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RESEARCH ARTICLE

Assessment of ship emissions through cold ironing method for Iskenderun Port of Turkey

Alper Kılıç[1], Mustafa Yolcu[2], Fuat Kılıç[3], Levent Bilgili[4,*]

[1]Bandirma Onyedi Eylul University, Dept. of Maritime Business Manag., 10200, Balıkesir, TURKIYE
[2]Port Authority, Iskenderun, TURKIYE
[3]Balikesir University, Dept. of Mechatronic Eng., 10145, Balikesir, TURKIYE
[4]Bandirma Onyedi Eylul University, Dept. of Naval Arch. and Marine Eng., 10200, Balikesir, TURKIYE

ABSTRACT

Ships are significant emissions sources, especially in port areas. Besides other emission sources, they have remarkable air pollution impacts on residential areas near ports. It is well known that these emissions have deleterious impacts on both human health, and ecosystems. The biggest ports are generally located near highly populated cities. Therefore, emissions occurred due to shipping activities in ports have a significant importance. This study examines shipping emissions at berth by using data of ships calling in Iskenderun Port in 2013 and compares the environmental performance of using shore side electricity. The study also investigates the external costs associated with the impacts of emissions on climate change, air quality, and human health. According to the results, utilization of shore side electricity instead of auxiliary engines in ports provide significant benefits on environmental and economic issues. In case of Iskenderun Port, it is concluded that shore side electricity eliminates approximately $ 23 million of external costs per year.

Keywords: Ship, port, emission, cold ironing, air pollution

1. INTRODUCTION

As a result of industrial and technological developments in addition to growth in population and global networks, energy demand and consumption have increased throughout the years by showing an absolute dependency to the fossil fuels especially to the oil. It is clear that the transport sector has a growing share of approximately 20% in oil consumption among other sectors such as housing, petrochemicals, agriculture, and industry [1]. Accordingly, transportation constitutes a significant portion of the carbon dioxide (CO_2) emissions from fossil fuels on a global scale. While total CO_2 emissions caused by fossil fuels increased 37.8% from 1990 to 2007, transport modes' share increases approximately 45% [2]. The relationship between consumption of oil and CO_2 emissions is well known. In this respect, maritime transport is the mode of transport that has the highest energy efficiency and generates the least greenhouse gas emissions. International Maritime Organization (IMO) estimated that the total CO_2 and CO_2 equivalent (CO_2e) emission amounts increased by 31,309 to 35,640 Mt and 34,881 to 39,113 Mt, respectively, which corresponds a 3.1% and 2.8% increasing rate annually [3].

Harmful emissions such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), CO_2, hydrocarbons (HC), and particulate matter (PM) are produced by the main (ME) and auxiliary (AE) engines of the ships These emissions have potential impacts on the environment by contributing to acid rain, eutrophication, greenhouse effect, ozone, and smog formation etc. In addition, ship flue gas emissions have significant contributions to air quality of the port-cities, which are located close to densely populated areas. For example, [4] emphasized that PM from ocean-going ships caused about 60,000 deaths a year due to cardiac diseases and lung cancer in Europe, East, and South Asia coastlines. IMO therefore calls for rapid action to control ship emissions. Estimates show that if no measures are taken, the greenhouse gas contribution of maritime transport can be around 18% by 2050.

Corresponding Author: lbilgili@bandirma.edu.tr (Levent Bilgili)
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Several reports have outlined that shipping emissions are significant air pollution sources in port areas worldwide [5-11]. There is increasing interest in adopting green shipping practices and reducing environmental externalities in ship and port operations. The main objective of emission reduction is to adopt a green port policy that includes a variety of approaches and methods for the sustainable maritime industry to improve air quality at port sites [12]. In this context, cold ironing has been a promising technique which is used to decrease emissions due to the ship hoteling process in port areas [13-14]. It is a basic process that provides shore side electrical power to the vessels at the dock by enabling them to shut down their AE [15].

Different methods can be applied to reduce emissions from vessels in port areas. For example, scrubbing systems can be used for SO_x emissions or selective catalytic reduction systems (SCR) can be used for NO_x emissions. However, such emission reduction methods are designed to eliminate only a particular type of emission. The vast majority of shipping emissions occur in hoteling mode where only the auxiliary generators of the ships run. Scrubber or SCR-like systems are used in the exhaust systems of the ship's main engines. Therefore, the shore connection system is the most convenient way to reduce all types of emissions from ships.

