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CHAPTER 6. LEGAL FRAMEWORK FOR THE USE OF HYDROGEN, GEOTHERMAL AND ENVIRONMENTAL ENERGY IN UKRAINE

6.1. Legal regulation of using of geothermal energy

The use of earth heat or geothermal energy in Ukraine is one of the most promising types of alternative energy, the further development of which will help to solve significant energy problems related to the replacement of traditional fossil fuels and the supply of mineral resources to the industry. The undoubted advantages of geothermal energy include environmental friendliness, economic attractiveness, practical inexhaustibility of the energy source, and, unlike other alternative sources, independence from weather conditions.

The experience gained over the past decades in the development of thermal energy from the Earth's interior shows that geothermal resources are successfully used in more than 90 countries to generate electricity and heat, while meeting various needs of human economic activity. The total capacity of operating geothermal power plants (thermal) and geothermal power plants (electric) in the world is about 85 GW, of which approximately 15% is used for electricity generation and the rest for heat generation. The leaders in the production of geothermal electricity and heat are the USA, Indonesia, the Philippines, Turkey, New Zealand, Mexico, Kenya, Italy, Iceland and Japan[1].

According to the State Agency on Energy Efficiency and Energy Saving of Ukraine, due to the thermo-geological features of the relief and geothermal resources, our country has a significant geothermal energy potential. The geothermal resources suitable for use in Ukraine include thermal waters, heat from heated dry rocks, and heated groundwater resources produced with oil and gas by operating wells in oil and gas fields.

However, at present, scientific, exploration and practical work in Ukraine is focused only on geothermal resources represented by thermal

[1] Долінський А. А., Халатов А. А. Геотермальна енергетика: виробництво електричної і теплової енергії. *Вісник НАН України*. 2016. № 11. С. 76–86.

waters. In particular, the economically feasible energy resource of thermal waters is up to 8.4 million tons of oil equivalent per year[2].

Large reserves of thermal water have been discovered in Chernihiv, Poltava, Kharkiv, Luhansk and Sumy regions. However, the thermal water wells that were in operation (hundreds of wells) in the country are now mothballed. However, in the future, they can be restored for further use as geothermal heat extraction systems. Currently, the most developed area in Ukraine is the use of heat from the upper layers of the Earth using heat pumping units. The country has enough geothermal deposits with a high temperature potential (120–180°C), which makes it possible to use geothermal heat for electricity generation.

Unlike other alternative energy sources, the rate of expansion of geothermal energy production capacities in Ukraine is much slower. Since the late 90s of the twentieth century, despite the availability of a strong scientific and technical base for the development of geothermal energy, work on its development has been drastically reduced. The state has made virtually no investment in the creation of technologies and equipment for its development. And this is despite the fact that the country has geothermal resources almost throughout its territory.

The Geothermal Energy Department of the Institute of Renewable Energy of the National Academy of Sciences of Ukraine is currently conducting successful research in the field of geothermal energy to provide scientific support and practical implementation of technologies for the production of heat and electricity based on the use of geothermal resources. In particular, in 2020, the Atlas of the Energy Potential of Renewable Energy Sources of Ukraine was published, which provides data on the distribution of electric geothermal potential in certain administrative regions of Ukraine and an electronic database of geothermal facilities in Ukraine[3]. It is believed that these achievements and experience in the development of methods in the field of geothermal energy extraction and use should be taken into account when developing the state policy for the development of the industry and legal support for its development. After all, despite all the advantages and great potential, geothermal energy can only develop if there is an appropriate state policy and support, including through the mechanism of legal regulation[4].

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[2] Геотермальна енергія / Державне агентство з енергоефективності та енергозбереження України. URL: https://saee.gov.ua/uk/ae/geoenergy (дата звернення: 01.07.2023 року)

[3] Відновлювані джерела енергії / За заг. ред. С.О. Кудрі. Київ: Інститут відновлюваної енергетики НАНУ, 2020. 392 с.

[4] Платонова Є. О., Дубінін Ю. С. Правові засади використання геотермальної енергії в Україні. *Juris Europensis Scientia*. 2023. № 2. С. 51–58.

A significant step in the development of relations in the use of geothermal energy resources was the adoption of the State Programme "Environmentally Friendly Geothermal Energy of Ukraine", approved by the Cabinet of Ministers of Ukraine on 17 January 1996 № 100[5]. In accordance with the goals declared in the programme, it was planned to increase the actual capacity of geothermal energy used to 250 MW by 2010, but this figure was not achieved due to the current state of development of the industry. By the way, under this programme, the Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine developed 6 projects and business plans for geothermal power plants for Zakarpattia, Poltava, Chernihiv regions and the Autonomous Republic of Crimea, designed and built 12 geothermal power plants on the Crimean Peninsula, and constructed a plant in the village of Medvedivka. Medvedivka (AR of Crimea), the station in Yantarne (AR of Crimea) was modernized, and geothermal plants were built in Berehove and Kosyno (Zakarpattia region). After the programme was closed, all geothermal energy use in Ukraine ceased.

Subsequently, in order to implement the state energy policy in the field of alternative energy sources development, various state programmes, strategies, national action plans/action plans were adopted in the country, which were supposed to reflect, among other things, the current state and prospects of geothermal energy development, and provide for the means and timing of their implementation. Instead, their common feature in terms of setting programme benchmarks for the use of alternative energy sources in the country was that the issues of geothermal energy development were considered indirectly by identifying the need to increase the use of geothermal energy, construction of pilot geothermal power plants, etc.[6]

Among the most important policy documents in this area is the Comprehensive State Energy Saving Programme of Ukraine, approved by the Cabinet of Ministers of Ukraine on 5 February 1997 No. 148[7]; Programme of State Support for the Development of Non-Traditional and

[5] Про Державну програму "Екологічно чиста геотермальна енергетика" України: постанова Кабінету Міністрів України від 17 січня 1996 року № 100. URL: https://zakon.rada.gov.ua/laws/show/100-96-п#Text (дата звернення: 17.08.2023 року)

[6] Платонова Є., Дубінін Ю. Сучасний стан та перспективи програмного забезпечення геотермальної енергетики в Україні. *Сучасна державна екологічна політика і безпека суверенної України: проблеми та перспективи правового забезпечення* (до 30-ї річниці Закону України "Про охорону навколишнього природного середовища" та до 20-ї річниці Закону України "Про нафту і газ"): матеріали Всеукр. наук.-практ. конф. (м. Київ, 28 січня 2022 року). Наук. ред. В. Устименко. Чернігів: Десна Поліграф, 2022. С. 164–169.

[7] Про Комплексну державну програму енергозбереження України: постанова Кабінету Міністрів України від 5 лютого 1997 року № 148. *Офіційний вісник України*. 1997. № 6.

Renewable Energy Sources and Small Hydro and Heat Power, approved by the Cabinet of Ministers of Ukraine on 31 December 1997, No. 1505[8]; The State Target Economic Programme for Energy Efficiency and Development of Energy Production from Renewable Energy Sources and Alternative Fuels for 2010-2021, approved by the Cabinet of Ministers of Ukraine on 1 March 2010, No. 243[9]; The State Programme for the Development of Domestic Production, approved by the Resolution of the Cabinet of Ministers of Ukraine dated 12 September 2011 No. 1130[10]; Energy Strategy of Ukraine for the period up to 2035 "Security, Energy Efficiency, Competitiveness", approved by the Cabinet of Ministers of Ukraine on 18 August 2017 No. 605-r (expired on 21.04.2023)[11].

However, given the programme nature of these documents, most of their provisions were declarative. General slogans about the need to increase the use of geothermal energy in the generation of electricity and heat were not supported by specific measures and mechanisms for their implementation.

The first state strategic document on the territory of independent Ukraine on the development of alternative energy sources, including geothermal energy, is the National Renewable Energy Action Plan for the period up to 2020, approved by the Cabinet of Ministers of Ukraine on 1 October 2014, No. 902-p[12]. Unfortunately, despite the plan's goal of "ensuring electricity generation by geothermal installations by commissioning new capacities of 20 MW in 2020", geothermal energy is currently absent from the installed capacity of renewable energy facilities. No information on state funding of geothermal energy projects was found in open sources.

