Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 14(4), 1474-1488, 2024
Journal of the Institute of Science and Technology, 14(4), 1474-1488, 2024

ISSN: 2146-0574, eISSN: 2536-4618

Environmental Engineering **DOI: 10.21597/jist.1509201**

Research Article

Received: 02.07.2024 **Accepted: 18.09.2024**

To Cite: Kaya, E. N., Aydın Er, B., & Ardalı, Y. (2024). Evaluation of Ports in Terms of Greenhouse Gas Emissions and Energy: A Case Study. *Journal of the Institute of Science and Technology*, 14(4), 1474-1488.

Evaluation of Ports in Terms of Greenhouse Gas Emissions and Energy: A Case Study

Eda Nur KAYA[1], Bilge AYDIN ER[2*], Yüksel ARDALI[2]

Highlights:

- It is seen that indirect emissions due to energy use in the port exceed other categories.
- In 2019, the growth in energy-related indirect emissions was driven by the use of electric cranes.
- Port's natural gas consumption decreased in 2019 compared to 2018, but increased significantly in 2020.

Keywords:

- Greenhouse gas
- Waste management
- Energy efficiency
- Renewable energy
- Green port

ABSTRACT:

This study considers green port-based strategies that improve environmental performance in the context of urban areas and promote sustainable solutions to combat climate change. As an important component of the city, ports have a significant impact on socioeconomic development. In fact, given that ports in Turkey operate in limited spaces and city centers, pollution from port operations has a direct impact on both urban life and port workers. In recent years, the green port approach has become increasingly important within the scope of climate change adaptation programs. Particularly in Turkey, a large number of the ports are situated in the center of the city, which is bad for both the environment and community life. Although the Green Port Project in Turkey is currently voluntary, it will become a mandatory initiative in the coming periods due to Turkey's participation in the Paris Climate Agreement. In this study, the efforts to make Samsun Port, one of the important ports of Turkey, a green port are discussed. Studies on greenhouse gas emissions and mitigation measures, renewable energy approaches and their impacts are mentioned. In addition, this study includes the evaluation of integrated management systems, adoption of renewable energy, sustainable waste management, and greenhouse gas emission calculations as important components of a large-capacity port in the Black Sea to contribute to regional development.

[1] Eda Nur KAYA (**Orcid ID:** 0000-0003-0726-5741) Samsunport-Samsun International Port Management Inc., No:35 İlkadım, Samsun, Türkiye

[2] Bilge AYDIN-ER (**Orcid ID:** 0000-0002-6546-0089), Yüksel ARDALI (**Orcid ID:** 0000-0003-1648-951X) Ondokuz Mayis University, Department of Environmental Engineering, Samsun, Türkiye

*** Corresponding Author:** Bilge AYDIN ER, e-mail: bilge.aydiner@omu.edu.tr

This study was produced from Eda Nur KAYA's Master's thesis.

INTRODUCTION

Maritime transportation is a critical element of the global economy (Liu et al., 2021; Yang et al., 2023), efficiently moving around 80% of the world's freight (Chen et al., 2023; Gao et al., 2022; Yi et al., 2023). Maritime transport has grown fast and enormously in recent years, driven by the needs of worldwide trade. This increase has caused ports and terminals to enhance their performance in order to become more competitive, efficient, and sustainable (Okşaş, 2023). Ports prioritize environmental sustainability and eco-friendly activities in the dynamic global landscape to bolster their reputation and secure their continued existence in the highly competitive modern commercial arena. Therefore, ensuring environmental sustainability has become crucial (Garcia-Freites et al., 2021). Port sustainability involves the strategies and activities that a port undertakes to protect and sustain human and natural resources while meeting the present and future needs of its users (Zhang et al., 2023).

Maritime transportation is responsible for approximately two to three percent of global greenhouse gas emissions. If unchecked, it is estimated that these emissions will increase to around 17% by 2050. In light of these projections, reducing energy consumption and greenhouse gas emissions in this industry becomes increasingly crucial in the face of climate change. The pivotal indicators of sustainability in green ports, such as the use of renewable energy, sustainable waste management, and the reduction of greenhouse gas emissions, are evaluated within an integrated management system. With rising trade and business volume, energy efficiency and energy consumption resulting from port operations have gained importance, emphasizing the significance of utilizing renewable energy within ports (Alamoush, 2022). Similarly, as observed in various sectors, shifts in consumption habits due to increased production and resultant growth in trade introduce numerous environmental impacts, emphasizing the pivotal role of waste management. Approximately 1.036 million tons of greenhouse gases are emitted annually from port-related shipping, accounting for 2.4% of global carbon emissions. Therefore, the reduction of greenhouse gas emissions becomes crucial within the indicators of green ports. The calculation of greenhouse gas emissions within the port aims to minimize emissions, reduce the carbon footprint, and achieve carbon-neutral operations by judiciously and resource-efficiently utilizing resources.