The analyses on cold ironing show that there are several cold ironing feasibility studies in which different types of source for the shore side electrical power has been evaluated. For example, an analysis was realized by applying cold ironing method to the vessels that visited Kaohsiung harbour. They stated that they could reduce SO_2 (63.2%), NO_x (49.2%), CO_2 (57.2%), HC (29.2%), and PM (39.4%) emissions by shutting down the AEs at specified rates [12]. The consequences of replacing diesel fuel with electrical power for gantry cranes and yard equipment in port operations was analysed and it was resulted that cold ironing might be a feasible solution for many ports to reduce emissions [16]. LNG fuel option for cold ironing was also evaluated by making it available for the usage of local port delivery trucks, locomotives, ferries a commercial harbour crafts in industrial port complexes and terminals [17]. It was stated that hybrid battery-diesel-electric propulsion and energy storage systems as a cold ironing approach can reduce fuel consumption and emissions as these systems supply sufficient energy to vessel for a certain voyage speed. It is also emphasized that cargo handling operations can also use the stored energy without running ship engines [18]. Compared to on-board generators, cold ironing systems reduce CO_2 emissions by more than 30%, NO_x and PM emissions by more than 95%, and also reduce local pollution and noise [19]. Cold ironing method was analysed by 12 different plug positions in the marine areas and showed that 10,000 tons of CO_2 emissions could be reduced annually for €13 million investments in ferry and container terminals [20]. In order to reduce the environmental impact of berthing ships, cold ironing or coastal power plants are installed in a number of cruise terminals [21]. The prospects of cold ironing were investigated considering all stakeholders and concluded that cold ironing provides significant economic benefits for the case of medium and high fuel prices. Consequently, it can be concluded that cold ironing approach has been placed in governmental policies in Europe, but it can be said that the practice is still quite limited in worldwide as in Turkey [22]. One of the last methods used to adopt green maritime practices and achieve the objective of reducing the environmental externalities of maritime activities was to reduce emissions at ports. Combining cold ironing with wind and solar energy is more effective solution to shipping emissions in port areas [23].

Turkey's coastline is more than 8,000 kilometres. Mediterranean, Aegean Sea, Marmara Sea, and Turkish Straits and Black Sea are the coasts of the country. There are many ports and shipyard facilities located on each sea for cargo, passenger, and fishing boats. Although there are some studies have been carried out for Turkish ports and straits [24-25], cold ironing method has been investigated for Turkish Ports in limited studies [26].

The main purpose of this study is to evaluate the application of cold ironing method as an alternative to AEs by calculating the ship emissions and their external costs in the vicinity of İskenderun Port.

2. MATERIALS AND METHODS

2.1. Economic analysis of cold ironing method

An economic analysis (i.e. a CBA) and a discussion of the results in terms of the potential positive socioeconomic benefits related to the reduction of pollutant air emissions as a result of using cold ironing technology were carried out.

Due to the electrification of ship systems, fuel saving, and emission reduction can be achieved. The operations of the vessels during their stay in the port are handled with three approaches: energy storage, auxiliary drives, and on shore power supply. The results demonstrate significant fuel and emission reductions during port operations and the importance of the ship's operational profile [27]. The environmental impact of an electric generator on a Ro-Ro ship was estimated using the Life Cycle Assessment (LCA) and determined that the environmental load caused by the generator was significant. Also, they indicated that a number of environmental impacts could be reduced by using facilities with suitable developing technologies (eg. photovoltaic systems, lithium-ion batteries, cold ironing, and PTOs supported by variable frequency drives installed in frequency converters and existing frequency plants) [28]. In another study conducted by LCA, the operations of diesel generators and the hybrid power system were compared and demonstrated the environmental benefits of a newly built hybrid power system [29]. A previous study found out that if the ships draw electricity from national electricity grids instead of generating electricity with their own generators, CO_2 emissions will be significantly reduced [30]. The cost of hoteling emissions from ships in the Port of Bergen was estimated between €10 and €21.5 million per year [31]. In another study, it was concluded that the use of a built-in power supply in ports is beneficial to the port area as the use of generators decreases [32]. Another study examined the applicability of medium-sized cold ironing to several small piers at a port in Aberdeen. Reimbursement scenarios were examined through SCBA based on the external costs of potential emission savings, and in the best-case scenario showed that the system would be reimbursed in just 7 years [33]. A recent study proposed an innovative power supply solution for the ports. This solution consists of an advanced static compensator with a rotating converter instead of a static converter [34]. Quantitative calculations show that in the long term, the use of coastal power has significant financial, environmental, and socio-economic benefits, while the cost of implementation is high. Furthermore, according to the qualitative interview data, perceptions of the current political and global economic climates are currently hampering such an initiative, despite being aware of these benefits [35]. As a result of the analysis of cruise ship traffic data in Copenhagen in 2012, assuming that 60% of the ships use cold iron, the total potential external health cost is estimated to be around €2.8 million per year [36].

