Energy-saving technologies for sustainable development of the maritime transport logistics market

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Abstract. The paper identifies ways to solve problems of further development of the maritime logistics market, based on the challenges posed by the recovery of increasing demand for transport services, and activation of the integration of the transport system of Ukraine into the European and world transport systems. Priorities for future economic changes have been proposed in the transport sector and increasing their effectiveness through the development of a legal framework and improving the management structure of the country's logistics system. Recognizing the magnitude of the climate change challenge and the importance of global action today, the development and implementation of energy-saving measures to address international shipping issues was analyzed. In order to succeed in further increasing the energy efficiency of the maritime sector, which is already the most energy-efficient way of mass transportation of goods, the document proposes pragmatic solutions from both a technical and a political point of view. The priorities and direction of action set out in the paper are formulated taking into account the state and place of each market segment in solving national tasks, their implementation requires significant capital investment and must be carried out taking into account the requirements of economic efficiency and environmental sustainability.

I. Introduction

Under modern conditions, the state of the logistics services market in Ukraine is determined by the state analysis of transport, warehousing, customs, information, financial infrastructures, characterized by disproportionate development and inconsistency of regulatory, organizational, technological, and international economic aspects.

Global trends in transport development have not escaped Ukraine - a country located at the intersection of major transit and foreign trade routes between the countries of the East Asian region and Europe. Therefore, the assessment of the objective potential of the Ukrainian transport system,

the formation of its international transit status, the development of appropriate infrastructure, as well as the development of a practical program of action is particularly important at the stage of market economy in the country. Solving them is the most important condition for the rise of the country's economy and its integration into the world economy.

When it comes to the comparative advantages that today determine the special place of Ukraine in the system of international trade in services, largely means its advantageous geographical position between the countries of East and West Eurasia. Traditionally high level of industrial development and favorable geographical location has led to the fact that Ukraine has a developed transport infrastructure, an extensive network of roads, a large number of vehicles. These are highways and railways, sea and river ports, airports, oil and gas pipelines.

Ukraine's transport potential in the context of independence is the object of purposeful state efforts and sometimes becomes the subject of international disputes. A natural fact was the transfer of control over the real estate infrastructure of Ukraine, as well as rolling stock, which belonged to domestic economic entities or was assigned to the relevant ports, stations, etc. (road, rail, and water vehicles of local and long-distance, air fleet, Black Sea Shipping and the Danube Shipping Company) to national owners and state regulators.

II. Theoretical background of research.

With the development of logistics in Ukraine, the formation of global and regional supply chains, the role of enterprises providing services for the promotion of goods flows and their effective management, i.e. logistics market operators.

From the point of view of world experience and modern trends in the global market of logistics services, Ukraine is currently at the stage of formation and consolidation of the industry, significantly inferior to European countries both in terms of quality and complexity of services provided by domestic transport companies.

Consider the place of Ukraine in the international logistics rankings (see Table 1).

Table 1. International rankings reflecting Ukraine's logistics and positioning

Rating / Report (Key Indicator)	Year of issue	Number of countries in the ranking	Place of Ukraine
DOING BUSINESS Measuring Business Regulations (EDBR)	2008	181	145
	2020	190	64
The Global Enabling Trade Report (GETI)	2008	118	68
	2016	136	95
The Global Competitiveness Report (GCI)	2008	134	72
	2020	130	92
IMD World Competitiveness Yearbook (IMD WC)	2008	55	54
	2020	63	55
Logistics Performance Index (LPI)	2007	150	73
	2018	160	66

Source: data based on [1], [5], [2], [3], [4]

In the competitiveness rating currently published by The World Bank Ukraine ranks 64th, and in the World Competitiveness rating published by the IMD World Competitiveness – 55th place. Therefore, consider in figure 1 logistics indicators in the systems of indicators/criteria of international ratings.

The main integration component for logistics is the development of transport infrastructure. Ukraine's transport infrastructure is characterized by priority development of rail transport, congestion of highways, low volume of air traffic and, as a consequence, weak interdependence of

multimodal and intermodal maritime transport, lack of effective coordination between all modes of transport (Table 2).

International freight transport by water plays a key role in world trade. The main "danger" of maritime trade is the optimization of logistics and information support, which reduces counter and geographically unjustified traffic, allows you to find sellers and buyers in the closest possible geographical areas.