The European Sea Ports Organization (Garcia-Freites et al., 2021) has developed a green guide for the marine industry that focuses on sustainability, addressing issues related to stakeholder engagement, climate change, and the environment (Botana et al., 2023; Wang et al., 2023). Ten environmental priorities are outlined in this guide based on survey data. Air quality, climate change, and energy usage are the top three issues in the most recent edition of the ESPO Green Guide for 2021. Because of the increasing energy consumption and decreasing greenhouse gas emissions resulting from climate change in sustainable green ports, this emphasizes the significance of investing in renewable energy. The development of green ports over time is indicative of a heightened global commitment to environmental sustainability and the avoidance of marine pollution. A number of significant agreements and rules have been crucial in determining the direction of green port management. The 1964 Port Convention, introduced in 1964, focused on establishing a port control system to address operational needs, provide financial support, and ensure the long-term sustainability of port management. In 1972, the London Convention aimed to safeguard the marine environment from pollution originating from ships and waste (Colarossi et al., 2022). This convention emphasized collaboration with international organizations to tackle environmental challenges. The 1973 MARPOL International Convention for the Prevention of Pollution from Ships was a landmark initiative to prevent maritime pollution comprehensively. It targeted the intentional, negligent, or post-accident release of oil and other harmful substances by ships, thus mitigating the risk of marine pollution. The 1990 Environmental Protection Law sought to regulate major industrial and process-related environmental pollution. It emphasized regular monitoring and control, integrated waste management, local governance for air pollution control, and enforceable measures related to waste disposal. In 1994, the Environmental Practice Regulation by the European Sea Ports Organization (ESPO) provided guidelines to European port authorities for environmental and climate management (Xiong et al., 2023). The ESPO Green Guide, established in 1993, assisted in realizing environmental and climate agendas and a dedicated database showcased exemplary green practices at European ports. Updates to maritime environmental laws in 2022 underscored the commitment to reducing greenhouse gas (GHG) emissions. The European Parliament's bill in October 2022 set concrete emission targets for large vessels, aiming for a 55% reduction compared to 1990 levels by 2030. Additionally, in December 2022, an agreement was reached to include the maritime transport sector in the EU's Emission Trading System. The Eco-Management and Audit Scheme (EMAS), introduced in 1995, aimed to enhance operational efficiency both environmentally and financially through the implementation of an environmental management system. This scheme demonstrated how reductions in port-generated waste, increased energy efficiency, and efficient resource utilization could lead to cost savings while minimizing environmental impact (Colarossi et al., 2022; Styhre et al., 2017; Winnes et al., 2015). The Paris Agreement in 2016 represented a global effort to unite countries under a common framework for addressing climate change. The agreement aimed to reduce global greenhouse gas emissions on a worldwide scale, emphasizing the need for collective action (Styhre et al., 2017). These milestones collectively demonstrate the evolution of international commitments and regulations towards achieving green ports and fostering sustainable practices in the maritime sector. In the scope of this study, the aim is to evaluate renewable energy and waste management for a port located in the Black Sea region of Turkey and highlight developments towards becoming a green port with greenhouse gas emissions. Additionally, based on the results obtained, recommendations are provided for sustainable integrated waste management.

MATERIALS AND METHODS

Turkey's principal port in the Black Sea is Samsun. It's the one that links the Black Sea to the railway. The hinterland of the port encompasses the following: Batumi, Poti, and Suchumi in Georgia; Soçi, Tuapse, Novorossiysk, Azov, Taganrog, Jdanov, Yalta, Berdyansk, and Geniçesk in Russia; Mis. Kız-Oğul, Feodosiya, Yalta, Todor, Sevastopol, Yevpatorskiy in the Crimea; Nikolayev, Odessa, and İliçhevski in the Ukraine; Konstanta in Romania and the port of Varna in Bulgaria (Alver et al., 2018). Samsun Port is a high density of commercial trading port in the Black Sea region of Turkey (Çetintürk & Ünlü, 2022). The Samsun Port, identified as the highest-capacity green port on the Black Sea (Figure 1), was selected as the study area. The port facility is situated in the Ilkadım district of Samsun province and was privatized in 2010 through a 36-year lease from the public sector. Employing approximately 250 individuals and operating 24/7, the Port facility encompasses a building construction area of approximately 37 000 m² and a site area of 445 000 m².

The research area for the greenhouse gas emission calculation study at Port Harbor is depicted in Figure 2 by the satellite image. This includes the territory inside these defined limitations as well as the organizational boundaries included in the reporting.

Figure 1. General Overview of The Port (Anonymous, 2024)

Figure 2. Organizational Boundaries of Samsun Port (Anonymous, 2024)

Green Port Environmental Initiatives in the Port

A few of the detrimental environmental effects that are highlighted in the literature about ports in relation to the Green Port project are the following: noise pollution from diesel engines, air pollution from handling bulk cargo, water pollution from ship fuels, soil, air, and water pollution associated with the processing of hazardous waste, and greenhouse gas effects from port vehicles and ship exhaust emissions (ESPO, 2021). The Port concentrates on enhancing environmental parameters linked to priority waste management, soil pollution from hazardous waste processing, water pollution from ship fuels, noise pollution from diesel engines, and greenhouse gas emissions in order to become a green port, taking into account the detrimental effects of ports on the environment. Table 1 shows the greenhouse gas emission values of Samsun Port and Table 2 shows the emission factors used in IPCC's greenhouse gas calculation.

Table 1. Greenhouse Gas Emissions for Samsun Port

Direct Greenhouse Gas Emissions			
Source Type	**Source**	**Activity Data**	**Emissions**
Mobile Combustion	Construction Machinery	Diesel Fuel	CO_2, N_2O, CH_4
	Marine Vehicles	Diesel Fuel	CO_2, N_2O, CH_4
	Passenger Vehicles	Diesel Fuel	CO_2, N_2O, CH_4
	Generators	Diesel Fuel	CO_2, N_2O, CH_4
Stationary Combustion	Natural Gas	Building Consumption	CO_2, N_2O, CH_4
Energy Indirect Greenhouse Gas Emissions			
Electricity Consumption	Construction Machinery	Electricity	CO_2, N_2O, CH_4
	Port Electricity Usage	Electricity	CO_2, N_2O, CH_4

Table 2. Greenhouse Gas Emissions Source & Factors (IPCC, 2006)

NATURAL GAS USE ACCOUNT DATA			
Emission Source	**Emission Factors**		
	CO_2	**CH_4**	**N_2O**
EF (Emission Factors) (kg CO_2 / TJ)	56100	1	3.9
NKD (Net Calorific Values) TJ / Gg	48	483.8	5.7
Density kg/m^3	0.78	4.15	28.6
KIP*	74.100	10	0.6
Fire Extinguishers (CO_2)	1	0	0
Fire Extinguishers (FM200)	3 350	0	0
Fire Extinguishers (FA236)	8 060	0	0
Energy-Related Indirect Emissions			
Emission Source	Emission Factors		
	CO_2	CH_4	N_2O
Port Electricity Consumption	0.4765	0	0
Construction Machinery Power Consumption	0.4765	0	0
Indirect Greenhouse Gas Emissions			
Emission Source	Emission Factors		
	CO_2	CH_4	N_2O
Employee Commuting Vehicles Diesel Consumption	74.100	3.9	3.9
Travel-Related Vehicles Diesel Consumption	74.100	3.9	3.9
3rd Party Electricity Consumption	0.4765	0	0

