Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2021, 66 (138), 28–33
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/466

Received: 07.03.2021
Accepted: 26.05.2021
Published: 30.06.2021

Estimation of global liquefied natural gas use by sea-going ships

Ewelina Chłopińska[1], **Jakub Tatesiuk, Jakub Śnieg**

[1] https://orcid.org/0000-0003-4270-1764

Maritime University of Szczecin, Faculty of Navigation
1-2 Wały Chrobrego St., 70-500 Szczecin, Poland
e-mail: [1]e.chlopinska@am.szczecin.pl
corresponding author

Keywords: liquefied natural gas, LNG-powered ships, demand, SECA areas, bunker fuel, forecast

JEL Classification: C69, Q42, Q47

Abstract

Environmental pollution is a growing concern for many organizations, commissions, state governments, and companies. The use of fossil fuels in transportation contributes significantly to increased emissions of harmful sulfur oxides (SO_x) and nitrogen oxides (NO_x). Maritime transport, as one of the largest emitters of such harmful compounds, has encountered many emission restrictions and legal limitations. These include the creation of areas of strict exhaust gas control (ECA). According to the MARPOL Convention, Annex VI, Special Emission Control Areas have been in force since 01.01.2015, and they include the following areas: the Baltic Sea, North Sea, North America (covering the designated coasts of the USA and Canada and portions of the Caribbean Sea near the USA). According to current regulations, vessels providing services in ECAs are required to maintain sulphur oxide emissions that do not exceed 0.1%. The introduction of new regulations results in costs that have to be covered by shipowners. To meet these standards, the two most popular methods are the use of special flushing systems (scrubbers) and low-sulphur fuels (e.g., LNG). This publication addresses the use of LNG as fuel for the main propulsion of sea-going vessels operating in areas covered by strict sulphur emission controls. It also presents LNG demand forecasts for various ship types, as well as possible solutions satisfying the Sulphur Directive. The purpose of this paper is to present a way to determine the size of the global demand for LNG. The percentage of vessels powered by LNG and other fuels was used as a basis for estimating global LNG demand in shipping until 2030.

Introduction

The continued growth of sea transport, leading to a considerable increase in the number and tonnage of cargo ships, has led to a permanent and dynamic increase in atmospheric pollution. To reduce the emissions of toxic compounds into the atmosphere, several regulations have been enacted. The implementation of revised standards with local, regional, and international coverage is expected to significantly reduce the impact of shipping on the continued degradation of the natural environment. The most important restriction for shipowners is Annex VI to the MARPOL 73/78 Convention, issued by the International Maritime Organisation (IMO) (IMO, 2004). Practical alignment with the relevant requirements of the Convention has forced shipowners to seek solutions that meet environmental regulations. One alternative for substantially decreasing toxic emissions is the use of environmentally friendly gas fuels for marine engines.

The global development of technology has led to solutions that are favourable to the natural environment (Zaleska-Bartosz & Klimek, 2011; IFC, 2016).

The process to which natural gas is subjected reduces its volume by 630-fold (Molenda, 1996; Herdzik, 2015).

The literature does not cover issues related to marine liquefied natural gas (LNG) distribution, and no LNG demand studies have been conducted. The use of LNG in the maritime economy concerns the development of sea units (Matczak, 2015); thus, the demand for the raw material will inevitably increase in areas subject to strict sulphur emission control due to pro-ecological legal regulations (Kalski et al., 2010; Grzelak, 2015; IGU, 2016).

Reasons for using liquefied natural gas at sea

Natural gas is liquefied to facilitate storage and transport. LNG is 600 times lower in volume than in its gaseous phase, which makes international seaborne transport economical. LNG is produced by cooling natural gas to its boiling temperature, i.e. about –162°C (–259°F). It is stored in double-walled cryogenic tanks at atmospheric pressure or slightly higher. LNG can be converted to its gaseous form by increasing its temperature. Extracted from hydrocarbon deposits, natural gas is composed of a range of hydrocarbon gases, including methane (CH_4), ethane (C_2H_5), propane (C_3H_8), and butane (C_4H_{10}). As LNG components have a wide range of boiling temperatures and heating values, they find different commercial applications in many areas of the economy (e.g., sea and road transport). Acidic compounds, such as hydrogen sulphide (H_2S) and carbon dioxide (CO_2), plus oil, mud, water, and mercury are removed to obtain clean, desulfurized gas flow (Bielski, 2005). When present in the gas, these contaminants may cause damage. For example, they can corrode steel pipes, and mercury can combine with aluminium in cryogenic heat exchangers, which may lead to costly damage.

