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ROADMAP FOR BIOENERGY DEVELOPMENT IN UKRAINE UNTIL 2050

The present position paper №26 of the Bioenergy Association of Ukraine belongs to the planned series of publications on the main issues of bioenergy development in Ukraine.

UABIO Position Paper presents the Roadmap for the development of bioenergy in Ukraine until 2050. The need for such a document is justified by absence of an action plan to achieve the goals for bioenergy development until 2035 set by the current Energy Strategy of Ukraine, by lack of long-term goals and guidelines for the bioenergy sector, as well as by possibility of using the materials elaborated when preparing the Roadmap for the development of other strategic documents. Next step seems to be the detailing and expansion of the Roadmap to the level of the Strategy for bioenergy development in Ukraine until 2050.

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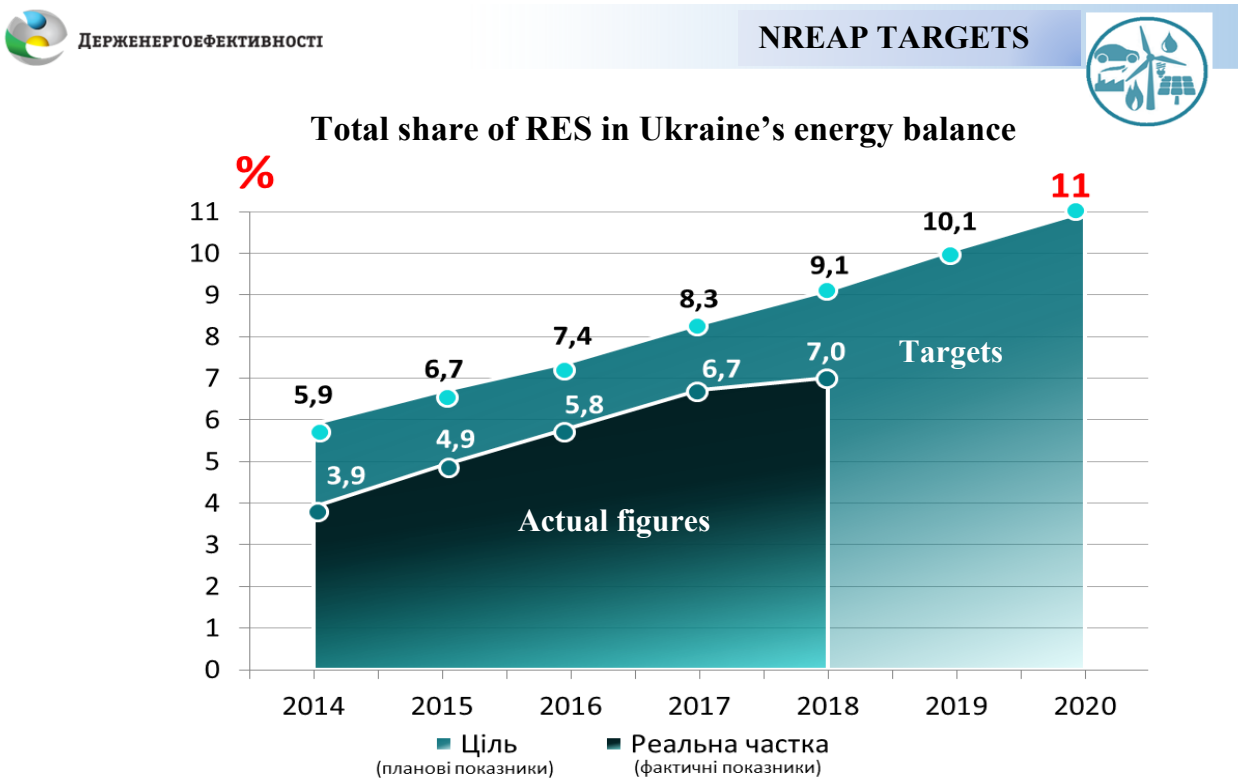
1. Current state of bioenergy development in Ukraine and targets until 2035

Renewable energy sources are playing an increasing role in Ukraine's energy sector. According to the Energy Balance for 2018, the amount of renewable energy in the final energy consumption was **3582** ktoe, which is equivalent to **7.0%** of the total final energy consumption (**Fig. 1.1**). Of these, the largest contribution is made by bioenergy – **77.3%.**



Notes: The shares are calculated according to requirements of Directive 2009/28/EC

Fig. 1.1. RES share in Ukraine's final energy consumption and their comparison with NREAP[1] targets (SAEE's data)

In Ukraine, there has been a steady trend of increasing energy production from alternative fuels, in particular, from biomass. According to the Energy Balance of Ukraine for 2018, the total supply of primary energy from biofuels and waste amounted to **3195** ktoe (**Fig. 1.2**), which is equivalent to the replacement of **4 bln m^3/yr** of natural gas. The share of biofuels in the total supply of primary energy is **3.4%** (over **70%** of the total supply of renewable energy). The growth of the sector in 2010-2018 averaged **31%** per year.

[1] National Renewable Energy Action Plan until 2020. Approved by CMU Resolution N 902-p of 01.10.2014 https://zakon.rada.gov.ua/laws/show/902-2014-%D1%80

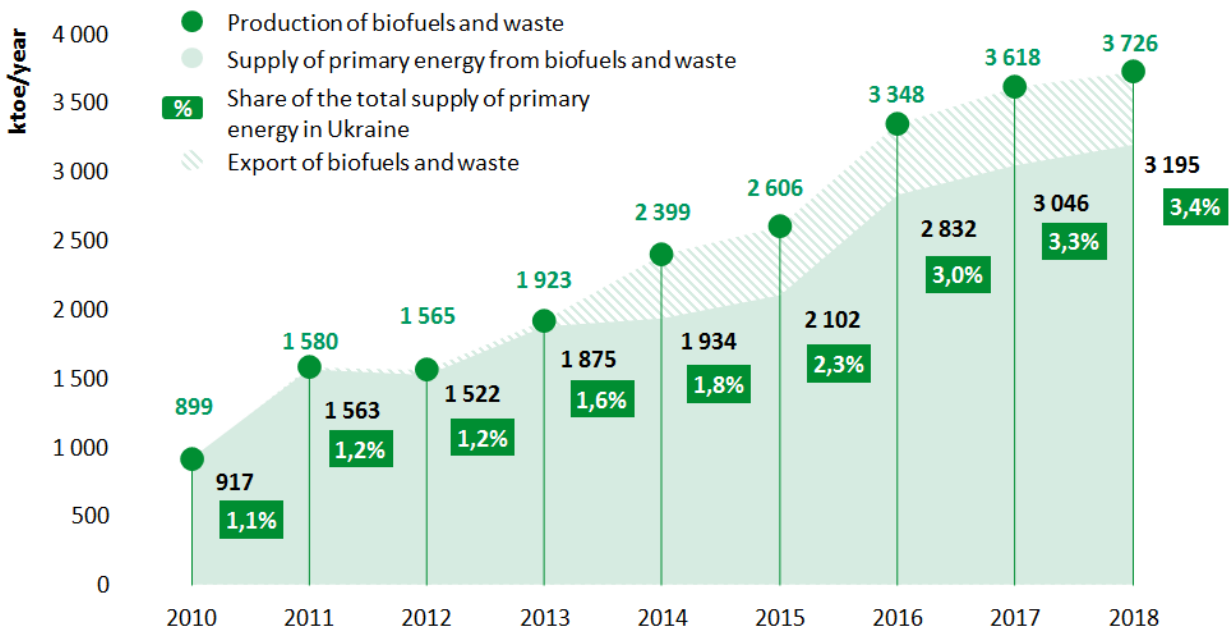


Fig. 1.2. Production and consumption of biofuels in Ukraine in 2010-2018 according to the Energy Balances issued by the State Statistics Service of Ukraine

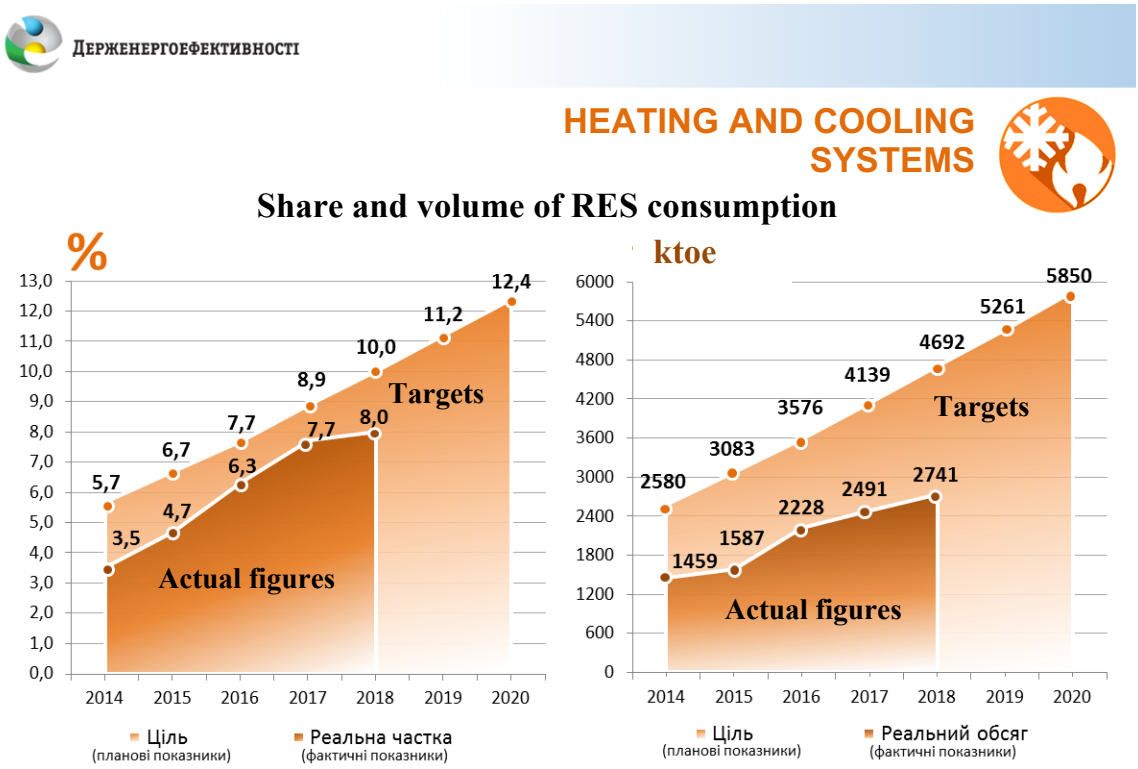
According to the current Energy Strategy of Ukraine until 2035[2], the contribution of biomass, biofuels and waste to the total supply of primary energy in 2035 should be **11** Mtoe, which is **50%** of the contribution of all RES (**Table 1.1**).

Table 1.1. Structure of the total supply of primary energy in Ukraine, Mtoe[2]

Type of sources	**2015 (fact)**	**2020 (forecast)**	**2025 (forecast)**	**2030 (forecast)**	**2035 (forecast)**
Coal	27.3	18	14	13	12
Natural gas	26.1	24.3	27	28	29
Oil products	10.5	9.5	8	7.5	7
Nuclear energy	23	24	28	27	24
Biomass, biofuels and waste	**2.1**	**4**	**6**	**8**	**11**
Solar and wind energy	0.1	1	2	5	10
Hydro power plants	0.5	1	1	1	1
Thermal ambient energy and waste energy	0.5	0.5	1	1.5	2
TOTAL, Mtoe	**90.1**	**82.3**	**87**	**91**	**96**

[2] CMU's Resolution on approval of the Energy Strategy of Ukraine until 2035 "Security, Efficiency, Competitiveness" (N 605-p of 18.08.2017) https://zakon.rada.gov.ua/laws/show/605-2017-%D1%80

Traditionally, bioenergy has played the most important role in heat production and made there the largest contribution among all the renewables: up to 80-90%. In 2018, the share of RES in heating systems was **8%** (**Fig. 1.3**), including **7%** of the total heat production covered at the expense of biomass. Therefore, the goal set in the Concept of implementation of the state policy in heat supply[3] is important for the development of bioenergy: to increase the share of alternative energy sources in heat production to **40%** in 2035.



Notes: The shares are calculated according to requirements of Directive 2009/28/EC

Fig. 1.3. RES share and consumption in heating/cooling systems compared with NREAP1 targets (SAEE's data)

Power production from biomass is underdeveloped in Ukraine as compared to solar and wind energy. Nevertheless, up to 20 CHPPs and TPPs running on wood chips and sunflower husk are in operation; projects of about 30 power plants are on different stages of development (from project idea to designing). In addition, there is a number of biogas cogeneration plants operating on manure, maize silage, sugar beet pulp as well as LFG power plants. Currently, the number of biogas producers in Ukraine comes to about 50 with the total installed capacity of about 100 MW.

Production and consumption of motor biofuels is the least developed sector of Ukraine's bioenergy. At the moment, the production of bioethanol is poorly developed; biodiesel seems not to be produced at all. One can expect the revival of the sector after the adoption of the draft Law of Ukraine

[3] Concept of implementation of the state policy in heat supply. Approved by CMU's Resolution N 569-p of 18.08.2017 https://zakon.rada.gov.ua/laws/show/569-2017-%D1%80

"On Amendments to certain legislative acts of Ukraine regarding the mandatory use of liquid biofuels (biocomponents) in the transport industry[4].

2. Justification of necessity of the Roadmap as a part of the Strategy for bioenergy development until 2050. Relation to other strategic documents

There are several important factors that necessitate the elaboration of a long-term strategy for the development of bioenergy in Ukraine and the Roadmap[5] as its important component.