* KIP : 2010 Guidelines to DEFRA / DECC's Conversion Factors for Company Reporting – Annex 5 - Table 5a

The port's greenhouse gas calculation

Significant efforts are being made to minimize greenhouse gas emissions and gradually improve pollution in the port, especially from ships. With the greenhouse gas emission calculations made at the port, it is aimed to meet the needs and expectations of stakeholders in line with the policy determined within the integrated management system, to fulfill the responsibilities towards the society, environment, and employees and to continuously improve the quality of service. The Port hopes that by calculating greenhouse gas emissions, it will raise awareness on a national and worldwide scale and establish itself as a model port for other ports that want to go green in the marine industry. Greenhouse gas emissions are calculated using fuel consumption activity data, which is the definition of the calculation method. The calculations are based on IPCC coefficients and calculation methods specified in IPCC sources.

Activity information for fossil fuel-powered cars is measured in liters, depending on the source of the emissions. Consequently, these data are mainly converted to kilograms. Fuel densities were taken from the "Regulation on Increasing the Efficiency of Energy Resources and Energy Use". To account for direct greenhouse gas emissions resulting from the port's activities and released directly and indirectly into the atmosphere, as indicated in Table 1, tracking and monitoring have been conducted. This includes emissions from fixed combustion sources and mobile combustion sources. Monthly consumption quantities obtained from invoices have been systematically tracked, allowing for the calculation of emissions for the years 2018-2021.

Accordingly, the calculation method for vehicles using fossil fuels is calculated as Net Calorific Value (NCV) (Tj/Gg) x Activity Data (L) x Density (kg/m^3) x Emission Factor (kg/TJ) for CO_2, CH_4, and N_2O emission factors. Only CO_2 is calculated in the fire extinguisher calculation, and the total emission quantity is calculated based on activity data (kg) x Global Warming Potential (GWP). Direct emission calculations include emission factors according to IPCC reports, which are shown in Table 3.

Table 3. Greenhouse Gas Emissions Calculations

NATURAL GAS USE ACCOUNT DATA			
	Emission Factors		
Emission Source	CO_2	CH_4	N_2O
EF (Emission Factors) (kg CO_2 / TJ)	56 100	1	0.1
NKD (Net Calorific Values) (TJ / Gg)	48	48	48
GWP (Global Warming Potential) (kg CO_2-e/ kg CH_4)		21	310
FUEL USE ACCOUNT DATA			
EF	74.100		
NKD	43		
ELECTRICITY USE ACCOUNT DATA			
Total amount of electricity produced in Türkiye in 2021 (GWh)	303 897.6		
Total emission amount of electricity production (tCO_2e(kt))	150 032.000		

Samsun Port natural gas total tCO_2e emission calculation for 2018:

$$\textbf{Emission} = \sum \textbf{FV Gg x EF x NKD x YF} \tag{1}$$

$$\textbf{Gg} = \sum \textbf{FV x Density of natural gas/1000} \tag{2}$$

$$\frac{Gg = 10.538\ m^3\ x\ 0.78 \frac{kg}{sm^3}}{1000000} = 0.0082\ Gg \tag{3}$$

$$Emission\ tCO_2e = \frac{0.0082\ Gg\ x\ 48\ Tj}{Gg} x \frac{56100\ kg\ CO_2}{1000} = 22.134\ tCO_2e \tag{4}$$

$$Emission\ kg\ CH_4 = \frac{0.0082\ Gg\ x\ 1\ kg\ CH_4}{Tj}\ x\ 48\ \frac{Tj}{Gg} = 0.39\ kg\ CH_4 \tag{5}$$

$$Emission\ CH_4 = 0.39\ kg\ CH_4\ x\ 21\ kg\ \left(\frac{tCO_2e}{kg\ CH_4}\right) = 0.0083\ tCO_2e \tag{6}$$

$$\boldsymbol{Emission\ kg\ N_2O = \frac{0.0082\ Gg\ x\ 0.1\ kg\ N_2O}{Tj} x\ \frac{48Tj}{Gg} = 0.39\ kg\ N_2O} \quad (7)$$

$$\boldsymbol{Emission\ N_2O = 0.39\ kg\ N_2O\ x\ 310\ (\frac{tCO_2e}{kg\ N_2O}) = 0.012\ tCO_2e} \quad (8)$$

$$\sum tCO_2e = 22.134\ tCO_2e\ +\ 0.0083\ tCO_2e\ CH_4\ +\ 0.012\ ttCO_2e\ N_2O\ =\ 22.154\ tCO_2e \quad (9)$$

In the calculation of indirect emissions, the Port calculated the electricity consumption of electrically operated machinery and the amount of electricity consumed separately and evaluated them separately. Port electricity consumption and electricity consumption from machinery activities are obtained by multiplying the activity data (kWh) by the emission factor (kg/kWh). Only CO_2 is calculated in the calculation of indirect emissions, and the total emission quantity is calculated based on activity data (kWh) x emission factor (kg/kWh). For indirect greenhouse gas emissions, a calculation method was established by considering the electricity consumption of third parties within Samsun port, fossil fuel consumption resulting from employee commuting, and fossil fuel consumption resulting from travel. Total emission quantities were calculated using the calculation method for fossil fuel consumption in direct emissions and indirect fossil fuel consumption in energy-related emissions.

RESULTS AND DISCUSSION

The Green Port objectives, achieved by the Port's efforts in this study, aim to raise awareness in the port sector about the calculation of emissions, establish a reference for emission data collection and evaluation among national and international ports, and support the port sector in achieving emission reduction targets.

