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Karadeniz Ereğli Liman Bölgesindeki Sıvı Dökme Yük Taşıyıcılarının Yakıt Tüketimi ve Ortaya Çıkan Emisyonlarının Hesaplanması

Calculation of the Fuel Consumption and Resulting Emissions of Liquid Bulk Carriers in Karadeniz Ereğli Port Region

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Özet:

Çalışmanın amacı, Karadeniz Ereğli liman bölgesindeki liman ve demirleme operasyonlarında tanker gemilerinden kaynaklanan salımların hesaplanmasıdır. Hesaplama, TC Ulaştırma ve Altyapı Bakanlığı tarafından yayınlanan veriler yardımıyla yapılmıştır. Limana gelen gemilerin ortalama gross tonajı belirlendikten sonra, ortalamaya benzer gros tonajlı bir gemi için uygulanabilir bir deniz dizel jeneratör seti bulundu. Üreticinin veri sayfası, deniz dizel jeneratörlerinin özelliklerini verdi ve jeneratörlerin çalışma modlarını, elektrik gereksinimlerini ve yük paylaşımını belirlemek için bir uzakyol gemisi tanker gemisinden alınan operasyon veriler kullanıldı. Çalışma modlarının kullanım saatleri için liman ve demirleme gemiden toplandı Sıvı dökme yük gemilerinden kaynaklanan gemi salımlarının belirlenmesinde tümevarım yöntem kullanılmış ve bulgular Türkiye'nin iç sularındaki tüm tanker kaynaklı salımlarla karşılaştırılmıştır. Sonuçlar, belirtilen bölgede yanaşma operasyonları sırasında tanker gemileri tarafından 5.257,79 t gemi dizel yakıtı tüketildiğini ve 16.856.49 t CO_2, 505.27 t NO_x ve 52.58 t SO_x salınımına neden olduğunu göstermiştir. Bu istatistikler, yeşil liman uygulamaları ile limandan gemilere elektrik sağlanarak jeneratörlerin kullanılmasını önlemenin önemini vurgulamaktadır.

Anahtar Kelimeler: Gemi Egzoz Emisyonları, Gemi Dizel Jeneratörleri, Karadeniz Ereğli Liman Bölgesi

Abstract:

The objective of the study is to calculate the emissions sourced by tanker vessels at port and anchorage operations in the Karadeniz Ereğli port region. The computation was performed using data that was authenticated by the Turkish Ministry of Transport and Infrastructure. A practicable marine diesel generator set for a vessel with a similar gross tonnage to the average was found after the average gt of the ships that arrived at the port was established. The manufacturer's data sheet gave the specs for the marine diesel generators, and operational data from an oceangoing tanker vessel was used to determine the generators' operating modes, electrical requirements, and load sharing. The port and anchorage for the operation modes' utilization hours were collected from the vessel the inductive method was used to determine ship emissions sourced by liquid bulk carriers, and the findings were compared to all tanker-based emissions in Turkey's inland waters. Findings indicated that 5,257.79 t of marine gas oil was consumed and resulting in 16,856.49 t of CO_2, 505.27 t of NO_x, and 52.58 t of SO_x emitted by tanker vessels during berthing operations in the specified region. These statistics emphasize the significance of cold ironing with green port applications.

Keywords*:* Ship Exhaust Emissions, Marine Diesel Generators, Karadeniz Ereğli Port Region,

1. Introductıon

Since the early 1900s, human activities and technological advancements have significantly increased environmental pollution around the world, which has led to climate change, global warming, health issues, the accelerated loss of natural resources, and a rise in the number of threatened animals (Konur et al., 2022). One of the main sources of greenhouse gases (GHG) is the commercial ship transport of goods around the world (Eyring et al., 2005). Since maritime traffic handles more than 70% of all worldwide trade, it has a considerable impact on air pollution (Yuksel & Koseoglu, 2022a). Marine vessels in the port and berthing areas are liable for a narrow portion of air pollutants globally, however, the impact on these pollutants involves a large portion of the population and wide regions (Eyring et al., 2005). The main air pollutants sourced from marine vessels are carbon dioxide (CO_2), carbon monoxide (CO), Sulphur oxides (SO_x), nitrogen oxides (NO_x), particulate matter (PM), and volatile organic compounds (VOC). In addition to the local effects of ship exhaust pollutants on the health of the populace and the state of the built environment, ports' proximity to urban areas highlights the worldwide effects of emitted greenhouse gases (GHGs). In this regard, the calculation of the shipping emissions in the port and berth areas gains importance to highlight the number of pollutants for policymakers and to develop prevention mechanisms. (Guo et al., 2015; Kuzu et al., 2021; Nunes et al., 2017; Tzannatos, 2010).

In the past twenty years, one of the most crucial issues in the globe has been the reduction of emission output. The International Maritime Organization (IMO), which was first established with the adoption of MARPOL Annex VI - Prevention of Air Pollution from Ships in 1997, has also endorsed the reduction of greenhouse gas emission production based on maritime transportation with new regulations and mandatory measures for ships. On January 1, 2013, modifications to the SEEMP (Ship Energy Efficiency Management Plan) and EEDI (Energy Efficiency Design Index) came into effect, establishing progressive CO_2 emission reduction goals for ships employing energy efficiency-improving methods and emission-reducing technologies. In the maritime sector, technological developments have hastened the accomplishment of these objectives. The impact of maritime transport GHG emissions on worldwide CO_2 Emissions, according to a report, grew from 2.76% (962 million t) in 2012 to 2.89% (1,056 million t) in 2018 (IMO, 2020). By adopting the inaugural strategy for reducing GHG emissions from ships, the International Maritime Organization (IMO) followed the Sustainable Development Goal 13 (climate action) of the United Nations (UN). By 2050, the policy seeks to cut annual ship-based GHG emissions by at least 50% from 2008 levels (IMO, 2018).