First, current Ukraine's Energy Strategy sets an ambitious goal of achieving 11 Mtoe of biomass, biofuels and waste in the total supply of primary energy in 2035. However, the Energy Strategy has not been accompanied by a document (a roadmap or an action plan) showing due to what types of biomass/biofuels and technologies, and in which sectors these 11 Mtoe in TPES will be actually reached. It is necessary to understand what types of equipment (boilers, CHP plants, TPPs) of what capacity and in which sectors (heat production, power production, cogeneration, and transport sector) should be introduced to most effectively achieve the goals.

Second, Ukraine has the international commitment to reduce greenhouse gas emissions under the 2015 Paris Climate Agreement, which means to implement so-called nationally determined contributions. At present, this reduction commitment is 40% of 1990 GHG emissions level, which must be achieved by 2030; however it may increase up to about 70% of 1990 GHG emissions level in the coming years. To meet this new target, Ukraine needs to turn to a low-carbon economy, significantly reduce fossil fuels consumption, actively develop energy efficiency and introduce renewable energy sources. According to some preliminary estimates, the share of RES in the energy sector of Ukraine may reach **60%** in 2050, of which more than a half is the contribution of bioenergy. Thus, bioenergy plays a significant role in Ukraine's implementation of its international obligations to reduce greenhouse gas emissions, which also necessitates the elaboration of a long-term strategy for bioenergy development.

The third factor is that equipment of most coal-fired power plants in Ukraine is already on the verge of its physical depreciation, because these power plants were put into operation in the 1960s. In addition, all possible terms of the prolonged operation of Ukrainian NPPs will expire by 2050. The bioenergy development strategy until 2050 will show how biofuels, bioenergy plants and technologies will contribute to replacing the coal/natural gas plants and NPPs that will be decommissioned by 2050.

Thus, Ukraine needs a long-term strategy for the development of bioenergy, which will:

- outline *prospects* for the development of the bioenergy sector until 2050;
- provide an action plan for achieving *the existing goals* for the development of the sector by 2035;
- present the role of bioenergy in fulfilling Ukraine's international commitment *to reduce GHG emissions*;
- show the contribution of bioenergy installations and technologies to the replacement of fossil fuel plants capacities and NPPs capacities that will be decommissioned by 2050.

An important component and the first step towards the preparation of a bioenergy development strategy is ***the Roadmap***, the description of which is the subject of this document.

[4] Draft Law #3356 as of 17.04.2020 http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?pf3511=68617

[5] Definitions of « roadmap» are given in Annex 1.

Materials of the Roadmap can be used in the development of NREAP until 2030 (the current NREAP[1] expires in 2020), as well as a new Energy Strategy of Ukraine with the extension of its coverage period until 2050. Regarding the latter, it should be noted that the National Security and Defense Council of Ukraine decided to ensure the revision of the Energy Strategy of Ukraine until 2035 "Security, Efficiency, Competitiveness"[6]. To implement this decision, the Government of Ukraine has developed a draft ***Concept of Green Energy Transition of Ukraine until 2050 (Ukraine Green Deal)***[7].

3. Analysis of existing scenarios for the development of energy sector of Ukraine until 2050

3.1. Concept of Green Energy Transition of Ukraine until 2050 (Ukraine Green Deal)

In January 2020, the Ministry of Energy and Environmental Protection of Ukraine presented the draft ***Concept of Green Energy Transition of Ukraine until 2050 (Ukraine Green Deal)***[8]. The document is developed taking into account the goals and objectives of the ***European Green Deal***[9], the description of which is presented in the next section.

The concept is aimed at achieving a **climate-neutral economy** of the country by 2070. Some selected main directions of decarbonization of the economy, including the energy sector as its important component, are identified as the following:

- development of RES use in combination with energy efficiency increase;

- reduction to zero consumption of carbon-intensive energy resources and maximization of the use of RES so that the agricultural and forestry sector switched to complete self-provision with energy resources;

- increasing sustainable production of **biomass, biofuels** and other RES to support the implementation of the green transition in other sectors of the economy;

- complete replacement of coal-fired power plants by 2050 due to the development of solar and wind generation, **biomass** power plants in combination with new highly maneuverable generating capacity on gas (in the longer term, on synthetic gas produced using RES);

- orientation of new DH CHP plants primarily to the use of **biomass and biogas**;

- intensification of the large-scale use of RES (**biofuels and waste**, renewable heat and power) in industrial processes to replace carbon-intensive resources.

In addition to achieving a climate-neutral economy by 2070, the Concept of Green Energy Transition also includes such areas as increase of energy efficiency, development of electric transport, circular economy (waste reduction), smart grids, demand management, as well as support for research and innovations (**Fig. 3.1**).

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[6] Resolution of the National Security and Defense Council of Ukraine of 02.12.2019 put into force by Order of President of Ukraine N 874/2019 of 02.12.2019 https://www.president.gov.ua/documents/8742019-30769

[7] Concept of Green Energy Transition of Ukraine until 2050 https://menr.gov.ua/news/34424.html

[8] Concept of Green Energy Transition of Ukraine until 2050, Ministry of Energy and Environmental Protection of Ukraine, 2020. Presentation: https://bit.ly/3edeS9u; text: https://bit.ly/2tR0P7n; https://bit.ly/2wtr8BM

[9] European Green Deal https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

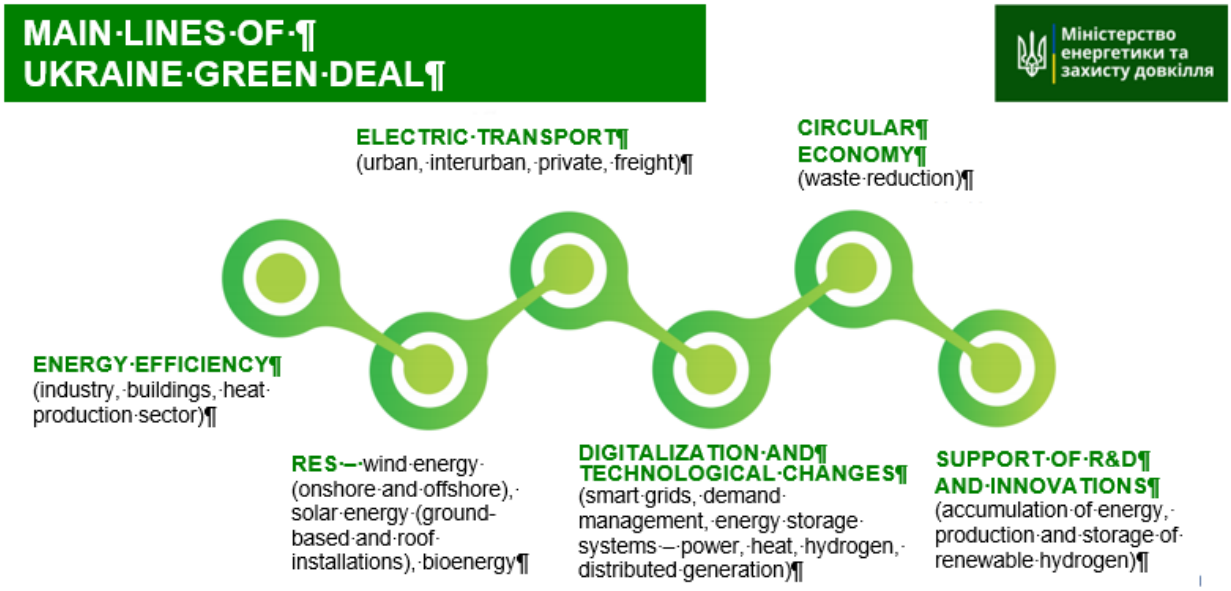

Fig. 3.1. Main directions of Ukraine Green Energy Transition until 2050[8]

3.2. Suggestions of UABIO for improving the Concept of Green Energy Transition of Ukraine until 2050

We fully support the general course of decarbonization of Ukraine's energy sector envisaged by the Concept of Green Energy Transition (Ukraine Green Deal). In general, we consider the presented Concept to be a holistic document, which for the first time at the official level demonstrates the views of Ukrainian Government on green energy transition with an extended horizon of planning until 2070.

Analysis of certain provisions of Ukraine Green Deal shows that it needs further improvement. Relevant ***proposals*** of the Bioenergy Association of Ukraine with their justification are presented below[10] [11].

1) The Concept envisages a complete abandonment of coal-fired power generation by 2050. This is certainly consistent with global trends in coal generation: coal use decreased on average by 2.5% in the world and at least by 20% in OECD countries during 2012-2017[12] (2017 is the last officially available reporting year of the International Energy Agency). According to the Concept, 70% of renewable sources and 20-25% of new NPPs based on the technology of small modular nuclear reactors will be used to replace coal in power generation sector in 2050. As of December 2019, the modular nuclear reactor technology is on research and development (R&D) stage and is not commercial yet. The levelized cost of electricity (LCOE, EUR/MWh) for newly constructed small modular reactor is currently slightly higher than that for newly constructed traditional NPPs, and significantly exceeds the LCOE of any renewable energy sources[13].

Therefore, we believe that the new construction of small modular reactors proposed by the Concept during 2035-2050 and beyond is **economically unjustified**, as electricity from this technology is

[10] UABIO's letter N 480 of 07.022020 on some suggestions regarding the Concept of Ukraine Green Energy Transition until 2050 https://uabio.org/news/7103/

[11] UABIO's letter N 482 of 24.02.2020 on some suggestions regarding the Concept of Ukraine Green Energy Transition until 2050 https://uabio.org/news/7115/

[12] IEA's data https://www.iea.org/sankey/#?c=OECD%20Total&s=Balance

[13] https://www.lazard.com/perspective/lcoe2019

much more expensive than electricity from other types of generation, including renewables. For the forecasting model, we propose to use the latest publicly available data on the LCOE of various technologies, based on operational data of specific implemented projects in different parts of the world[14].

2) The Concept, at least based presentations that accompanied it, provides for the following technologies for balancing the power system with a high share of RES starting from 2050: CHP on biomass, biogas plants, battery energy storage, and electric transport. As of January 2020, these technologies, without a combination with highly maneuverable gas facilities, cannot fully provide the characteristic rate of response (seconds-minutes) to changes in load in certain periods of the day for a power system with a high share of RES. The technology of balancing with highly maneuverable gas facilities is currently the major in such power systems and has the lowest cost of balancing electricity when it works in combination with the technologies specified in the Concept. In addition, in the EU-28 starting from 2012-2013, natural gas for highly maneuverable gas facilities is being actively replaced by biomethane, which is a renewable gas.

Therefore, we consider it necessary **to add** highly maneuverable gas facilities on natural gas and **biomethane** to the list of technologies for balancing the power system with a high share of RES.

3) The concept provides for the use of renewable hydrogen in transport and in industry. This, of course, is in line with global trends in the development of energy sector and transport. However, the Concept does not mention biomethane at all, while it is a renewable gas like hydrogen. Currently, the use of biomethane is growing rapidly, especially in the OECD and EU-28 countries[15], most of which have plans for green transition.

We consider it necessary **to add biomethane** to the list of renewable gases, on a par with hydrogen, and also to determine that both gases will be used in all energy sectors: power production, heat production and transport.

4) The Concept states: "*In the heat supply sector, it is expedient to expand the use of highly efficient cogeneration and trigeneration. New cogeneration units for district heating should focus primarily on the use of biomass and biogas…*». We can agree with this, because cogeneration and trigeneration on biomass are advanced technology for DH systems of the 4th (highest) generation[16]. However, other technologies such as the use of biomass boilers in DH systems are not mentioned. At the same time, biomass boilers are mentioned with regard to their using in local boiler plants and in private buildings, which we support. In a similar manner, we propose to include the use of biomass boilers in district heating systems.

The Concept states: "… *at the level of urban heating systems it is reasonable to switch to decentralized systems with free access of producers to the networks and consider the possibility of electrification of heating systems,…, the use of geothermal energy technologies, heat pumps.*" First, we believe that the Concept should clearly define the tendency to expanding district heating systems, increasing their efficiency and using RES in them. For example, in the EU-28, the main contribution to the

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[14]: LAZARD'S LEVELIZED COST OF ENERGY ANALYIS, v.13.0, November 2019: https://www.lazard.com/media/451086/lazards-levelized-cost-of-energy-version-130-vf.pdf
Renewable Energy statistics by IRENA, 2019: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jul/IRENA_Renewable_energy_statistics_2019.pdf
Power generation renewable energy cost by IRENA, 2018 (based on worldwide implemented projects pool): https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf

[15] IEA's data: https://webstore.iea.org/Content/Images/uploaded/Bioenergy_2017_Annex3.pdf

[16] https://www.sciencedirect.com/science/article/abs/pii/S0360544214002369?via%3Dihub

decarbonisation of the heat supply sector by 2050 is expected through the development of DH systems[17]. To this end, the Concept should include the idea of transition from "district heating systems" to "**efficient** district heating systems" within the meaning of Directive 2012/27/EU[18], as well as the introduction of the principle of "zoning" – defining mandatory zones for DH in settlements. Second, the transition from centralized to decentralized heat supply systems should take place in accordance with certain criteria, for example, at low density of heat load of a settlement or its separate area. With regard to the mentioned free access of heat producers to heat supply networks, which we support, it is consistent with the Concept's principles on the introduction of competition and open markets, as well as with the principles of RED II Directive[19].

In addition, in our opinion, the Concept overestimates the role of electrification in heat supply, as the use of electric boilers for DH requires the construction of additional infrastructure, in particular, new power supply networks to such boiler plants. We suggest a broader look at heat production technologies, namely, to add to the list those already used in efficient heating systems: biomass boilers, heat recovery units, waste heat, production of heat and power from MSW, solar collectors. We also propose to make a clearer distribution of generation types separately for the three main subsectors of heat consumption: individual heating, district heating, and industry.