Environment Management in the Port

Samsun Port initiated waste management activities in accordance with regulations in 2006 and the waste acceptance facility belonging to Port was licensed by the Ministry of Environment and Forestry in the same year. Samsun Port Harbor's management started designing and rebuilding the garbage acceptance facility after the port was privatized in 2010 in order to create a new waste management system that would be in line with port goals and current feasibility studies Following a rebuild, the waste reception facility's overall capacity grew from 240 m^3 to 745 m^3, allowing for the collection of both liquid and solid ship wastes and supporting recycling and marine conservation. In waste management, law and regulations are adhered to in order to reduce the negative effects on the environment. Reduction and recycling initiatives for both hazardous and non-hazardous waste have been stepped up in this setting.

Periodic exhaust emission measurements were carried out and reported for vehicles such as cranes and construction machines utilizing fossil fuels in order to prevent pollution from equipment inside the Port area. A number of steps were taken to reduce their negative effects on the environment, such as switching from fossil fuel-powered cars to greener models that run on renewable energy. Corporate greenhouse gas emissions have been calculated and reported at the Port since 2018. The validation of these calculations by authorized national and international institutions is part of the port's goals. In green port initiatives, the goals outlined in the "Green Port/Eco Port" project prepared by the Ministry of Transport and Infrastructure, Directorate General of Maritime, and the Turkish Standards Institution have been taken into consideration. These goals include reducing the amount of pollution that ships and ports produce into the environment, saving energy and improving port operations' energy efficiency, reducing greenhouse gas emissions, creating and executing renewable energy projects, cutting down on the quantity of waste produced by port operations, and implementing the appropriate safety and occupational health precautions. The Port has established procedures for the environmental management system, appointed a unit responsible for the system, and conducted planning activities in line with the goals, while also implementing necessary follow-up and corrective/preventive actions. Samsun Port has defined waste disposal methods in its environmental compliance obligations plan. All waste is collected in temporary waste storage areas to be recycled and disposed of in accordance with laws without causing harm to the environment.

Greenhouse gas inventory management

Direct greenhouse gas emissions

Figure 3 shows the tCO_2e value related to direct greenhouse gas emissions for Samsun Port from 2018 to 2021. When investigating Samsun Port's direct greenhouse gas emission values over time, makes it clear that fuel use accounts for the majority of emissions. Fossil fuel consumption, aside from negatively impacting air quality, also contributes to the greenhouse gas effect by releasing emissions into the atmosphere. Consequently, it is imperative to reduce this substantial emission quantity.

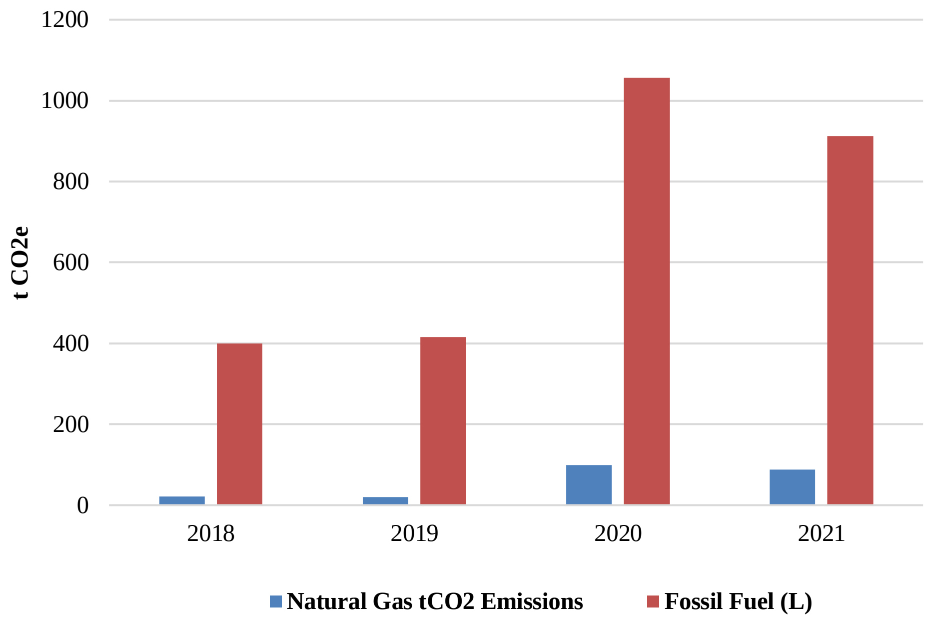

Figure 3. Direct Emissions Amounts Between 2018-2021

Samsun Port's fuel use increased until 2020; however, in 2021, advances in energy efficiency resulted in a decrease. This reduction in fuel consumption can be attributed to the active use of electric machinery. Samsun Port's natural gas consumption decreased in 2019 compared to 2018, but increased significantly in 2020. As a result, it is clear that the facility needs to make improvements in order to handle this increase. By 2021, it will be clear that utilizing the energy audit report is crucial to cutting fuel and natural gas usage.

Indirect greenhouse gas emissions from energy

Indirect greenhouse gas emissions from energy have been determined and monitored based on electricity consumption. The machinery's current electricity consumption data is regularly recorded, which makes it possible to calculate the electricity consumption that corresponds to workload and seasonal fluctuations. Consequently, greenhouse gas emissions and the carbon footprint have been computed accordingly. The calculations have been performed according to the ISO 14064:2006 Greenhouse Gas Emission Standards, which ensure the design, development, management, and reporting of emissions at the organizational level. By including emissions pertaining to subcontractors, this standard has expanded the range of indirect greenhouse gas emissions computation. This modification aims to raise awareness of the increasing emissions from organizations and improve greenhouse gas inventories by incorporating various indirect emissions within the organization. The category of other indirect greenhouse gas emissions has been renamed as indirect greenhouse gas emissions (TSE, 2021). Figure 4 shows the indirect emission values of Samsun port in terms of CO_2 equivalent from 2018 to 2021.