Four GHG studies on ship emissions were carried out by the IMO in the years 2000 (IMO, 2000), 2009 (IMO, 2009), 2014 (IMO, 2014), and 2020 (IMO, 2020). As evidenced by Annex VI of the MARPOL Convention, the first and primary rule that stressed air pollution prevention measures from ships and was enacted in 1997, IMO first concentrated on lowering NO_x and SOx emissions due to international shipping activities. The Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP), which were developed in Annex VI in 2011 and entered into effect in 2013, were the first measures to reduce carbon dioxide-based airborne emissions from ships. While the Ship Energy Efficiency Management Plan (SEEMP) is a low-cost operational approach by applying energy efficiency measures that creates a framework for improving the energy efficiency of existing or newly constructed marine vessels, EEDI is a technological criterion that clarifies a minimum energy performance level measured in kilograms of CO_2 per ship's capacity-mile for new ships to encourage the adoption of more energy-efficient equipment and engines. The Energy Efficiency Existing Indicator (EEXI) and Carbon Intensity Indicator (CII) were developed by the IMO to reduce ship GHG emissions through periodic surveys beginning no later than 2023 (DNV, 2022). A marine vessel rating system based on operational/in-service efficiency is called CII (LR, 2022). Based on emissions in the atmosphere brought on by vessel traffic, the carbon pricing market is anticipated to be active in recent years. EEXI and CII will go into force in January 2023. Bunker fuel sales tax rates are anticipated to approach $100 per ton (Gerretsen, 2022).

Researchers have investigated comprehensively ship-related emissions in the port areas for twenty years. Cooper, (2003) conducted a research article that formulates the ship-sourced exhaust emissions during berthing operations. The measurement of the air pollutants was ensured on the 22 auxiliary engines having power outputs between 720 to 2675 kW. Findings depicted that empirically generated emission equations that use dead weight tonnage can function as a reliable and affordable tool for harbor emission inventories. Abdul-Wahab et al., (2008) simulated the NO_x emissions resulting from ships at berth and the simulation results demonstrated that the major part of the ship-sourced NO_x can be carried to the urban areas. Tzannatos, (2010) investigated ship-sourced air pollutants at the Port of Piraeus and the possible cost-effective solutions to reduce exhaust emissions. Findings indicated that a total of

915.6 t of air pollutants are emitted annually due to cruise vessels' energy needs at berth. Hulskotte & Denier van der Gon, (2010) conducted a series of surveys on-board to estimate the emissions sourced by oceangoing marine vessels at berth. Results showed that 75% of the emissions sourced by ships at berth were covered by oil tankers (30%), container vessels (25%), and passenger vessels (20%). Du et al., (2011) developed a berth allocation strategy considering vessels' fuel consumption and resulting emissions. Results illustrated that the proposed strategy can reduce fuel consumption and emissions effectively. McArthur & Osland, (2013) analyzed the quantity and costs of shipping emissions generated during the berthing operations in the Port of Bergen, Norway. The outputs highlighted that the annual cost of the emissions is between 10 to 21.5 euros. (Yuksel & Koseoglu, 2022a). Maragkogianni & Papaefthimiou, (2015) investigated the social price of cruise vessel-related air pollutants in the large ports of Greece. The estimated health effects of ship emissions can cost up to €24.3 million, or €5.3 per passenger, demonstrating the need for policies and initiatives aimed at making the cruise sector more efficient or at reducing the pollution cruise ships emit in port towns. Cullinane et al., (2016) predicted the container vessel-related air pollutants in the major ports of Taiwan. The findings depicted that container ships are responsible for a large portion of the emissions in the examined ports. Chen et al., (2016) forecasted the ship emission in the port of Tianjin using the automatic identification system (AIS) data. It was predicted that in 2014 29300 t of SO_2, 41300 t of NO_x, 40300 t of PM_{10}, 3720 t of $PM_{2.5}$, 1720 t of VOC, and 3570 t of CO were emitted in the port region. Nunes et al., (2017) evaluated the various ship types sourced emissions in the four different Portuguese ports, and found that tankers were the primary emitters in the two examined ports. When navigation-based emissions were included, containers were the largest emission generators. Styhre et al., (2017) examined shipping GHG emissions in various ports located on different continents using case study-based simulations. For Gothenburg, Long Beach, Osaka, and Sydney, respectively, the model predicted total GHG emissions of 150,000, 240,000, 97,000, and 95,000 t CO_2 annually. Alver et al., (2018) presented a model that forecasts the emissions sourced by shipping activities in the Samsun Port in the years between 2010 and 2015. NO_x, SO_2, hydrocarbons, and PM_{10} were estimated as 728, 574, 32, and 64 t, respectively while the general cargo ships were responsible for the highest emission values. Murena et al. (2018) analyzed the effect of cruise vessel-based emissions on the air quality of Naples, Italy. Tichavska et al., (2019) assessed the effectiveness of the regulations on shipping emissions in ports. Results and reduced emission profiles highlight disparities in Sulphur control as well as prospective gains from new policy initiatives (polluter pays principle, cold ironing, and others) for accounting operational modes and shipping sub-sectors. Durán-Grados et al., (2020) calculated the ship-sourced carbon emission in the Strait of Gibraltar and the impact of the COVID-19 pandemic on emissions. The primary conclusion is that when all international traffic is taken into account, reductions in all pollutants and GHGs in the Strait of Gibraltar were found to be up to 12%, whereas the reduction in emissions from domestic traffic was only 51%. Fameli et al., (2020) estimated the shipping emissions in the two ports of Greece. NO_x, SO_2, and CO were the emissions that are released in the greatest amounts from ships at the ports of Mytilene and Chios. The majority of ship emissions in ports came from berthed ships because maneuvering takes between 15 and 20 minutes while they are at berth. Liu & Wang, (2021) developed a model-based emission computation method for container terminals and found that NO_x is the principal air pollutant, and ships are the largest source of CO_2 and NO_x emissions, which account for 90.7% and 80.4% of all ship emissions, respectively. CO_2 and NO_x emissions during ship navigation account for 60.7% and 53.9% of all ship emissions. Kuzu et al., (2021) predicted and analyzed the ship-related air pollutants emitted at the berth in Bandirma Port, Turkey. Findings illustrated that PM_{10}, NO_x, SO_2, and CO emissions were found as 182.4, 7,996.6, 1,681.6, and 239.6 t, respectively. The environmental cost of the air pollutants was obtained as €41,146,400. Progiou et al., (2021) conducted a research article that evaluates the shipping emissions from Piraues Port, Greece in terms of cost and air quality aspects. The estimated external expenses associated with the health and other harms that ship emissions cause total 23.7 million euros according to the findings. Chen et al., (2021) proposed a methodology based on the operation modes for the air pollutants emitted from ships in port. The findings suggest that port managers can minimize emissions by restricting the amount of sulfur in fuel oil and mandating that tugs undertake to push and pull tasks with less engine load. Nguyen et al., (2022) examined the ship emissions resourced by the hotel and cargo transfer loads of the vessels in southeast Asia terminals. The outputs of the study depicted that the Southeast Asian container port system is highly polluted due to a rise in the number of containers and ship calls. Woo & Im, (2022) assessed the effectiveness of the decrease of vessel speed to lower emissions in Busan Port, South Korea, using AIS data. Results demonstrated that in 2020, a 19.2% decrease in emission per gross tonnage (gt) was achieved due to the execution of the vessel speed reduction policy. Tran et al., (2022) evaluated emissions sourced by container ships in the port of Singapore using the AIS data. Findings highlighted that container feeder vessels were responsible for 46% of the overall emissions. Gan et al., (2022) estimated and analyzed the ship exhaust emissions in Shenzen port, China. The findings indicated that cargo ships and container ships contribute at the highest rates, whereas ship emissions during cruising and hoteling are more significant than those during maneuvering and slow steaming situations. Durán-Grados et al., (2022) examined the impact of emissions sourced by maritime transport on the air quality in the Gibraltar Strait. It is found that daily ship-based SO_x concentrations were over 215 $\mu g/m^3$, and the highest PM_{10} concentrations were estimated inside the Strait at 8.5 $\mu g/m^3$.