5) The Concept does not mention liquid biofuels at all, namely, first and second generation bioethanol and second generation biodiesel for transport. Currently, these biofuels are already used in the transport sector, including Ukraine's one (as gasoline and diesel additives). In addition, draft Law on the mandatory use of liquid biofuels (biocomponents) in the transport sector (№ 3356[20] of 17.04.2020) was registered in Ukraine. The draft Law determines obligation on the mandatory share of liquid biofuels (biocomponents) in the volume of automotive gasoline[21] and sustainability criteria for the production of liquid biofuels:

from 01.07.2021 – at least 5% (vol.) at the relative error of ±0,5%;
from 01.07.2022 – at least 6% (vol.), at the relative error of ±0,5%;
from 01.07.2023 – at least 7% (vol.), at the relative error of ±0,5%.

We propose **to add** to the Concept the use of **bioethanol and biodiesel** in transport for the entire planning horizon until 2050.

[17] For example, see detailed analytical material on justification of the dominating role of DH systems development in decarbonization of EU's energy sector until 2050 – Towards a decarbonised heating and cooling sector in Europe by Aalborg University, Denmark in cooperation with Danfoss, Engie, et.all, November 2019: https://vbn.aau.dk/ws/portalfiles/portal/316535596/Towards_a_decarbonised_H_C_sector_in_EU_Final_Report.pdf

[18] Directive 2012/27/EU "On Energy Efficiency": https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0027

[19] Directive RED-II (EU) 2018/2001, 11 Dec 2018: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC

[20] Draft Law on the mandatory use of liquid biofuels (biocomponents) in the transport sector (№ 3356 of 17.04.2020) http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?pf3511=68617

[21] For the purposes of this Law, the normatively determined mandatory share of content of liquid biofuels (biocomponents) in the volume of automobile gasoline means the content of liquid biofuel (biocomponents) in **all volumes of automobile gasoline** released from places of fuel production, places of its wholesale and retail trade, with the exception of gasoline with octane number of 98 and above and gasoline supplied for the needs of the Ministry of Defence, the State Reserve and for the creation of minimum reserves of oil and oil products.

6) We believe that the general course for decarbonization of Ukraine's energy sector envisaged by the Concept is correct and should be based on two main **principles**, which we propose **to include** in the Concept:

- Abolition of any subsidies for fossil fuels and energy obtained from them.
- Introduction of a carbon tax or a similar energy tax on fossil fuels.

7) The concept envisages the use of 70% of RES in electricity generation. However, in Mr. Oleksandr Dyachuk's presentation of 21.02.2020, the figure of 40-45% of RES in TPES in 2050 was also announced.

Yes, the power sector is undoubtedly important, but not the only one that requires decarbonization and transition to RES. **Fig. 3.2** presents structure of the final energy consumption of Ukraine in 2007-2017 divided into three categories: power, heat and cooling, transport (UABIO's calculations). One can see that the heat and cooling sector consumes more than a half of the country's total final energy consumption. The picture is similar in most EU countries. It is obvious that without the decarbonization of this sector, as well as the transport sector, it will not be possible to fulfill general plans of the countries on decarbonization and transition to RES.

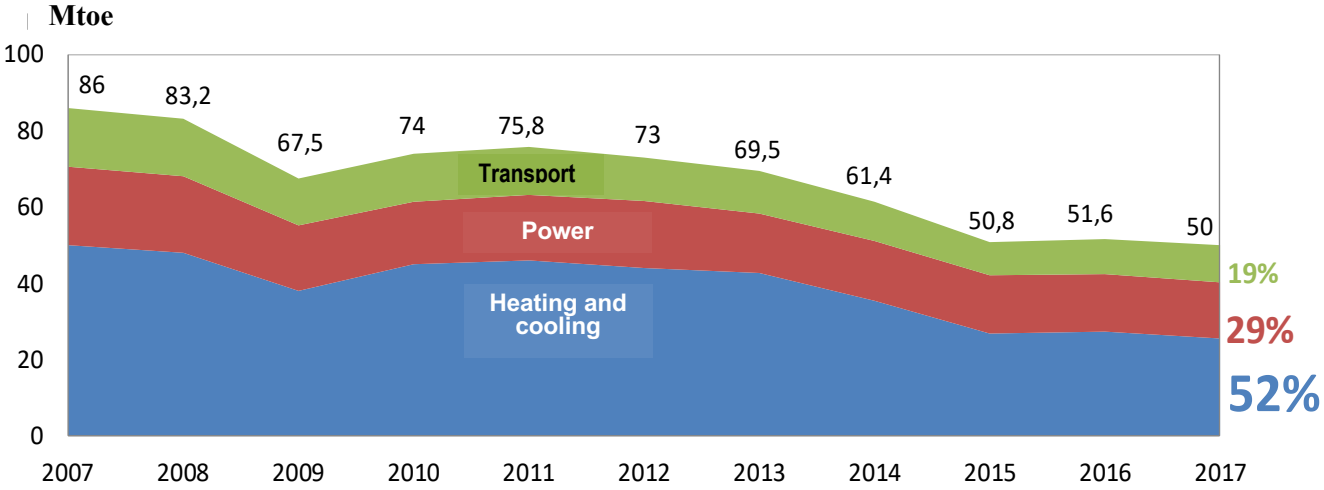
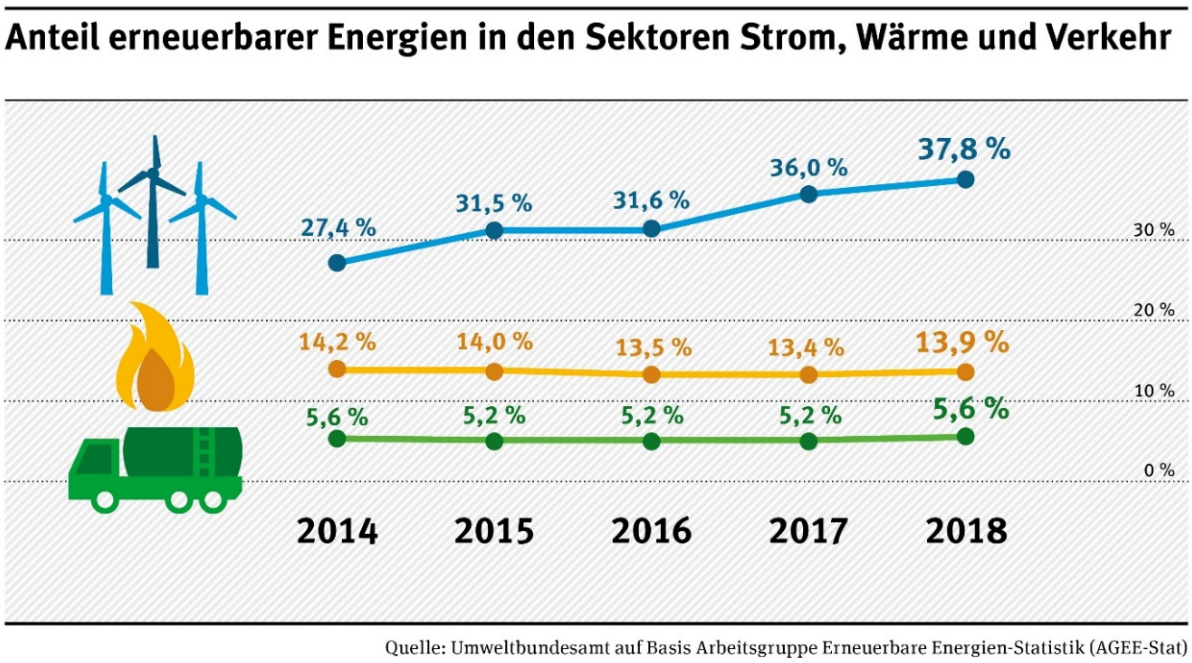


Fig. 3.2. Structure of Ukraine's final energy consumption, 2007-2017[22]

The example of Germany is indicative in this context. The share of RES in Germany's final energy consumption reached 16.6% in 2018, the figures by sectors being: 37.8% of RES in the consumed electricity, 13.9% of RES in the consumed heat and 5.6% of RES in transport (**Fig. 3.3**). One can see obvious trends of the rapid development of renewable electricity at stagnation in renewable heat and transport sectors. As a result, Germany's goal of reducing GHG emissions by 40% in 2020 (as compared to 1990 levels) will not be achieved. In 2018, this figure was only 30.8%. German politicians recognize the need to rectify the situation and accelerate the development of renewable heat and transport sectors.

[22] Estimated by UABIO's experts based on data of Ukraine's Energy Balances.



Notes: The blue line is RES share in power industry, the yellow line is RES share in heating and cooling systems, the green line is RES share in transport.

Fig. 3.3. RES share in the final energy consumption of Germany, 2014-2018

Unfortunately, the shares of RES planned for 2050 in heat production and in transport are not given in the Concept. However, based on the figure of 70% RES in electricity and 40-45% RES in TPES, we can estimate that the Concept envisages up to 40% RES in heat production and up to 10% RES in transport in Ukraine:

70% (RES in power production)×0.29 + 40% (RES in heat production)×0.52 +
10% (RES in transport)×0.19 = 46.9% RES in TPES.

Based on this, the Bioenergy Association of Ukraine has a number of additional ***proposals***:

- We consider 70% of RES in power production to be an ambitious and correct indicator. However, 40-45% of RES in TPES is not at all. Ukraine will have about 10% of RES in TPES in 2020, and then 40% of RES in TPES in 2050 corresponds to the RES growth rate of 1%/yr in the period 2020-2050. This is well below the planned rate of RES growth in the EU, required to achieve CO_2-neutrality in 2050 – more than 2%/yr. We consider the growth rate of 1%/yr to be obviously insufficient for Ukraine.
  Our vision of the target is at least 60% RES in TPES in 2050.
- In our opinion, the target of 40% of RES in heat production in 2050 is unreasonably low. This goal has already been set by the Government as official for this sector by 2035.
  Our vision of the target is at least 65% of RES in heat production in 2050.
- In our opinion, the target of 10% of RES in transport is obviously insufficient.
  Our vision of the target is at least 35% of RES in transport in 2050.
- Based on the figure of 70% of RES in electricity, 65% of RES in heat and 35% of RES in transport, we have obtained **over 60%** of RES in TPES in 2050:

70% (RES in power production) × 0.49 + 65% (RES in heat production) × 0.37 +
35% (RES in transport) × 0.14 = 63% RES in TPES.

- We consider it necessary to include the following indicators for 2050 in the Concept:
  - the share of RES in the power production;
  - the share of RES in the heat production;
  - share of RES in transport;
  - the share of RES in TPES as a whole.

The Bioenergy Association of Ukraine supports the immediate approval of the Concept, provided that the above comments are taken into account. We consider it necessary to develop and approve a new "green" energy strategy for Ukraine until 2050 by the end of 2020.

3.3. Views of Public Union Global 100RE Ukraine

From the point of view of long-term strategic planning of energy and, in particular, renewable energy in Ukraine, the position of the ***Public Union Global 100RE Ukraine***[23], among the founders of which is the Bioenergy Association of Ukraine, is of considerable interest.

Ukraine's energy system is one of the least flexible in the world. It critically lacks maneuverable facilities and energy storages. They should be built urgently. So, there is still a need to form a new generation, and it is important to reasonably determine which one. Energy is a conservative industry. It may take up to ten years to build a power plant. To have a balanced energy system in 2050, it needs to be planned now, and plans must start with a clear strategy[24].

The Paris Agreement sets a goal of keeping the global temperature growth on the Earth within 2°C until 2100. However, according to the expected nationally determined contributions (NDCs) of the signatory countries, GHG emissions from these countries will cause the global temperature rise by 3.5°C until 2100. This poses a challenge for the parties to the Paris Agreement, including Ukraine, to make more ambitious commitments to reduce greenhouse gas emissions. In particular, Ukraine has officially announced a goal to reduce GHG emissions by 40% by 2030 relative to the level of GHG emissions in 1990. However, according to the global target of the Paris Agreement (2°C), assuming that the GHG emissions are proportional to the global temperature change, the announced target should be updated from 40% to 70% in 2030 compared to 1990. Ukraine may have to make such tough commitments in the next climate talks. These commitments will not leave room for coal in the country's energy system.

Ukraine's own coal is expensive and subsidized. No one in the world extracts coal in such deep mines – up to 1 km. The fuel contains a lot of sulfur, which requires the installation of desulfurization systems. Such coal becomes too expensive.

In 2018, Ukraine provided itself with gas by 65% of demand, with oil by 20%, and with coal by 61%. The overall rate of dependence on energy imports, including nuclear fuel, was 51% in 2015. This is a significant risk to the country's energy security. Over $ 17 billion is spent on imported energy resources per year, while these funds can be spent much more efficiently.

According to the International Energy Agency, energy efficiency (40%) and renewable energy sources (30%) will play a key role in preventing the global warming by more than 2°C and achieving the corresponding reduction in CO_2 emissions by 2050. Therefore, the new "green" energy strategy of Ukraine until 2050 should be based on the development of two main directions: reduction of energy resources consumption by increasing energy efficiency, and energy saving along with the use of RES.

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[23] Public Union Global 100RE Ukraine (100 RE UA) https://100re.org.ua/en/structure/

[24] O. Dombrovskyi, G. Geletukha. Ukraine needs new "green" energy strategy (in Ukrainian) https://www.epravda.com.ua/columns/2020/01/3/655486/

Another report by the well-known analytical agency Lazard[25] confirmed the expectations of analysts: renewable energy continues to fall in price. Lazard calculates the cost of electricity production. It includes construction costs and total operating costs for the entire period of operation divided by the amount of energy produced during the entire period of operation of the power plant. Wind energy has the lowest production price of MWh – 28-54 USD. Solar energy occupies the second place with 32-42 USD/MWh, while a coal MWh costs 66-152 USD, and a nuclear MWh costs 118-192 USD.