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[8] Про Програму державної підтримки розвитку нетрадиційних та відновлюваних джерел енергії та малої гідро– і теплоенергетики: постанова Кабінету Міністрів України від 31 грудня 1997 р. № 1505. URL: https://zakon.rada.gov.ua/laws/show/1505-97-п#Text (дата звернення: 17.08.2023 року)

[9] Про затвердження Державної цільової економічної програми енергоефективності і розвитку сфери виробництва енергоносіїв з відновлюваних джерел енергії та альтернативних видів палива на 2010-2021 роки: постанова Кабінету Міністрів України від 01 березня 2010 року № 243. *Офіційний вісник України*. 2010. № 16. Ст. 762.

[10] Про затвердження Державної програми розвитку внутрішнього виробництва: постанова Кабінету Міністрів України від 12 вересня 2011 року № 1130. *Офіційний вісник України*. 2011. № 86. Ст. 3139.

[11] Про схвалення Енергетичної стратегії України на період до 2035 року "Безпека, енергоефективність, конкурентоспроможність": розпорядження Кабінету Міністрів України від 18 серпня 2017 року № 605-р. *Урядовий кур'єр* від 08 вересня 2017 року № 167. *(втратила чинність 21.04.2023 року)*

[12] Про Національний план дій з відновлюваної енергетики на період до 2020 року: розпорядження Кабінету Міністрів України від 01 жовтня 2014 року № 902-р. *Офіційний вісник України*. 2014. № 81. Ст. 2298.

On 20 January 2022, the draft resolution of the Cabinet of Ministers of Ukraine "On the National Renewable Energy Development Action Plan for the period up to 2030", approved by the Ministry of Energy of Ukraine, was published for public discussion on the official website of the State Agency on Energy Efficiency and Energy Saving. It states that Ukraine has a sufficient resource base and developed geothermal technologies to extract and develop the following types of geothermal energy sources sub-geothermal – heat from the upper layers of the Earth up to a depth of 500 m, which is used by heat pumping units; hydrothermal – heat from deep underground thermal waters and parahydrothermal waters, which is used by heat and power generating units; petrothermal – heat from overheated "dry" rocks, which is used by borehole heat exchangers or by creating artificial underground permeable collectors. However, the most widespread and currently suitable source of geothermal energy in Ukraine for technical use is hydrothermal resources. It is noted that, given the current situation, conditions and available potential, Ukraine can ensure the production of electricity by geothermal installations by commissioning new capacities in the amount of 100 (with a total capacity of 20 MW)[13].

At present, the legal framework for the use of geothermal resources is established by numerous legal acts regulating relations in the field of natural resources use, environmental protection, payment of rent, development of alternative energy sources, etc. In such circumstances, it is difficult for ordinary developers and investors to navigate the existing array of ambiguous and sometimes contradictory legal requirements for their use, especially given the current dynamism of energy, natural resources and environmental legislation[14].

First of all, it should be noted that the current state of legal regulation of the use of groundwater, which is a key resource for geothermal energy, is characterized by the dual legal nature of groundwater. Both water and subsoil legislation consider them as their own object of regulation: water – as part of the water fund (Article 3 of the Water Code of Ukraine), subsoil – as a mineral resource, a component of the subsoil (Article 5 of the Subsoil Code of Ukraine). According to the Resolution of the Cabinet of Ministers of Ukraine "On Approval of Lists of Mineral Resources of National and

[13] Проект розпорядження Кабінету Міністрів України "Про Національний план дій з розвитку відновлюваної енергетики на період до 2030 року" від 20 січня 2022 року / URL: https://saee.gov.ua/uk/content/elektronni-consultatsii(дата звернення: 01.07.2023 року)

[14] Платонова Є. О., Дубінін Ю. С. Правові засади використання геотермальної енергії в Україні. *Juris Europensis Scientia*. 2023. № 2. С. 51–58.

Local Importance", groundwater as a mineral resource of national importance is divided into mineral, drinking, industrial, heat and power[15].

Separate legal norms on the protection and use of natural therapeutic resources are found in Articles 15-19 of the Law of Ukraine "On Resorts"[16]. According to these regulations, thermal waters are classified as "natural medicinal resources", as their use is primarily based on their medicinal properties. At the same time, Ukraine does not have a single state standard for medicinal waters, which can also be classified into medicinal mineral waters, drinking mineral waters, and thermal waters. At the same time, thermal waters are a type of groundwater and at the same time, in terms of their geological structure, are minerals. Therefore, the use of these natural resources, given their dual legal regime, should be governed by both water and subsoil legislation. The complex legal nature of groundwater leads to complications in the implementation of legal norms in the field of geothermal resources use and difficulties in law enforcement, in particular in court practice[17].

Geothermal energy uses the heat (thermal energy) of groundwater obtained by taking water from a water body (including groundwater) and generating electricity or heat from it. Heat extraction from geothermal sources usually requires the construction of geothermal power plants: Geothermal power plants (thermal) or Geopower plants (electric). According to experts, in general, in Ukraine, geothermal power generation can be developed in the following directions: 1) medium-sized geothermal power plants with a unit capacity of 10-20 MW based on deposits with a temperature above 120°C; 2) small geothermal power plants with a unit capacity of 0.05-5 MW with a temperature of 90-120°C; 3) combined power plants using geothermal energy and organic fuels (coal, gas, peat, biomass); 4) combined energy units for the production of electricity, heat and valuable products from geothermal waters. By the way, state national standards have been adopted in this area, namely: SSTU 7498:2014 "Geothermal Energy. Terms and Definitions", SSTU 7955:2015 "Geothermal Energy. Geothermal thermal power plants. General technical requirements", SSTU

[15] Про затвердження переліків корисних копалин загальнодержавного та місцевого значення: постанова Кабінету Міністрів України від 28 грудня 2011 року № 1370. URL: https://zakon.rada.gov.ua/laws/show/827-94-п#Text (дата звернення: 18.08.2023 року)

[16] Про курорти: Закон України від 5 жовтня 2000 року. *Відомості Верховної Ради України*. 2000. № 50. Ст. 435.

[17] Обіюх Н. М. Правове регулювання використання термальних вод за законодавством країн Європейського Союзу та України. *Науковийвісник Ужгородського національного університету*. СеріяПРАВО. 2015. Вип. 35. Ч. II. Т. 2. С. 50–54.

8300:2015 “Geothermal energy. Electric geothermal power plants. General technical requirements”[18].

According to the regulatory requirements of Articles 48 and 49 of the Water Code of Ukraine[19] These activities, which are carried out by legal entities and individuals to meet energy needs, *are classified as special water use*, are paid for and require a special water use permit.

At the same time, groundwater is a type of mineral resource of national importance. In accordance with Articles 16 and 21 of the Subsoil Code of Ukraine [20] stipulates that the use of subsoil for the extraction of groundwater (except for mineral water) is carried out on the basis of a special permit for the use of subsoil without the provision of a mining allotment. Currently, these special permits are granted to the winners of auctions for the sale of special permits for subsoil use in accordance with the procedure approved by the Resolution of the Cabinet of Ministers of Ukraine dated 23 September 2020[21].

The specificity of groundwater use in this case is actually the implementation of special water use and special subsoil use. Thus, the acquisition of the right to use groundwater requires the simultaneous receipt of two documents: a) a special water use permit and b) a special subsoil use permit. The special subsoil use permit gives the right to extract groundwater, while the special water use permit gives the right to use it.

At the same time, the Subsoil Code of Ukraine provides for cases in which business entities have the right to extract groundwater without a special permit for subsoil use. Such cases are envisaged by Article 23 of the Subsoil Code of Ukraine, which establishes the right of landowners and land users to extract groundwater (except for mineral water) for all purposes, except for the production of packaged drinking water, within the boundaries of their land plots without special permits and mining allotments, provided that the volume of groundwater extraction from each water intake does not exceed 300 cubic meters per day. Thus, a land user or land owner, legal entity or individual shall withdraw groundwater by means of a well (structure, technical device), provided that the water intake

[18] Відновлювані джерела енергії / За заг. ред. С.О. Кудрі. Київ: Інститут відновлюваної енергетики НАНУ, 2020. 392 с.