The findings of the literature review indicated that there are numerous studies to calculate shipping emissions during berth-related operations in various ports. The major emitters among the ship types have been found as containers and tankers while the majority of investigated ports were located in Europe and Asia. The frequent use of these ship types in world transportation and the fact that operations based on ship generators in port operations were carried out more on these ships were effective in obtaining these results. In this regard, this study aims to calculate tanker ship-sourced emissions around the port of Karadeniz Ereğli, Turkey. The construction of an emission inventory for the port can highlight the current air pollution potential and can lead to the utilization of renewable technologies in the port. To ensure the analysis, the data provided by the Turkish Ministry of Transport and Infrastructure were utilized. Using the data, the average gt of the ships that visited the port was detected, and a suitable diesel generator set to the ship having the average gt was determined. The specifications of the marine diesel generators were gathered from the manufacturer, while the operation modes, electrical demands, and load sharing of the generators were taken from the operational data of an oceangoing tanker vessel. The utilization hours of the operation modes which involve port and anchorage times were also obtained. Emissions from tanker ships were calculated using the inductive approach and the results were compared with all emissions in Turkey's inland waters.

2. System Description and Methodology

The number of vessels that visited Turkish inland waters and Karadeniz Ereğli Port has been taken from the statistical data recorded by the Turkish Ministry of Transport and Infrastructure. According to the data, in 2021 51,199 ships having a total gt of 829,618,101 came to the Turkish ports (UAB, 2022). Figure 1 illustrates the number of ships and gt distribution regarding port authorities which handled over 7,000,000 gt.

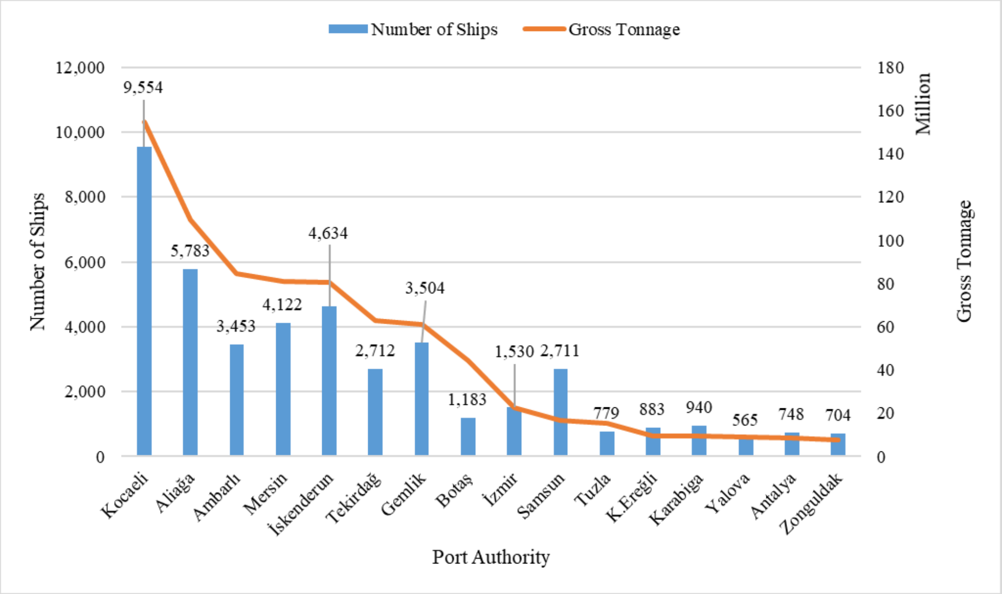

Figure 1. Distribution of the number of ships and their total gross tonnage regarding port authority in 2021 (UAB, 2022).