The vision of PU Global 100RE Ukraine of Ukraine's energy strategy until 2050 is based on the priority development of RES. This is the most appropriate scenario from an economic and environmental point of view. It is possible to achieve 100% RES in the production of power and heat by 2050, and 100% RES in transport and in the whole energy sector by 2070[23] [24]:

- Implementation of Ukraine's green energy transition to **100%** RES: 2020 – 10%, 2030 – 25%, 2040 – 45%, 2050 – 65%, 2060 – 85%, 2070 – 100% (**Fig. 3.4**).
- Reduction of the energy intensity of Ukraine's GDP to the average value of EU countries by 2050.
- Reduction of GHG emissions in Ukraine to **80%** of the level of 1990 by 2050 and to **100%** of the level of 1990 by 2070 (**Fig. 3.5**).
- Refusal of coal by 2050.
- Refusal of nuclear power by 2050.
- Transition to **100%** RES in the production of power and heat by 2050.
- Transition to **100%** RES in transport by 2070.

Several countries are already close to achieving 100% RES: Iceland, Paraguay, Costa Rica, Norway, Nicaragua, and Scotland. A number of countries are already on this path. A total of 53 countries have targets for the transition to 100% RES in certain sectors (mainly in power production). Sweden and Denmark have already approved official energy strategies for the transition to 100% RES in all sectors by 2050. In addition, 247 cities and 33 individual states and regions have also set targets for the transition to 100% RES[26].

An interesting example is Germany where from 2021 they propose to introduce an obligation to transport 1% of renewable and decarbonized gases, including biomethane and green hydrogen, by NG networks, and to increase their share to 10% by 2030. Moreover, it is likely that Germany will import a significant part of these renewable gases, which creates new opportunities for Ukraine.

[25] Levelized Cost of Energy and Levelized Cost of Storage 2019 https://www.lazard.com/perspective/lcoe2019
[26] Звіт IRENA «TOWARDS 100% RENEWABLE ENERGY» (2019 p.)
https://coalition.irena.org/-/media/Files/IRENA/Coalition-for-Action/IRENA_Coalition_100percentRE_2019.pdf

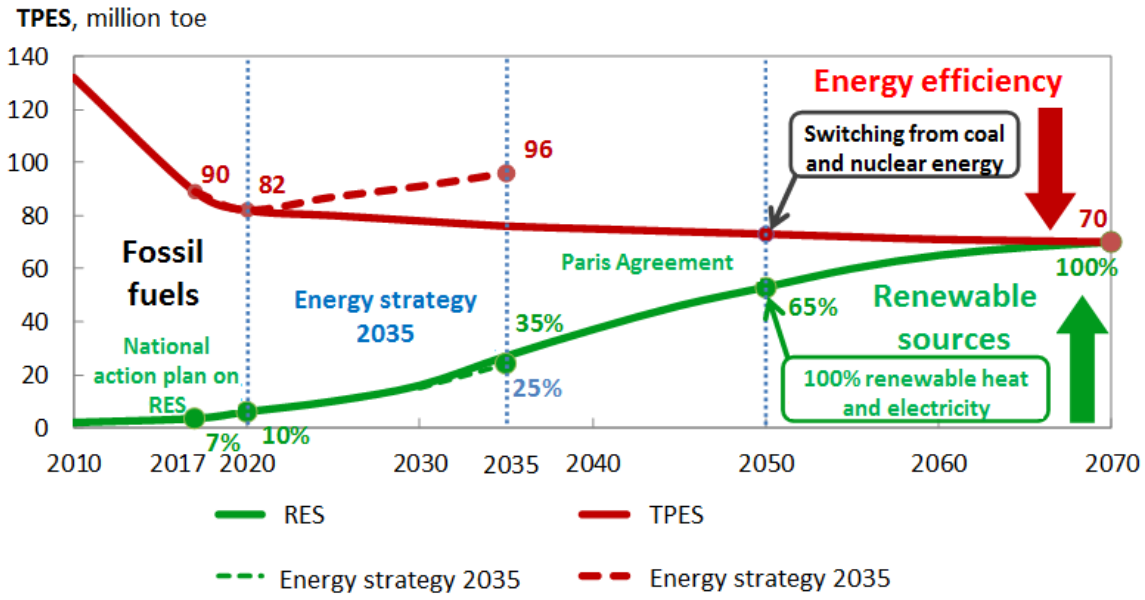
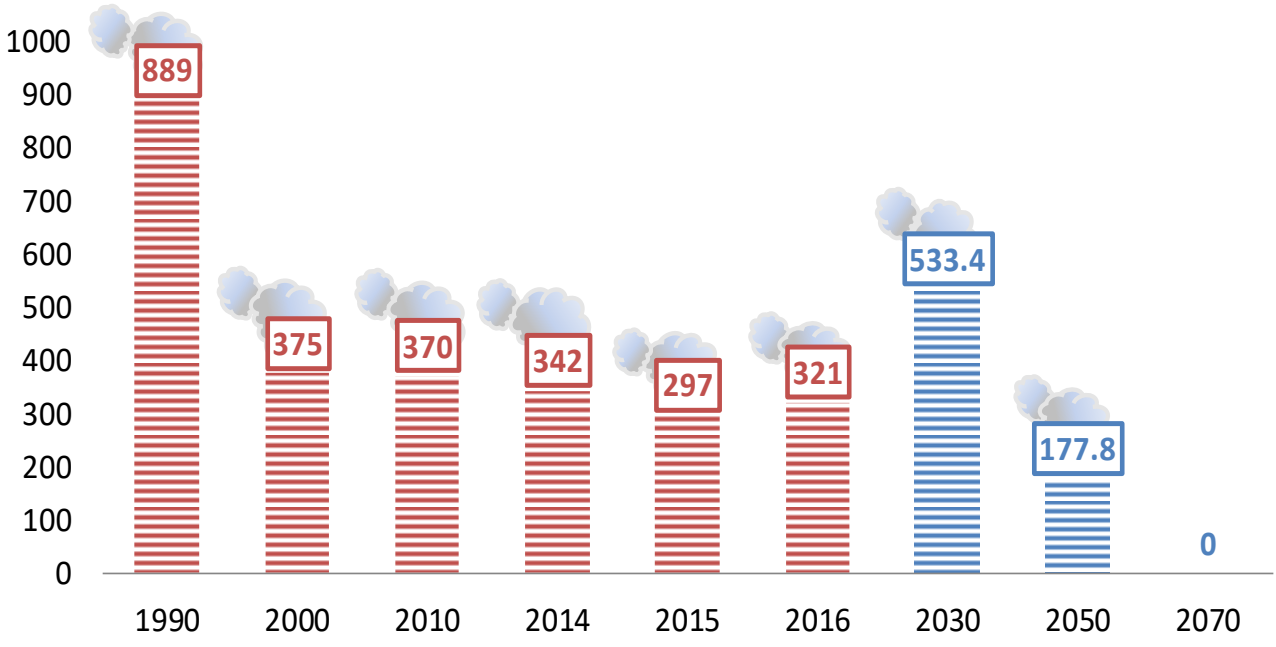


Fig. 3.4. Conception of Ukraine's transition to 100% RES (vision of PU 100 RE UA)



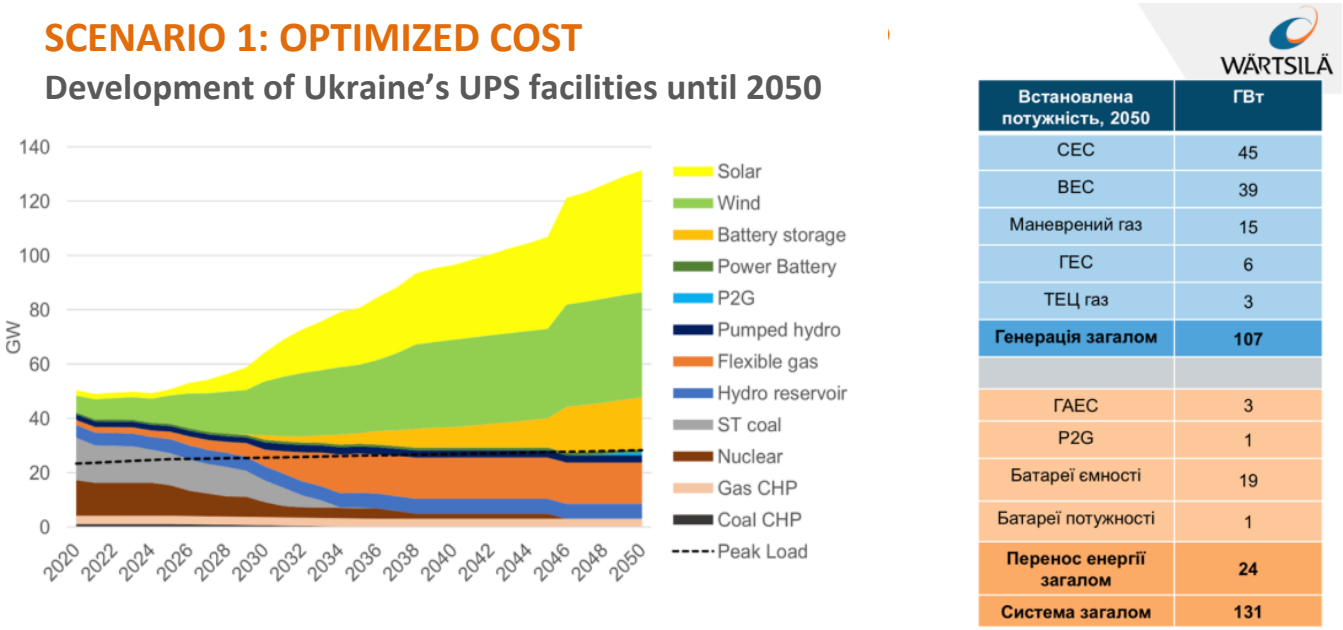
2030: reduction of GHG emissions by 40% of the level of 1990, which is the target of Ukraine's NDC;
2050: reduction of GHG emissions by 80% of the level of 1990, which corresponds to the scenario of keeping the temperature growth within 2°C and proportional distribution of additional obligations between the countries (potential obligations of Ukraine under the Paris Agreement);
2070: 100% reduction of GHG emissions according to the vision of 100 RE UA

Fig. 3.5. GHG emissions in Ukraine during 1990-2016 (Mt CO2-eq/yr) and the vision of 100 RE UA until 2070

3.4. Modeling of Ukraine's energy system until 2050 by Wärtsilä Energy

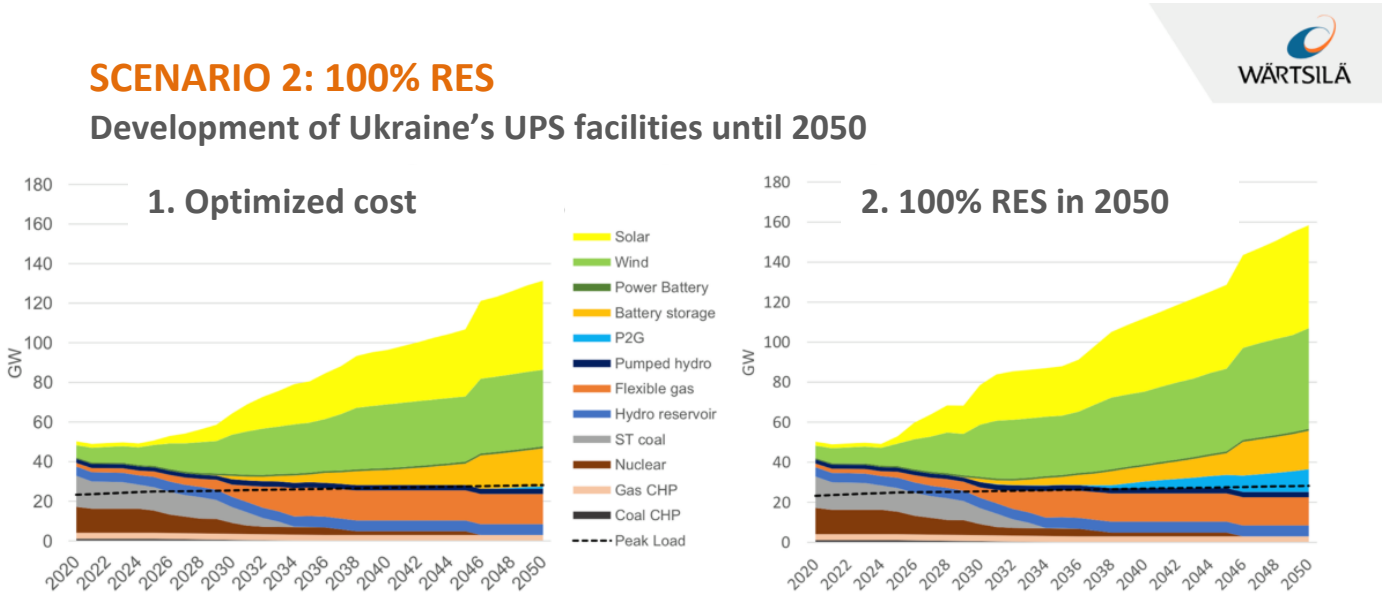
In its recent study, Wärtsilä, a world leader in modeling of scenarios of power systems development, elaborated a mathematical model of the Unified Power System of Ukraine using the

PLEXOS® software package, which is a specialized tool for planning and optimization in power industry. ***Two scenarios*** of the power system development during the next 30 years have been analyzed (**Fig. 3.6**)[27].



