"Mircea cel Batran" Naval Academy Scientific Bulletin, Volume XX – 2017 – Issue 1
The journal is indexed in: PROQUEST / DOAJ / Crossref / EBSCOhost / INDEX COPERNICUS / DRJI / OAJI / JOURNAL INDEX / I2OR / SCIENCE LIBRARY INDEX / Google Scholar / Academic Keys/ ROAD Open Access / Academic Resources / Scientific Indexing Services / SCIPIO / JIFACTOR

MODELLING OF TURKISH MARITIME TRANSPORTATION FLEET'S EMISSIONS AND REFERENCE ENERGY SYSTEM

Aydin TOKUSLU[1a]
Egemen SULUKAN[2]
Murat Kagan KOZANHAN[2]
Dogus ÖZKAN[3]
Volkan DEMIR[4]
Erinc DOBRUCALI[5]
[1] PhD Candidate, Institute of Marine Sciences and Management, Istanbul University, Istanbul, Turkey
[2] Capt (N) PhD, Turkish Naval Academy, National Defense University, Istanbul, Turkey
[3] LtCdr (N) PhD, Turkish Naval Academy, National Defense University, Istanbul, Turkey
[4] Asst. Prof. PhD Eng, Institute of Marine Sciences and Management, Istanbul University, Istanbul, Turkey
[5] Asst. Prof. PhD Eng, Turkish Naval Academy, National Defense University, Istanbul, Turkey
[a] Corresponding Author, e-mail: atokuslu@dho.edu.tr

Abstract: *Maritime transportation is the most environmentally-friendly mode of transport with respect to air and road transport and considered as a safe system for years. This form of transportation is increasing due to the globalization of manufacturing processes and the increase of global-scale trade. However, maritime transport is seen as an important source of emissions worldwide. Maritime shipping produces an estimated 2.7% of the world's CO_2 emissions, there are also other emissions from ships respectively NOx, SOx, CO, HC, VOC and particulate matter (PM). All these emissions threat people's health, life quality and environment. For that reason, ship based emissions have to be analized carefully. Following this target, this paper is concerned with the optimal fuel consumption pattern focusing on Turkish Maritime Transport Fleet emissions within the next 40 years (up to 2050). Using MARKAL (an acronym for MARKet ALlocation) Maritime Transportation model, various steps as designing of ''Reference Energy System (RES)'' of the model, data processing and prepare of scenario are followed.*
Key words**:** *emission, maritime, fleet, model, MARKAL.*

Introduction

Maritime transportation is the most environmentally-friendly mode of transport with respect to air and road transport and considered as a safe system for years. This form of transportation is increasing due to the globalization of manufacturing processes and the increase of global-scale trade. However, maritime transport is seen as an important source of emissions worldwide. International Maritime Organization (IMO) states that all ships globally consume 300 million tons of fuel annually (IMO, 2014). Consumed fuels generate huge amount of emissions, which are nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO), carbon dioxide (CO_2) and particulate matter (PM).
According to Third IMO GHG Study 2014, annual shipboard NOx emission on 2012 was 19.002 million tons, SOx emission was 10.240 million tons, which are 15% and 13% of global NOx and SOx emissions, respectively, and CO, CO_2 and PM emissions were 936 thousand tons, 949 million tons and 1.402 million tons on 2012, respective to emission type (IMO, 2014).
These anthropogenic greenhouse gas (GHG) emissions which is on the global and regional scales impact on human health, climate and ecosystems. Virtually 70% of ship emissions are estimated to occur within 400km of land (Endresen et al., 2003), ships have the potential to contribute significantly to air quality degradation in coastal areas.
All these emissions threat people's health, life quality and environment. For that reason ships emissions have to be analyzed carefully.
The goal of the this study is to review existing studies dealing with the impact of shipping emissions on air quality of Turkish Maritime Transport Fleet and analyzing its impacts to environment at global degree within the next 40 years (up to 2050). Using MARKAL (an acronym for MARKet ALlocation) Maritime Transportation model, various steps as designing of ''Reference Energy System (RES)'' of the model, data processing and prepare of scenario are followed.