The requirements for the sulphur content in diesel oil were outlined in Directive 1999/32/EC, which specifies the allowable sulphur level in heavy fuel oils, bunker fuel oils, marine gas oils, and gas oils. These regulations have been adopted by the International Maritime Organisation (IMO), a measure intended to support international monitoring and enforcement systems. The impact of the European Commission on the reduction of environmentally harmful emissions from the combustion of fuel has resulted in the IMO's introduction and enforcement of new shipping regulations. Once the new strict standards protecting the environment were formulated, ship operators became obliged to reduce the sulphur content in marine fuels used in trading ships in sulphur emission control areas (SECA). The Sulphur Directive entered into force on 01.01.2015 as an amendment to Annex IV of the MARPOL Convention. Since then, operators and owners of ships trading in the Baltic Sea, the North Sea, the English Channel, and the North American costs have had to use fuels with sulphur levels not exceeding 0.1% (this figure was 1% till the end of 2014).

To reduce the operating costs of ships, many shipowners have decided or are planning to buy LNG-fuelled ships. With its environmentally friendly chemical composition, the gas is commonly called *blue fuel*. The amounts of permissible sulphur emissions in the world and in SECA areas show a remarkable drop in atmospheric sulphur (Figure 1). Future years will see even more restrictive limits imposed on sulphur emissions (Chłopińska & Gucma, 2018).

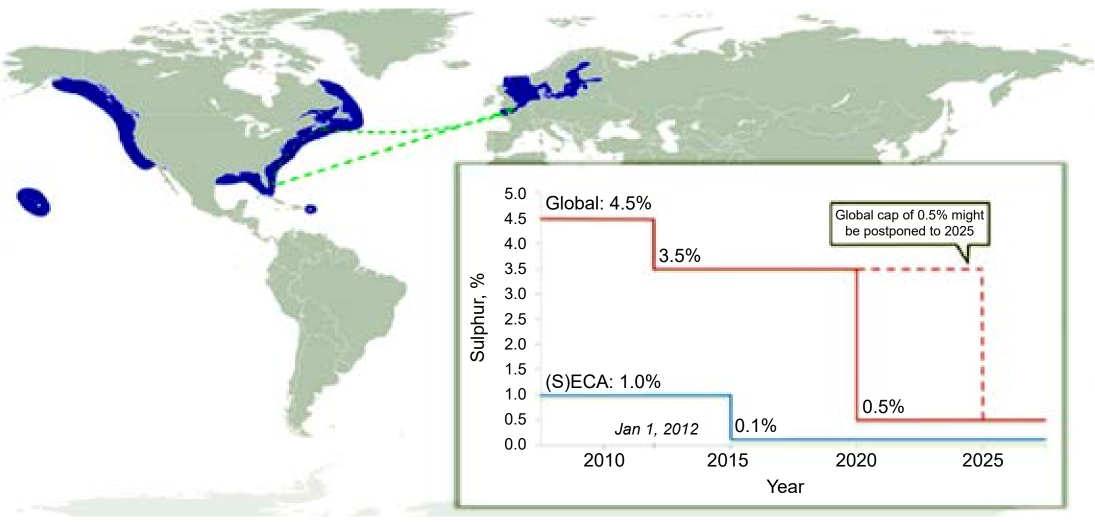

Figure 1. Sulphur emission control areas (SECA) (Gu, Wallace & Wang, 2018)

The sulphur directive has spurred the investigation of alternative fuels for the maritime industry. Compared with other marine fuels, LNG has better combustion parameters (Table 1). Consequently, LNG-powered vessels are expected to account for an increasing proportion of new builds.