Iskenderun is a district in the province of Hatay on the East Mediterranean coast of Turkey. Iskenderun Port is located in the North East of the Mediterranean Sea and provides transit sea transportation services to Middle East countries. The port is also connected to the national railway system. Fig 1 presents the Iskenderun Port Region.

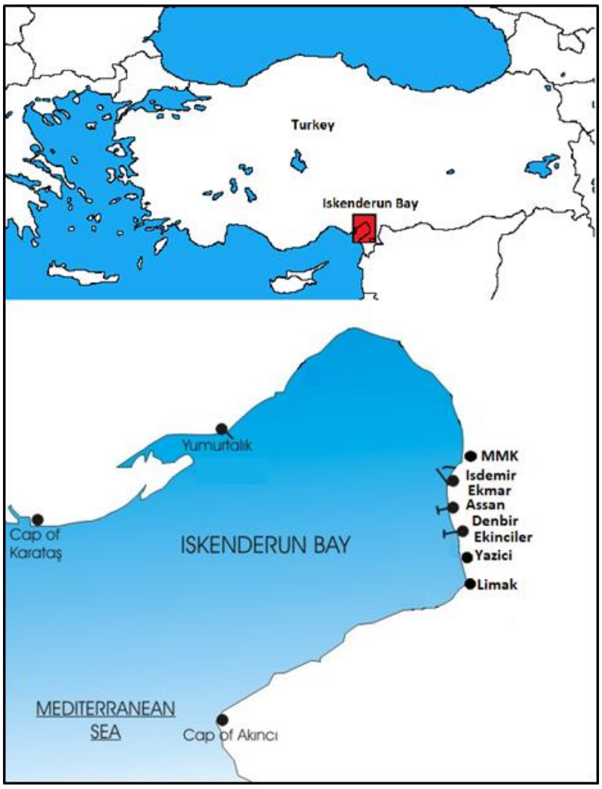

Fig 1. Iskenderun Port region

There are three numbers of pilotage points in Iskenderun Port area, which are called North, East, and South. Properties of ports are listed in Table 1.

Number of ships calling at these ports are given in Table 2 below. According to port statistics, 2,839 number of ships called at this port area in 2013. In 2014 number of ships call decreased to 2,787.

Table 1. Overview of Iskenderun Port area

Pilot Area	Berth number	Berth length (m)	Max Capacity (DWT)	Cargo Handling capacity (t year^{-1})	Ship Type
North	8	1,800	100,000	12,000,000	Bulk, Gen. Cargo, Ro-Ro, Container
	6	1,536	180,000	16,000,000	Bulk, Gen. Cargo
East	2	680	250,000(TEU)	n/a	Container
	6	812	55,000	n/a	Bulk, Gen. Cargo
	2	422	70,000	n/a	Bulk, Gen. Cargo
	10	1,150	n/a	7,500,000	Bulk, Gen. Cargo
South	8	1,652	n/a	2,000,000 1,300,000(TEU)	Bulk, Gen Cargo, Ro-Ro, Container

Table 2. Number of ships called in Iskenderun Port region

Port	Bulk Carrier	General Cargo	Container	Ro-Ro/Container	Chemical/Oil Tanker
North	93	436	10	-	-
North	166	416	32	-	21
East	3	72	-	204	-
East	8	106	-	-	17
East	49	317	-	6	-
East	39	127	3	-	-
South	25	299	-	251	-
Total	**383**	**1773**	**45**	**461**	**38**

2.2. *Ship particulars*

The general particulars of ships that called to Iskenderun Port region are summarized in Table 3. Totally 34 number of different ships surveyed on board while they were at port according to sample of technical file which is in the Appendix 1 of RESOLUTION MEPC.214(63), 2012 Guidelines on Survey and Certification of the Energy Efficiency Design Index (EEDI) (MEPC 63/23/Add.1).