Review of emission analysis models

Several studies have been conducted at this area. Corbett et al. (2000) presented an inventory of emissions from marine vessels engaged in waterborne commerce (i.e., cargo transport) on the U.S. navigable waters. Eyring et al. (2005) presented an emission inventory for international shipping for the past five decades to be used in global modeling studies with detailed tropospheric chemistry. He estimated a fuel consumption of 280 million metric tons (Mt) for the year 2001 and 64.5 Mt in 1950. This corresponds to 187 (5.4) Tg CO_2 (NOx) in 1950, and 813 (21.4) Tg CO_2 (NOx) in 2001.

DOI: 10.21279/1454-864X-17-I1-023

Qinbin et al. (2002) examined the transatlantic transport of anthropogenic ozone and its impact on surface ozone in Europe and North America by using a 5-year (1993–1997) simulation with the GEOS-CHEM global three-dimensional model of tropospheric chemistry.

Corbett et al. (1999) estimated geographically resolved global inventories of nitrogen and sulfur emissions from international maritime transport for use in global atmospheric models.

Wallington et al. (2014) estimated direct emissions of N2O from global transportation (land, air, water). Viana at al. (2014) calculated impact of maritime transport emissions on coastal air quality in Europe. Lagoudis and Shakri (2015) constituted a framework formeasuring carbon emissions for inbound transportation and distribution Networks.

Kesgin and Vardar (2001) made a study on exhaust gas emissions from ships in Turkish Straits. They calculated NOx emissions on the Bosphorus are 2720 t from domestic passenger ships and 4357 t from transit ships.

Deniz and Durmusoglu (2008) estimated shipping emissions in the region of the Sea of Marmara, Turkey, Total emissions from ships in the study area were estimated as 5,451,224 t y− 1 for CO2, 111,039 t y− 1 for NOx, 87,168 t y− 1 for SO2, 20,281 t y− 1 for CO, 5801 t y− 1 for VOC, 4762 t y− 1 for PM.

Kilic and Deniz (2009) made an inventory of shipping emissions in Izmit Gulf, Turkey. Kilic et al. (2009) calculated the annual exhaust gas emissions from Turkish Flagged ship fleet.

Methodology

In this study, MARKAL-Answer software is used for modelling energy balance system. Reference energy system is initiated from 2010 years and ended at 2050 by 5 years periods and 2010 data have been utilized to generate Reference Energy System (RES).

General Information About MARKAL&ANSWER Software

ANSWER is a windows interface with learning curve specifically improved for operating with the MARKAL or TIMES energy system analysis model. The MARKAL and TIMES model generators were improved by the International Energy Agency's Energy Technology Systems Analysis Program (IEA-ETSAP). The ANSWER software for working with MARKAL was first available in 1998 and for the newer TIMES model in 2008.

The ANSWER interface grants the energy analyst with tools for data entry/edit/browse, for initiation of GAMS TIMES model run, and for results handling. The principles of operation of ANSWER is summarized below (www.climatesmartplanning.org):

- Data is stored in an access database.
- Data may be entered into the ANSWER database either manually using the ANSWER interface, or loading data from "smart" Excel spreadsheets.
- RES network diagramming facilitates viewing the underlying energy system structure.
- User-defined technology sets may be used to controlling viewing of subsets of the technology as well as in user constraints.
- MARKAL or TIMES model runs may be seamless submitted to GAMS, results from the run can be brought back into ANSWER, and/or results imported into VEDA-BE.
- Model run initiation from ANSWER creates the text files (in GAMS format) and produces as output text files containing model results.