Table 1. The emission coefficient for marine fuel (IMO, 2014)

Emission	HFO	MDO	LNG
SO_x	0.049	0.003	slight amounts
CO_2	3.114	3.206	2.750
CH_4	Small amount	Small amount	0.051
NO_x	0.093	0.087	0.008
PM	0.007	0.001	Small amount

Figure 2. An assembly of scrubber installation for exhaust desulfurization (Blenkey, 2019)

The increasing demand for natural gas has caused LNG production to rise. Gas liquefaction technology has made it possible for natural gas in all parts of the world to be utilized commercially, while previously it was simply burnt. The liquid state facilitates its storage and transport and has led to increased production worldwide.

LNG-fuelled ships

As a result of emission restrictions, ship operators have been forced to seek solutions that will satisfy new requirements. One solution is the use of fuel treatment methods where sulphur is removed from exhaust gases via scrubber technology (Figure 2). The major disadvantages of the technology are its high costs and the large size of the equipment.

LNG is an alternative solution for ship propulsion, but this often comes at the expense of cargo-carrying space (Figure 3); however, for large-scale operations based on LNG, a fleet needs appropriate bunkering infrastructure (Paulauskas et al., 2018). The adaptation of seaports to LNG-powered ships is a relatively long process.

LNG has a higher volume reduction than compressed natural gas (CNG), so the energy volume density of LNG is 1.4 times higher (at 200 bar) or 60% higher than that of fuel oil. LNG properties make it cost-effective and flexible for long-distance sea transport. LNG is exported to countries all over the world, where it is subjected to regasification and then distributed via pipelines as natural gas.

There is a relation between ship type and the type of fuel used (Figure 4). Globally, ferries occupy the largest percentage of LNG-fuelled ships: car/passenger – 19% (47 ships), tankers – 17,4% (43 ships), offshore vessels – 18.2% (45 ships). On the other hand, general cargo ships – 2% (5), car carriers – 1.6% (4) and bulk carriers – 2.4% (6) represent the smallest fraction of LNG-fuelled ships.

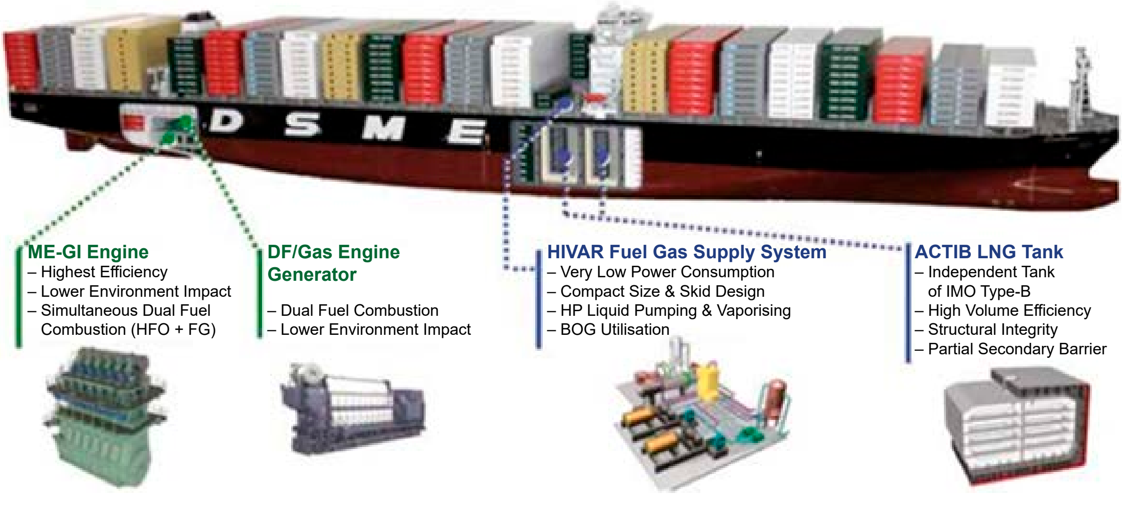

Figure 3. LNG-fuelled container ship (MAN Diesel & Turbo, 2012)