883 ships arrived having a total gross tonnage of 9,532,736 to the port of Karadeniz Ereğli which has the 12th largest capacity in Turkey in 2021. The average gross tonnage of the ships is 10795.8504 for Karadeniz Ereğli, and 16203.79502 for all ships (UAB, 2022). Figure 2 indicates the monthly distribution of the number of ships arrivals for Turkey, and Figure 3 illustrates the monthly arrivals for Karadeniz Ereğli in 2021.

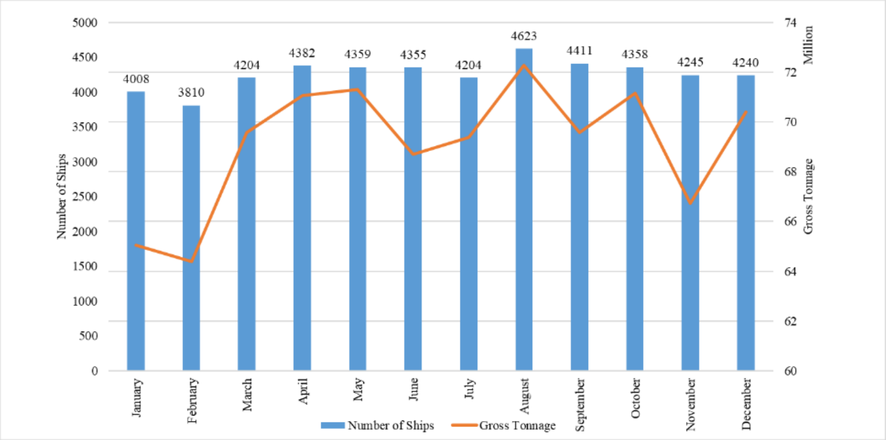

Figure 2. Monthly Distribution of the number of ships and their total gross tonnage in Turkey (UAB, 2022).

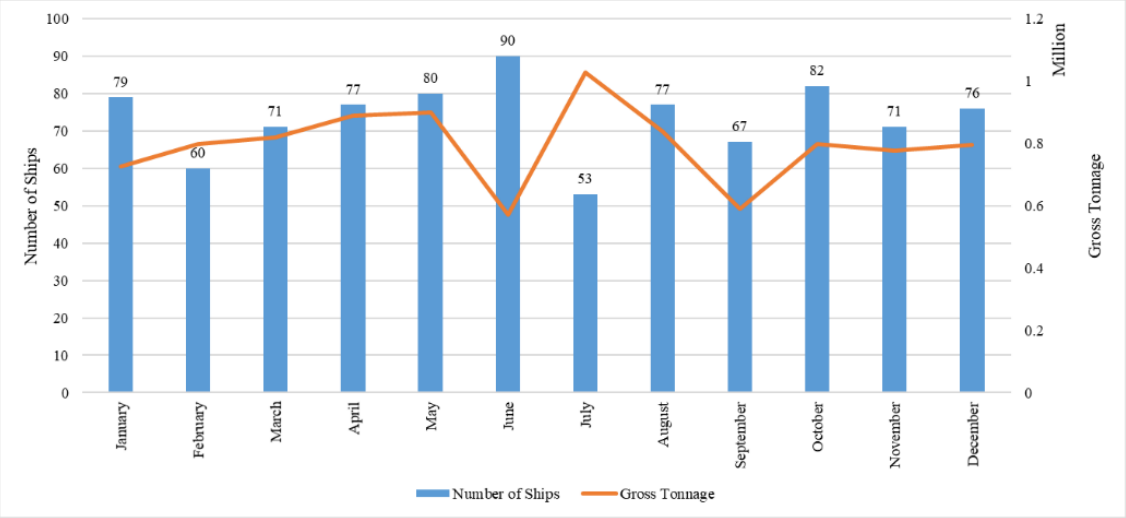

Figure 3. Monthly Distribution of the number of ships and their total gross tonnage in Karadeniz Ereğli (UAB, 2022).

Table 1 indicates the distribution of handled cargo types in detail while Figure 4 illustrates the portion of each main cargo category processed in Turkish ports. The percentages indicated in the figure were also used to determine the types of ships arriving at the selected port authority.

Table 1. Handled cargo types in Turkish Ports (UAB, 2022).

Cargo Type	**Cargo Handling**	
	Percentage	**Tonnage**
Agricultural products and live animals	3.0324%	15,959,900
Food products and animal feed	2.3693%	12,469,549
Solid mineral fuels	7.2936%	38,386,612
Petroleum products	27.4459%	144,449,433
Ores and metal waste	9.1032%	47,910,956
Metal Products	7.3058%	38,451,158
Crude and manufactured minerals, building materials	10.0114%	52,690,587
Fertilizers	1.6233%	8,543,690
Chemicals	3.1547%	16,603,390
Containers	28.5696%	150,363,651
Arms and ammunition	0.0001%	550
Other carried goods	0.0907%	477,308