Survey values of 34 different ships called at Iskenderun Port are used to create average values for each ship type. Survey values of ships include not only ship particulars such as ship length, gross tonnage, engine power but also additional information about ship's stay at Iskenderun port such as arrival and departure times, running hours of auxiliary engine and auxiliary boilers (AB), fuel consumption values for these auxiliary machineries. Table 4 below present average ME, AE, and AB at maximum continuous rating (MCR) values for each ship type.

Marine type fuels have different sulphur content values and there are different regulations on sulphur content in marine fuel for different port areas. Therefore, total amount of different fuels at ship's tank and consumption values are monitored carefully in ship surveys at port and recorded. Table 5 below show the average running hours and fuel consumption values of auxiliary machinery for each ship type based on survey data of ships called at Iskenderun Port.

Table 3. Ships particulars in Iskenderun Port region

Ship Type	Number of ships	Average Ship Speed at 75% MCR (knots)	Average L_{OA} (m)	Average GRT	Average DWT
Bulk Carrier	14	13.4	175	20,748	34,775
Container	2	20.6	195	26,128	30,722
General Cargo	11	11.5	99.8	3,706	5,701
Heavy Lift Cargo	2	13.3	177	22,923	27,703
Multi-purpose Dry Cargo	2	13.8	158.4	15,041	20,170
Oil & Chemical Tanker	1	12.5	122	4,347	6,276

Table 4. Average ME, AE and AB powers of ship types

Ship Type	Average ME MCR (kW)	Average AE MCR (kW)	Average AB Power (kW)
Bulk Carrier	7,368	515	341
Container	20,888	1,178	485
General Cargo	2,453	214	303
Heavy Lift Cargo	4,904	560	931
Multi-purpose Dry Cargo	5,330	443	1,493
Oil & Chemical Tanker	2,642	400	2,001

Table 5. Average running hours and consumptions of auxiliary machinery

Ship Type	Running hours at port (h)		Consumptions at port (t)	
	Aux. Eng.	Aux. Boiler	Aux. Eng.	Aux Boiler
Bulk Carrier	170.14	60.28	10.05	4.42
Container	28.50	22	5.6	3.31
General Cargo	150	59.63	2.88	1.7
Oil Chemical	67	35	2.51	7
Multipurpose Dry Cargo	100.5	59.5	10.6	1.05
Heavy Lift Cargo	107	23.5	8.07	4.7

2.3. Methodology

Ship emissions are estimated mainly based on two different methodologies. The first one is top-down approach which relies on marine bunker statistics. The second method is the recommended ship movement methodology when detailed technical information on ships is available in addition to detailed ship movement data. In this study, emission estimation methodology offered by Trozzi (2013) (Tier 3) is applied for a sample group of ships called to Iskenderun Port. In this study, berthing emissions were calculated based on the time spent at the port, the number of arrivals at the port, the average fuel consumption of the auxiliary machinery and the pollutant emission factors of AE. Average values of ship types are illustrated in Table 4, but emissions were calculated for each ship individually [37].

Tier 3 emission factors from Trozzi (2013) are used for estimating the emissions from ships in Iskenderun Port based on real and detailed information of ships such as ships movements, powers of main and auxiliary engines, fuel types, and fuel consumptions of each fuel types at manoeuvring and hoteling modes by engine technology as units of mass of pollutant per tonne of fuels. Emission factors are calculated in two different ways. First method is to calculate emission values by derived power (kWh) by using machine power (kW) and machine working hours (h). Second method is based on calculation of emission values by consumed fuel per capita.

