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DUAL LOGISTICS MODEL IN GERMAN ENERGY MANAGEMENT

ДУАЛЬНА ЛОГІСТИЧНА МОДЕЛЬ У МЕНЕДЖМЕНТІ ЕНЕРГЕТИКИ НІМЕЧЧИНИ

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The issues of energy development management of Germany at the present stage, in the near and long term are analyzed. The sources of fuel resources typical for the country's economy are considered taking into account many criteria. Considerable attention was paid to logistical issues, the construction of terminals for receiving reduced natural gas, which will make it possible to receive it from producers from many regions of the world. It is noted that in the future, as production expands and costs decrease, it is planned to use such terminals to receive hydrogen, one of the promising types of fuel supplied to the country by sea, which is the essence of the dual logistics model. A model for the development of the German energy sector is proposed. It is shown that in the future the leading role in providing the country with energy will be played by wind and solar power plants, which have economic and environmental advantages.

Keywords: dynamics, management, logistics, energy, natural gas liquefaction, terminals, ecology, power plants, structure, reserves, economic efficiency, prospects, wind, solar power plants, hydrogen fuel.

Аналізуються питання менеджменту енергетичного розвитку ФРН на сучасному етапі, у найближчій та віддаленій перспективі. Розглянуто характерні для економіки країни джерела енергоресурсів з урахуванням різних критеріїв. Значну увагу приділено логістичним питанням, спорудженню терміналів для прийому зрідженого природного газу, які дозволять отримувати його від виробників із багатьох регіонів планети. Проаналізовано причини, через які вказані термінали у ФРН раніше не споруджувалися, хоча досвід їх будівництва та використання у сусідніх країнах Європи був успішним. Зазначено, що LNG-термінали надалі, в міру розширення виробництва та зниження собівартості, планується використовувати для прийому водню, одного з перспективних видів палива, що буде поставлятися в країну морським шляхом. Це є суттю дуальної логістичної моделі. Показано роль, яку відігравали в енергобалансі ФРН різні види електростанцій, проаналізовано їх

позитивні та негативні риси з урахуванням логістичних та екологічних факторів. Розглянуто погляди провідних парламентських політичних сил країни на атомну енергетику. Показано як негативне ставлення низки партій до цієї проблеми, самого існування атомних електростанцій, так і визнання необхідності функціонування таких станцій, і навіть перспективних досліджень та можливостей розвитку атомної енергетики. У цьому контексті наведено також думку влади ключової для Німеччини у політичному та економічному сенсі федеральної землі Баварії. Вказується на виразно домінуюче позитивне ставлення німецької громадськості, виборців країни до атомної енергетики. Наводяться відомості про успішне будівництво та введення в експлуатацію LNG-терміналів. Показаний прогноз, згідно з яким у 2024 році у ФРН буде щонайменше шість діючих LNG-терміналів: два – у Вільгельмсхафені, по одному у Брунсбюттелі та Штаді, два – у Лубміні. Запропоновано модель розвитку енергетики ФРН. Показано, що в перспективі провідну роль у забезпеченні країни енергією гратимуть вітрові та сонячні електростанції, що мають економічні та екологічні переваги.

Ключові слова: динаміка, менеджмент, логістика, енергія, зрідження природного газу, термінали, екологія, електростанції, структура, запаси, економічна ефективність, перспективи, вітрові, сонячні електростанції, водневе паливо.

Formulation of the problem. The problem of providing energy carriers is one of the most difficult factors of development and is especially aggravated in the current conditions. The new challenges of modern reality receive management solutions corresponding to their complexity, which, it seems, will be able to ensure the functioning of the economy, and then its transition to a new, qualitatively higher level.

Analysis of recent research and publications. Various literary sources actively discuss the development of the German economy. Recent articles also analyze the issues of energy development and climate conservation. These issues are discussed, in particular, in the publications of such well-known experts: Claudia Kemfert, Franziska Holz, Christian von Hirschhausen, Robin Sogalla, Mikhail Krutikhin, Sergey Romashenko, Andrey Gurkov. These publications reflect current trends in the development of the world economy, show important problems in the development of the energy sector.