[19] Водний кодекс України від 6 червня 1995 року. *Відомості Верховної Ради України*. 1995. № 24. Ст. 189.

[20] Кодекс України про надра від 27 липня 1994 року. *Відомості Верховної Ради України*. 1994. № 36. Ст. 340.

[21] Про затвердження Порядку проведення аукціонів з продажу спеціальних дозволів на користування надрами: постанова Кабінету Міністрів України від 23 вересня 2020 року № 993. *Офіційний вісник України*. 2020. № 88. Ст. 2825.

capacity does not exceed 300 cubic meters per day and it does not produce packaged drinking water[22].

The specificity of groundwater use in this case is actually the implementation of general subsoil use and special water use. Thus, the acquisition of the right to use groundwater requires obtaining only one document – a special water use permit.

For the use of groundwater, the Tax Code of Ukraine provides for a rent payment for special use of water (Article 255) and for the use of subsoil for the extraction of minerals[23]. In other words, the legislation has created a situation where potential geothermal energy producers pay twice for the same natural resource – groundwater – as for water and as for a mineral resource. It is believed that the second payment is not for groundwater (as a mineral resource), but for the use of subsoil during its extraction.

The analysis of the current energy legislation gives grounds to note that currently the basis for legal regulation of the use and promotion of alternative energy sources, including geothermal energy, is contained in the laws of Ukraine: "On Alternative Energy Sources" of 20 February 2003, "On Heat Supply" of 2 June 2005, "On Amendments to Certain Laws of Ukraine on Establishing a Green Tariff" of 25 September 2008. The first versions of these laws only set national goals in the field of alternative energy, but did not define specific mechanisms to encourage the use of geothermal energy sources. In addition, until 2016, the Law of Ukraine "On Alternative Energy Sources" did not contain a definition of geothermal energy, but only referred to geothermal energy as one of the types of alternative energy sources. The Law of Ukraine "On Energy Saving" did not define this concept either, although it also referred to the Earth's heat as one of the non-conventional and renewable energy sources.

Certain positive changes in the direction of simplifying the conditions for conducting business in the field of geothermal energy occurred in connection with the adoption of the Law of Ukraine "On Amendments to the Law of Ukraine "On Alternative Energy Sources" regarding the classification of heat pumps as equipment that uses renewable energy sources" of 1 November 2016[24]. The adoption of this Law was necessitated by the need to ensure the fulfilment of Ukraine's obligations to adapt its

[22] Сердюк О. В. Актуальніправовіпроблемивикористання підземнихвод. *Проблеми законності*. 2011. Вип. 116. С. 160 – 167.

[23] Податковий кодекс України від 02 грудня 2010 року. *Відомості Верховної Ради України*. 2011. № 13-14, № 15-16, № 17. Ст. 112.

[24] Про внесення змін до Закону України "Про альтернативні джерела енергії" щодо віднесення теплових насосів до обладнання, яке використовує відновлювані джерела енергії: Закон України від 01 листопада 2016 року. *Офіційний вісник України*. 2016. № 98. Ст. 3179.

national legislation to the Energy Community legislation, in particular Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable energy sources, namely the regulation of the issue of the classification of energy used by heat pumps as energy from renewable sources.

It should be noted that in many countries of the world, along with the construction of geothermal thermal power plants (Geothermal Power Plants), geothermal heat supply systems based on heat pumps have been actively developing in recent years. According to estimates, heat pump systems account for 70.95% of the total capacity of geothermal heat systems in the world. These technologies are most developed in the USA, China, Sweden, Germany and France. These systems use low-potential (up to 55°C) thermal water and petrothermal energy from the upper layers of the Earth's crust as the primary heat source[25].

Almost all regions of Ukraine have significant reserves of low-potential thermal waters that can be used in heat supply systems with heat pumps. Uniform requirements for geological exploration, geological and economic assessment of heat and power groundwater deposits and conditions for determining their readiness for industrial development are set out in the Instruction on the Application of the Classification of Mineral Reserves and Resources of the State Fund of Subsoil to Heat and Power Groundwater Deposits, approved by Order No. 182 of the State Commission of Ukraine for Mineral Reserves of 07 June 2007.

According to scientist Platonova, in order to improve the legal regulation of relations in the field of environmental energy use in Ukraine, it is necessary to develop a state strategy for the development and use of environmental energy, as well as an effective mechanism for legal support for the development of thermal energy production from natural energy sources of the environment[26].

Let us consider the most common fundamental legal mechanisms for stimulating the development of geothermal energy in Ukraine.

At present, the main incentive instrument of the state policy aimed at the production of electricity from geothermal sources is the application of the

[25] Долінський А. А., Ободович О. М. Світовий досвід використання геотермальної енергії та перспективи її розвитку в Україні. *Вісник НАН України*. 2016. № 3. С. 62–69.

[26] Платонова Є. О. Правові аспекти використання енергії довкілля України в умовах євроінтеграції. Європейський вибір України, розвиток науки та національна безпека в реаліях масштабної військової агресії та глобальних викликів XXI століття (до 25-річчя Національного університету "Одеська юридична академія" та 175-річчя Одеської школи права): у 2 т.: матеріали Міжнар. наук.-практ. конф. (м. Одеса, 17 червня 2022 року) / за заг. ред. С. В. Ківалова. Одеса: Видавничий дім "Гельветика", 2022. Т. 1. С. 644–647.

feed-in tariff, as participation in auctions for the distribution of support quotas for energy producers from geothermal sources is voluntary. Thus, according to the Law of Ukraine "On Alternative Energy Sources", the feed-in tariff for business entities producing electricity from geothermal energy is set at the level of the retail tariff for consumers of the second voltage class as of January 2009 multiplied by the feed-in tariff coefficient for electricity produced from geothermal energy. The amounts of such coefficients are given in part 22 of Article 91 of the Law, according to which, for electricity produced from geothermal energy, they are as follows for facilities or its start-up complexes commissioned: a) from 1 July 2015 to 31 December 2019 – 2.79; b) from 1 January 2020 to 31 December 2024 – 2.51; c) from 1 January 2025 to 31 December 2029 – 2.23. It is easy to see that there are no such coefficients for facilities commissioned before 30 June 2015.

In the case of electricity generation by consumers, including energy cooperatives, from geothermal energy by generating facilities with an installed capacity of less than 150 kW, the feed-in tariff is set at the level of the retail tariff for consumers of the second voltage class as of January 2009, multiplied by the feed-in tariff coefficient for electricity generated by consumers.

In accordance with part 24 of Article 91 of the Law "On Alternative Energy Sources", the coefficients are set at the following levels: a) from 1 January 2019 to 31 December 2019 – 2.79; b) from 1 January 2020 to 31 December 2024 – 2.51; c) from 1 January 2025 to 31 December 2029 – 2.23. Thus, such coefficients were introduced only in 2019.

This provision can undoubtedly be considered one of the significant attempts to stimulate the development of small and medium-sized enterprises in Ukraine, in particular, by including energy cooperatives in the list of entities that are encouraged to produce electricity from geothermal sources on the basis of a feed-in tariff. However, the absence of special systemic state support for the geothermal sector of alternative energy negates all positive developments in this area.

It is believed that the lack of effective economic incentives for the construction and operation of geothermal thermal and power plants necessitates the legislative establishment of economically attractive feed-in tariff coefficients for geothermal energy, comparable to those for electricity generated from solar energy by ground-based power facilities[27].

[27] Платонова Є. О., Дубінін Ю. С. Правові засади використання геотермальної енергії в Україні. *Juris Europensis Scientia*. 2023. № 2. С. 51–58.