Significance of Maritime Transportation in Energy Sector

The international shipping industry is responsible for the transportation of about 90 % of world trade and is crucial to the functioning of the global economy. The world's population and economy is expected to continue to grow and shipping will need to respond to the demand for its services. When compared modes of transport according to CO_2 emissions, while the maritime sector is the greenest one.

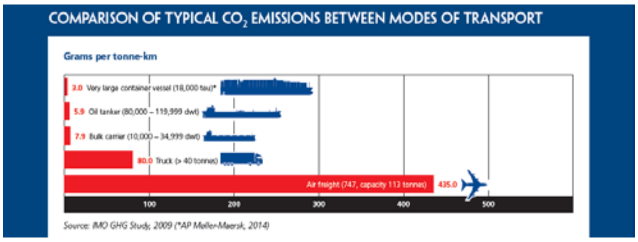

Figure 1. Modes of Transport According to CO2 Emissions (source : Buhaug et al, 2009;. Endresen, 2007)

Maritime transportation is becoming much more important than other types of transportation, because of it is more economical and can be transported large amounts of cargo by sea, and be possible between the regions where sea transport is not connected to land.

This transportation sector is increasing every day to meet people's needs. For that reason, it is the major energy consumer among other sectors such as rail and land transportation. Maritime sector is still expanding and becoming major transportation area in Turkey.

There are 50,054 merchant vessels which are 16224 of them is dry cargo, 8687 of them is bulk cargo, 4831 of them is container, 13175 of them is

DOI: 10.21279/1454-864X-17-I1-023

tanker, 6597 of them is passenger ship involved in international trade, as of October 2010 (IHS Fairplay, October 2010).
Turkish Flagged ship fleet has 1203 merchant vessels which are 370 of them is dry cargo, 84 of them is bulk cargo, 78 of them is container, 146 of them is tanker, 168 of them is passenger ship as of 2015 (Ministry of Maritime Transport and Communications).

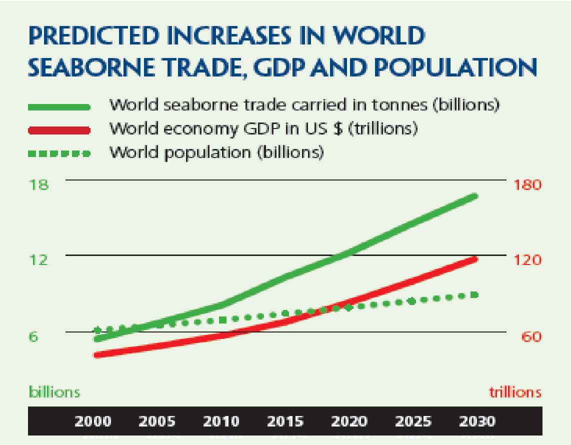

Figure 2. Increases in Seaborne Trade (source: IHS Global Insight, 2014)

Most part of the energy demand in maritime transportation sector is provided by oil products. Primal oil-product carriers in maritime transportation sector are marine diesel. Considering the energy consumption level in the maritime transportation sector and its share among different economic sectors, application of energy saving programs and rationalization of energy consumption in this sector can improve the energy efficiency, decrease the energy consumption, reduce costs and finally affect the economy thoroughly.

Reference Energy System for Turkish Maritime Transportation Fleet

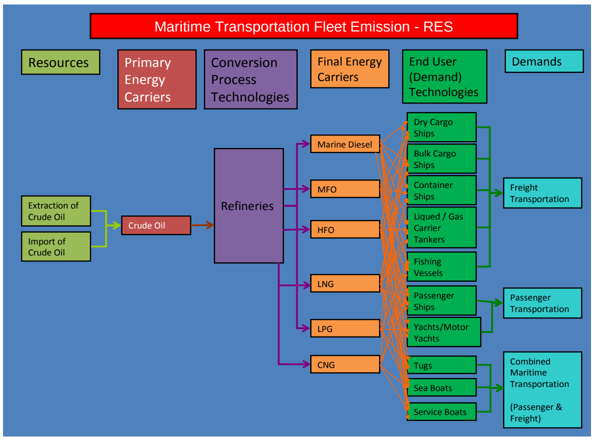

Figure 3. Reference Energy System for Turkish Maritime Transportation Fleet

As illustrated in Fig. 3, RES of the maritime transportation sector in Turkey consists of six subsystems, which are resources, primary energy carries, conversion and process technologies, final energy carries, demand technologies, and end-use demands. These subsystems are linked to each other and interconnected.