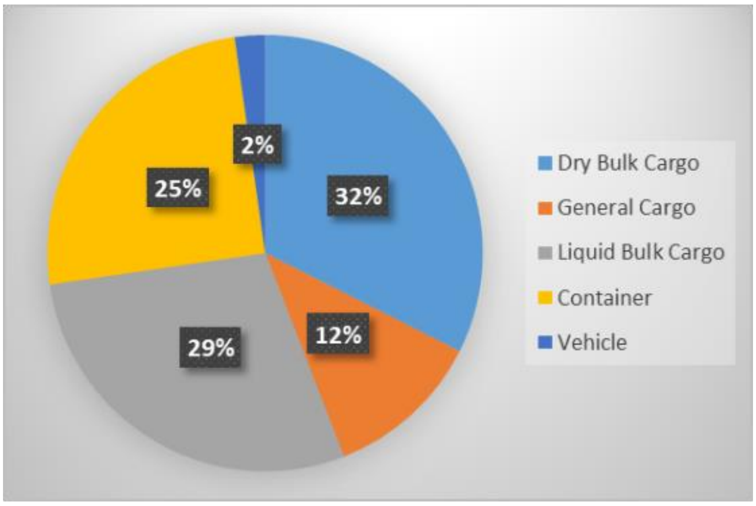

Figure 4. Cargo handling distribution for main categories in Turkish ports (UAB, 2022)

To calculate the fuel consumption of the tankers that arrived at Karadeniz Ereğli port, a reference oceangoing tanker vessel having a close gross tonnage to average value is determined. The specifications of the auxiliary engine are obtained from the engine manufacturer. The electrical load demand for different operation modes, the utilization hours of the operation modes, load sharing characteristics of the generators are gathered from a sample ship utilized in the studies of Konur et al., (2023) and Yuksel & Koseoglu, (2022). Table 2 illustrates the technical specifications of the selected marine diesel generator, and Figure 6 demonstrates the specific fuel oil consumption (SFOC) in g/kWh and power (kW) characteristics for a varying load.

Table 2. Technical specifications of the selected diesel engine (YANMAR, 2018; Yeryganov & Varbanets, 2018.)

Model	Number of Cylinders	Engine Speed	Bore	Stroke	Continuous Rating Power
6EY18ALW	6	900 rpm	180 mm	280 mm	745 kW

Table 3 depicts and explains the operation modes of the ship's electricity distribution plant while Table 4 indicates, the number of working generators and the load/power of one generator regarding operation modes. The distribution of yearly utilization hours regarding operation modes is shown in Figure 6.

Table 3. Definitions of operation modes (Konur et al., 2023; Yuksel & Koseoglu, 2022a, 2022b.)

Operation Mode	**Definition**
Sea Going	Navigation operations
Sea Going with TH	Navigation operations with a cargo that requires tank heating (TH)

At Port	Involves cargo loading, and waiting times
At Cargo Handling	Involves cargo discharge operations
At Harbor	Anchorage operations
At Harbor with TH	Anchorage operations with a cargo that requires tank heating

Table 4. Power, load, and generator demand of the operations (Konur et al., 2023; Yuksel & Koseoglu, 2022b, 2022a.)

Operation Mode	Running Generators	Load	Power (kW)
Sea Going	1	81.01%	603.74
Sea Going with TH	2	56.94%	424.20
At Port	2	53.43%	398.12
At Cargo Handling	3	56.56%	421.22
At Harbor	1	54.41%	405.57
At Harbor with TH	1	82.19%	611.93

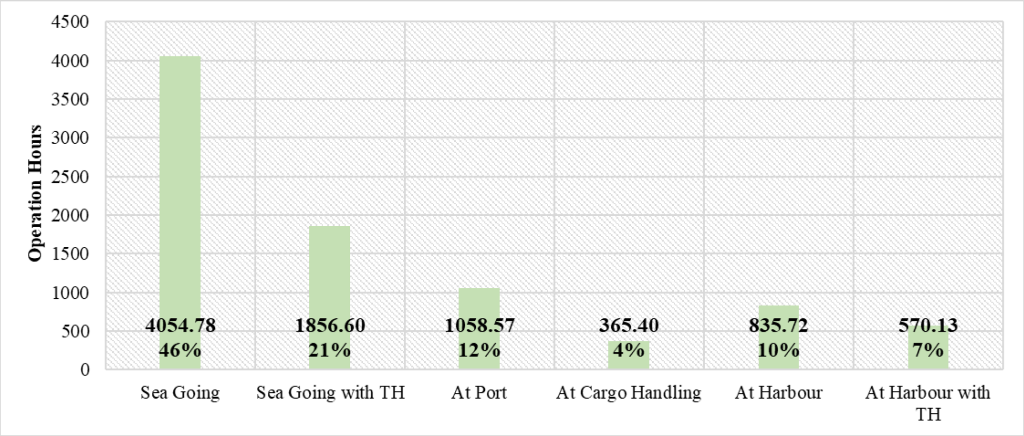

Figure 6. Yearly utilization hour distribution according to operation modes (Konur et al., 2023.)

The fuel consumption of each operation mode is extracted from look-up tables provided by the manufacturer considering the corresponding load. Fuel consumption (FC) of a single ship in port and anchorage operations is calculated using Equation 1.

$$FC = SFOC * P * h \tag{1}$$

where P represents power in kW, and h is the operation hour. The total average fuel consumption (TFC) for all ships and ships coming to Karadeniz Ereğli Port is computed using Equation 2.

$$TFC = FC * n \tag{2}$$

where n is the number of arrived ships. Emissions (E) from the ships are calculated using emission factors (EF) for marine gas oil (MGO) and heavy fuel oil (HFO) indicated in Table 5 using Equation 3.

Table 5. EF for MGO and HFO (g emission/ g fuel) (Kuzu et al., 2021.)

Pollutant	**CO_2**	**N_2O**	**NO_x**	**NMVOC**	**CO**	**PM_{10}**	**SO_2**
EF MGO	3.206	0.00015	0.0961	0.00308	0.00277	0.00097	0.01
EF HFO	3.114	0.00015	0.0903	0.00308	0.00277	0.00278	0.025

$$E_{i,} = \sum_{k} TFC * EF \tag{3}$$

where k is the operation mode, and i is the pollutant.