According to Article 7 of the Law of Ukraine "On Heat Supply[28]", one of the main directions of development of heat supply systems is use of geothermal water as a type of alternative energy source. The implementation of this provision is manifested in the use of such an economic and legal means of stimulating the production of heat energy from alternative sources as an incentive tariff for heat energy. Its essence lies in the fact that tariffs for heat energy for business entities that produce it at facilities using alternative energy sources, including thermal power plants, thermal power plants and cogeneration plants, for the needs of institutions and organizations financed from the state or local budget, as well as for the needs of the population, are set at 90% of the tariff for heat energy produced using natural gas for the needs of the relevant category of consumers (part 4 of the Law).

The establishment of such a tariff should have a positive impact on the generation of heat from geothermal energy sources, as it allows to reduce the cost of heat energy, which may have a favorable impact on the formation of tariffs for end consumers. However, insufficient state funding for geothermal energy projects creates risks that such projects will not be profitable. In addition, the establishment of incentive tariffs for heat energy "not from gas" without differentiation of RES used for its production creates unequal conditions for producers of heat energy from geothermal sources[29].

These legal mechanisms for stimulating the development of geothermal energy are supplemented by tax benefits (exemption from value added tax) and customs benefits (exemption from customs duties) for the importation into the customs territory of Ukraine or exportation outside of it of materials, equipment, components for construction that are not produced in the country.

In her research, scientist Platonova E. O. concludes that the state policy in the field of geothermal energy development in the country is declarative and extremely ineffective, and that the legal mechanisms for its development and stimulation are imperfect. This is due to shortcomings and strategic miscalculations in the legal regulation of geothermal energy relations. It is established that geothermal resources are not only a significant energy resource that is currently successfully used for electricity and heat production, but also a mineral resource and part of water resources. In the process of exercising the right to use underground thermal waters, as the most developed

[28] Про теплопостачання: Закон України від 2 червня 2005 року. *Офіційний вісник України*. 2005. № 27. Ст. 1532.

[29] Платонова Є. О., Дубінін Ю.С. Правові засади використання геотермальної енергії в Україні. *Juris Europensis Scientia*. 2023. № 2. С. 51–58.

type of geothermal resources, there is a complex use of several natural objects, namely: a water body, a subsoil area and a plot of land.

Thus, relations in the field of groundwater use are heterogeneous by their legal nature, since such a natural object as thermal waters determines different types of their use: subsoil use, water use and land use, which are interrelated, but regulated by different regulatory legal acts of natural resource and land legislation. For example, the right to extract underground thermal waters is regulated by subsoil legislation; the right to use them is regulated by water legislation; and the provision of land plots for geothermal installations is regulated by land legislation. The legal, economic, environmental and organizational framework for the use of geothermal energy is determined by energy legislation. The payment of rents for the use of subsoil for mining and special water use is regulated by tax legislation.

Under the influence of current energy trends, Ukraine has already laid the groundwork for legal regulation of geothermal energy use. However, these positive developments in the direction of stimulating the production and consumption of geothermal energy cannot yet ensure the competitiveness and investment attractiveness of geothermal thermal and power plant construction projects in Ukraine. As a result, there are currently no operating geothermal power plants in the country. Therefore, there is no doubt that the existing economic and legal incentives for the use of geothermal energy need to be improved and refined.

6.2. Environmental energy as a source of renewable energy: legal section of the issue

Energy of the environment, in particular, surface sources of thermal waters, as well as layered thermal waters lying in the sedimentary shell of the earth's crust, was used by mankind even before the beginning of our era. It is known that thermal waters from springs and wells were used in ancient Rome to heat artificial pools and baths of noble patricians. And nowadays, in some regions of Italy, thermal reservoir waters are used for domestic and, even, industrial purposes. A vivid example can be the exploitation of the Larderello high-temperature water deposit in the Toscano region, where even in the last century steam was extracted, which operated a built power plant with a capacity of 200,000 kW per year. In California (USA) in the area of the development of geysers, the electric generators-built produce electricity with a total capacity of more than 400 thousand kW per year. Examples of industrial use of thermal water energy in New Zealand and other countries can also be given. Despite the fact that Ukraine has a significant energy potential of underground thermal waters, as evidenced by

direct measurements of temperatures in drilled wells in all three oil and gas-bearing regions (Western, Eastern and Southern), the problem of using hydrothermal resources as a priority task has not been considered so far[30]. The current global energy crisis brings both new opportunities and new challenges for renewable energy. The natural energy sources of the environment include the heat of atmospheric air, water of rivers, seas, topsoil and groundwater.

The use of geothermal, hydrothermal and aerothermal energy in Ukraine are promising directions for the development of alternative energy sources, since our country is a member of the Energy Community, and in accordance with the accepted obligations in 2020, the mandatory share of renewable energy in the total structure of energy consumption should have been 11%. Such obligations are dictated by the provisions of Directive 2009/28/EU on the promotion of the use of energy produced from renewable sources, the plan of measures for the implementation of which was approved by the order of the Cabinet of Ministers of Ukraine in 2014[31]. However, the process of development of renewable energy is very slow, because the share of energy produced from renewable sources in the total amount of energy as of the beginning of 2020 was 8.1%, and at the end of 2020, it was only about 9.2%. The main indicators of the development of renewable energy are the volume of electricity generation and the annual indicator of the introduction of new capacities.

Geothermal energy is energy stored in the form of thermal energy under the solid layer of the Earth's surface. Speaking about hydrothermal energy, some scientists define it as a type of geothermal energy, which is produced due to the heat of water and steam that are deep underground. This heat is produced by the Earth's internal heat sources, including the decay of radioactive elements and the heat of the Earth's molten core, and is harnessed by special power plants and other technologies. One of the main advantages of hydrothermal energy is its reliability and predictability. Like other forms of renewable energy, such as solar and wind energy, hydrothermal energy is constant and reliable, making it an important base-load energy source. In addition, hydrothermal energy is a clean and

[30] Орлов О. О., Омельченко В. Г. Проблема використання гідротермальної енергії землі як альтернативи вуглеводневим джерелам енергоносіїв в Україні. *Розвідка та розробка нафтових і газових родовищ.* 2010. № 1 (34). С. 121–131.

[31] Про Національний план дій з відновлюваної енергетики на період до 2020 року: розпорядження Кабінету Міністрів України від 01 жовтня 2014 року № 902-р. *Офіційний вісник України*. 2014. № 81. Ст. 2298.

renewable energy source with little or no greenhouse gas emissions, making it a greener alternative to fossil fuels[32].

There are several challenges in the development and use of hydrothermal energy. One major challenge is the high upfront costs of building hydroelectric power plants and other infrastructure, which can make it difficult for energy providers to justify the investment. In addition, there are also concerns about the potential environmental impact of hydrothermal energy development, such as possible air and water pollution, and potential disruption of local ecosystems.

Aerothermal energy is based on the transportation of thermal energy from one space to another, thanks to a device called a heat pump, whose function is to transfer heat from the environment by reversing the natural flow of heat. Its main advantages are: it is a natural and inexhaustible energy that does not use fossil fuels; high level of energy efficiency and productivity; return of investments mostly occurs in a short time; no smoke or other waste is produced in the production process, since there is no combustion. Disadvantages of aerothermal energy are: high initial investment in equipment; low performance in very cold climates[33].

The need to comply with and fulfill international obligations in the energy sector, technological development, existing in the civilized world mechanisms for stimulating the development of thermal energy production from natural low-potential sources require the introduction of effective legal regulation in the field of environmental energy use in our country as well[34].

According to the State Agency for Energy Efficiency and Energy Saving of Ukraine, the annual technically achievable energy potential of environmental energy in Ukraine is 12.6 million kW per year, and its use will save about 15.6 billion cubic meters natural gas[35].