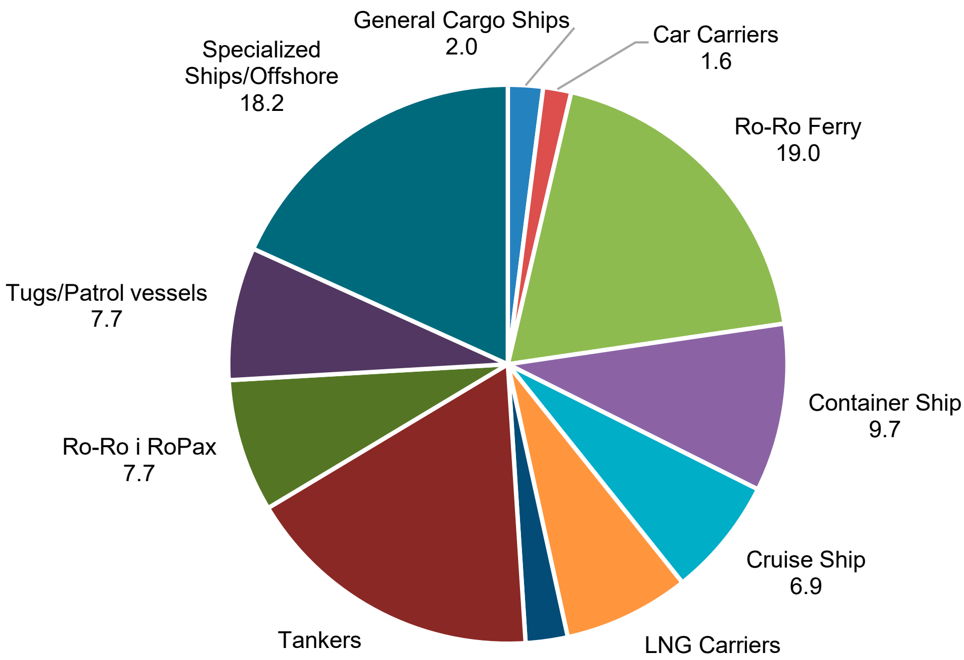

Figure 4. Percentage of global LNG-fuelled ships, by type, as of April 2018 (author's elaboration based on (DNV GL, 2018))

Determination of LNG demand

To determine the demand for LNG and verify the presented data, theoretical models were used, which are based on a physical theory that can characterize actual situations, and empirical models that complement theoretical models by synthesizing the results of real research.

When looking into LNG as a fuel for the future, we should consider the number of ships and their annual fuel consumption (Table 2). By analysing these data, we can calculate annual estimates of LNG production that satisfy the LNG demand of the global fleet.

By categorizing the above ship types, we obtained Table 3.

Given the percentages of LNG-fuelled ships (Figure 4) and average LNG fuel consumption by specific types (Table 3), the weighted average can be calculated:

$$\bar{x} = \frac{1*(\%)+2*(\%)+3*(\%)+4*(\%)+5*(\%)}{100\%} + \frac{6*(\%)+7*(\%)+8*(\%)+9*(\%)\text{Total}+10*(\%)}{100\%} \quad (1)$$

$$\bar{x} = 5752.5 \text{ [t]}$$

Table 2. Annual LNG consumption by ship type (Olmer et al., 2017)

Category	Fuel consumed [million tonnes LNG eq.]	Number of vessels	Average consumption [tonnes LNG eq.]
Container	52.5	5,009	10,491
Bulk carrier	436	10,650	4,097
Oil tanker	316	6,395	4,938
Chemical tanker	14.2	4,720	2,999
General cargo	132	10,973	1,202
LPG/LNG tankers	12.7	1,687	7,509
Cruise	9.6	477	20,170
Ferry (RO-RO and PAX)	10.2	5,288	1,933
Vehicle/ RO-RO	114	2,236	5,658
Service	88	25,317	397
Refrigerated	38	4,876	779
Offshore	3.5	785	4,477
Other + Unclassified	23.0	21,021	1,094
Total	**2381**	**99,434**	**2,393**

Table 3. Average LNG consumption for selected types of ship (author's elaboration based on (Olmer et al., 2017))

NP	Type of ship	Average LNG consumption [t]
1	General cargo	4097
2	Gas tankers	7509
3	Tugs and patrol ships	397
4	Container ships	10,491
5	Bulk carriers	1202
6	Passenger/vehicle ferries	1933
7	Car carriers	5658
8	Special/Offshore	4477
9	Tankers	7937
10	Cruise ships	20,170

Table 4. Forecast of global LNG-fuelled ships (author's elaboration based on (DNV GL, 2018))

Year	Ships in operation	Ships ordered	Annual increase [%]
2012	35	0	0
2014	56	0	60
2016	97	0	73
2018	121	51	25
2020	172	105	42
2022	277	159	61
2024	436	213	57
2026	649	267	49
2028	916	321	41
2030	1237	375	35

By analysing the number of global LNG-powered ships and orders for future years, we can predict their increases until 2030 (Table 4).