3. Results and Discussion

The fuel consumption and emissions from berthing operations (At Port, at cargo handling, at the harbor, at the harbor with TH) are calculated for all ships that came in Turkey, and Karadeniz Ereğli port. Figure 7 illustrates the monthly TFC for all ships, and Figure 8 shows the TFC in Karadeniz Ereğli port.

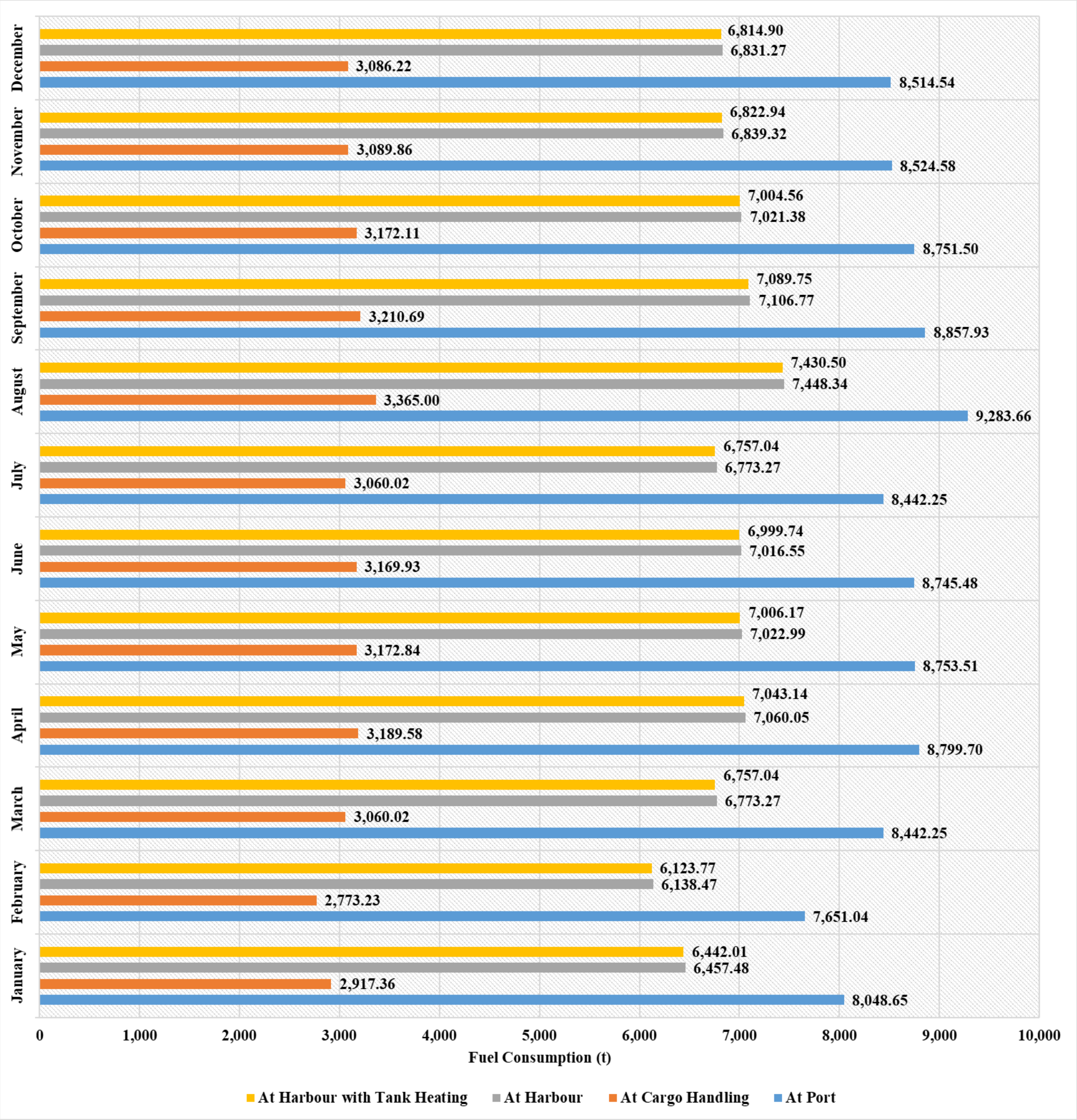

Figure 7. Monthly fuel consumption distribution of ships at berth in Turkey in 2021

102,815.1 t for port operations 37,266.9 t for cargo discharge operations, 82,489.2 t for anchorage operations, and 82.291.58 t for anchorage with heating required cargo operations in total 304,862.7 t of MGO were consumed by commercial tanker ships at berth in Turkish inland waters. It should be noted that the reference ship's operations involve a majorly heating required liquid cargo transportation. That's why the share of this operation remained high. Since the cargo discharge durations of the reference ship are also very low, and the waiting times are taken as the port operations, the fuel consumption of the cargo unloading operations is calculated as relatively low. Monthly average fuel consumption is calculated as 8,567.92;

3,105.57; 6,874.10; 6,857.63 t for port, cargo unloading, anchorage, and anchorage with TH respectively.