The expediency of using aerothermal, hydrothermal and geothermal energy for the production of thermal energy from renewable energy sources in the conditions of Ukraine is emphasized in the draft order of the Cabinet of Ministers of Ukraine "On the National Action Plan for the Development

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[32] Hydrothermal energy URL: https://www.daviddarling.info/encyclopedia/H/AE_hydrothermal_energy.html (дата звернення: 01.07.2023 року)

[33] What is aerothermal energy and what are its advantages and disadvantages? URL: https://www.ketier.com/en/blog/what-is-aerothermal-energy-and-what-are-its-advantages-and-disadvantages/ (дата звернення: 01.07.2023 року)

[34] Заверюха М. М. Енергія довкілля як джерело відновлюваної енергетики: правовий розріз питання. *Юридичний науковий електронний журнал.* 2023. № 7. С. 206-209.

[35] Енергія довкілля / Державне агентство з енергоефективності та енергозбереження України. URL: https://saee.gov.ua/uk/ae/termo-energy (дата звернення: 01.07.2023 року)

of Renewable Energy for the Period Until 2030"[36]. It states that in 2020, the gross final volume of energy consumption from renewable sources in heating and cooling systems was 52,000 tons of the Earth's thermal energy due to heat pumps, including aerothermal – 36,000 tons, geothermal – 10,000 tons, hydrothermal – 6,000 tons. Also, in the draft of this order, it is established that the assessment of the total contribution (final volume of energy consumption) expected for each source of renewable energy to achieve mandatory indicative goals and an indicative intermediate trajectory of achieving the share of energy from renewable sources in heating and cooling systems by 2030 should make up: aerothermal – 460,000 metric tons; geothermal – 160,000 tons per year; hydrothermal – 80 thousand tons per year.

In addition, the National Economic Strategy of Ukraine for the period until 2030, approved by Resolution No. 17 of the Cabinet of Ministers of Ukraine dated March 3, 2021[37], defines as one of the key guidelines in the economic policy of Ukraine the decarbonization of the economy (increasing energy efficiency, development of renewable energy sources, development of circular economy and synchronization with the "European Green Course" initiative). Considering the Economic Development Strategy of Donetsk and Luhansk Regions for the period until 2030, approved by the decree of the Cabinet of Ministers of Ukraine dated August 18, 2021 No. 1078-r[38]. Special attention will be paid to the development of renewable electricity in the Donetsk and Luhansk regions. A favorable area for the development of renewable energy is the exclusion zone of the Chernobyl NPP, which has a developed electric power infrastructure and is located in an energy deficit region.

The analysis of modern energy legislation provides reasons to note that the foundations of legal regulation of environmental energy use are fragmentarily contained in the Law of Ukraine "On Alternative Energy Sources" of February 20, 2003[39], by which aerothermal, geothermal, hydrothermal are classified as renewable energy sources. Certain positive

[36] Проект розпорядження Кабінету Міністрів України "Про Національний план дій з розвитку відновлюваної енергетики на період до 2030 року". URL: https://saee.gov.ua/uk/content/elektronni-consultatsii (дата звернення: 01.07.2023 року)

[37] Про затвердження Національної економічної стратегії на період до 2030 року: постанова Кабінету Міністрів України від 03 березня 2021 р. № 179.*Офіційний вісник України*. 2021. № 22. Ст. 1015.

[38] Про затвердження Стратегії економічного розвитку Донецької та Луганської областей на період до 2030 року: розпорядження Кабінету Міністрів України від 18 серпня 2021 року № 1078-р. *Офіційний вісник України*. 2021. № 75. Ст. 4720.

[39] Про альтернативні джерела енергії: Закон України від 20 лютого 2003 року. *Офіційний вісник України*. 2003. № 12. Ст. 522.

developments in the direction of establishing legal basic principles in this area took place in connection with the adoption of the Law of Ukraine "On Amendments to the Law of Ukraine "On Alternative Energy Sources" regarding classification of heat pumps as equipment that uses renewable energy sources" dated November 1, 2016[40]. The adoption of this Law was conditioned by the need to ensure the fulfillment of the obligations assumed by Ukraine regarding the adaptation of national legislation to the legislation of the Energy Community, in particular Directive 2009/28/EU of the European Parliament and of the Council on the promotion of the use of energy produced from renewable energy sources, namely the regulation the question of whether the energy used by heat pumps belongs to energy from renewable sources.

The innovations made to the Law of Ukraine "On Alternative Energy Sources" were as follows. First, the definitions of the terms: geothermal energy, hydrothermal energy and aerothermal energy were provided (Article 1). All the listed types of energy are energy stored in the form of thermal energy: geothermal energy – under the solid layer of the earth's surface; hydrothermal energy – in surface waters; aerothermal energy – in the air environment. Secondly, aerothermal, hydrothermal or geothermal thermal energy obtained with the help of heat pumps refers to that extracted from renewable energy sources, provided that the final energy output significantly exceeds the primary energy consumption required to operate the heat pumps (article 10).

The calculation of the share of energy produced by heat pumps, with the aim of forming a report for the Energy Community on the progress achieved in the promotion and use of energy from renewable sources, is carried out in accordance with the methodology approved by the order of the Ministry of Regional Development, Construction and Housing of Ukraine dated March 12, 2018 No 52[41]. Heat pumps, depending on the type of heat transfer medium for extracting/returning heat, are divided into classes: "soil-air", "soil-water", "water-air", "water-water", "air-air", "air-water". Directive of the European Parliament and Council 2010/31/EC of May 19, 2010 on the energy performance of buildings (new edition) in clause 18 of Art. 2 defines a "heat pump" as a machine, device or installation that

[40] Про внесення змін до Закону України "Про альтернативні джерела енергії" щодо віднесення теплових насосів до обладнання, яке використовує відновлювані джерела енергії": Закон України від 01 листопада 2016 року. *Офіційний вісник України*. 2016. № 98. Ст. 3179.

[41] Про затвердження Методики обчислення частки енергії, виробленої тепловими насосами з відновлюваних джерел: наказ Міністерства регіонального розвитку, будівництва та житлово-комунального господарства України від 12 березня 2018 року. № 52. *Офіційний вісник України*. 2018. № 34. Ст. 1210.

transfers heat from a natural medium such as air, water or soil to buildings or for industrial applications by changing the direction of the natural flow of heat so that it flows from a lower temperature to higher[42]. Thus, aerothermal heat pumps use air as a low-potential source (the most common in Europe), water heat pumps use the water energy of natural and artificial reservoirs, and geothermal heat pumps are based on the use of soil and groundwater energy. At the same time, despite the obvious advantages, heat pump technologies have not yet found proper distribution in Ukraine[43].

Clause 31 of Directive 2009/28/EC of the European Parliament and of the Council of April 23, 2009 on the promotion of the use of energy produced from renewable sources and which amends and subsequently repeals Directives 2001/77/EC and 2003/30/EC, it is informed that heat pumps that allow the use of aerothermal, geothermal or hydrothermal thermal energy at the appropriate temperature level require electricity or any other auxiliary energy for their operation. Therefore, the energy used to operate heat pumps must be deducted from the total heat energy used. Only heat pumps should be taken into account, the performance of which significantly exceeds the amount of primary energy resources required for their operation[44].

Regarding the Law of Ukraine "On the Electric Energy Market" dated April 13, 2017[45], there are certain inconsistencies with the Law of Ukraine "On Alternative Energy Sources". The fact is that the Law of Ukraine "On the Electric Energy Market" does not include such types of energy as hydrothermal and aerothermal, which creates a certain legal conflict. In the Law of Ukraine "On Energy Lands and the Legal Regime of Special Zones

[42] Директива Європейського Парламенту і Ради 2010/31/ЄС від 19 травня 2010 р.про енергетичні характеристики будівель (нова редакція). *Офіційний вісник Європейського Союзу.* 2010. L 153. стор. 13.

[43] Платонова Є. О. Правові аспекти використання енергії довкілля України в умовах євроінтеграції. *Європейський вибір України, розвиток науки та національна безпека в реаліях масштабної військової агресії та глобальних викликів XXI століття (до 25-річчя Національного університету "Одеська юридична академія" та 175-річчя Одеської школи права):* у 2 т.: матеріали Міжнар. наук.-практ. конф. (м. Одеса, 17 червня 2022 р.) / за заг. ред. С. В. Ківалова. Одеса: Видавничий дім "Гельветика", 2022. Т. 1. С. 644 – 647.