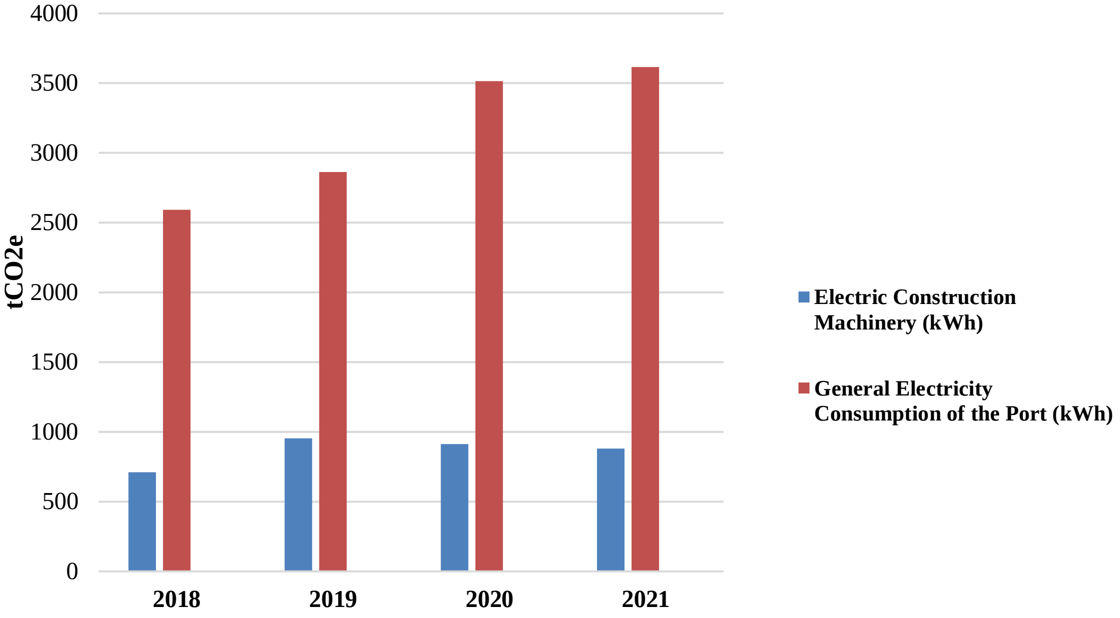

Figure 4. Indirect Emissions Amounts Between 2018-2021

The emissions connected to electric machinery, which was implemented in 2018, have been individually included in the calculations when considering the energy-related indirect emissions at Samsun Port for the years 2018–2021. Consequently, the emission quantity from electric machinery increased in 2019 compared to 2018. The greenhouse gas emission inventory for 2021 does not include any calculated uncertainties. The reason for this is the inability to obtain reliable and accurate uncertainty values. The port has initiated improvement efforts in this regard, and uncertainty assessments are planned to be carried out in the next reporting period. The verification process is carried out by the Turkish Standards Institution within the scope of TS EN ISO 14064-3 Standard at a reasonable (materiality ≤5%) confidence level.

Total greenhouse gas emissions

Samsun Port has assessed its environmental impact by calculating greenhouse gas emission quantities between 2018 and 2021 in accordance with ISO 14064-1:2006 standard. This includes accounting for consumption-related electricity, natural gas, gasoline, diesel, generators, fire extinguishing systems, personnel commuting, travel, third-party electricity consumption, and electric machinery consumption. A correlation between rising CO_2 emissions and an increased workload can be seen when looking at the statistics throughout time. The total quantities of emissions between 2018 and 2021 according to the type of resource produced are given in Table 5. Indirect emissions amounts, which correspond to the volume of cargo handled, have been compared annually as presented in Figure 5.

Table 4. Total Emission Quantities at Samsun Port for the Years 2018-2021

	2018	2019	2020	2021
Source	**tCO_2e**	**tCO_2e**	**tCO_2e**	**tCO_2e**
Direct Emissions	422.37	445.17	1 155.77	1 004.67
Indirect Energy-Related Emissions	3 304.89	3 816.45	4 423.81	4 495.77
Indirect Emissions	341.41	378.14	448.85	462.70
Total	4 068.67	4 639.76	6 028.43	5 963.15