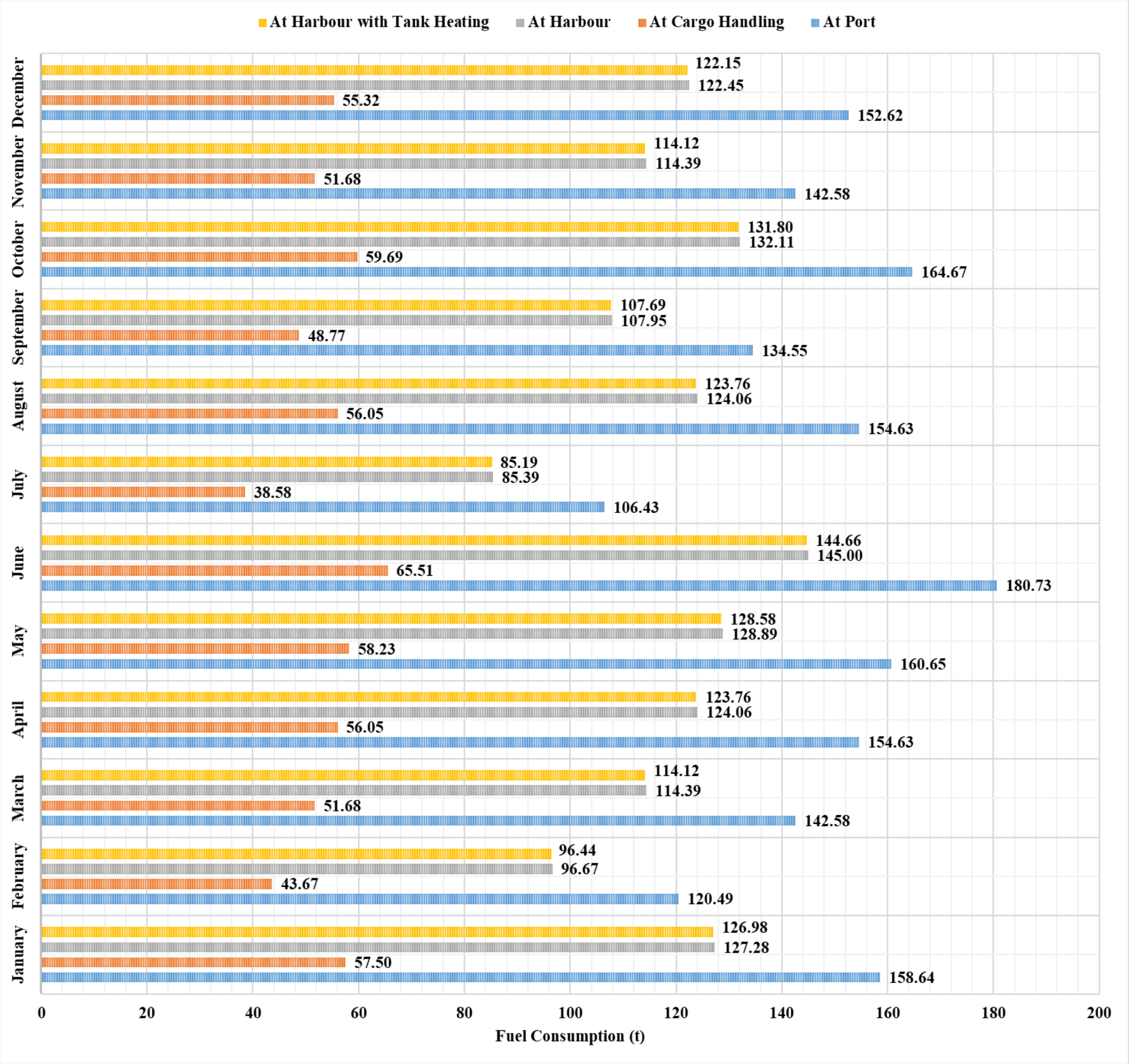

Figure 8. Monthly fuel consumption distribution of ships at berth in Karadeniz Ereğli region in 2021

1,773.19 t for port operations 642.72 t for cargo discharge operations, 1,422.64 t for anchorage operations, and 1,419.24 t for anchorage with heating required cargo operations in total 5,257.79 t of MGO were burnt by tanker ships at berth in Karadeniz Ereğli port and anchorage regions. Monthly average fuel consumption is calculated as 147.77; 53.56; 118.55; 118.27 t for port, cargo unloading, anchorage, and anchorage with TH respectively. Figure 9 indicates the CO_2 emissions and Figure 10 demonstrates the remaining calculated emissions for both ships in Turkey, and in the Karadeniz Ereğli region in 2021.