Tier 3 approach calculates the emissions on each operation modes [38]:

$$E_{trip} = E_{Hotelling} + E_{Manouvering} + E_{Cruising} \quad (1)$$

The emission of pollutant i for a trip can be calculated as follows:

$$\mathrm{E_{Trip,i,j,m}} = \sum_{\mathrm{P}}\left(\mathrm{FC_{j,m,p}} \times \mathrm{EF_{i,j,m,p}}\right) \quad (2)$$

where;

E_{trip}: emission over a complete trip (tonnes)
FC: fuel consumption (tonnes)
EF: emission factor (kg tonne^{-1})
i: pollutant
m: fuel type
j: engine type
p: operation mode

Tier 3 calculation method of Trozzi includes hoteling, manoeuvring, and cruising modes. As the scope of this study is to investigate port emissions and socio-economic benefits of using alternative shore-based electricity at ports, emission calculations are conducted for only hoteling mode. Average emission factors have been developed by conducting literature review of the marine emissions studies and presented in Table 6 below.

Table 6. Emission factors (kg ton^{-1} fuel)

Emission Type	Main EF Kg ton^{-1}	Aux EF Kg ton^{-1}	Reference
CO_2	3.114	3.114	[3]
NO_x	44.3	59.7	[27]
PM	4	1.4	[27]
CO	2.51	2.38	[3]
VOC	6.6	1.8	[27]
SO_x	52.7	52.7	[3]

3. RESULTS AND DISCUSSION

3.1. Shipping activities at Iskenderun Port

At open sea, ships are propelled by main engine(s) at economic load which is generally equal to 80-85% of MCR. For the requirement of the generation of electricity for light, pumps, air conditioning etc., normally one generation is enough for energy demand. Vessels are usually equipped with super-heaters that generate steam using the waste heat from the exhaust gases of the main engines. The resulting steam is converted to work using the turbine or to electrical energy via a generator. In addition, there are shaft generators on the ships which generate electrical energy by means of an alternator connected to the propeller shaft which are operated only during the cruising of the ship.

In port regions, two operation modes, manoeuvring and hoteling, appear as emission sources: At manoeuvring mode, unlike the cruising mode at open sea ships use main engines at reduced power, but the power demand varies due to changing the ships' course, reducing and increasing the ships speed. Thus, in this mode, ships consume more energy than cruising mode at the same distance. Furthermore, ships use additional auxiliary diesel engines which are synchronized for prevention of accidents may result from possible black outs. At hoteling mode, ships require electricity for dock activities such as handling of the cargo by means of cranes or pumps. Except for shifting operations inside the ports, ships do not use main engines at hoteling modes. According to the survey conducted on ships in Iskenderun Port, main engines of all ships use heavy fuel oil (HFO) and marine diesel oil (MDO). However, not every ship use duel fuel for AE and AB. Although HFO is cheaper than MDO, it requires heating to decrease the viscosity. Thus, using HFO at ports is not a common practice. Besides, local legislation requires marine engines of ocean-going ships to be run on low sulphur fuel at ports. In this section, emission estimation results are discussed and investment in adapting cold ironing system for Iskenderun Port is analysed.

3.2. Annual emission estimations for ships

Emission estimations based on fuel consumption values of auxiliary machinery at port are presented in Table 7 below. In 2013, approximately 19,796 tons of fuel have been consumed by ships docked at Iskenderun Port based on hoteling mode calculations.

Table 7. Emission estimations by ship type for Iskenderun Port in 2013

Ship Type	Total emissions (t)					
	NO_x	**PM**	**CO**	**VOC**	**SO_x**	**CO_2**
Bulk Carrier	331	8	13	10	292	17,258
Container	24	1	1	1	21	1,249
General Cargo	485	12	19	15	428	25,287
Oil & Chemical Tanker	22	1	1	1	19	1,126
Multipurpose Dry Cargo	321	8	13	10	283	16,725
Total	**1,183**	**30**	**47**	**37**	**1,043**	**61,645**

For a fair comparison, environmental damage costs should be considered as well as fuel prices. Therefore, it would be possible to calculate real costs of fossil fuel usage by analysing external costs of emissions. Some studies have been conducted regarding to damage cost issue for Europe. Based on these studies, external costs of emission types per ton are given in Table 8.

Table 8. Unit costs per pollutant emission ton [26]

Pollutant	Unit costs per pollutant emission ton (USD)			
	Human health	**Ecosystem**	**Climate change**	**Total**
NO_x	7002	1228	0	8,230
PM	429,936	0	0	429,936
CO	36	0	41	76
VOC	1,155	86	0	1,241
CO_2	0	0	26	26
SO_2	7,739	246	0	7,985

Based on above unit costs of pollutants, total external cost of emissions by ships calling at Iskenderun Port in 2013 were calculated and results are presented in Table 9 below.