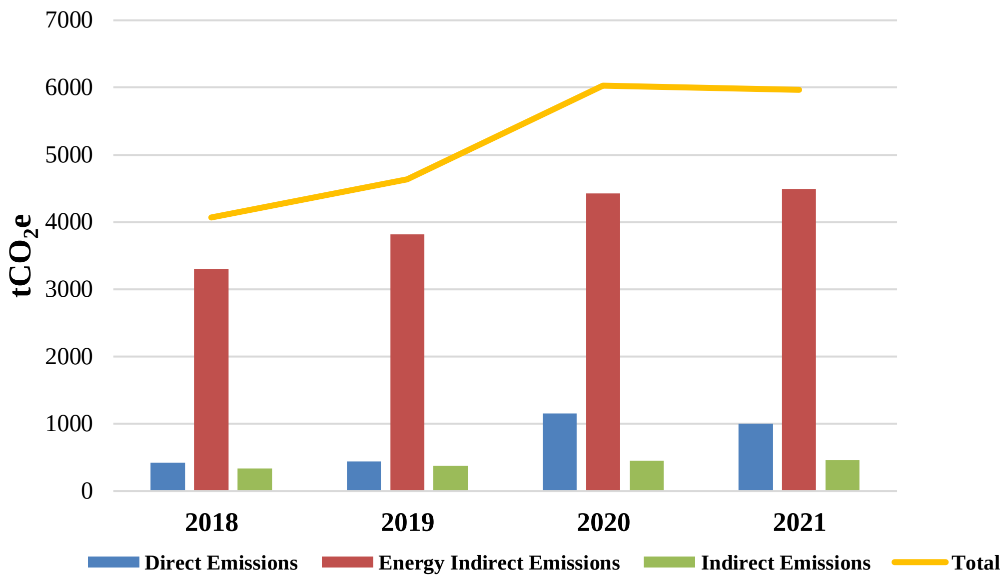

Figure 5. Total Emissions Amounts Between 2018-2021

A correlation between rising CO_2 emissions and an increased workload can be seen when looking at the statistics throughout time. As shown in Figure 5, the tCO_2e levels have been compared annually and correlate with the volume of cargo handled. A comparison of tCO_2e emissions between 2018 and 2021 shows that there was an increase in 2019 over 2018. Nonetheless, the pandemic's effects on the commerce industry resulted in a decrease in emissions in 2020. In contrast, greenhouse gas emissions increased somewhat in 2021. There were 4 068.7 tCO_2e emissions reported in 2018. 10% percent of the total emissions were direct, 81% percent were indirect emissions related to energy, and 9% were other indirect emissions. A total of 4 639.755347 tCO_2e emissions were reported in 2019. 10% of the overall emissions were found to be direct, 82% to be indirect emissions connected to energy, and 8% to be other indirect emissions. Direct and other indirect emissions did not change from 2018 to 2019, however energy-related indirect emissions did increase. The active usage of electric cranes is the reason for the growth in energy-related indirect emissions in 2019. In 2020, a total of 5 661.231226 metric tons of CO_2 emissions were recorded. It has been determined that within the total emissions, 20% were direct emissions, 72% were energy-related indirect emissions, and 7% were other indirect emissions. A comparison with the year 2019 reveals an increase in direct emissions, a decrease in energy-related indirect emissions, and a decrease in other indirect emissions. The decrease in energy-related indirect emissions compared to the previous year can be attributed to the slowdown in trade due to the pandemic, while the increase in direct emissions is linked to the continuous operation of ports in the logistics sector, operating around the clock without interruption. In 2021, a total of 1 004.674854 metric tons of CO_2 emissions were recorded. It has been determined that within the total emissions, 17% were direct emissions, 75% were energy-related indirect emissions, and 8% were other indirect emissions. There was a rise in indirect emissions linked to energy, a decrease in direct emissions, and an increase in other indirect emissions as compared to 2020.

In-depth examination of the emissions data unveiled several key findings. First, it was observed that energy-related indirect emissions had surpassed other categories, emphasizing the critical importance of addressing energy management and efficiency. In light of these findings, it is imperative to develop a comprehensive plan focused on energy management and conservation, accompanied by an increased utilization of renewable energy sources. Furthermore, the Port recognized that, beyond energy-related indirect emissions, direct emissions constituted a notable environmental concern within the organization. It is advised to strategically switch to the use of electric vehicles in order to minimize direct emissions and lower diesel use. Also, it is recommended to place a strong emphasis on reducing resource usage by utilizing energy-efficient devices like faucets and lighting with sensors. For increased energy efficiency, thermostatic valve installation is suggested as a specific solution to the rise in natural gas-related emissions within direct emissions. These valves, regulated based on ambient temperature, open and close accordingly, ensuring optimal indoor temperature levels for comfort and significant energy savings. About twenty-five radiators are in use at the Port's administrative building right now. Notably, a 1°C increase in room temperature consumes an extra 6–15% of energy. Current radiators do not have thermostatic valves, which leads to constant high energy use.

Consequently, installing thermostatic valves in place of radiators could result in up to 10% in energy savings. Samsun Port may want to think about acquiring carbon credits and enacting green tariffs as part of its commitment to sustainable practices. These actions would reduce carbon emissions and benefit the environment. Optimizing heating, ventilation, and air conditioning systems can provide in high-efficiency operations with lower energy usage, hence improving energy efficiency even further. For energy efficiency, it is advised to keep indoor temperatures at least 24°C in the summer and 22°C in the winter. Even a 1-degree difference in temperature can alter energy use by 7%. Regular maintenance and monitoring of air conditioning systems, coupled with adherence to set values, can further enhance energy efficiency and environmental contributions. Upon examining the mechanical installation systems used for building heating at Samsun Port, it was identified that although the pipes were insulated, the mechanical elements within the system lacked insulation. Uninsulated components, such as valves/flanges, result in heat loss equivalent to that lost from 3-5 meters of uninsulated piping.

In light of these findings, it is recommended that the Port insulate all uninsulated pipes in accordance with the TS-12241 Mechanical Installation Insulation Standard to mitigate energy losses. Based on these outcomes, it is advised that the Port minimize energy losses by insulating all exposed pipes in compliance with TS-12241 Mechanical Installation Insulation Standard.

Renewable energy at samsun port

Environmentally friendly practices were used in all of Samsun Port's investments following its privatization. In this context, solar energy systems (also known as photovoltaic or PV systems) have been put on warehouse roofs, and LED lighting has been installed throughout the port area. Energy needs have increased as a result of the Port's expanded storage capacity. Additionally, as part of its green port activities, the Port has switched to solar energy systems (Photovoltaic systems, or PV systems) in recognition of the significance of reducing the greenhouse gas effect for environmental and human sustainability. Early in 2018, the Port launched its Renewable Energy System (RES) project in accordance with the green port framework, mounting a 2 MW solar energy power plant on the rooftops of its depots and warehouses. This solar energy power plant became Turkey's first to be established within a port area and commenced electricity generation in January 2018.

In this research paper, a comparative data analysis has been conducted for the years 2018 to 2021, focusing on Samsun Port's Renewable Energy System (RES) data, including production and consumption. This data encompasses the total electricity consumption of the organization, including the electricity generated by solar panels installed on the roofs of warehouses within Samsun Port. In addition, the electricity consumption data of the machines that switched from diesel fuel to electricity were also analyzed.

In 2018, Samsun Port embarked on a transformative green project, investing 16 million Turkish Liras (TL) to launch a solar energy system for renewable and efficient energy production. The installation of 8.448 high-efficiency monocrystalline solar panels across 23.500 m² within the port premises generated an annual average of approximately 2 500.000 kWh (kilowatt-hours). This initiative is projected to reduce around 32 000.000 kg of CO_2 emissions over 30 years, contributing significantly to environmental preservation.