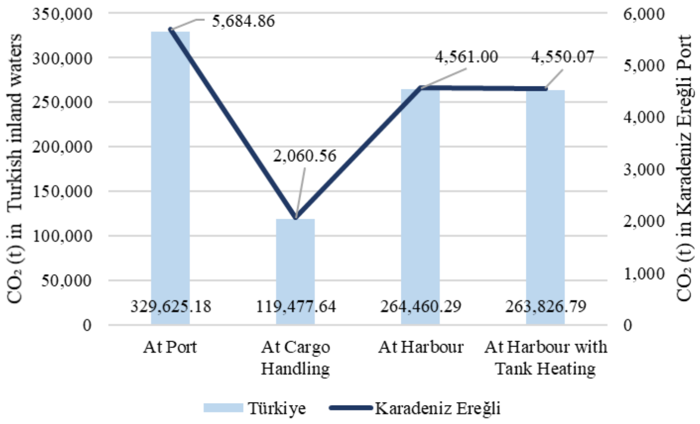

Figure 9. CO_2 emissions

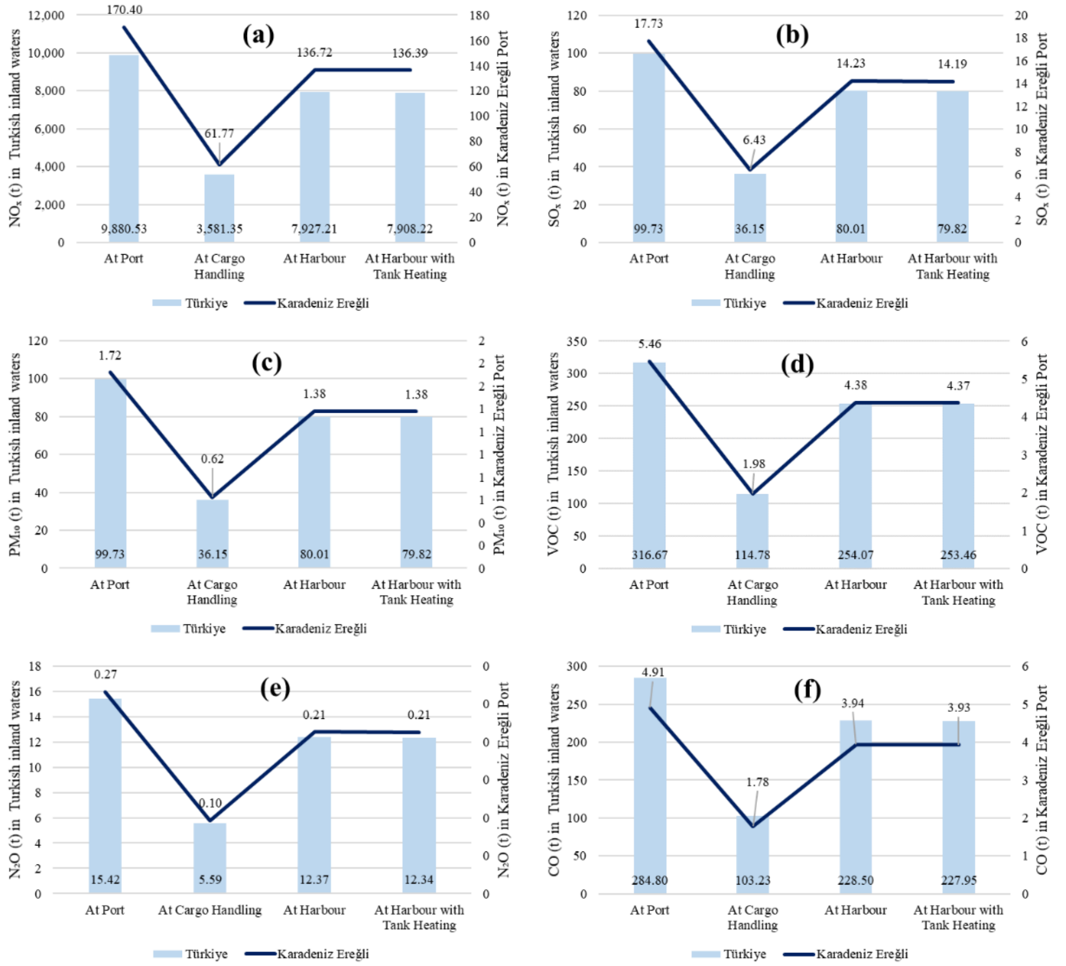

Figure 10. Emissions (a) NO_x, (b) SO_x, (c) PM_{10}, (d) VOC, (e) N_2O, (f) CO sourced by ships at berth.

977,389.90 t of CO_2, 29,297.31 t of NO_x, 3,048.63 t of SO_x, 938.98 t of VOC, 844.47 t of CO, 295.72 t of PM_{10}, and 45.73 t of N_2O were calculated to be emitted in 2021 by tanker ships at berth in Turkish inland waters. Among these values, 16,856.49 t of CO_2, 505.27 t of NO_x, 52.58 t of SO_x, 16.19 t of VOC, 14.56 t of CO, 5.10 t of PM_{10}, and 0.79 t of N_2O have polluted the Karadeniz Ereğli region in one year.

4. Conclusion

This study aimed to calculate the air pollution caused by tanker ships at berth operation in the Karadeniz Ereğli port region. To provide the calculation, the data ensured by the Turkish Ministry of Transport and Infrastructure were used. The average gt of the ships that arrived at the port was determined, and a feasible marine diesel generator set to the vessel having a similar gt to the average was determined. The specifications of the marine diesel generators were provided by the manufacturer's datasheet, while the operation modes, electrical demands, and load sharing of the generators were gathered from the operational data of an oceangoing tanker vessel. The utilization hours of the operation modes which include port and anchorage times were also obtained. Emissions from tanker ships were calculated using the inductive approach and the results were compared with all emissions in Turkey's inland waters. The main conclusions derived from the study can be listed as:

- 5,257.79 t of MGO was consumed by the tanker vessels during berthing operations in the analyzed region.
- 16,856.49 t of CO_2, 505.27 t of NO_x, and 52.58 t of SO_x were emitted due to the fuel consumption of the vessels.
- Considering the whole of Turkish inland waters 304,862.73 MGO is consumed by ships in port and anchor that yielded the generation 977,389.90 t of CO_2, 29,297.31 t of NO_x, and 3,048.63 t of SO_x.
- These amounts highlight the importance of cold ironing with green port applications and the concepts call for long-term solutions that fully incorporate the use of alternate fuels and energy sources.
- Although green ports and the electricity they provide to ships seem promising, they only work to reduce air pollution in urban areas, and their development is still in progress. The hybridization of the plant utilizing alternative energy or waste thermal energy can be applied as a short-term onboard solution. They can help minimize the emission from marine diesel generators and are quicker to install and use. Among the

onboard emission reduction applications scrubber applications to reduce SO_x emissions and technologies to decrease NO_x such as selective catalytic reduction (SCR), and exhaust gas recirculation (EGR) have been growingly utilized for recent years.

The findings in the study can be used by academicians and experts who work in related areas and can be a preliminary study to create the emission inventory for the specified region. The policies, regulations, investments, and technological framework can be accelerated by the emphasis on air pollution in the port areas. Future studies may involve more detailed data collection for ships to improve the calculation and the implementation of an alternative energy

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