The results were compared with two previous studies, which focused on the calculation of emission inventories and dispersion modelling of these emissions.

First study was conducted on Ambarli and Kocaeli ports, which both are located in the Marmara Sea. During the period of 2017-2018, while Ambarli Port has 629 ship calls, Kocaeli Port has 2798 ship calls. The shipping activities cause 41,190.8 t of CO_2, 706.8 t of NO_x, 388 t of SO_2, 1 t of VOC and PM, and 32.2 t of CO in Ambarli Port. Similarly, the shipping activities cause 76,307.0 t of CO_2, 1353.8 t of NO_x, 718.8 t of SO_2, 1.7 t of VOC and PM, and 59.7 t of CO in Kocaeli Port. Considering that Iskenderun Port has 2700 ship calls, it is obvious that the emission amounts changes. The results occur in accordance with the number of ship calls [39].

Another study was carried out an emission inventory calculation of shipping activities occurred in Bandirma Port, which is located in the south of the Marmara Sea. During the study period, the port has 1577 ship calls of different types of ships. It was estimated that these ships cause 272,301 t of CO_2, 7,997 t of NO_x, 1,682 t of SO_2, 182 t of PM, and 240 t of CO. Although Iskenderun Port has almost twofold of ship calls than Bandirma Port, it can be seen that the shipping activities in Bandirma Port cause much more emissions. This difference may be caused by the hoteling duration or the fuel types [40].

Table 9. Total emission costs (USD)

Pollutant	Cost (USD)
NO_x	9,726,189
PM	11,915,009
CO	3,588
VOC	44,204
CO_2	1,590,381
SO_2	426,752
Total	**23,706,122**

Total fuel consumption for the auxiliary machinery of ships are calculated as 19,796 tons within 2013. Average MGO price for that year was 995 $ ton^{-1} in the Mediterranean region. Therefore, total cost of fuel is $19,696,324 [41]. It indicates that external costs of emissions are much higher than the total cost of consumed fuel.

Since the total fuel consumption data are available, the total power can be calculated using the lower heating value of the fuel consumed (MGO) and the thermal efficiency of the diesel engine [42]. As shown in Table 10, the required total power of the ships in the port is calculated using the total fuel consumption. The table also shows that the total power required for ship operations such as lighting, pumping, loading, unloading and heating is 81 million kWh.

Table 10. Total emission costs (USD)

Total fuel consumption	19,796 ton
Lower heating value	42,700 kJ kg^{-1} 11.9 kWh kg^{-1}
Thermal efficiency of AE	36%
Efficiency of alternator	95%
Overall efficiency	34.2%
Total required power	80,562,912 kWh

Cost of electricity in 2013 is provided by Turkish Energy Market Regulatory Authority (EPDK) as 0.12 USD/kWh for industrial use [43]. Therefore, total cost of electricity would be $9,667,549.433. Table 11 below summarizes the comparison of total fuel consumption values and total power requirements and their costs.

In case of meeting electricity energy demand by renewable sources, it would be possible to eliminate the approximately $23 million per year external costs of emissions. Table 11 below presents the total consumption and cost values.

Table 11. Total consumption and cost values (USD)

Consumption Values		
Power Source	**Value**	**Cost (USD)**
Total LS MGO (ton)	19,795.33	19,696,323.5
Total Electricity (kWh)	80,562,911.94	9,667,549.433
Cost Difference		10,028,774.07

3.3. Port investment on electricity supply

It is not enough to build the electricity distribution infrastructure on the land side to implement coastal power. At the same time, a number of transformations are needed to connect ships to shore electricity. These transformations are often more complex than building new vessels designed for cold ironing. In addition, the size of the power supplies and the proximity to the port are important factors in determining the power distribution infrastructure on the shore [44]. Since the electrical infrastructure of a terminal with cold ironing is more than a conventional terminal, emission reduction credits may be used to help cover this expense [45]. Possible configuration of cold-ironing system is illustrated in figure below.