Встановлена потужність, 2050	ГВт
СЕС	45
ВЕС	39
Маневрений газ	15
ГЕС	6
ТЕЦ газ	3
Генерація загалом	**107**
ГАЕС	3
P2G	1
Батареї ємності	19
Батареї потужності	1
Перенос енергії загалом	**24**
Система загалом	**131**

Scenario 1: the installed capacity in 2050: SPPs – 45 GW, WPPs – 39 GW, maneuverable gas – 15 GW, HPPs, gas CHPPs, HAPPs – 3 GW, P2G – 1 GW, batteries of volume – 19 GW, batteries of capacity – 1 GW. Total generation – 107 GW; total energy transfer – 24 GW; Total system – 131 GW.



Scenario 2: The carbon-free system requires extra 17 GW of solar and wind plants as well as power-to-gas capacity that is enough for the production of fuel for 100% RES generation

Fig. 3.6. Two scenarios for the development of Ukraine's power system until 2050 (modelling by Wärtsilä Energy)[28]

[27] UPDATED: Energy transition in Ukraine is possible. Results of modeling of energy system until 2050 https://www.finnishenergyhub.com/post/energy-transition-is-possible-in-ukraine-modeling-of-power-system?fbclid=IwAR3ggj94WrjPOumEo_pnTJSPD4QbnbBNlnm9W6PYwFVW6Uwzri7q5wnqF9M

The first, ***optimal*** scenario, involved finding the lowest cost of electricity. The study is based on the current state of Ukraine's energy system: the need to replace old facilities with new and more efficient ones. A schedule for closure of coal and nuclear power plants was developed taking into consideration the service life of the plants. Based on economic and technical indicators of various generation technologies, the mathematical apparatus of the model has selected the most optimal composition of the new equipment to achieve the lowest cost of electricity. Both existing and prospective technologies, as well as all options of alternative sources that can come forward have been taken into account having regard to the cost of equipment and fuel for it.

The optimal energy system will move towards the increasing share of renewable energy and will reach **88%** of RES in the energy balance in 2050. The other 12% is gas maneuverable facilities, which will balance unstable solar and wind generation. This proves that the use of coal and nuclear energy is more expensive.

The second, ***carbon-free scenario***, envisaged a given parameter – **100%** RES and a corresponding forced reduction of CO_2 emissions to zero by 2050. As a result, the path of development with cost optimization has been modeled. The system replaced 12% of the gas facilities with artificial gas – renewable methane obtained from "green" hydrogen. This scenario increases costs by 9% compared to the first one – the cost of additional 17 GW of RES and 11 GW of renewable gas.

Despite different formulation of the problem, both scenarios offer similar routes of the development, namely investment in RES, maneuverable facilities and storage systems. The carbon-free features additional need for RES facilities and renewable gas conversion systems. No scenario suggests the construction of traditional heat generation.

The vision of the Bioenergy Association of Ukraine is that *bioenergy will play a significant role* in future energy sector of Ukraine even taking into account results of the presented scenarios for the development of Ukraine's energy system until 2050.

Wärtsilä's modeling was done *only for the power industry* and did not deal with the heat and transport sectors where bioenergy has traditionally had strong position. In particular, biomass combined heat and power plants have not been considered. We believe that even in the power industry, bioenergy will occupy a significant place, in particular, in the form of biomass CHP plants and maneuverable generation on biomethane.

In addition, the second scenario involves the conversion of "green" hydrogen into methane, the price of which is set at $650 per 1000 m^3. However, biomethane obtained by fermentation or thermochemical gasification is quite competitive with such synthetic methane: the price of biomethane varies from $350 to $700 per 1000 m^3.

In their presentation, authors of the modeling express their opinion that there are not enough biofuels available at the global level[28]. We believe that this does not apply to Ukraine as there are enough biofuels in Ukraine, and the biomass resources can replace at least all imported gas and coal.

[28] Presentation of Wärtsilä Energy http://bit.ly/2VDIuWQ, http://bit.ly/39f82NU

4. European Green Deal

The European Green New Deal was presented by the European Commission in December 2019. It aims to transform the Union into a modern, resource-efficient and competitive economy where there are ***no net emissions of greenhouse gases by 2050***, economic growth is decoupled from resource use, and no person and no place is left behind. The European Green Deal is the roadmap for making the EU's economy sustainable and covers all sectors of the economy, notably transport, energy, agriculture, buildings, and industries such as steel, cement, ICT, textiles and chemicals[9] [29] [30].

To meet the 2050 climate neutrality target, the European Commission submitted a draft European Climate Law[31] to the European Parliament and other responsible bodies in early March 2020. It is planned that EU member states will monitor their trajectory of zero greenhouse gas emissions by 2050, review the current situation every five years and adjust the measures taken if necessary.

Reaching this target will require a lot of actions by all sectors of the EU's economy, including:

- investing in environmentally-friendly technologies;
- supporting industry to innovate;
- rolling out cleaner, cheaper and healthier forms of private and public transport;
- decarbonising the energy sector;
- ensuring buildings are more energy efficient;
- working with international partners to improve global environmental standards.

The European Green Deal also aims to develop circular economy, reduce pollutant emissions, and preserve biodiversity. With this in mind, the Green Deal includes the development and approval of the European Industrial Strategy, a Circular Economy Action Plan, and the EU Biodiversity Strategy for 2030.

Complementing other initiatives announced under the Green Deal, the European Green Deal Investment Plan will mobilize at least €1 trillion of sustainable investments over the next decade. A greater share of spending on climate and environmental action from the EU budget than ever before will crowd in private funding, with a key role to be played by the European Investment Bank. The EU will also provide financial support and technical assistance to help people, businesses and regions that are most affected by the move towards the green economy. This is called the Just Transition Mechanism and will help mobilise at least €100 billion over the period 2021-2027 in the most affected regions[32].

In today's conditions, **the European Green Deal** is becoming even more relevant as the European Union considers it the best way out of the crisis for the EU economy after the end of the COVID-19 pandemic.

Ten main factors how the implementation of the green strategy will affect the lives of ordinary people and, as a result, future generations are presented in **Fig. 4.1**.

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[29] The European Green Deal sets out how to make Europe the first climate-neutral continent by 2050 https://ec.europa.eu/commission/presscorner/detail/e%20n/ip_19_6691

[30] Annex to the Communication on the European Green Deal Roadmap - Key actions https://ec.europa.eu/info/sites/info/files/european-green-deal-communication-annex-roadmap_en.pdf

[31] Commission proposal for a regulation: European Climate Law https://ec.europa.eu/info/files/commission-proposal-regulation-european-climate-law_en https://ec.europa.eu/info/sites/info/files/commission-proposal-regulation-european-climate-law-march-2020_en.pdf

[32] Financing the green transition: The European Green Deal Investment Plan and Just Transition Mechanism https://ec.europa.eu/commission/presscorner/detail/en/ip_20_17

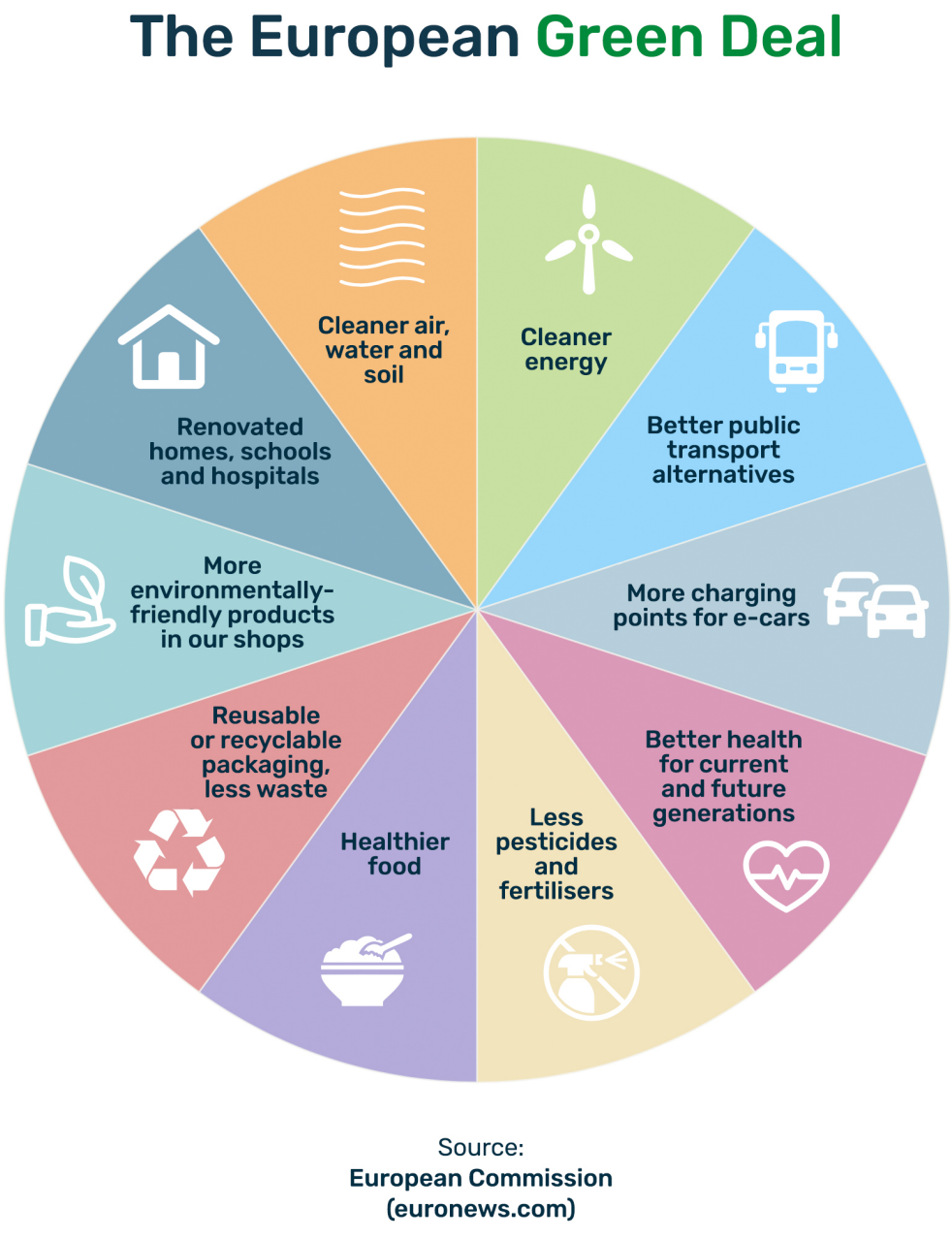


Fig. 4.1. Ten main factors of the European Green Deal influence

5. Basic approach and characteristics of the Roadmap for Ukraine's bioenergy development until 2050

5.1. Goal, timeframe and benchmarks of the Roadmap

The goal of the Roadmap is to present a realistic long-term scenario for the development of bioenergy, which corresponds to Ukraine's transition to 100% RES in 2070.

The proposed Roadmap covers the period of 2020-2050 and has several benchmarks. One of them is the year 2030 as the new NREAP is to be developed until 2030, in which at least **8** Mtoe of biomass, biofuels and waste should be consumed according to the current Ukraine's Energy Strategy. The second benchmark takes into account the goal of bioenergy development set by the Energy Strategy of Ukraine for 2035 – **11** Mtoe of biomass, biofuels and waste in the total supply of primary energy.

The Roadmap is in line with the scenario of achieving over **60%** of RES in the energy balance of Ukraine in 2050 (**Fig. 5.1**), including the individual sectors:

- power production – **70%** of RES (**Fig. 5.2**);
- heat production – **65%** of RES (**Fig. 5.3**);
- transport – **35%** of RES (**Fig. 5.4**).

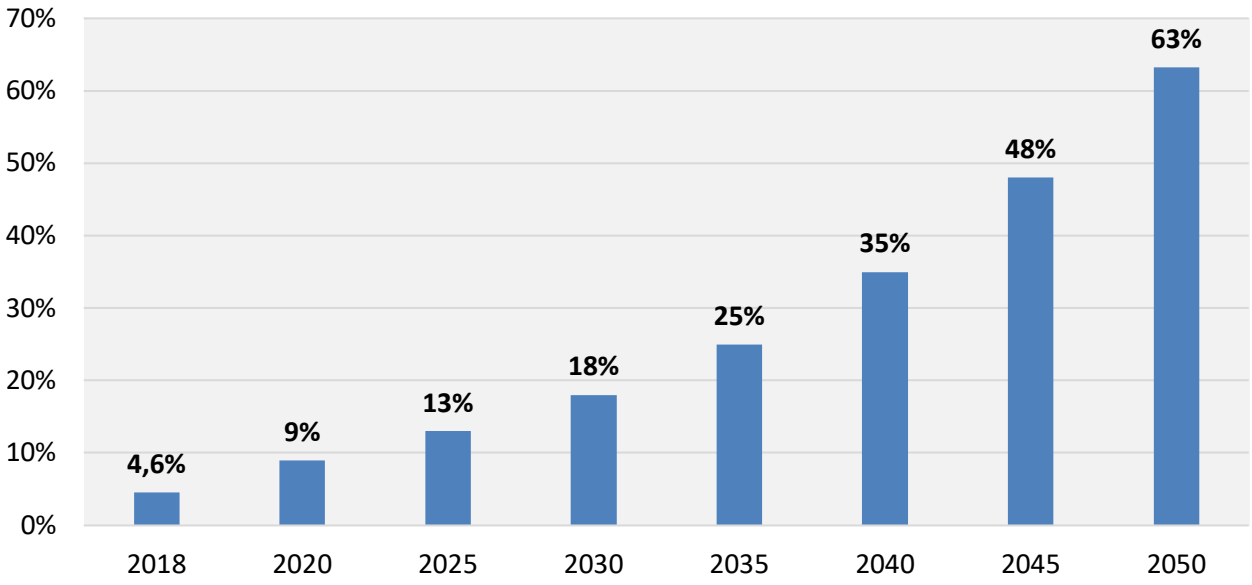


Fig. 5.1. Forecasted share of RES in Ukraine's total primary energy supply until 2050[33]

[33] The figure of 4.6% in TPES in 2018 is according to Ukraine's Energy Balance for 2018 prepared by the State Statistics Service of Ukraine. The figure of 25% in TPES in 2035 is according to the Energy Strategy of Ukraine until 2035.