Resources

Generally RES's contains two resources which are import crude oil and extraction of crude oil.

Primary Energy Carriers

Primary Energy Carriers supplied energy is crude oil which is obtained from imported crude oil and extracted of crude oil.

Conversion and Process Technologies

As conversion and process technologies, refineries are used to product marine diesel, MFO, HFO, LNG, LPG and CNG from crude oil.

Final Energy Carriers

In this reference energy system six type final energy carriers are used for supply demands, they are respectively; marine diesel, MFO, HFO, LNG, LPG and CNG are used.

Demand Technologies

The produced energy carriers by conversion and process technologies are used in demand technologies in other words end user technologies. These technologies produce energy and materials in order to supply demands like passenger and freight transportation. Demand technologies used in maritime transportation in Turkey are listed below:

- Dry Cargo Ships,
- Bulk Cargo Ships,
- Container Ships,
- Liqued / Gas Carrier Ships,
- Fishing Vessels,
- Passenger Ships,
- Yachts / Motor Yachts,
- Tugs,
- Sea Boats,
- Service Boats.

Demands

In this study, the aim is supplying the required energy for passenger and freight transportation and also combined maritime transportation demands. While Dry Cargo Ships, Bulk Cargo Ships, Container Ships, Liqued/Gas Carrier Ships, Fishing Vessels are used for supplying freight

DOI: 10.21279/1454-864X-17-I1-023

transportation demands, Passenger Ships and Yachts/Motor Yachts are utilized for supplying passenger transportation demands, and Tugs, Sea Boats, Service Boats are used in combined transportation demands as passenger and freight transportation.

Modeling Process

Four steps above are necessary for applying any optimization process in MARKAL-ANSWER model just as other energy modeling support tools:

1. Since energy models are fundamentally supported RES concept, a RES should be designed reflecting the current situation of the base system.
2. The second step is gathering and classifying the unprocessed data.
3. Next step is creating scenarios, regarding special characteristics of the system.
4. Planners can enter RES and data to the model and then finally run it.

Important Variables/Parameters

There are five set of indicators which form the model: energy resources, conversion technologies, final energy carries, demand technologies and time (Fig 4.). The model is created in order to indicate the results between years 2010 and 2050. Every period of time applies to five years; the initial time t=0 is 2010, t=1 refers to year 2015, and the cycle goes until t=8 which is year 2050.

Figure 4. Demonstration of sets in the model

Conclusion

Transportation sectors in developing countries suffer from increasing of energy consumption. Integrated energy planning in transportation sector is a solution for these countries to alter their suboptimal pattern and reduce their energy consumption.

The MARKAL models expresses forceful tools for energy planning analysis with its environmental impacts. The MARKAL models gives a pliable, understanding, proven, verifiable and maturing methodology that can advance sensibilities to assist with informed decision-making (TUİK Statistics of Maritime Transportation).

In this paper, we tried to design reference energy system of Turkish Maritime Transportation Fleet for Turkey. A database is not constructed for a system run, since it is very hard to collect the relevant quality data in a short time. The basic RES for Turkish Maritime Transportation Fleet is developed as an important step, and the related data and alternatives scenarios can be combined when required.