The forecast of LNG-fuelled vessels through 2030 was determined by knowing the annual growth of LNG-fuelled vessels from 2012 to 2020. The predicted number of sea-going LNG-fuelled ships in 2030 is 1237, which represents an increase in the LNG fleet of 1,065 vessels compared with the 2020 value (Figure 5).

Based on the projected fleet of LNG-powered ships L_j and the weighted average fuel consumption for different types, the demand for liquefied natural gas (Z_{LNG}) in 2030 was calculated using the following equation:

$$Z_{\text{LNG}} = Z_j \times \bar{x} \tag{2}$$

$$Z_{\text{LNG}} = 7{,}115{,}842.5 \text{ t}$$

The calculated amounts of LNG needed by ships for 2030 will force the global economy to develop a wide range of new technologies. Producing more liquefied natural gas will ensure uninterrupted supply to individual households, as well as global industries.

By considering blue fuel as a resource of the future, ship operators will pay special attention to environmental protection. LNG resources are ample, allowing unrestricted growth of various sectors of the global economy. The maritime industry is becoming a pioneer in setting new directions for an environmentally friendly economy.

Summary

By summarizing the analyses carried out in the work, it can be concluded that:

- LNG is an alternative fuel for shipping.

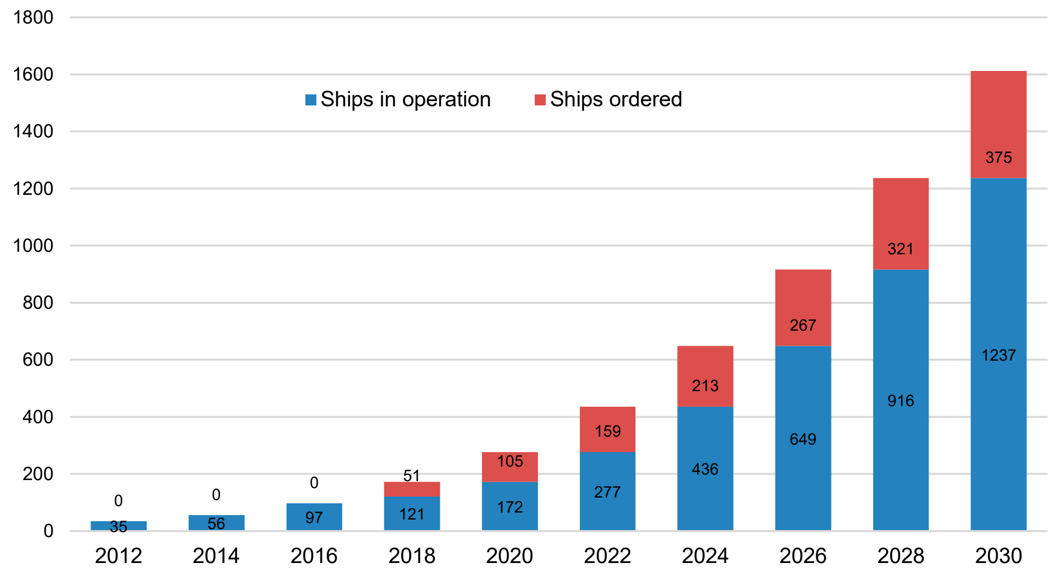

Figure 5. The forecasted increase in the number of ships till 2030 (globally)

- LNG as bunker fuel for marine vessels is an alternative to the linear gas network.
- Modern technology has made it possible to create an LNG distribution system.
- Forecasts of the demand for liquefied natural gas as bunker fuel for marine vessels are divergent (from 0.1% to 3%).
- Increasing the demand for LNG as a bunker fuel will ensure a quick return on investments.

Among the available alternative fuels – LNG, LPG, hydrogen, methanol, biofuel – the LNG sector is developing the fastest. This is due to the widespread and constantly developing maritime infrastructure (including LNG bunkering networks) and access to modern technologies used in the entire fuel distribution system.