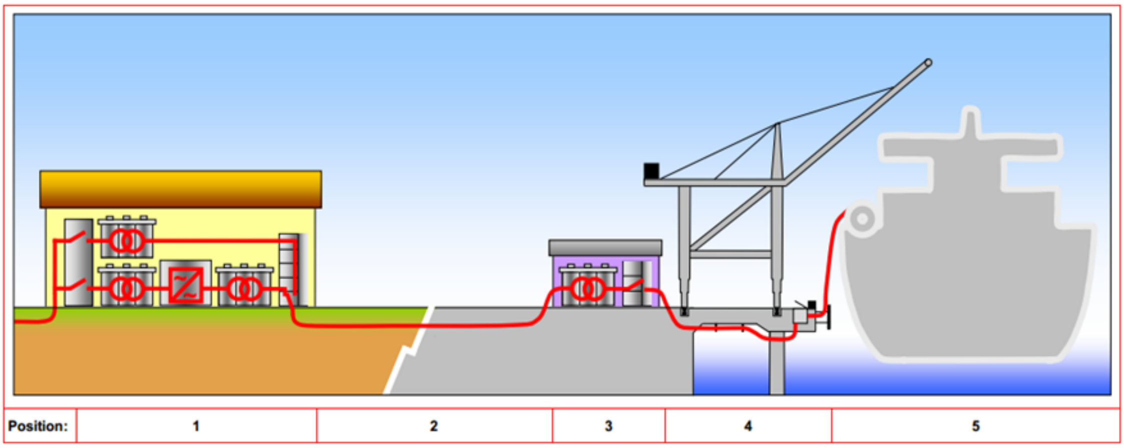

Fig 2. Overview illustration of cold-ironing system design [46]

Positions and descriptions of each facility are given in Table 12. Position 1 is the main substation building which represents the centre of the system. Main components of the shore side power system are located in this building. Technical details are presented in the table for each equipment.

Position 2 shows the cable arrangement, preferably consisting of underground cables above 24 kV, to reduce the current in the conductors as much as possible. mEU grid system is 380 kV-50 Hz, regional grid system is 150 kV-50 Hz and Euromax grid is 25 kV-50 Hz. Ports usually have 3.5 MVA-6.6 kV-60 Hz systems for bigger tonnage ships and 3.5 MVA-6.3 kV-50 Hz for smaller feeder ships. In Turkey national grid is 380 kV-180 kV and main substitution output is 34.5 kV. Frequency converter output should be 6.6 kV with 50-60 Hz option. The use of coastal power does not completely eliminate emissions from ships due to the necessity of operating boilers or the use of propellants in port manoeuvres. However, the use of coastal power will greatly reduce atmospheric emissions from ships in the port. Developing a renewable energy supply for cold ironing clearly requires national efforts [47].

Table 12. Descriptions of related equipment for model cold ironing system design

Position	Description	Size/Length	Scope	Properties
1	Main Substation Building	28*15 m= 420 m2	Frequency converter	6-11 MVA 6.6 kV
		One station for each port	Double bus bar switchgear	Enable 50-60 Hz, Suitable up to 24 kV
			Circuit-Breaker	-
2	Cable arrangement	5 km	Underground cables	Preferably 24 kV
3	Shore-side transformer station	5*2,6m = 13 m2	Transformer	Min. size 50 Hz&60 Hz 7.5 MVA 6.6 kV
		One station for each berth	Shore side Switchgear	
4	Shore-side connection arrangement	Three sets for each berth	Connection box	Placed along the berth at regular distances approx. 70 m
			Connection cable	350 A, 4MVA 6.6 kV
5	Vessel connection requirements			
6	Shore side power supply control: SCADA control system			

4. CONCLUSIONS

The annual shipping emission calculations have been carried out according to hoteling operation modes of various ship types (bulk carriers, chemical tankers, container ships, general cargo ships, heavy lift cargo, multipurpose dry cargo, and oil tankers) in Iskenderun Port region for the year 2013. It is concluded that, diesel engines have much lower thermal efficiency than electrical engines therefore use of direct shore power instead of auxiliary diesel engines at ports would provide crucial benefits on economic and environmental perspective.

In Iskenderun Port Area, external cost of burned fuels are much higher than the total cost of consumed fuel. In case of meeting electricity energy demand by renewable sources, it would be possible to eliminate the approximately $23 million of external emission costs per year. Adaptation of a cold ironing system requires both ports and shipping companies to invest in power transmission equipment.

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