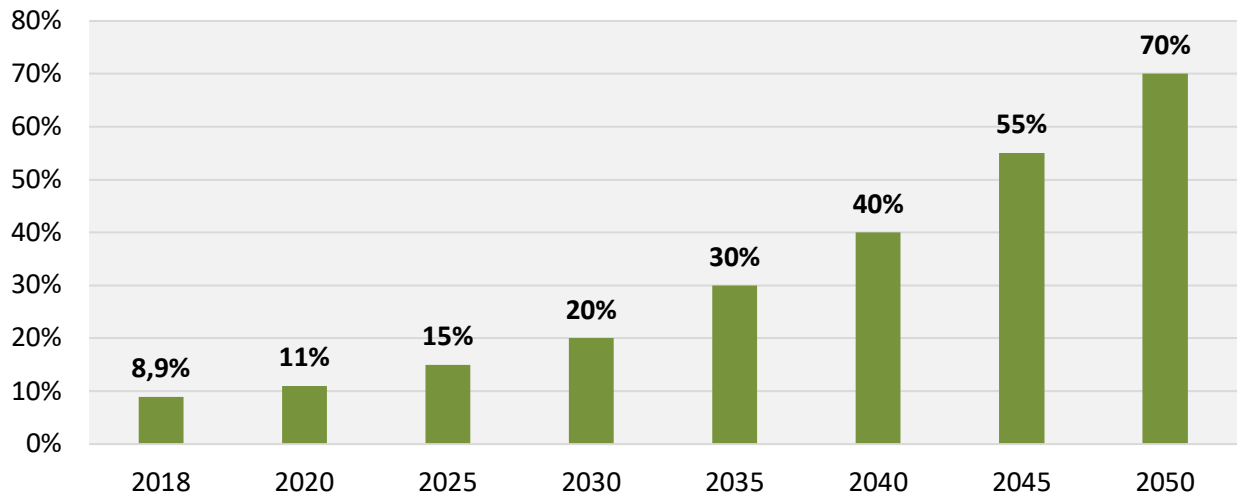


Fig. 5.2. Forecasted share of RES in the power production until 2050[34]

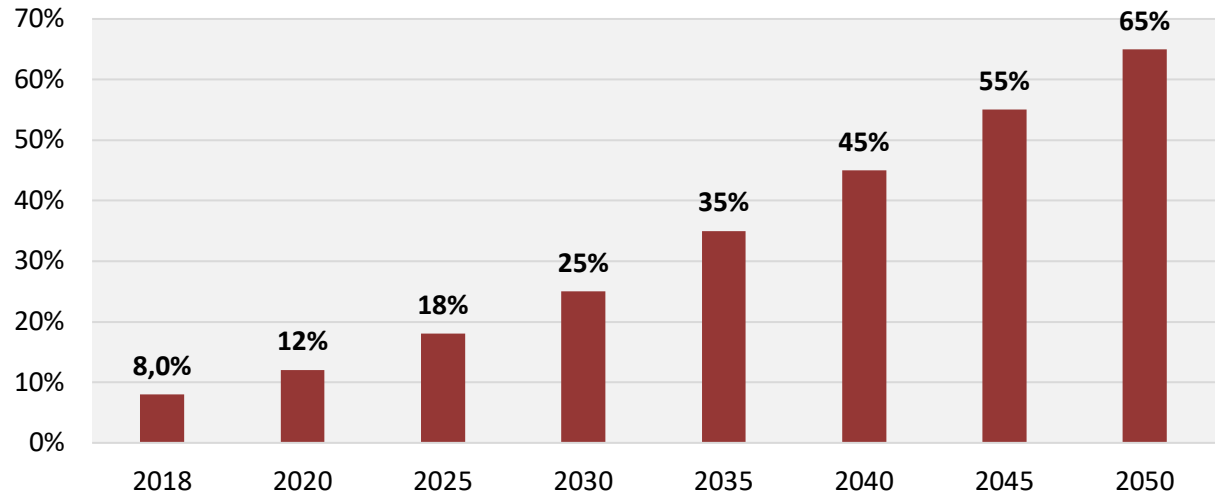


Fig. 5.3. Forecasted share of RES in the heat production until 2050[34]

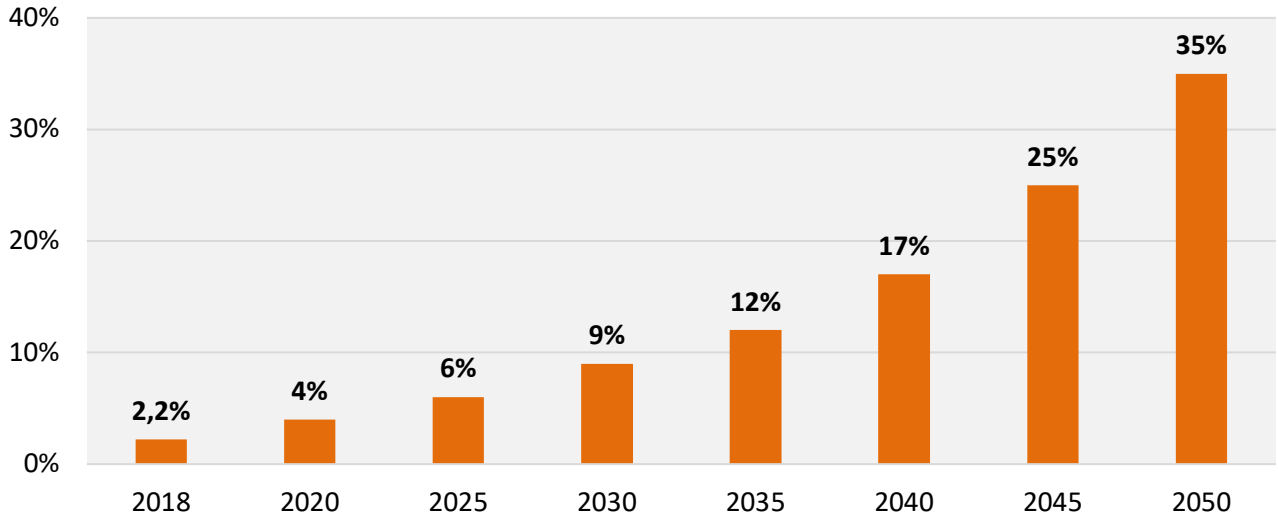


Fig. 5.4. Forecasted share of RES in the transport sector until 2050[34]

[34] The figures for 2018 correspond to SAEE's data on RES shares in power consumption, heat consumption and renewable energy in transport sector.

The realization of these goals is possible under the condition of reducing TPES in 2050 compared to 2018 (93.2 Mtoe) by 9% (up to 85 Mtoe).

Regarding the production of heat from RES, it should be noted that up to 85-90% of the total amount is now provided by biomass. According to the forecast of the Bioenergy Association of Ukraine, in the future, the biggest share of heat production from RES will also fall to biomass. This approach runs counter to some "radical" predictions that Ukraine may completely move to electrical heating in the future.

The example of Lithuania, where the production of heat from biomass is actively developing with some ambitious plans for the future, seems to be demonstrative. According to Lithuania's National Energy Independence Strategy[35], by 2030, 90% of heat will be produced from RES, mainly through modern biomass CHP plants. By 2050, all heat consumed in Lithuania will be produced from RES and other clean energy sources. The Lithuanian District Heating Association notes that Lithuania has enough resources to provide 100% heating based on biofuels without causing a negative impact on the environment[36].

Taking into account the above considerations, the Roadmap for the development of Ukraine's bioenergy until 2050 provides for high biomass shares of all RES in heat production (**Fig. 5.5**). According to the dynamics of changes in TPES and its structure assumed in the Roadmap, this corresponds to the share of biomass in the total heat production in 2050 – 44% (**Fig. 5.6**).

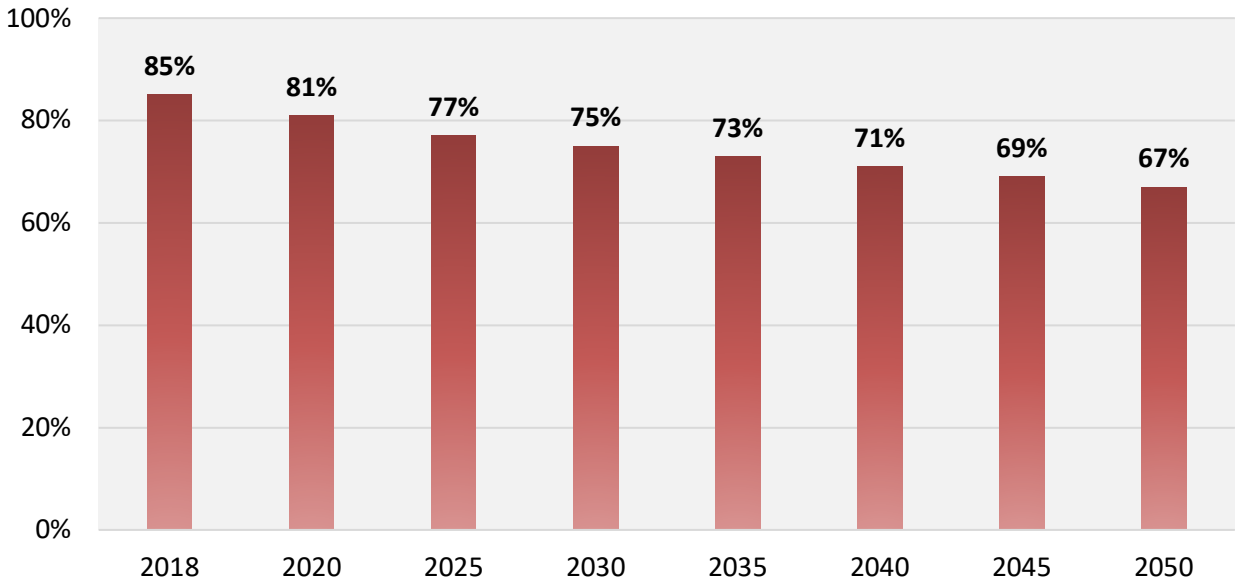


Fig. 5.5. Forecast for biomass share of all RES in heat production[37]

[35] Lithuania's National Energy Independence Strategy
http://enmin.lrv.lt/uploads/enmin/documents/files/National_energy_independence_strategy_2018.pdf
[36] ABOUT DH SECTOR https://lsta.lt/en/about-dh-sector/
[37] The figure for 2018 is UABIO's estimation.

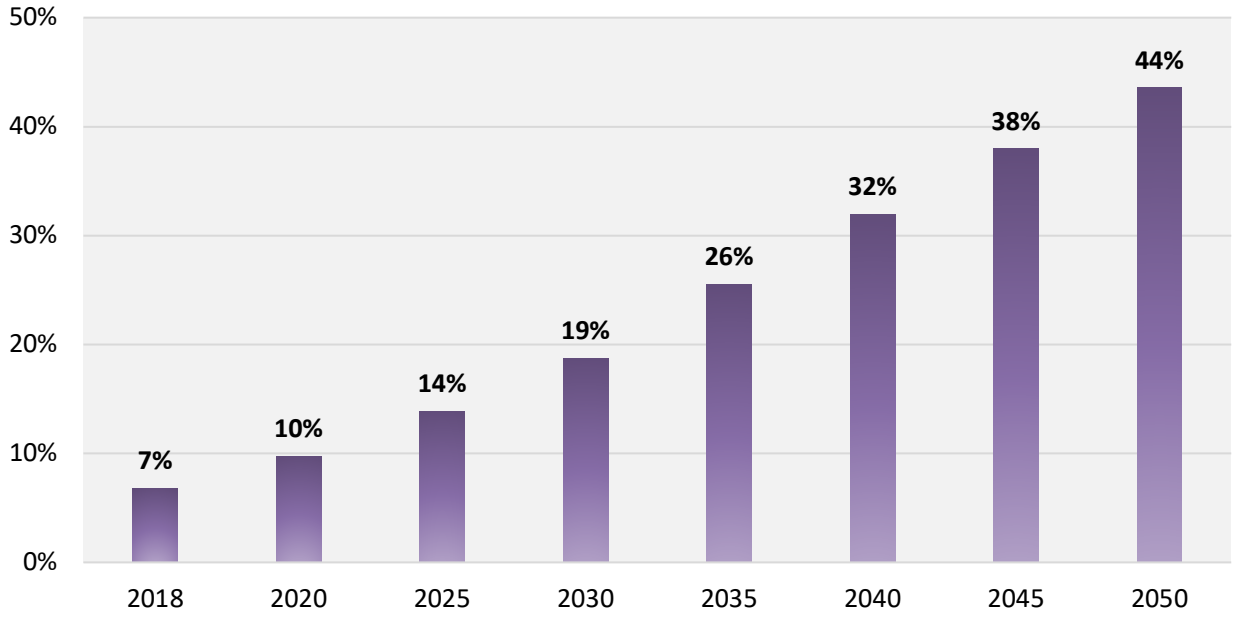


Fig. 5.6. Forecast for biomass share in heat production[37]

Assumed in the Roadmap biomass shares of all RES in electricity production and obtained respective contribution of biomass to the total electricity production until 2050 are presented in **Fig. 5.7**, **5.8**.