The overall level of toxic atmospheric emissions from ships is so high and harmful to the environment and human health that implementing and applying legal regulations to reduce adverse impacts have become a priority. The global maritime fleet has effectively reduced atmospheric pollution from ships propelled by engines burning hydrocarbon fuels.

Considering the activities of environmental groups with increasing impact on marine fuel control and fuel costs, we can anticipate that shipowners will continue to order more LNG-powered ships; however, some ship types, e.g., bulk carriers, have not quite followed the trends to change to LNG fuel. To protect the environment, shipowners must maintain the growing trend towards green technologies and operations.

References

1. Bielski, J. (2005) Rozwój globalnego handlu gazem LNG. Już nie tylko Azja. *Nafta & Gaz Biznes* 04–05.2005.
2. Blenkey, N. (2019) Alfa Laval marks tenth anniversary of first Pure SOx scrubber installation. [Online] 30 January. Available from: https://www.marinelog.com/shipping/environment/alfa-laval-marks-tenth-anniversary-of-first-puresox-scrubber-installation [Accessed: July 03, 2020].
3. Chłopińska, E. & Gucma, M. (2018) The impact of a liquefied natural gas terminal on the gas distribution and bunkering network in Poland. *Scientific Journals of the Maritime University of Szczecin, Zeszyty Naukowe Akademii Morskiej w Szczecinie* 53 (125), pp. 154–160.
4. DNV GL (2018) Data of DNV GL.
5. Grzelak, S. (2015) Liquefied Natural Gas – a Strategic Fuel. Poland's Security with Regard to Gas Fuels. *Kontrola Państwowa* 60, 6 (365), pp. 133–145.
6. Gu, Y., Wallace, S.W. & Wang, X. (2018) Integrated maritime fuel management with stochastic fuel prices and new emission regulations. *Journal of the Operational Research Society* 70, 5, pp. 707–725.
7. Herdzik, J. (2015) Uwagi dotyczące metod skraplania gazu ziemnego w przemyśle wydobywczym. *Logistyka* 3, pp. 1808–1814.
8. IFC (2016) *Environmental, Health, and Safety Guidelines for Liquefied Natural Gas* (*LNG*) *Facilities*. IFC report.
9. IGU (2016) *World LNG Report*. Norwegia.
10. IMO (2004) The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).
11. IMO (2014) Data of IMO.
12. Kalski, M., Nagy, S., Rychlicki, S., Siemek, J. & Szulej, A. (2010) Gaz ziemny w Polsce – wydobycie, zużycie i import do roku 2030. *Górnictwo i ekologia* 5, 3, pp. 27–40.
13. MAN Diesel & Turbo (2012) *Costs and Benefits of LNG as Ship Fuel for Container Vessels*. Denmark.
14. Matczak, M. (2015) Wykorzystanie LNG jako paliwa żeglugowego na Morzu Bałtyckim – przesłanki stosowania, kierunki rozwoju oraz formy wsparcia. *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Problemy Transportu i Logistyki* 30, pp. 73–85.
15. Molenda, J. (1996) *Gaz ziemny. Paliwo i surowiec*. 2nd Edition. Warszawa: Wydawnictwo Naukowo-Techniczne.
16. Olmer, N., Comer, B., Roy, B., Mao, X. & Rutherford, D. (2017) *Greenhouse gas emissions from global shipping, 2013–2015*. ICCT.
17. Paulauskas, V., Henesey, L., Paulauskas, D., Ronkaitytė, I., Gerlitz, L., Jankowski, S. & Canepa, M. (2018) *LNG Bunkering Stations Location Optimization on Basis Graph Theory*. Proceedings of 22nd International Scientific Conference. Transport Means 2018, pp. 660–664.
18. Zaleska-Bartosz, J. & Klimek, P. (2011) Łańcuch dostaw skroplonego gazu ziemnego – aspekty ekologiczne. *Nafta – Gaz* 10, pp. 724–728.

Cite as: Chłopińska, E., Tatesiuk, J. & Śnieg, J. (2021) Estimation of global liquefied natural gas use by sea-going ships. *Scientific Journals of the Maritime University of Szczecin, Zeszyty Naukowe Akademii Morskiej w Szczecinie* 66 (138), 28–33.