Previously unsolved parts of the overall problem. Many different articles on the development of the German economy still do not consider in detail the issues of managing the transition of the country's energy sector to new conditions. This highlights the complexity of the problem. It is necessary to study in more depth the issues of managing the process of forming an environmentally optimal energy sector in Germany in the new conditions, taking into account the previously formed energy capacities. Such a complex process has alternative development paths. Choosing the right path is essential.

Presentation of the main research material. The traditionally formed long-term model of Germany's energy supply did not provide for marine terminals for receiving ships with liquefied natural gas (Liquefied natural gas, LNG). As a result of the decisions taken, Germany is expected to have at least six operating LNG terminals in 2024: two in Wilhelmshaven, on the North Sea coast, one each in Brunsbüttel and Stade, they also belong to the North Sea, two – in Lubmin, on the coast of the Baltic Sea [1].

We are talking about LNG terminals – special regasification vessels (Floating Storage and Regasification Units, FSRU). The capacity of each FSRU is an average of 5 billion cubic meters of gas per year. The projects of such terminals are actively supported by the government of Germany, in particular the Vice Chancellor, Minister of Economy and Climate Protection of Germany, Robert Habeck. On May 5, 2022, Habek took part in the event for the opening of the construction of the first LNG terminal in the port of Wilhelmshaven on the North Sea [2]. This reflects the emphasized importance that the country's authorities attach to this event. The choice of Wilhelmshaven, one of the most deep-sea ports not only in Germany, but also in Europe, is determined by the possibility of entering here even the largest LNG tankers, the development of the infrastructure, as well as the fact that in the vicinity of this port city there is one of the largest underground storage facilities in the EU of Etzel gas, which has long been connected to the gas transportation systems of the Federal Republic of Germany, as well as the neighboring Netherlands.

The project will be implemented by the well-known German energy company Uniper. It provides [2; 3]:

– allocation of investments in the amount of EUR 65 million;

– expansion and modernization of the already existing infrastructure in Wilhelmshaven;

– preparation of the berth for the mooring of the floating regasification plant, in favor of which the choice was made at the initial stage of the project development due to the efficiency of the work. In the future, it may be possible to build a more powerful, expensive stationary regasification plant designed for growing needs.

A floating LNG receiving terminal, for example, has been operating since 2014 in Klaipeda, Lithuania, supplying gas not only to Lithuania. The German government has developed and submitted to the parliament a special law designed to accelerate the construction of LNG terminals, which are needed now to overcome the energy problem as soon as possible. This draft law provides for the simplification of bureaucratic procedures related to the approval of similar energy projects, the holding of tenders for participation in construction. Subsequently, the bill was passed by the parliament, which meets the requirements of the time.

The terminal in Wilhelmshaven was supposed to be completed by the end of 2022, and it will be the first of such facilities, the construction of which is planned in the near future. In total, terminals are being built in Wilhelmshaven, Brunsbüttel, Stade and Lubmen, and there should have been four of them at first. In the summer of 2022, one of the private German companies announced that it would put the fifth receiving terminal into operation. And on September 1, 2022, the Ministry of Economy of the Federal Republic of Germany announced another, already sixth project [1].

The history of the development of the issue of the construction of LNG terminals in Germany is characterized by inconsistency in decision-making and actions. Thus, projects for the construction of terminals in Wilhelmshaven, Brunsbüttel and Stade were considered back in 2019 by the previous government of the country, headed by Chancellor Angela Merkel and Vice Chancellor, Minister of Finance Olaf Scholz. However, none of the projects was implemented.

The LNG terminals planned for construction are already being considered, as emphasized by Robert Habek, in the direction of gas supply not only to Germany, but also, if such a need arises, to European countries in general.

The German authorities note that the currently implemented projects, in which the lease of regasification vessels will be used, are "still a temporary, transitional solution" [2]. In the future, stationary terminals are planned to be built in Wilhelmshaven, Brunsbüttel, Stade, and Lubmin. It is also extremely important that stationary terminals should be able to receive not only LNG, but also hydrogen. At the same time, it is noted that in the light of the ecological aspirations of modern Germany, this hydrogen must be produced from water by the electrolysis method and, what is especially important, must necessarily use renewable energy sources, most likely solar or wind, and come to Germany from countries where such energy is excessive for consumption.