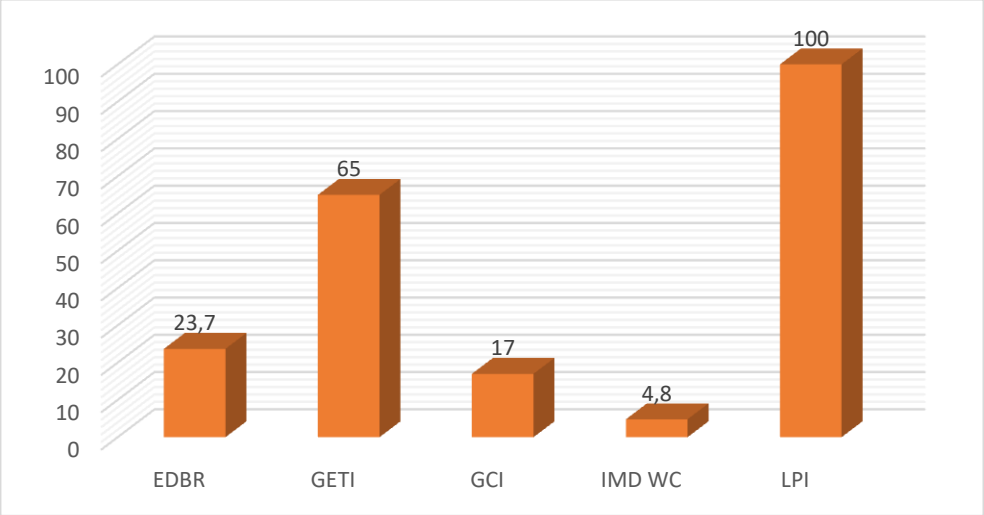


Figure 1. The share of logistics indicators in the systems of indicators/criteria of 5 international ratings, %

Source: data based on [8]

Table 2. Volume of freight transportation by type of carrier (thousand tones)

Year	Railway		Sea	River	Motor vehicles	Air	Pipeline
	shipment	transportation					
2000	295921,0	357381,6	6316,3	8349,8	938916,1	23,2	218164,9
2005	378911,7	450277,3	8575,2	12868,6	1120715,3	126,3	212556,8
2010	357969,1	432897,0	4067,8	6989,5	1168218,8	87,9	153436,6
2015	294301,2	349994,8	3291,6	3155,5	1020604,0	69,1	97231,5
2020	261252,8	305480,4	1812,2	3788,4	1232391,9	88,3	97464,7

Source: data based on [7]

The basis of the nomenclature of maritime transport of Ukraine is those types of goods traditionally considered strategic in the international economic activity of our country.

According to export items, these are metals (45-50%), ores (10-15%), grain cargoes (10-15%), chemical and mineral fertilizers (7-10%). Oil and oil products (about half of the total mass), metals (10-15%), chemical and mineral fertilizers (10-15%) predominate in transit traffic. But the physical obsolescence of the fleet, the lack of necessary investments in the repair and modernization of ships, as well as the construction of new ones led to a reduction in traffic. The maritime and river fleets are characterized by the dispersion of funds between small companies, many of which are unprofitable and unable to carry out timely repairs and maintenance of rolling stock and port infrastructure. Therefore, the urgent task is to create several powerful and highly competitive in the international market of water transportation of shipping companies.

Maritime transport traditionally plays an important role in the system of international economic activity of Ukraine. Ukraine has several "warm" ports: Odessa, Illichyvsk, Kherson, Mykolaiv, Feodosia, Mariupol, Kerch. The largest of them: Odessa - handles 30 million tons of cargo per year, the second - Illichyvsk - 22 million tons.

Consider the transportation of goods (Table 3, figure 2) and passengers (figure 3) by maritime.

Table 3. Maritime cargo transportation (thousand tons)

	2000	2005	2010	2015	2016	2017	2018
All loads	**6316**	**8575**	**4068**	**3292**	**3033**	**2253**	**1892**
By types of cargo:							
- oil and oil products	344	10	29	71	53	32	30
- coal	271	99	45	28	-	-	-
- coke	89	37	-	6	27	34	23
- red ore	1038	758	206	892	725	272	38
- construction	965	1812	704	110	68	95	71
- chemical and mineral fertilizers	201	211	46	32	17	10	12
- forest	262	259	30	7	55	4	6
- paper	97	25	0	3	-	-	3
- different metals	1003	2038	535	1170	1077	1063	1006
- cereal	247	1062	656	110	100	204	473
- cargoes in containers	733	781	92	30	38	8	0
- other cargoes	1066	1483	1505	833	873	531	230
By types of communication:							
- foreign	5241	6334	2959	2046	1903	1408	1207
- cabotage	1075	2241	1109	1246	1130	845	685