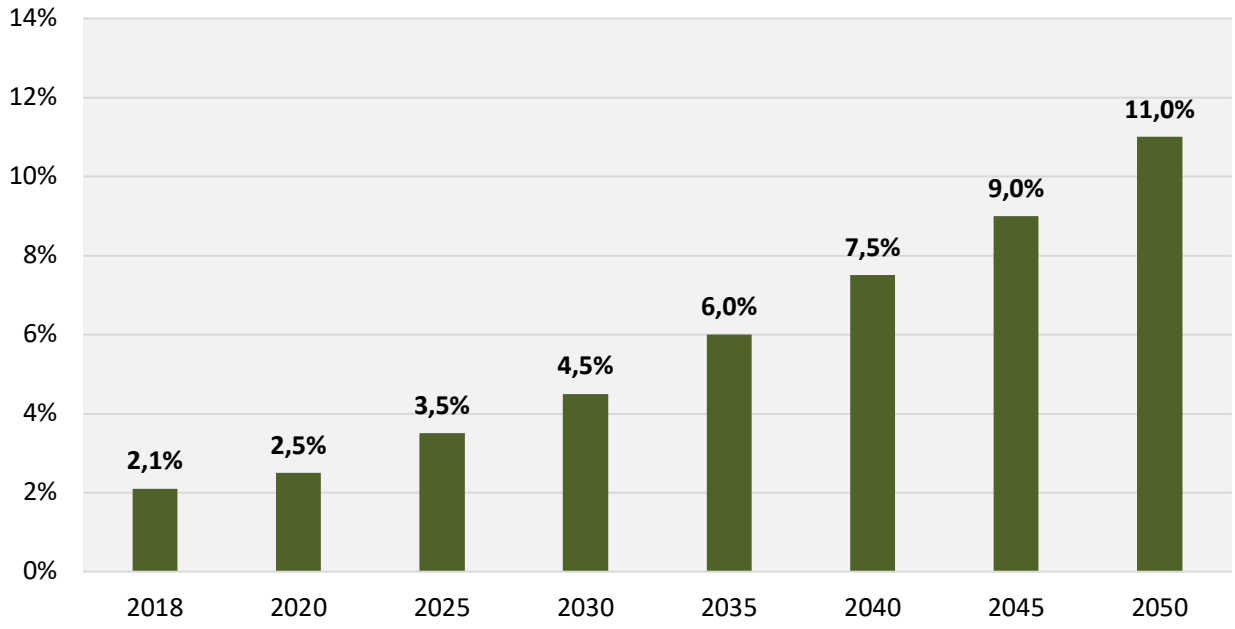


Fig. 5.7. Forecast for biomass share of all RES in power production[38] [39]

[38] The figure for 2018 is according to the Energy Balance of Ukraine for 2018.

[39] When predicting, the authors took into account data of GLOBAL ENERGY TRANSFORMATION. A Roadmap to 2050, IRENA, 2018 (http://energytransition.in.ua/wp-content/uploads/2018/12/IRENA_Report_GET_2018.pdf) considering Ukraine's conditions (current and future bioenergy potential, state of the art and prospects for the development of other RES etc.).

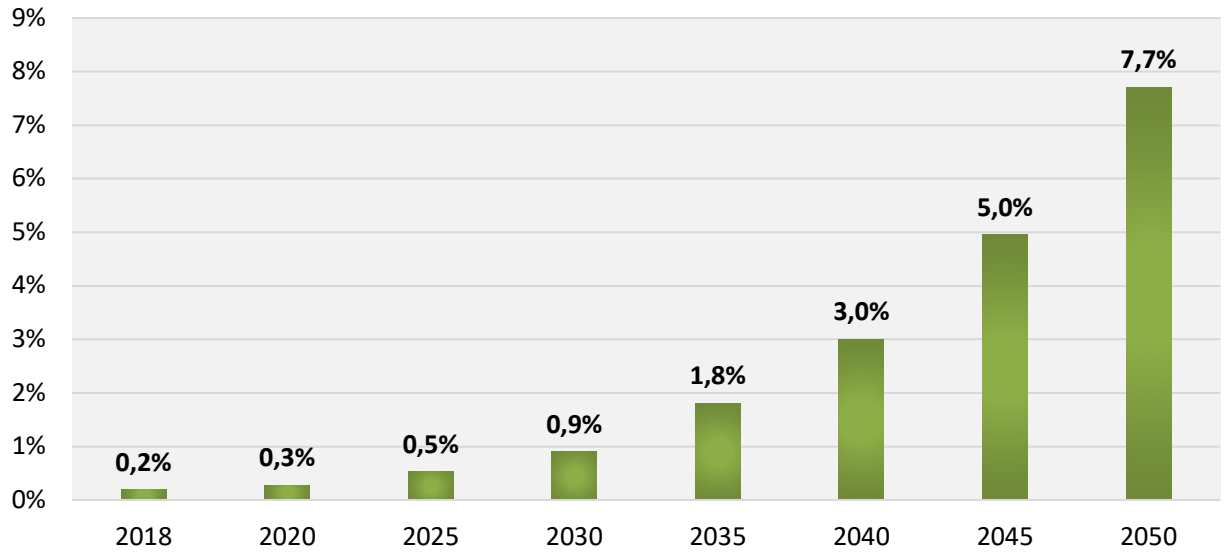


Fig. 5.8. Forecast for biomass share in power production[40]

When modelling the development of the motor biofuels sector in Ukraine, we used some results of the project "Modalities to foster use of renewable energy sources in the transport sector by the Energy Community Contracting Parties"[41] (**Fig. 5.9, 5.10**) and data of IRENA's Roadmap to 2050[42] for the global energy transformation (**Fig. 5.11**).

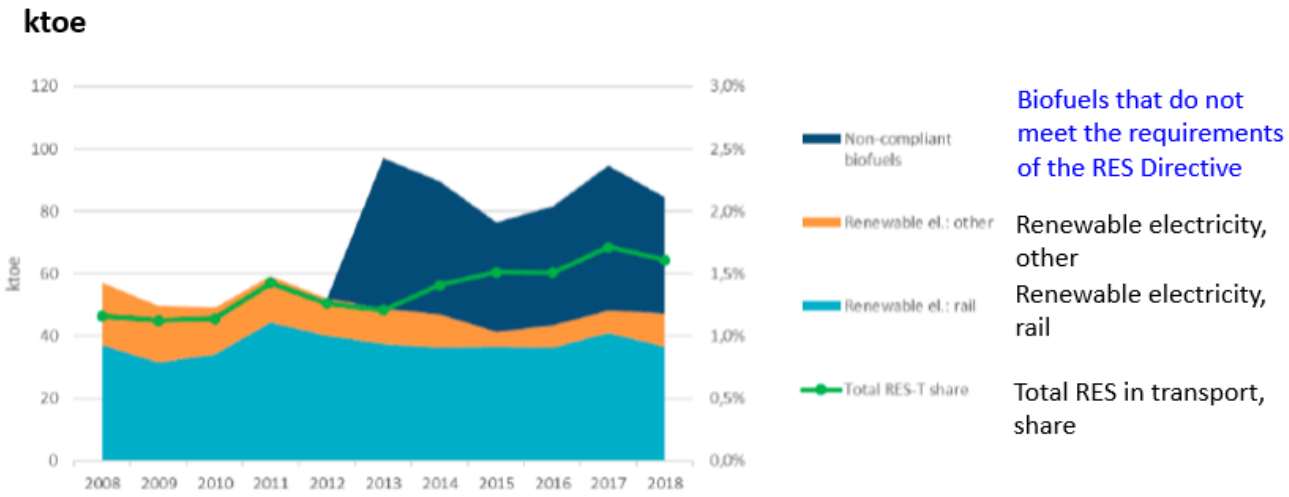


Fig. 5.9. Renewable energy consumption in transport sector in Ukraine[41]

[40] The figure for 2018 was calculated based on data of the Energy Balance of Ukraine for 2018 and SAEE.
[41] Project "Modalities to foster use of renewable energy sources in the transport sector by the Energy Community Contracting Parties" (2019-2020) was carried out in cooperation with SAEE. Project results regarding Ukraine were presented at a webinar on 16.10.2020.
[42] GLOBAL ENERGY TRANSFORMATION. A Roadmap to 2050, IRENA, 2018 (http://energytransition.in.ua/wp-content/uploads/2018/12/IRENA_Report_GET_2018.pdf)

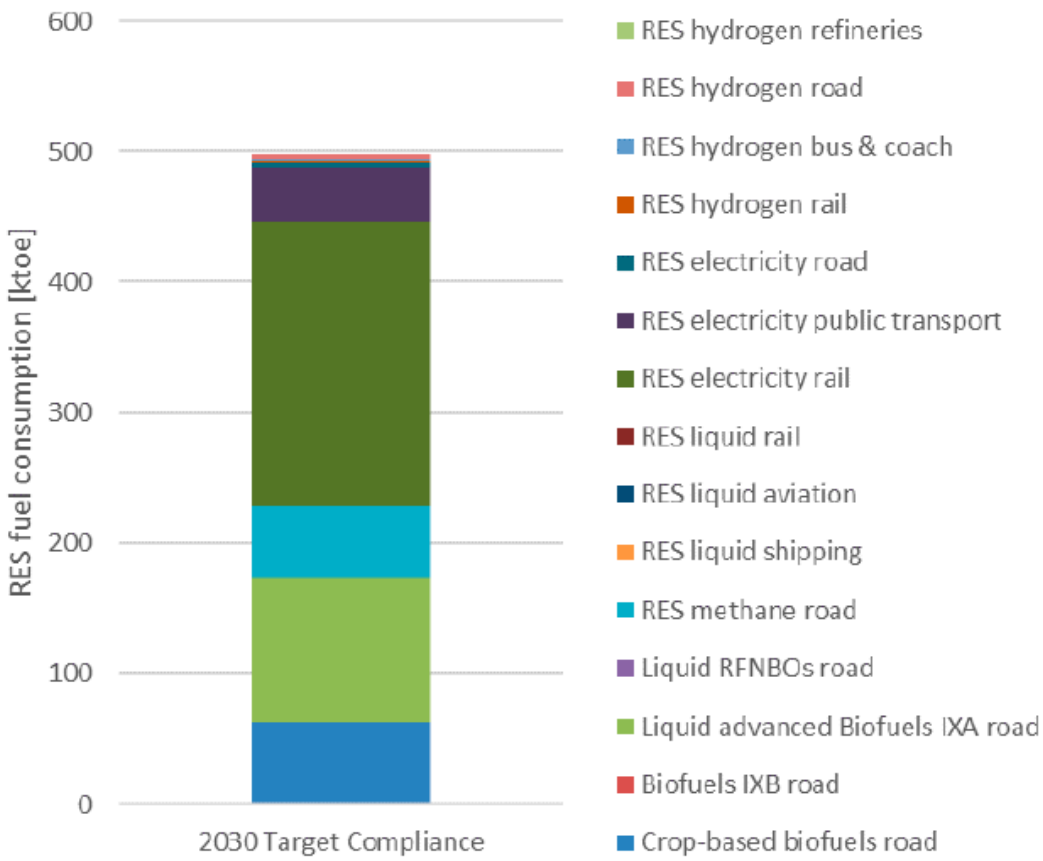


Fig. 5.10. Forecasted structure of renewable energy consumption in Ukraine's transport sector in 2030[41]

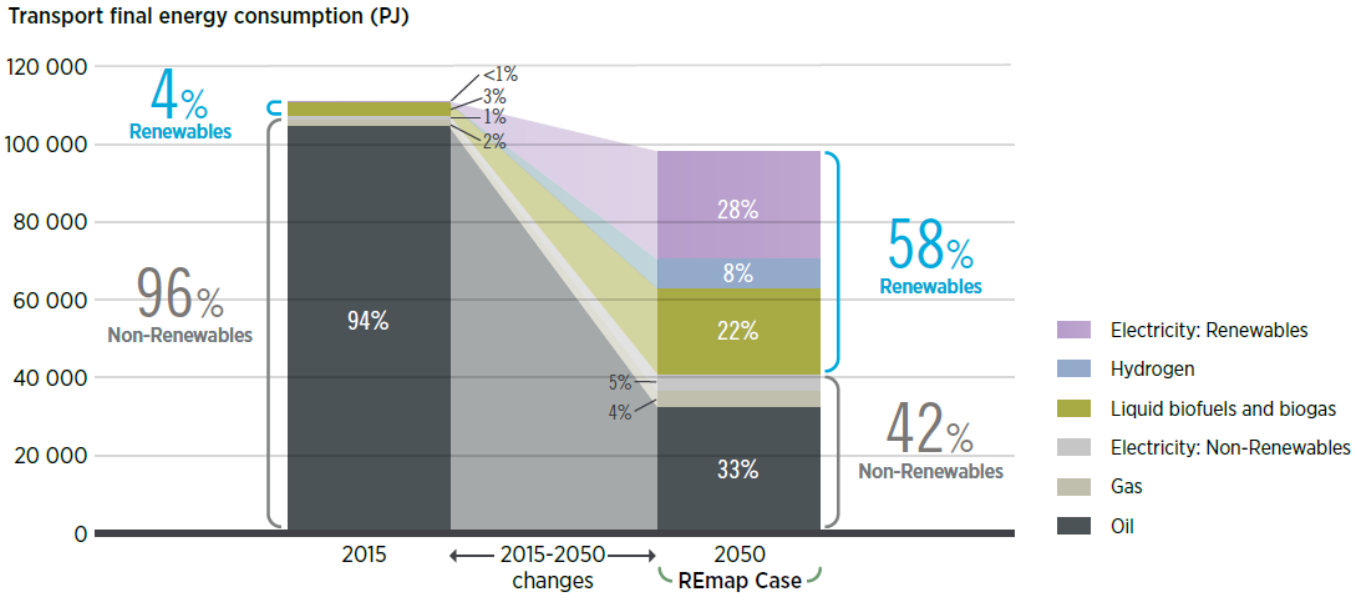


Fig. 5.11. Structure of the global transport final energy consumption until 2050[42]

Assumed in the Roadmap biomass shares of all RES in transport sector and obtained respective contribution of biomass to the total energy consumption in transport until 2050 are presented in **Fig. 5.12**, **5.13**.