Investments in LNG terminal projects are carried out by the German state in cooperation with major representatives of reputable German and foreign companies within the framework of probably the largest public-private partnership in the entire history of Germany. According to [2; 3], "Uniper is implementing the project in Wilhelmshaven, in Brunsbüttel – the German energy concern RWE, the Dutch state company Gasunie, and the German state bank KfW, which will contribute 50% of the capital. The American chemical giant Dow, the Belgian gas transport company Fluxus, and the German logistics holding Buss Group are behind the project in Stadt. Such a partnership shows the high degree of interest of the German state in the implementation of these projects in the shortest possible time, creates favorable conditions for business, contributes to the wide involvement of financial and production resources, leading specialists in this field on a global scale, and the possible rapid solution of energy problems not only in Germany, but also parts of other European countries.

The progress of project implementation is very successful. In December 2022, the first LNG terminal in the city of Wilhelmshaven began operating [4].

In January 2023, the second LNG terminal for the reception of liquefied natural gas began operation in the German city of Lubmin [5].

The third floating LNG terminal was opened in Brunsbüttel in January 2023 [6].

Without a doubt, other LNG terminals will be built on time.

The question of which energy sources, along with natural gas, were used at the largest (capacity of 1000 MW and above) power plants of the Federal Republic of Germany in 2020 is of interest (Table 1).

Lignite occupies a very important place as a fuel source in Germany's electric power industry. Among the country's largest power plants are three lignite plants: Neurath with a capacity of 3919 MW, Niederaußem – 2812 MW and Boxberg – 2427 MW. The total capacity of large lignite power plants reaches 12,518 MW and is 45.9% of the total capacity of the group of gas, nuclear fuel, and coal-fired power plants presented in the table (Figure 1).

The second most important source of energy resources for the largest power plants in the Federal Republic of Germany was (until April 2023) nuclear fuel: it was used at the nuclear power plants Brokdorf (capacity 1410 MW), Isar 2 (1410 MW), Grohnde (1360 MW), Kernkraftwerk Emsland (1336 MW), Kernkraft Gun-

Table 1

The largest (1000 MW and above) electric stations of the Federal Republic of Germany

Name of the power plant/ Energy carrier	Net installed capacity, MW					
	Brown coal	Natural gas	Nuclear fuel	Non-renewable energy carriers	Pumped-storage hydroelectricity	Coal
Neurath	3919	–	–	–	–	–
Niederaußem	2812	–	–	–	–	–
Boxberg	2427	–	–	–	–	–
Weisweiler	–	400	–	1961	–	–
GKM	–	–	–	–	–	1958
KW Jänschwalde	1860	–	–	–	–	–
Emsland	–	1837	–	–	–	–
Schwarze Pumpe	1500	–	–	–	–	–
Brokdorf	–	–	1410	–	–	–
Isar 2	–	–	1410	–	–	–
Grohnde	–	–	1360	–	–	–
Rheinhafen-Dampfkraftwerk	–	–	–	–	–	1351
Kernkraftwerk Emsland	–	–	1336	–	–	–
Gemeinschaftskernkraftwerk Neckarwestheim II	–	–	1310	–	–	–
PSW Vianden	–	–	–	–	1291	–
Kernkraft Gundremmingen	–	–	1288	–	–	–
KW Walsum	–	–	–	–	–	1095
Goldisthal	–	–	–	–	1052	–
Markersbach	–	–	–	–	1045	–
Total	12518	2237	8114	1961	3388	4404

Source: based on [7]