Source: data based on [9]

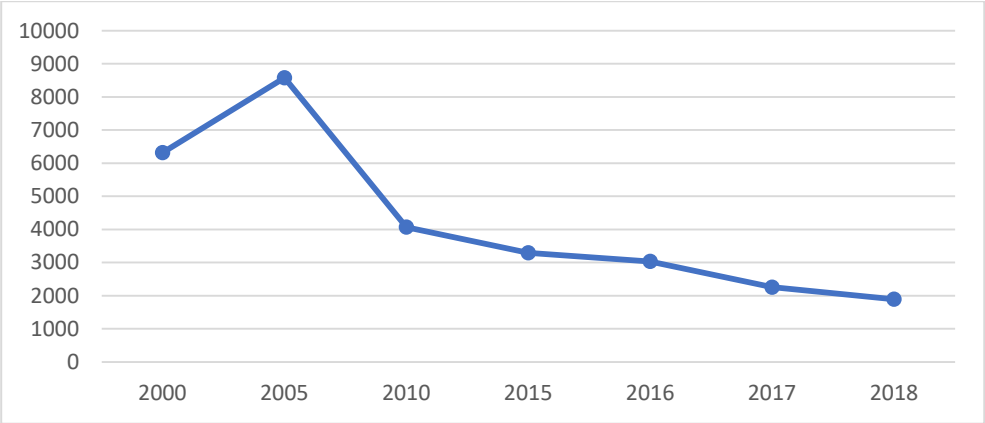
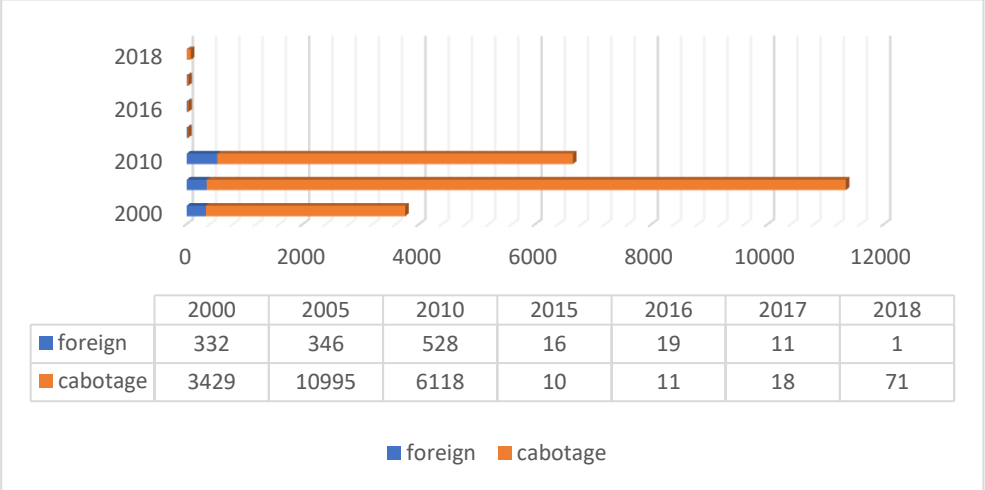


Figure 2. Dynamics of maritime cargo transportation, thousand tons
Source: data based on [9]

Taking into account the above, the goal of sustainable development is the integration and coordination of environmental, social and economic aspects in the regional logistics system for the purpose of ecologically oriented logistics management of the development of maritime transport. At the same time, the coordination of economic benefits, social and environmental effects, as well as improvement of the logistics system to achieve the goal should be based on the principle of Pareto-optimality. Thus, the main mechanism for the implementation of sustainable development involves, first of all, the assessment of the eco-destructive impact of logistics activities and its components, the development of effective tools for the coordination of economic, social, environmental interests of business and the resolution of emerging contradictions.



	2000	2005	2010	2015	2016	2017	2018
foreign	332	346	528	16	19	11	1
cabotage	3429	10995	6118	10	11	18	71

Figure 3. Sea passenger transportation by types of communication (thousand passengers)
Source: data based on [9]

Maritime transport is considered one of the most efficient modes of transport. The share of carbon dioxide emissions into the atmosphere by this mode of transport is 3.1% of total emissions, while this mode of transport accounts for 90% of all transported goods in world trade. Despite the problem of environmental pollution and rising fuel prices, along with the growth of world trade volumes, the greatest attention is paid to increasing energy efficiency. This is the main challenge for the maritime industry, which is expected to make a significant contribution to the preservation of the environment in the future.