[44] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/ EC. *Official Journal*. 05.06.2009. L 140.

[45] Про ринок електричної енергії: Закон України від 13 квітня 2017 року. *Офіційний вісник України*. 2017. № 49. Ст. 1506.

of Energy Facilities" dated July 9, 2010[46] there is a mention of geothermal, hydrothermal and aerothermal energy, in particular in Art. 14 provides that alternative energy facilities using renewable energy sources (solar, wind, aerothermal, geothermal, hydrothermal, energy waves and tides, hydropower, biomass energy, gas from organic waste, gas from sewage treatment plants, biogas), regardless of the purpose of such land plots. In addition, in Art. 7 established that the land of energy-generating enterprises includes land plots provided for the location, construction and operation of facilities for the production of electric and thermal energy – nuclear installations and facilities intended for the management of radioactive waste, thermal power plants, thermal power plants, hydroelectric power plants, hydroelectric power plants, wind power plants, power plants using solar energy, geothermal power plants, bioelectric power plants and power plants using other renewable sources of electricity. It can be determined that the legislator includes aerothermal and hydrothermal energy as other renewable sources of electricity generation.

As the scientist M. M. Zaveriukha defines, despite these problems, hydrothermal, geothermal and aerothermal energy has the potential to play a significant role in the transition to a more sustainable and low-carbon energy system. Thanks to the development of technology and a better understanding of the environmental impact of the development of these types of energy, the importance of these renewable energy sources is likely to continue to increase in the coming years[47].

6.3. Legal regulation of hydrogen energy

Climate security is a rather complex category that depends on many factors, in particular, the achievement of climate neutrality throughout the world. Most of the leading countries declared their intentions in this direction, and the most successful in turning the slogan into reality were such leaders as the USA, EU countries, Latin America, China, Japan, and South Korea. The economic activity of these countries is already today characterized by the introduction of new methods and technologies, re-equipment and modernization of production, reduction of negative emissions into the atmosphere in order to prevent its pollution and the occurrence of inevitable consequences. This is largely facilitated by the

[46] Про землі енергетики та правовий режим спеціальних зон енергетичних об'єктів : Закон України від 09 липня 2010 року. *Відомості Верховної Ради України.* 2011. № 1. Ст. 1.

[47] Заверюха М. М. Енергія довкілля як джерело відновлюваної енергетики: правовий розріз питання. *Юридичний науковий електронний журнал.* 2023. № 7. С. 206–209.

transition and comprehensive use of alternative energy sources, in particular, hydrogen in various spheres of social life.

The process of decarbonization of industry, transport, utilities and construction in many developed countries has become possible thanks to the use of hydrogen as an energy source. Experts of the Council on hydrogen technologies (Hydrogen Council) in their recent report claim that "by 2050, hydrogen will be needed for 18% of all energy needs of the world. According to other forecasts, by this time world hydrogen consumption will grow to 370 million tons per year (by 2100 – up to 800 million tons)"[48].

Depending on the variety, hydrogen is characterized by different degrees of environmental friendliness. There are the following types of hydrogen:

– "green" hydrogen is seen as the biggest contributor to global decarbonization. It is obtained from completely ecologically neutral sources: water transformed thanks to alternative energy sources. The main lobbyist for green hydrogen in Europe is considered to be Germany, which has already abandoned nuclear energy and plans to abandon fossil fuels by 2045;

– "black" or "brown" hydrogen – produced on coal, that is, a fossil fuel that harms the environment, accelerates inevitable changes in the surrounding natural environment and gradually recedes into the past;

– "pink" hydrogen, which is produced from nuclear electricity;

– "grey" hydrogen is obtained from natural gas. It is used in more than 90% of the world's production, but it leads to significant emissions of carbon dioxide, which is considered responsible for global warming. Such hydrogen is relatively cheap compared to "green";

– "blue" hydrogen is produced from gas, but CO2 emissions are disposed of. The production of "blue" hydrogen is supported by Norway and the Netherlands[49].

By the end of 2019, the world consumed 75 million tons of hydrogen, mainly in oil refining and ammonia production. More than 3/4 of them are produced from natural gas, for which more than 205 billion cubic meters of blue fuel were consumed. Almost all other hydrogen was obtained from coal. And only 0.1% (100,000 tons) was produced without the use of fossil hydrocarbons. However, in 2020, the total capacity of newly launched electrolyzes for the production of hydrogen on the planet immediately increased several times, although it still amounts to a still insignificant 120 MW of capacity worldwide. However, a real breakthrough may occur in the

[48] Перспективи використання водню та роль України в Європейській водневій енергетичній революції. URL: http://www.atomforum.org.ua/publications/articles/2020/perspektivi_vikoristannya_vodnyu_ta_rol_ukrayini_v_yevropejskij_vodnevij_energetichnij_revolyuciyi (дата звернення: 01.07.2023 року)

[49] Воднева енергетика в Україні : веб-сайт. URL:https://saee.gov.ua/sites/default/files/3_Repkin_24_11_2020.pdf (дата звернення: 01.07.2023 року)

coming years. For comparison: Germany alone plans to build 3 to 10 GW of electrolyzes by 2030. It is planned that this will reduce Europe's dependence on fossil energy sources, reduce the level of carbon dioxide emissions into the atmosphere by 50% and significantly reduce the cost of fuel and energy carriers[50].

The advantages of hydrogen energy on the global energy market today include the following factors:

– hydrogen can be produced from ordinary water by electrolysis, electricity for which is also taken from alternative sources: wind, sun, biomass. This makes such an energy resource completely ecologically neutral;

– hydrogen can be used as a means of storing excess electricity produced from renewable media when its availability exceeds demand. For example, with the help of hydrogen, energy is accumulated and stored, which due to certain circumstances is not consumed in full. Instead, it is processed into hydrogen, which can be stored for years in salt caves or gas storage, just as natural gas is currently stored. And when energy from renewable sources is not enough, this hydrogen is used either to produce electricity or as gas.

The use of hydrogen, in addition to its positive aspects, also has its drawbacks:

– hydrogen is much more explosive than natural gas. In addition, it very easily penetrates metals, destroying them. Hence the problems associated with transportation, and hence the additional costs of the infrastructure, which must be in perfect condition to be used for such purposes;

– the cost of hydrogen is the second problem of this alternative energy source. Experts point out that even the cheapest hydrogen produced in the standard way using the cheapest electrolysis technology will still be more expensive than current market prices for fossil sources. However, over time, technologies will not only develop, but also become cheaper, reducing the cost of alternative energy sources.

With the aim of turning Europe into a climate-neutral continent, improving the welfare of citizens, protecting biological diversity, and greening the economy, on December 11, 2019, the European Green Deal was announced in the EU, which is a set of political initiatives put forward by the European Commission. This document envisages reducing

[50] Перспективи використання водню та роль України в Європейській водневій енергетичній революції. URL: http://www.atomforum.org.ua/publications/articles/2020/perspektivi_vikoristannya_vodnyu_ta_rol_ukrayini_v_yevropejskij_vodnevij_energetichnij_revolyuciyi (дата звернення: 01.07.2023 року)

greenhouse gas emissions by at least 50% by 2030 and up to 55% compared to 1990 levels. The plan is to review each existing law regarding its climate benefits, as well as to introduce new legislation that would facilitate and stimulate the implementation of these transformations and innovations. Unlike a similar set of initiatives introduced in the US and designed to last 10 years, the EU intends to reach net zero within three decades. However, in scientist K.M. Karakhanian opinion, the European Green Deal is not so much about climate policy as it is about the green concept of economic modernization and economic growth, stimulation to ensure human life in harmony with the planet and its resources[51].