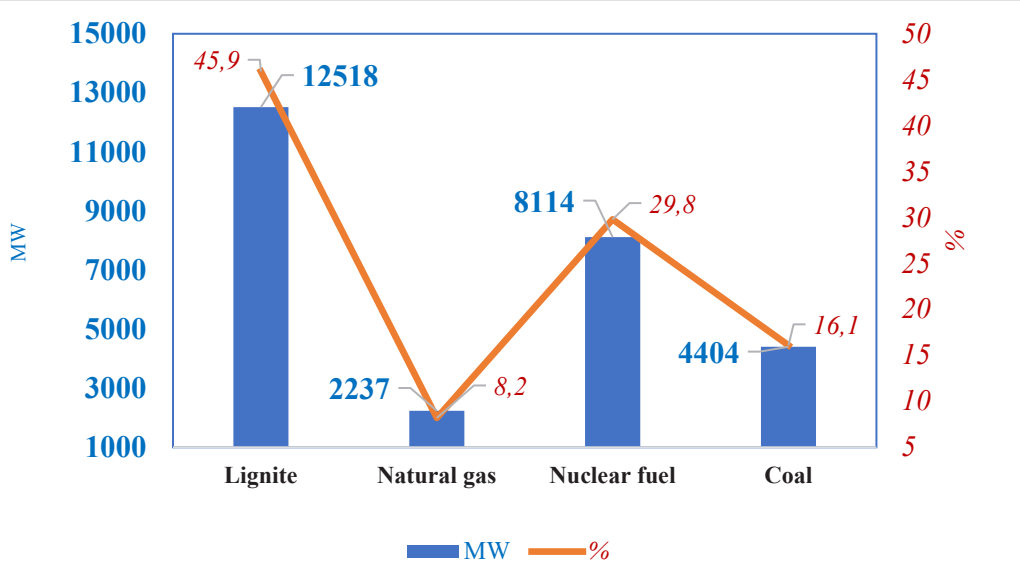

Figure 1. Power and specific weight by type of fuel of the largest power plants of the Federal Republic of Germany

Source: based on [7]

dremmingen (1288 MW) (Figure 1). The total capacity of nuclear power plants reached 8114 MW (1.5 times less than lignite) and accounted for 29.8% of the total capacity of the group of large power plants.

In April 2023, Germany shut down the last operating nuclear power plants [8].

Bavarian Prime Minister Markus Söder wants the nuclear power plant Isar 2, which was disconnected from the grid, to be brought back into operation under the responsibility of the state authorities [9].

Economic decisions depend on politicians. Correct actions for the development of the economy should be expressed in the formation in society, among the voters of the country, of reasonable scientifically and practically substantiated views on the development of energy, including nuclear energy. Public sentiment cannot be ignored by politicians, even if it happens belatedly. The optimal course for the development of the energy sector, which can be developed by specialists, who has received the support of the country's voters, is most likely to be implemented.

Lignite and nuclear power plants of the considered group together provided 75.7% of the produced energy, which made them extremely important for the country's energy sector.

The role of large power plants that use hard coal and natural gas is much smaller.

Analysis of the operation of power plants of the Federal Republic of Germany operating on brown coal showed the following:

– high technical level of such stations, large capacity, availability of systems for catching a significant part of harmful emissions;

– large reserves of lignite on the territory of the country, which does not cause the need to import such raw materials, excludes the influence of the increase in world prices and fuel and energy resources, which occurs, for example, in the case of oil and natural gas;

– very large volumes of lignite mining in the country, which is produced in an open manner using powerful, technically advanced equipment.

The nuclear power plants of the Federal Republic of Germany were distinguished by high efficiency, perfect technical level, produced a large amount of electricity and were provided with the necessary logistics. Their importance grew especially during the period of high global oil and natural gas prices for a long time.

Gas-fired power plants are very efficient and cause less environmental damage than coal-fired power plants. Currently, the efficiency of such stations is in conflict with the high cost of natural gas and complex logistical problems. Logistics issues seem to be resolved in the near future, and as for gas prices, they are likely to remain at a fairly high level in the future.

Model of energy development
of the Federal Republic of Germany.

The development of Germany's energy industry, as it seems, in the near and distant perspective can be carried out taking into account the following factors.

I. It is necessary to take into account the currently existing energy system of the country, which was formed over a long time and useful elements of which must be used.

II. The development of the energy industry in the near and distant perspective will differ significantly in the content of its most important elements, while a number of promising directions that exist at the moment or are just emerging will not only retain their importance, but will also receive active growth.

III. In the near future, the electricity industry of the Federal Republic of Germany seems to be guided by the following main elements:

1. Power plants on brown coal, which is mined in the country in very large volumes and has a relatively low cost, which will make it possible to produce a significant amount of electricity at already existing capacities, which is critically important for the country's economy. The use of lignite is a temporary forced measure and will gradually decrease with the growth of electricity production in other more efficient and environmentally sound ways.