The analysis of shipping energy efficiency over the past decades is shown in Figure 4.

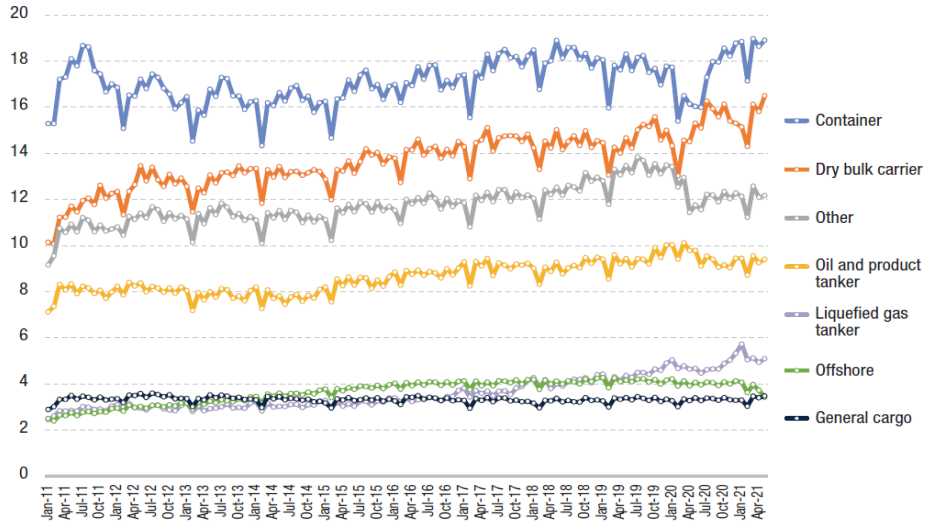


Figure 4. Carbon dioxide emissions by ship type (monthly, million tons)
Source: adapted from [10]

III. Results

The logistics complex of Ukraine nowadays in the conditions of sharp growth of a share of international transportations in the total volume of transports needs serious restructuring and updating of fixed assets, improvement of technology of transportations and increase of quality of logistic services according to requirements of market economy, European and world quality standards.

In order to eliminate the main cause of the critical condition of the logistics system of Ukraine and its further development on an innovative basis, it is necessary to form a state policy aimed at providing the transport industry with investment resources for its comprehensive development. Trying to identify and analyzed the main problems by segments of the logistics market and suggested possible solutions see Table 4.

Based on the data of the analysis, the dynamics of the development of the logistics market of Ukraine should be based on the interaction of different types of transport, the broad development of multimodal cargo transportation based on logistics principles, and financial support. Also, due to the insufficient development of the regulatory and legal framework and the low investment potential of the logistics infrastructure, the wear and tear of technical means increases, their design deteriorates, adequate traffic safety is not ensured, and the negative impact of transport on the environment and people's health increases. All this in conditions of fierce competition leads to the displacement of Ukrainian carriers from the international markets of transport services, lowers the quality of service for domestic enterprises and the population, and creates a real threat to the economic security of the state.

Thanks to the adoption of technical and design measures, as well as a regulatory approach, it is expected that by 2030 emissions into the atmosphere of carbon dioxide will be reduced by approximately 23%, which is approximately equivalent to the value of 330 million tons of carbon dioxide.

Moreover, the achievable Energy Efficiency Design Index (EEDI) is intended to stimulate the further development of energy-efficient design and technical solutions in marine shipbuilding. The shipowner also has freedom of choice in the applied technologies, the main criterion of which is compliance with the required EEDI value.

Table 4. Analysis of problems by segments of the logistics market and search for possible solutions

Maritime transport	
Lack of third generation ports in Ukraine, non-use or poor use of the latest logistics achievements	– This problem is purely managerial, as it does not require large investments, but only a revision of the traditional way of doing ports. First of all, it is necessary to involve management staff that could act competitively in a market economy. – Creation of a single information space based on existing information technologies – Definition and development of the structure of economic activity of contiguous companies for optimal use of their production potential in transit nodes – Establishment of centers for coordination of operations and appropriate coordination and coherence of management decisions – Unified policy on shipping safety and environmental protection.
The practice of "hanging" social objects	– Ports are state-owned enterprises, so they are still subject to the practice of "hanging" social facilities (kindergartens, hospitals), which usually increases the costs of enterprises and reduces their profitability. Accordingly, either the structure of ports should be restructured or a mechanism should be developed to provide tax benefits to those ports that take over the social obligations of the state.
Slow growth of container traffic	– As the volume of container traffic in the world is constantly growing, this type of cargo transportation is quite promising. Therefore, it is necessary to create a structure of fees that would contribute to the development of this area of maritime transport in Ukraine.