This concept of "green" transition was reflected in the adoption of national hydrogen strategies in many leading countries of the world, and on July 8, 2020, a single document was adopted at the EU level. *The European hydrogen strategy* for a climate-neutral Europe is designed to ensure energy efficiency in production and consumption, as well as to contribute to the decarbonization of the latter. An important part of the European energy policy is international cooperation. The EU intends to develop cooperation on renewable electricity and clean hydrogen with neighboring countries and regions to support their clean energy transition and sustainable development. Taking into account the natural resources, interconnectedness of the infrastructure and technological development, the countries of the Eastern and Southern Partnership are named as priority partners of the EU in this case, and Ukraine is named separately. According to the estimates of the European Commission, by 2030 it will be possible to install electrolyzes for the production of hydrogen with a total capacity of 40 GW in the countries of the Eastern and Southern Partnership. It is important that this hydrogen must be produced from renewable energy sources, that is, it must be "green".

The development of hydrogen technologies in Ukraine is an integral component of energy independence, which acts as a guarantee of the state's national security. First of all, Ukraine joins the efforts of the EU regarding this initiative by implementing the principles of sustainable development, reducing greenhouse gas emissions, increasing the use of alternative energy sources, preserving natural ecosystems, protecting the health and well-being of citizens from the consequences of climate change, reducing the production and consumption of energy-intensive products, ensuring the competitiveness of Ukrainian manufacturers and enterprises.

[51] Караханян К. М., Заверюха М. М. Міжнародно-правові аспекти розвитку водневої енергетики та місце України в цьому процесі. *Дніпровський науковий часопис публічного управління, психології, права". 2*022. № 5. С. 72–76.

The European Hydrogen Strategy envisages that every fourth hydrogen generation outside the EU will be produced by Ukraine. At the same time, the European Commission clearly stated that our country is not going to be turned into a commodity appendage as a producer and supplier of "green" hydrogen. The EU is ready to contribute financially and organizationally to the creation of the internal market so that innovative technologies are integrated into the national economy and industry. Thus, in order to enter the European market, Ukraine must provide conditions for the use of hydrogen in transport, in the metallurgical and chemical industries. Germany should provide key assistance in this direction. The two countries signed the "Joint Statement on the Start of Energy Partnership", which will include, in particular, cooperation in the field of hydrogen supplies from Ukraine to Germany, as well as the construction of hydrogen production capacities at Ukrainian hydroelectric power stations.

The main directions of such production are three colors of hydrogen: "blue" from natural gas, "green" from renewable energy sources, and "pink" from nuclear energy. In addition, the export of hydrogen is possible thanks to the use of the national gas transportation system for its transportation to Europe. Therefore, the conversion of the gas transportation network and hydrogen storage facilities will allow Ukraine to maintain its importance as a transit country of energy resources in the 21st century.

The European Green Course creates a wide space for mutually beneficial synchronization of Ukrainian policy and legislation with relevant EU legislation, as well as cooperation between Ukraine and the EU in key areas of the energy complex. "Hydrogen, as an ecologically clean source of energy, has a chance to achieve not only climate neutrality, but also to ensure the growth of our country's economy, get rid of energy dependence and be a worthy player on the international stage. As experts note, hydrogen energy in the world is a large competitive market with a geopolitical component[52].

Since 2020, the Government of Ukraine, with the support of the United Nations Economic Commission for Europe, has been working on the Road map for the development of the domestic hydrogen market, as well as the preparation of the Concept of Hydrogen Energy and legislation for the effective functioning of the latter. Our country actively participated in the use of alternative energy and began to modernize its own industries, paying significant attention to hydrogen energy. In 2021, the Ministry of Energy of

[52] Воднева енергетика – можливість для України стати потужним гравцем на міжнародній енергетичній арені. URL: https://www.kmu.gov.ua/news/vodneva-energetika-mozhlivist-dlya-ukrayini-stati-potuzhnim-gravcem-namizhnarodnij-energetichnij-areni. (дата звернення: 01.07.2023 року)

Ukraine developed a project of the Road map for the production and use of hydrogen in Ukraine, which was intended to become the basis for the development of the Hydrogen Strategy of Ukraine and to promote the creation of hydrogen energy as a new energy subsector of the country. The latter, through the implementation of the latest technologies, the creation of domestic scientific, scientific and technical, technological and production infrastructure, will gradually provide a significant share of the needs of the energy and transport industries of Ukraine in environmentally clean energy.

The road map for the production and use of hydrogen envisages the concept of using hydrogen in the energy, transport, and industrial sectors of the economy. In addition, three stages of formation of the specified industry are defined. In the short term, it is predicted to transport hydrogen in a gaseous state in tanks – with the help of trucks. In the medium-term "horizon" – the transportation of liquid hydrogen by railways and water transport (in particular, along the Danube River, which can be a source of fresh water for electrolysis). And in the long term, the use of gas pipeline infrastructure for transporting synthetic gas in large volumes, including for export [53].

A detailed analysis of the document shows that, despite all its positive and progressive achievements, the Road map does not contain a specific plan, detailed budget and investment calculations, technological documentation, or even more technical standards and regulations. It is more like a "declaration of cooperation", which should be detailed both in regulations and in technical and estimate documents. Another shortcoming of this act is that it does not take into account a complex set of negative factors that may make it impossible to implement hydrogen energy in our country within the next 10 (if not 20) years. Among the latter, the following can be named:

– the high cost of production, which is that while emphasizing the positive environmental effect of hydrogen, at the same time, we should not forget that from an economic point of view, this segment is currently too expensive. Hydrogen energy requires significant financial infusions and currently appears to be a loss-making sector compared to other alternative energy carriers, not to mention fossil sources;

– in order for hydrogen to truly be an ecological energy resource, it must be produced by electrolysis using renewable energy sources. However, the most important problem in this context is the lack of large capacities of renewable energy and places for the accumulation and storage of hydrogen

[53] Граждан О. Воднева енергетика: чому про неї так багато говорять і до чого тут Україна. URL: https://ucap.io/vodneva-energetyka-chomu-pro-neyi-tak-bagato-govoryat-i-do-chogo-tut-ukrayina/ (дата звернення: 01.07.2023 року)

energy. In Ukraine, the role of maneuverable capacities is performed by coal-fired thermal power plants, which, according to statistics, are the biggest polluters of the environment. Therefore, under such circumstances, the production of "green" hydrogen is hardly justified and realistic;

– even "environmentally clean" electrolysis technology for energy hydrogen production is associated with significant emissions of carbon dioxide, which will only worsen the environmental situation. Thus, the development of hydrogen energy is impossible without the introduction of effective carbon utilization or processing technologies. At present, methods of injecting carbon dioxide "underground" are used abroad (so far on a limited scale) – in particular, to wells left over from oil and gas extraction, saline and coal layers that have lost their industrial value. There is another way: using carbon dioxide as a raw material for obtaining useful oxygen-containing compounds. However, the widespread use of this technology, again, requires strong investments, which are currently insufficient;

– the unsatisfactory condition of the gas transportation system, which should be used for the transportation of energetic hydrogen. European experience shows that such objects can function normally only if they are in proper technical condition, because due to volatility and low atomic mass, hydrogen slips through the smallest cracks and is explosive[54].

With the aim of developing hydrogen energy on a par with EU countries, using the existing gas transportation system, determining the logistics capabilities of the country, as well as supplying energy produced from hydrogen to industrial and household consumers in 2021, the process of preparing the Hydrogen Strategy of Ukraine was started. This document was supposed to become the basis for achieving energy independence of the country and international cooperation, especially with the USA.

In December 2021, the presentation of the country's Hydrogen Strategy project took place: "Hydrogen Country. Energy revolution", the authors of which were the Ukrainian Hydrogen Council and the Institute of Renewable Energy of the National Academy of Sciences of Ukraine. This document contains a complete list of measures that are necessary for the green transformation of the country. In addition, it is emphasized that the production and export of hydrogen will contribute to the attraction of investments in the national energy, industry and transport sector. At the same time, the State budget will be able to receive considerable revenues, and Ukrainians – thousands of new jobs. The immediate goal of the

[54] Тітамир О. Воднева енергетика в Україні: лише на рівні розмов, а чи реально? URL : https://www.ukrinform.ua/rubric-economy/3315760-vodneva-energetika-v-ukraini-lise-na-rivni-rozmov-a-ci-realno.html (дата звернення: 01.07.2023 року)

Hydrogen Strategy of Ukraine should also be the development of a regulatory framework for the regulation of the hydrogen energy sector, as well as the transformation of Ukraine into a leader in hydrogen technologies by 2030, and into a hydrogen hub of Europe by 2050[55].