2. Nuclear power plants, as they exist now, are large, and may be rebuilt taking into account the new developments of small modular reactors, which appear to be very promising. In the current difficult global energy situation, with high prices for oil and natural gas, and the presence of logistical problems, Germany's rejection of nuclear energy, while many of the world's leading economically developed countries continue its use and development, seems wrong. Revising views on the use of nuclear energy will require legislative changes.

3. Gas power plants, which have a relatively high efficiency and a relatively low negative environmental impact, should receive significant development, as it was foreseen by the programs previously adopted in the country. At the same time, preference should be given to liquefied natural gas instead of pipeline gas, which seems to be able to ensure sustainable supplies of this type of resource to Germany from the most economically advantageous sources, regardless of

their geographical location. The construction of six terminals for the reception of liquefied natural gas, which is carried out in an emergency manner, is aimed at this.

4. Coal-fired power plants should continue operating for some time due to their importance for the country's energy sector. At the same time, unlike lignite stations, such stations use imported raw materials, which creates price and logistical problems. Further development of such stations is impractical.

5. Solar power plants have now and will continue to have the most important importance for the energy industry. Their development is connected, apparently, in the conditions of Germany to a greater extent with the placement of solar panels on the roofs of various buildings and structures, as well as on unused territories. Such stations are advantageous from an ecological, logistical and generally economic point of view. In the existing realities, solar energy should be developed at the maximum possible pace.

6. Wind power plants already today produce about 25% of all electricity in Germany and are key, of primary importance for ensuring the country's economy, possessing all the elements of efficiency. Their functioning is not directly related to the supply of resources from abroad, the conjuncture of world energy prices. Such stations can be both large and very small in size, used in private farms, but in mass quantities. It is important to emphasize that wind power plants can be successfully combined with the development of electric mobility, which is the main direction of development. The construction of offshore wind farms in the North and Baltic Seas in cooperation with other European countries is of particular interest to Germany.

IV. In the distant future, the electric power industry of the Federal Republic of Germany seems to be able to develop in the following directions:

1. Gas power plants, the main fuel of which is not natural gas, but hydrogen. This type of fuel can be imported by sea using terminals currently being built to receive liquefied natural gas, which are specially prepared for this purpose. Some hydrogen can also be supplied via European pipelines from neighboring countries or produced on the territory of Germany itself. Such stations will have undeniable environmental advantages and can function in the long term.

2. Wind power plants. Such stations, especially located in the seas, will be the basis of the electric power industry and, in combination with energy storage and energy distribution between the countries of Europe, will replace almost all types of power stations that exist today, with the exception of solar and hydrogen fuel stations.

3. Solar power plants. They will receive a very wide development, inferior only to wind and, perhaps, stations on hydrogen fuel.

4. Power plants on brown and hard coal will practically cease to exist. It would be advisable to use nuclear power plants in the form of small modular reactors, but such use is likely to be opposed by environmental movements and is unlikely. The solution to humanity's energy problem would be the use of thermonuclear power plants, which is an extremely difficult problem and currently impossible.

Conclusions. Thus, the analysis showed the following:

– the model of providing Germany with natural gas, which has developed historically, provided for the pipeline way of obtaining it and excluded the supply of raw materials by sea from other countries, which served as the reason for the lack of terminals for receiving LNG in German ports;

– the large-scale changes that took place led to a rethinking of the traditional model of gas supply, as a result of which the emphasis shifted towards the construction of LNG terminals in a number of German seaports;

– projects for the construction of LNG receiving terminals are actively supported by the government of Germany;

– the choice of ports for the placement of terminals is determined by the possibility of the arrival of large sea vessels and the presence of already existing infrastructure, the proximity of large underground gas storage facilities and integration into the gas transport system of Germany and other European countries;

– LNG terminal projects are considered in the context of gas supply not only to Germany, but also to other European countries;

– stationary terminals, which are to replace floating ones in the future, should be structurally capable of receiving both LNG and hydrogen;

– investments in LNG terminal projects are carried out by the German state in cooperation with representatives of the largest global companies within the framework of a large-scale public-private partnership;

– in the future, wind, solar power plants, and thermal power plants based on ecological hydrogen should play a decisive role in the energy sector of Germany.

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