as CO_2 equivalent.	TS parent company	3957	97426	4.1	1, 2, 3	purchased green electricity	produced green electricity
Measure 7: One of the biggest measure for reduction of the TS GHG is to redirect the ships to the use of shore power. When (either produced or purchased) green electricity is used in electricity production, it is possible to reduce the GHG emissions by 47,646 tons as CO_2 equivalent.	TS parent company	47646	97426	48.9	1, 2, 3	purchased green electricity	produced green electricity

Measure	**Organization**	**Quantity of GHG reduced by measure (tons as CO_2 equivalent)**	**Organization's total emissions (tons as CO_2 equivalent)**	**GHG emissions (%) subject to reduction in organization's total emissions**	**Scope**	**Time perspective of implementability of measures**	
						Short	**Long**
Measure 8: By transferring pilot boats and tugboats to alternative fuels (e.g. hydrogen or green electricity), it is possible to reduce the GHG emissions by 941 tons as CO_2 equivalent.	TS parent company	941	97426	1.0	1, 2, 3	green electricity	hydrogen
Measure 9: Giving priority to these vessels which GHG emissions are lower, it is possible to also reduce, in the longer term, this part of the ships' GHG emissions which is related to manoeuvring in the port water area.	TS parent company	3491	97426	3.6	1, 2, 3		differentiated port charges
Measure 10: In the case TS redirects the operators to consume green energy and/or produces itself green energy to its operators, it is possible to reduce the GHG emissions by 18032 tons as CO_2 equivalent.	TS parent company	18032	97426	18.5	1, 2, 3	purchased green electricity	produced green electricity

Measure	**Organization**	**Quantity of GHG reduced by measure (tons as CO_2 equivalent)**	**Organization's total emissions (tons as CO_2 equivalent)**	**GHG emissions (%) subject to reduction in organization's total emissions**	**Scope**	**Time perspective of implementability of measures**	
						Short	**Long**
Measure 11: By transferring the operators' boiler houses to green gas, it is possible to reduce the total GHG emissions of the TS parent company (scope 1-3) by 9462 tons as CO_2 equivalent.	TS parent company	9462	97426	9.7	1, 2, 3		green gas
Measure 12: In the case TS redirects the operators' stationary equipment running on diesel and natural gas to consume green energy, it is possible to reduce the GHG emissions by 1482 tons as CO_2 equivalent.	TS parent company	1482	97426	1.5	1, 2, 3		green energy