It should be noted that the calculated EEDI energy efficiency ratio reflects energy efficiency only from a technical point of view, but does not reflect operational indicators.

Therefore, it is impossible to reflect the operating parameters of a marine vessel with this indicator alone. To solve this issue, the concept of the Ship Energy Efficiency Management Plan (SEEMP) was developed, which is mandatory for implementation on all sea vessels and allows monitoring the energy efficiency of a sea vessel or the entire fleet of the company. Along with the SEEMP, compliance with the rules of the constructive EEDI is mandatory when receiving an international energy efficiency certificate. The certificate is individual for each sea vessel and must be kept on board the sea vessel during various inspections and audits.

The EEDI formula contains four main components that reflect the power of the main and auxiliary engines, the innovative technologies of marine engines, as well as the operation of the transport. It can be expressed as the ratio of "environmental cost" divided by "Benefit for Society" (Figure 5).

The EEDI coefficient reflects CO_2 emissions of a marine vessel as a specific technical structure in relation to the performed transport work. It is calculated as the sum of CO_2 emissions produced by the ship's engine, diesel generators, as well as auxiliary engines, from which savings in the form of innovative energy-saving technologies are subtracted.

EEDI reflects the relationship between environmental damage and economic value. The smaller the value of EEDI, the more energy efficient is the marine vessel as a design system.

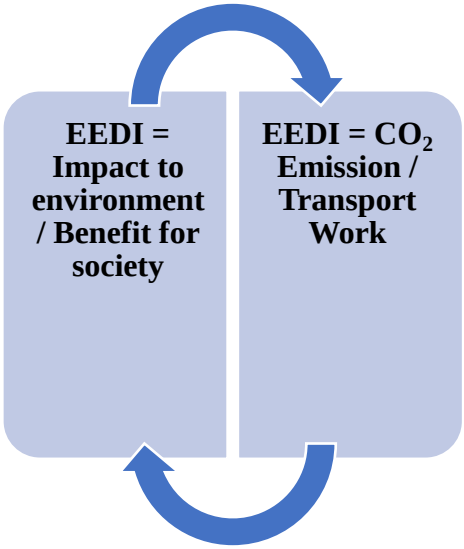


Figure 5. What is EEDI?

Source: data based on [11]

Innovative energy-saving technologies must be considered from the point of view of compatibility with each specific marine vessel. Their main task is to improve the achievable EEDI without changing the nominal speed of the vessel or its carrying capacity, which, in turn, are often determined by the charterer, and can also create certain limitations in the operating modes of the vessel.

Innovative energy-saving technologies are mainly divided into several groups (Figure 6).

Attained EEDI can be reduced by increasing the deadweight of the marine vessel. The power of the main engine increases in proportion to the increase in deadweight and is 75% of its change. However, it is worth taking into account the value of the baselines, so with an increase in the deadweight of the vessel, the required KKEE will decrease, thereby increasing the requirements. Add, in turn, can be changed due to the main characteristics of the sea vessel - length, width, draft, as well as due to the coefficient of completeness of the tonnage. A change in the tonnage fullness factor

leads to a change in the nominal speed of the vessel and/or a change in the required engine power. With these parameters, it is possible to optimize the design of the vessel to achieve a lower EEDI. An increase in deadweight can be the basis for higher operational energy efficiency in economic terms, but freight rates can increase significantly because of this. There are also proposals to increase the deadweight by reducing the weight of the seagoing vessel itself when empty.

Attained EEDI can also be reduced by reducing the nominal speed of the vessel. The power of the main engine increases in cubic dependence on the number of revolutions per minute. The number of revolutions of the main engine, in turn, is proportional to the speed. Accordingly, the EEDI will decrease when the nominal speed of the vessel decreases.