From February 24, 2022, due to the military aggression of the Russian Federation against Ukraine, the implementation of the specified projects and plans was temporarily suspended. The primary task of the post-war reconstruction of the country should be energy security, where "green" transformation will be a priority direction. In addition, the energy sector should develop on European principles and values, priority among which is the preservation of the natural environment and sustainable development of society, including through the use of hydrogen technologies. The final revision and adoption of the Hydrogen Strategy of Ukraine should determine the ways of development of hydrogen technologies and the corresponding infrastructure in all spheres of the economy, outline plans and sources of financing in the following directions. According to scientists, the mandatory components of the Strategy should be:

1) the issue of the volume of hydrogen production in Ukraine for the needs of the domestic market and export;

2) criteria for the development of hydrogen energy infrastructure (production of own electrolyzers and other equipment);

3) development of the hydrogen accumulation, storage and transportation system (use of the gas transportation system, construction of gas holders, etc.);

4) conversion of municipal transport to hydrogen (production of fuel cells);

5) application of hydrogen technologies in the field of heavy industry.

An important aspect of the development of the national hydrogen market is the inclusion of this area in the list of National programs of the project of the Recovery Plan of Ukraine, on which the post-war reconstruction process will be based. The volume of future investments in the national program "Energy Independence and Green Course" is currently estimated at 130 billion dollars. In particular, it envisages increasing the power of "green" energy by 3 times – up to 30 GW. In addition, 15 GW of electrolysis

[55] До 2050 року Україна стане водневим хабом Європи: презентовано Водневу стратегію України. URL: https://hydrogen.ua/ua/novyny/1519-do-2050-roku-ukrajina-stane-vodnevim-khabom-evropi-prezentovano-vodnevu-strategiyu-ukrajini#:~:text=Найближчою%20метою%20Водневої%20стратегії%20України,початок%(дата звернення: 01.07.2023 року)

capacity for the production of “green” hydrogen will be built, and hydrogen transport infrastructure will be tested and expanded[56].

Ukraine’s participation in the transition to hydrogen technologies will give the country a chance to rebuild the destroyed energy system, for which renewable generation and the attraction of new investments are important. In January 2023, the Vice-President of the European Commission, Frans Timmermans, together with the country’s top political leadership, discussed the energy sustainability of Ukraine and agreed that its post-war reconstruction should be based on the principles of the European Green Deal, as it has high indicators of alternative energy that can be used to reduce European dependence from Russian fossil fuels. During the meeting, clear rules for the production of hydrogen as a leading “green” energy carrier were discussed. Together with representatives of the hydrogen and energy sectors of Europe, the “Timmermans Recovery Plan” was developed[57]. This Plan will help rebuild Ukraine with an emphasis on its renewable energy sources and ability to become a major player in the hydrogen sector. The plan includes the following issues:

a) post-war restoration of Ukraine’s energy infrastructure;

b) production of hydrogen from alternative sources and ammonia, the reserves of which are available on the territory of the state;

c) storage and transportation of hydrogen intended to meet EU needs;

d) development of national sectors of the economy, in particular, transport, industry, which are adjacent to the energy sector;

e) involvement of Ukraine in large investment “green” projects as an equal player.

In February 2023, Ukraine and the EU signed a Memorandum of Strategic Partnership in the field of renewable gases. The last ones are hydrogen and biomethane. Thanks to the Memorandum, Ukraine can become a key supplier of hydrogen for Europe and thereby improve its economic situation and ensure its energy independence. As experts note, “the great war and the lack of a legislative basis should have completely stopped the introduction of hydrogen technologies in Ukraine. Instead, Ukrainian business continues to persistently put hydrogen facilities on the country’s energy map”[58].

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[56] Проєкти нацпрограми. URL: https://recovery.gov.ua/project/program/energy-independence-and-green-deal (дата звернення: 01.07.2023 року)

[57] План Тіммерманса по відбудові України. URL: https://hydrogen.ua/ua/novyny/1646-plan-timmermansa-po-vidbudovi-ukrajini (дата звернення: 01.07.2023 року)

[58] Рєпкін О. Україна увійшла до світової системи водневих долин. URL: https://www.epravda.com.ua/columns/2023/06/8/700973/(дата звернення: 01.07.2023 року)

6.4. European hydrogen strategy: definition, tasks, institutions for implementation

The use of fossil fuels causes up to 73% of all greenhouse gases in the world to enter the atmosphere. The energy and transport sectors, which operate mainly on coal, gas and oil, are priorities for reform. Therefore, the fulfillment of the objectives of the European Green Course will be facilitated by an increase in the share of renewable energy sources, as well as the production of new generation energy carriers with their help, in particular, hydrogen. Hydrogen is expected to transform the economy in four major application areas: transportation, industry, energy, and utilities. This includes industrial hydrogen production, storage, transportation and power supply, clean energy for buildings, and heating and cooling.

This concept was reflected in the adoption of national hydrogen strategies: in Japan (2017), South Korea (2019), New Zealand (2019), Australia (2019), the Netherlands (2020), Norway (2020), Portugal (2020), Germany (2020), France (2020), and on July 8, 2020, a single document was adopted for the entire EU – the European Hydrogen Strategy or, as it is also called, the Hydrogen Strategy for a Climate Neutral Europe.

The purpose of this document is to initiate a new technological revolution in Europe. The main priority of the Strategy is promoting the use of "green" renewable hydrogen, decarbonization of production, as well as supporting the European industry in the construction of capacities for the production of the latter. It is planned to replace carbon-based energy carriers and by 2050 to turn Europe into the first continent where emissions of greenhouse gases into the atmosphere will not exceed the volume absorbed by the ecosystem.

The strategy contains a road map that provides for three phases of the transition to full-scale production and use of pure hydrogen:

– 2020-2024: it is planned to install pure hydrogen electrolyzes with a capacity of 6 GW and produce 1 million tons of hydrogen; carry out decarbonization of existing hydrogen production from fossil sources;

– 2025-2030: hydrogen should become an integral part of the integrated energy system, there will be a need for its long-distance transmission; the installed capacity of pure hydrogen electrolyzes should reach 40 GW, and its production should reach 10 million tons;

– 2030-2050: pure hydrogen should become a self-sufficient and widespread energy carrier, which should be combined with significant development of renewable sources of electricity.

At the first stage of the implementation of the Strategy in the EU, the European Clean Hydrogen Alliance was created, which includes government bodies, public agencies, research centers, financial institutions,

leading European energy and industrial companies, and public organizations. The purpose of the Alliance's action is the implementation of the European Hydrogen Strategy, as well as the discussion of investments in the infrastructure of the hydrogen economy throughout Europe, the volume of which may reach 430 billion euros by 2030. In 2021, Ukraine joined the European Pure Hydrogen Alliance.

In addition to the road map, the Strategy contains the following tasks:

– promoting investments in the hydrogen sphere, in particular, through the use of funds from the EU and the European Clean Hydrogen Alliance (only in the field of hydrogen production, the expected need for investments is 180-470 billion euros by 2050);

– support for the production and consumption of pure hydrogen, including transportation and final consumption (oil refining, steel, ammonia, truck and rail transport, synthetic fuels);

– standardization and certification;

– development of infrastructure (networks) and market rules for pure hydrogen;

– promotion of research and innovation;

– international energy cooperation, in particular, with Ukraine.

It is international cooperation that is designed to ensure the implementation of the Strategy, since the production of only half of the required volume of hydrogen is planned in the EU countries, the rest must be imported to Europe, including from Ukraine. According to the estimates of the same Institute of Renewable Energy of the National Academy of Sciences, our state has the potential to produce more than 500 billion cubic meters of "green" hydrogen per year. This should be enough for both domestic needs and exports.