Expanding the capacity of the solar energy system aims to generate electricity equivalent to the needs of nearly 2.000 households, a crucial step in the quest for environmental sustainability. In 2021, Samsun Port conducted an energy audit in compliance with the "Energy Efficiency Law" and the "Regulation on Increasing Efficiency in the Use of Energy Resources and Energy." Acknowledging the pivotal role of energy efficiency in sustainable development for green ports, Samsun Port prioritized enhancing its energy efficiency measures. The port's energy manager received specialized training, and plans were set in motion to establish and certify the ISO 50001 Energy Management System by 2023's end.

The energy audit revealed the facility's total energy consumption in 2020 was 856 TEP (tonnes of oil equivalent), predominantly attributed to electricity (63%), natural gas (5%), and diesel fuel (32%) consumption. The total energy cost amounted to 6 374.662 TL, with a unit energy cost of 7.447 TL/TEP for the facility in 2020. These findings underscore Samsun Port's unwavering dedication to renewable energy adoption, energy efficiency, and environmental sustainability. The investment in solar energy systems not only curtails greenhouse gas emissions but also optimizes energy resource utilization, aligning perfectly with green port objectives and sustainable development. The focus on energy management and pursuit of ISO 50001 certification exemplify the port's commitment to achieving top-tier standards in energy efficiency and environmental stewardship. In 2021, the port implemented capacity enhancements in GES production, achieving an increase of 95 kWh, resulting in a total capacity of 2.825 kWh. Consequently, in 2021, the proportion of energy consumption relative to the port's production stood at 35%.

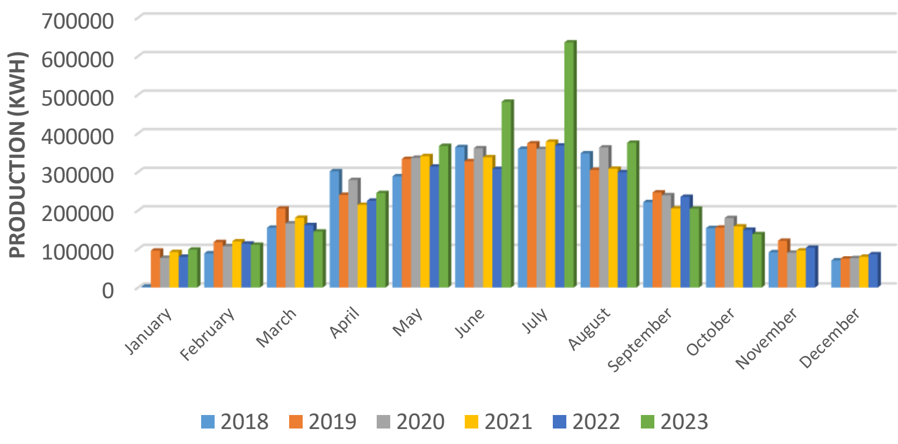

Figure 6. Solar Energy System (SES) Data for the Port Between 2018-2023

As illustrated in Figure 6, during the year, there is a period, notably in June, when production and consumption approximately align, with production at 337.977 kWh and consumption at 327.628 kWh. As part of the green port project, the port transitioned from using diesel-powered Mobile Harbor Cranes (MHC) to electric ones (E-MHC) in 2018. This transition led to a significant reduction in fossil fuel consumption, with total fossil fuel usage decreasing from 469.010 in 2017 to 399.467 l in 2018, marking an average 14% reduction in fuel consumption within a year.

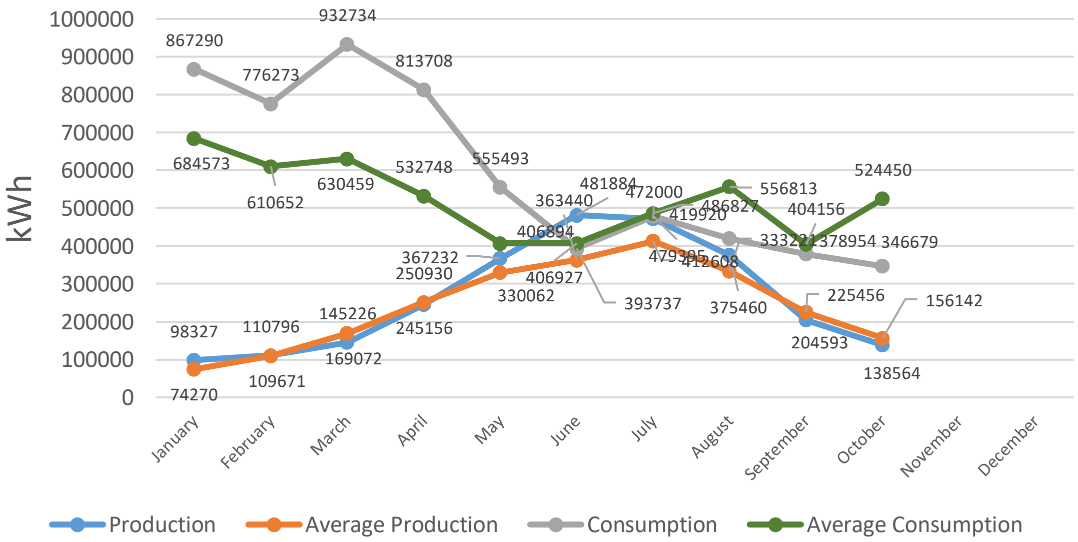

Figure 7. Comparison of Average Production and Consumption in the Port for the Year 2021

When examining the solar energy system data spanning the years 2018 to 2021, it becomes evident that there is a discernible pattern of increased production during the months of June and July, coupled with a noticeable decline in production during the winter months. According to Figure 7, it is apparent that the peak production occurred in the year 2021, registering at 378.378 kWh. After the year 2021, the highest recorded SES production data took place in July 2019, with a measurement of 374.043 kWh. In 2021, Samsun Port implemented capacity enhancements in GES production, achieving an increase of 95 kWh, resulting in a total capacity of 2.825 kWh.

The energy management issue in the port sector highlights the necessity for conscious and efficient action development as well as management. The functional organization required to provide environmental protection and sustainable development to the highest standards of compliance and accountability is referred to in this study as environmental management. In a nutshell, it's the process of managing environmental effects that result from port operations and activities.