Innovative energy-saving technologies				
Main engine power savings			Saving the power of diesel generators	
Category A	Category B-1	Category B-2	Category C-1	Category C-2
It is an integral part of the ship	*It is not an integral part of the vessel*		*Have no restrictions*	*Have limitations*
	$fe_{ff(i)} = 1$	$fe_{ff(i)} < 1$	$fe_{ff(i)} = 1$	$fe_{ff(i)} < 1$
- dyeing materials; - type of steering device; - advanced technologies of the main engines (piston stroke length, electronic control of fuel injection).	Technologies for reducing water resistance	- technologies using wind energy; - nuclear energy	- heat-saving technologies; - flexible energy supply system.	Solar panels

Figure 6. Innovative energy-saving technologies

Source: adapted from [13]

For example, if the vessel's rated speed is reduced by 50%, the EEDI is reduced by 75%. However, the influence of the shipowner on the main characteristics of the ship is quite limited, therefore, first of all, these parameters are selected for a specific charterer and correspond to his interests in the deadweight and nominal speed of the ship. Moreover, some types of ships, are initially operated at relatively low speeds. As a result, such measures are unsuitable for this type of sea vessels. Reducing the nominal speed is the most simple and affordable solution, and also requires minimal costs, but also shifts the emphasis to technical and constructive improvements. In such a case, a larger number of seagoing vessels may also be required to service a particular line.

In the future, the EEDI value can be reduced due to the use of alternative fuel sources, such as liquefied natural gas. These types of sources have lower emissions of carbon dioxide, but can also lead to an increase in the share of other greenhouse gases in atmospheric emissions, as well as significant modification of ship engines and fuel tanks. At the moment, the availability and pricing of such fuels are unstable. With reports from the International Maritime Organization predicting a 300%

increase in fuel prices between 2009 and 2050, we can already see that the demand in the maritime transport industry is focused on more efficient and green energy.

The energy efficiency of the operation of a sea vessel in a certain period of time and also depends on the trade route can also be displayed using the Energy Efficiency Operational Index (EEOI).

EEOI is defined as the ratio of the mass of carbon dioxide emitted into the atmosphere per unit of transportation work performed. To determine the EEOI, the following sequence of actions is required:

- determine the period for which the EEOI will be calculated;
- identify data sources for their further collection;
- data collection;
- translation of data into the required format;
- calculation of the EEOI.

In an ideal case, the method of data collection for calculations should be unified in order to make data collection as simple as possible, as well as to streamline the process of working with the necessary information. Data obtained from the marine vessel should include the distance travelled, the amount and type of fuel used, and any additional fuel data that may affect the amount of carbon dioxide emitted into the atmosphere. Likewise, documented procedures applied on an ongoing basis should be developed.

IV. Conclusions

Summarizing the results of research and analysis, we can conclude that the main problems that constrain the growth of the volume and quality of demand for maritime logistics services in Ukraine are: weak degree of use of the geopolitical position of Ukraine and the possibilities of its transport communications for the international transit of goods; slow transport connection with the production, trade, warehousing, and customs technologies; low level of digitization of the transport process and informational interaction of sea transport with other branches of the economy; low attention to the issue of energy-saving technologies in the maritime sector.

When developing energy-saving procedures, the next elements should be taken into account: identification of operations or actions that have an impact on efficiency; determination of sources of necessary data and measurements, as well as their dimensions; setting the frequency of data collection and personnel, responsibility for their collection; support of data quality control procedures and their verification.

The results of such a procedure can be checked and used as indicators of the success and reliability of the applied system, as well as to determine the system's weak points and its further improvement.

However, it should be noted that not all energy-saving measures for sustainable development can be applied to all ships, or even to the same ship in different operating conditions, and that some of them are mutually exclusive. The initial measures can lead to energy (and cost) savings - results that can then be reused for more complex or expensive efficiency measures. Improving the energy efficiency of ships does not necessarily depend only on ship management. Instead, it may depend on many stakeholders, including ship repairers, owners, operators, ship charterers, cargo owners, ports and traffic management services. The better the coordination between the stakeholders, the greater the increase can be expected. In most cases, this coordination or overall management is best done by the company rather than the vessel. In this sense, it is recommended that the company also prepare an energy management plan for the management of its fleet (if it does not already have such a plan) and carry out the necessary coordination between the stakeholders. Such human resource development is recommended and should be considered an important component of planning as well as an essential element of implementation. Once the ship and the company have identified the energy-saving measures that need to be implemented, it is important to create a system for implementing the established and selected measures by developing energy management procedures, defining tasks and assigning them to qualified personnel.

The solution to the considered problems of energy-saving technologies for sustainable development of the maritime market needs to be considered at the state-institutional level.

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