Bibliography:

[1] International Maritime Organization (IMO), 2014. IMO GHG Study 2014.
[2] Endresen, Q., Sørgard, E., Sundet,J.K., Dalsøren,S.B., Isaksen, I.S.A., Berglen, T.F., and Gravir, G., (2003). Emission from international sea transportation and environmental impact. Journal of Geophysical Research, Vol. 108, No. D17, 4560, Doi:10.1029/2002jd002898, 2003
[3] Corbett, J.J., Fishbeck, P.S., 2000. Emissions from waterborne commerce vessels in United States continental and inland waterways. Environmental Science and Technology 34, 3254-3260.
[4] Eyring, V., Köhler, H. W., van Aardenne, J. And Lauer, A. (2005). Emissions from international shipping: 1. The last 50 years, Journal of Geophysical Research.Vol 110.
[5] Corbett, J., Fischbeck, P., and Pandis, S. (1999). Global nitrogen and sulfur inventories for oceangoing ships, Journal of Geophysical Research, 104, 3457-3470.
[6] T.J. Wallington, P. Wiesen, N2O emissions from global transportation, Atmospheric Environment, Volume 94, September 2014, Pages 258-263, ISSN 1352-2310, http://dx.doi.org/10.1016/j.atmosenv.2014.05.018.
[7] Viana, M., Hammingh, P., Colette, A., Querol, X., Degraeuwe,B., Vlieger, I., Aardenne, J., Impact of maritime transport emissions on coastal air quality in Europe, Atmospheric Environment, Volume 90, June 2014, Pages 96-105, ISSN 1352-2310
[8] Ioannis N. Lagoudis, Aamil Raza Shakri, A framework for measuring carbon emissions for inbound transportation and distribution networks, Research in Transportation Business & Management, Volume 17, December 2015, Pages 53-64, ISSN 2210-5395, http://dx.doi.org/10.1016/j.rtbm.2015.11.001.
[9] Qinbin, L., Jacob, D., Bey, I., Palmer, P., Duncan, B., Field, B., Martin, R., Fiore, A., Yantosca, R., Parrish, D., Simmonds, P., and Oltmans, S. (2002). Transatlantic transport of pollution and its effects on surface ozone in Europe and North America, Journal of Geophysical Research, 107 (D13)
[10] Kesgin, U., Vardar, N., A study on exhaust gas emissions from ships in Turkish Straits, Atmospheric Environment, Volume 35, Issue 10, April 2001, Pages 1863-1870, ISSN 1352-2310,

DOI: 10.21279/1454-864X-17-I1-023

http://dx.doi.org/10.1016/S1352-2310(00)00487-8.
[11] Deniz, C., Durmuşoğlu, Y., Estimating shipping emissions in the region of the Sea of Marmara, Turkey, Science of The Total Environment, Volume 390, Issue 1, 1 February 2008, Pages 255-261, ISSN 0048-9697, http://dx.doi.org/10.1016/j.scitotenv.2007.09.033.
[12] Kılıç, A., Deniz, C., (2009). Inventory of shipping emissions in Izmit Gulf, Turkey, Environmental Progress and Sustainable Energy , Volume 29, Issue 2, July 2010, Pages 221-232.
[13] Kılıç, A., Deniz, C., Durmuşoğlu, Y., and Çetin, B.Y. (2009, a). The Annual exhaust gas emissions from Turkish Flagged ship fleet, 13th Congress of Intl. Maritime Assoc. of Mediterranean IMAM 2009, İstanbul, Türkiye, 12-15 Oct. 2009
[14] IHS Fairplay, October 2010
[15] Ministry of Maritime Transport and Communications statistics
[16] Energy balance of Turkey, 2010, www.dektmk.org.tr/upresimler/2010Denge.pdf
[17] TUİK Statistics of Maritime Transportation, Turkey
[18] DET NORSKE VERITAS, Report Shipping 2020, Oslo, 08.2012
[19] Nicolae F. : Environmental Management Activities in Shipping Industry. E-learning Platform of Naval Academy Mircea cel Batran Press, 2012, 2013, 2014 www.adlanmb.ro.
[20] www.climatesmartplanning.org

DOI: 10.21279/1454-864X-17-I1-023