CONCLUSION

This study includes the evaluation of integrated management systems, the adoption of renewable energy, sustainable waste management, and greenhouse gas emission calculations as significant components in a large-capacity port in the Black Sea, contributing to regional development. While Samsun Port has made commendable progress in waste management, greenhouse gas accounting, and energy management, there is a need to strengthen energy management and technological infrastructure. By doing so, it can take more significant steps towards becoming a model green port both in Turkey and on a global scale.

Mandatory greenhouse gas emission assessments for all candidates green ports in Turkey, regardless of voluntariness, are necessary to reduce air pollution and facilitate energy transformation. Priority should be given to the widespread adoption of electric vehicles and the development of a sustainable clean transportation network. Simultaneously, zero waste practices should be developed in all port areas, waste management leaders should be trained, collaborative initiatives with universities and non-governmental organizations should be encouraged, and social responsibility projects should be expanded to become an integral part of port culture.

Conflict of Interest

The article author declares that there is no conflict of interest.

Author's Contributions

The authors declare that they have contributed equally to the article.

REFERENCES

Alamoush, A. S., Ölçer, A. I. & Ballini, F. (2022). Ports'role in shipping decarbonisation: A common port incentive scheme for shipping greenhouse gas emissions reduction. *Cleanar Logistics and Supply Chain*, 3, 100021.

Alver, F., Saraç, B. A., & Şahin, Ü. A. (2018). Estimating of shipping emissions in the Samsun Port from 2010 to 2015. *Atmospheric Pollution Research*, *9*(5), 822-828.

Anonymous, (2024). https://samsun.ktb.gov.tr/TR-216771/samsun-limani.html (Accessed on 10 February 2024)

Botana, C., Fernández, E., & Feijoo, G. (2023). Towards a green port strategy: the decarbonisation of the port of vigo (NW Spain). *Science of the Total Environment*, *856*, 159198.

Chen, K., Guo, J., Xin, X., Zhang, T. & Zhang, W. (2023). Port Sustainability Through Integration: A port capacity and profit-sharing joint optimization approach. *Ocean & Coastal Management*, 245, 106867.

Colarossi, D., Lelow, G. & Principi, P. (2022). Local energy production scenarios for emissions reduction of pollutants in small-medium ports, Transportation Research Interdisciplinary Perspectives, 13, 100554.

Çetintürk, K., & Ünlü, S. (2022). The first observation of antifouling organotin compounds and booster biocides in sediments from Samsun Port area, Black Sea, Turkey. *Marine Pollution Bulletin*, *176*, 113408.

European Sea Ports Organization (ESPO), (2021). ESPO Environmental Report 2021; ESPO: Brussel, Belgium.

http://www.espo.be/media/ESP-844%20(Sustainability %20Report%202021)_WEB.pdf

Gao, S., Xin, X., Li, C., Liu, T. & Chen, K. (2022). Container ocean shipping network design considering carbon tax and choice inertia of cargo owners. *Ocean & Coastal Management*, 216, 105986.

Garcia-Freites, S., Gough, C. & Röder, M. (2021). The greenhouse gas removal potential of bioenergy with carbon capture and storage (BECCS) to support the UK's net-zero emission target. *Biomass and Bioenergy*, 151, 106164.

IPCC, (2006). Guidelines for National Greenhouse Gas Inventories: Volume 5 - Waste. Retrieved from https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

ISO (2006) ISO 14064-1: greenhouse gases – part 1: specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals. International Organization for Standardization, Geneva.

Liu, Y., Xin, X., Yang, Z., Chen, K. & Li, C. (2021). Liner shipping network-transaction mechanism joint design model considering carbon tax and liner alliance. Ocean & Coastal Management, 212, 105817.

Okşaş, O. (2023). Carbon emission strategies for container handling equipment using the activity-based method: A case study of Ambarlı container port in Turkey. Marine Policy, 149, 105480.

Sornn-Friese, H., Poulsen, R. T., Nowinska, A. U. & de Langen, P. (2021). What drives ports around the world to adopt air emissions abatement measures?. *Transportation Research Part D: Transport and Environment*, 90, 102644.

Styhre, L., Winnes, H., Black, J., Lee, J. & Le-Griffin, H. (2017). Greenhouse gas emissions from ships in ports-Case studies in four continents. Transportation Research Part D: Transport and Environment, 54, 212-224.

TS EN ISO 14064-3 Standard (2021). Quality Management Systems - Basic Principles, Terms and Definitions https://www.tse.org.tr/sera-gazi-emisyonlarinin-takibi-hakkinda-yonetmelik-kapsamin-dogrulama/ (Access date: 23.04.2024)

Xiong, T., Liu, Y., Yang, C., Cheng, Q., & Lin, S. (2023). Research overview of urban carbon emission measurement and future prospect for GHG monitoring network. *Energy Reports*, *9*, 231-242.

Wang, B., Liu, Q., Wang, L., Chen, Y., & Wang, J. (2023). A review of the port carbon emission sources and related emission reduction technical measures. *Environmental Pollution*, *320*, 121000.

Winnes, H., Styhre, L., & Fridell, E. (2015). Reducing GHG emissions from ships in port areas. *Research in Transportation Business & Management*, *17*, 73-82.

Yang, S., Zhang, J., & Zhou, S. (2023). The cost transportation game for collaboration among transportation companies. *Annals of Operations Research*, 1-25.

Yi, T., Meiping, W., & Shaorui, Z. (2023). Pricing and contract preference in maritime supply chains with downstream competition impact of risk-aversion and contract unobservability. *Ocean & Coastal Management*, *242*, 106691.

Zhang, Z., Song, C., Zhang, J., Chen, Z., Liu, M., Aziz, F., ... & Yap, P. S. (2023). Digitalization and innovation in green ports: A review of current issues, contributions and the way forward in promoting sustainable ports and maritime logistics. *Science of the Total Environment*, 169075.