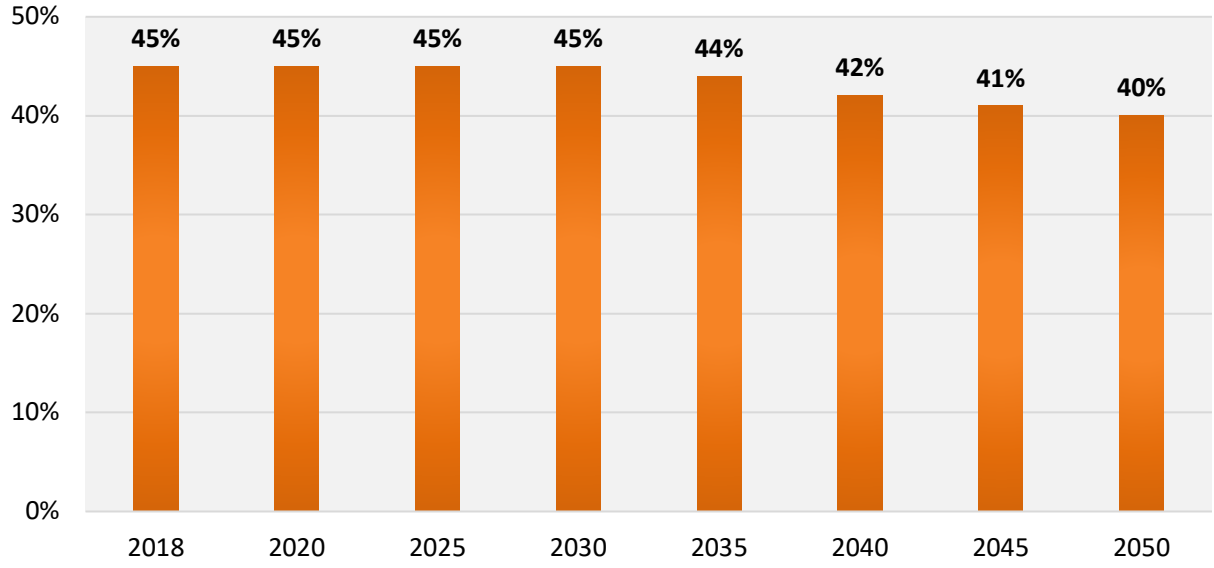


Fig. 5.12. Forecast for biomass share of all RES in transport sector[43]

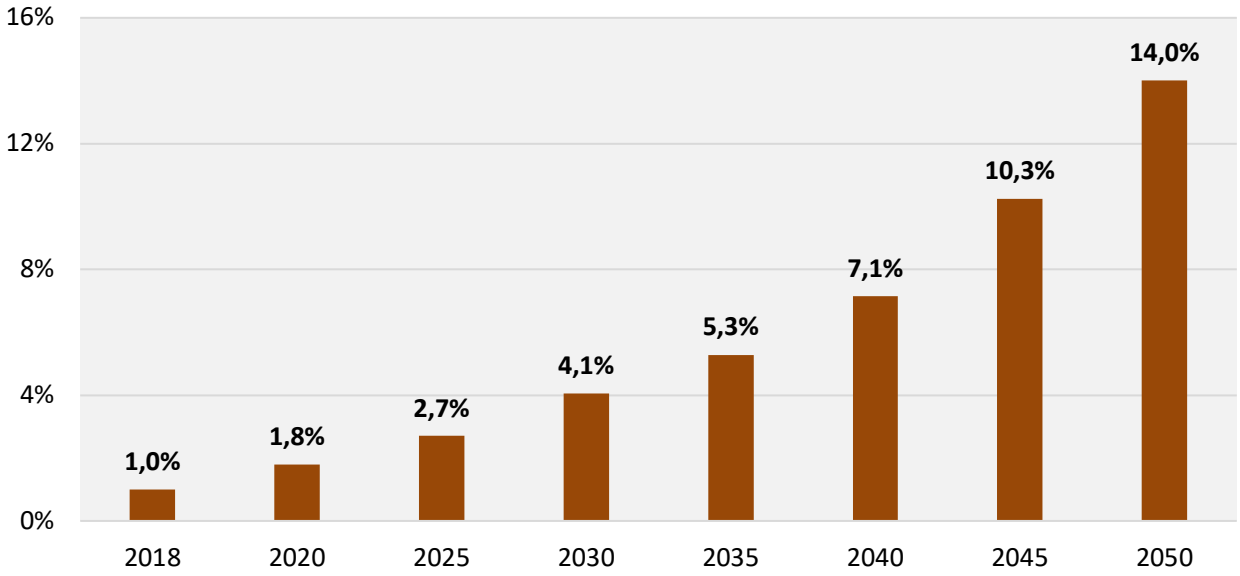


Fig. 5.13. Forecast for biomass share in the total final energy consumption in transport[44]

[43] Figures for 2018 and 2030 are estimation of project "Modalities to foster use of renewable energy sources in the transport sector by the Energy Community Contracting Parties" (2019-2020).

[44] Figure for 2018 is calculated based on data of project "Modalities to foster use of renewable energy sources in the transport sector by the Energy Community Contracting Parties" (2019-2020) and SAEE.

Based on the forecasted bioenergy development in the heat, electricity and transport sectors, we have obtained data on the possible contribution of biomass/biofuels to renewable energy production and to the total primary energy supply in Ukraine by 2050: 38% and 24% in 2050, respectively (**Fig. 5.14, 5.15**).

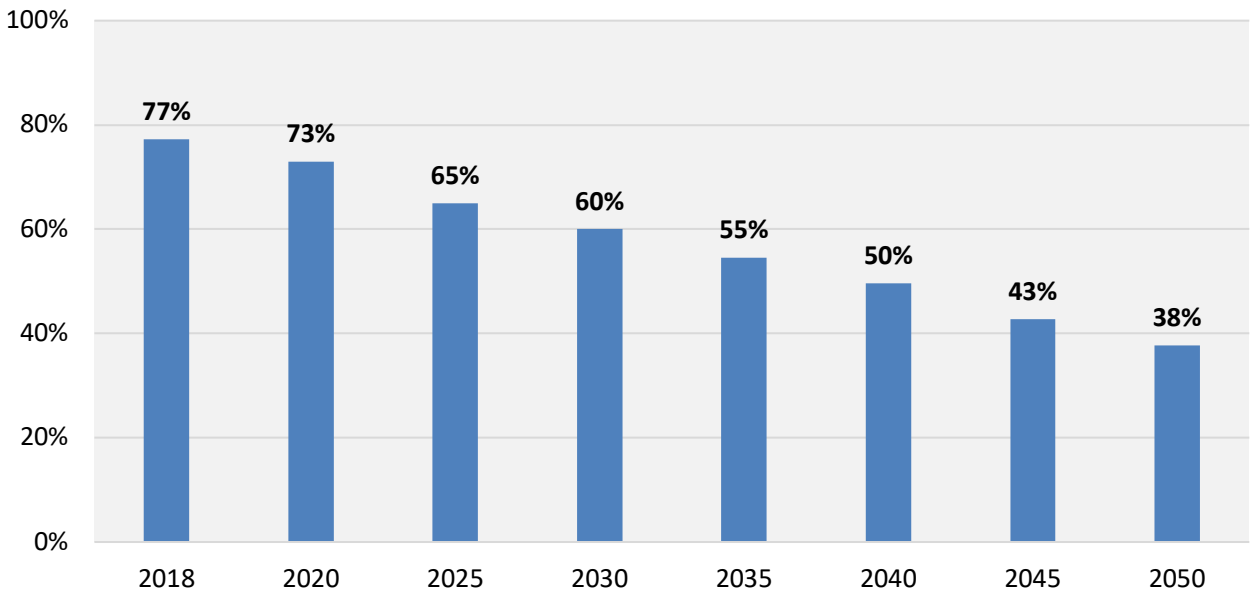


Fig. 5.14. Forecasted biomass shares of all RES in Ukraine's total primary energy supply[38]

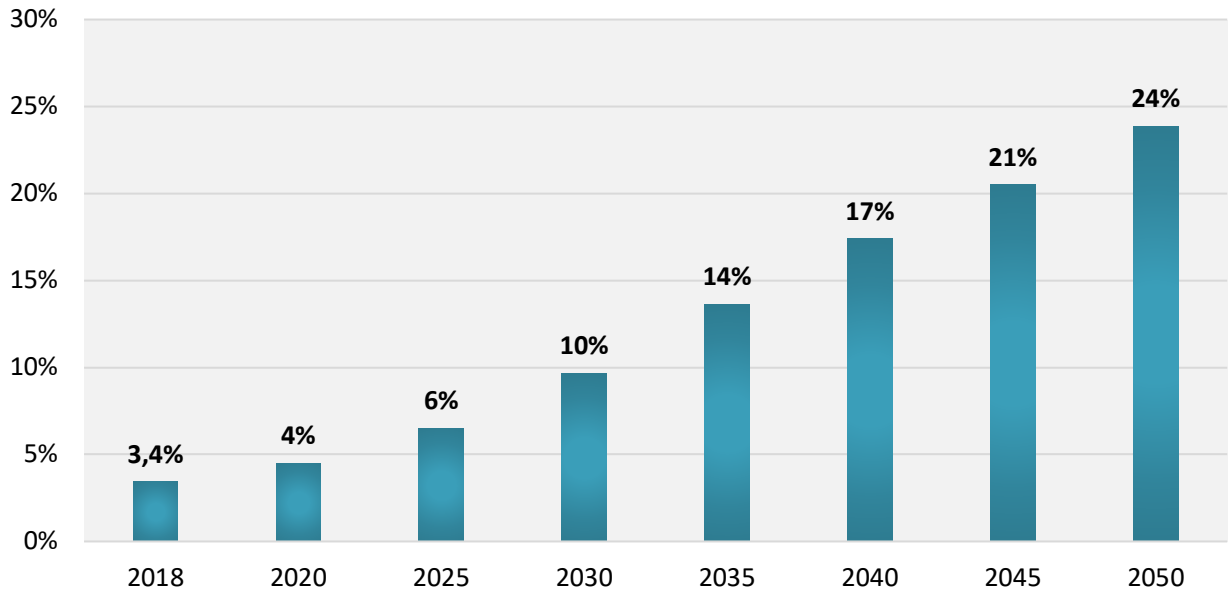


Fig. 5.15. Forecasted contribution of bioenergy to Ukraine's total primary energy supply[38]

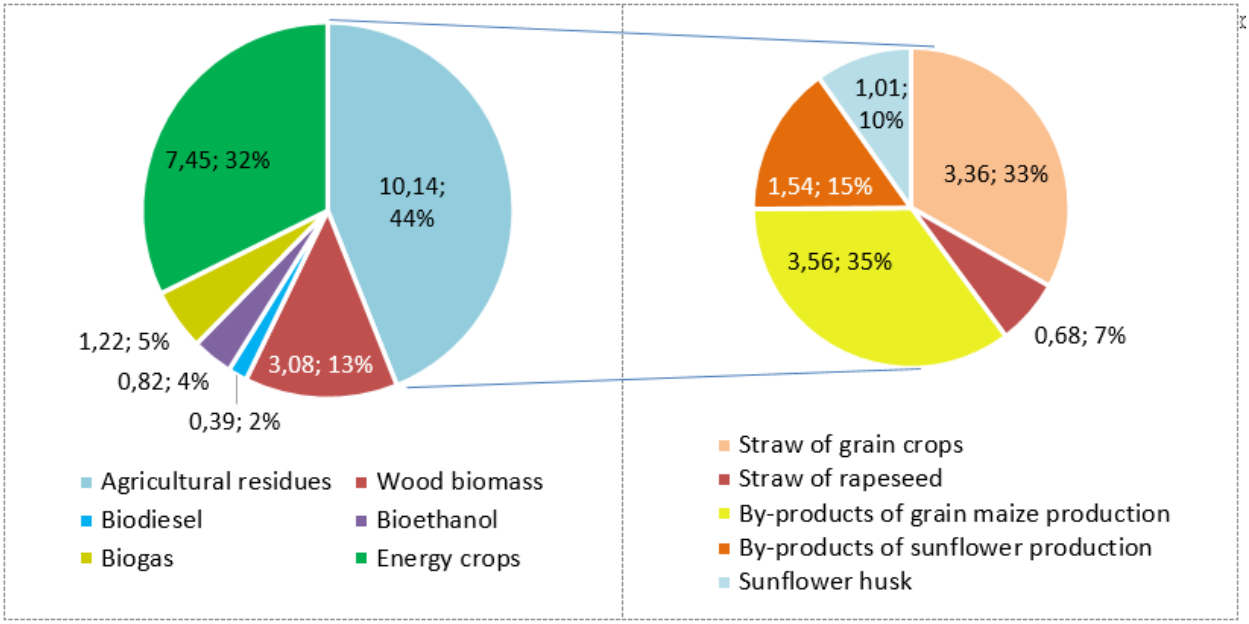
5.2. Biomass potential in Ukraine and its estimation until 2050

According to 2018 data, the potential of biomass for energy in Ukraine is about **23** Mtoe, the biggest constituents being agricultural residues (44% of the total) and energy crops (32%) (**Table 5.1, Fig. 5.16**). Within the agricultural residues, the largest amounts fall to the shares of grain crops straw (33%) and by-products of grain maize production (35%).

Table 5.1. Bioenergy potential in Ukraine in 2018

Type of biomass	Theoretical potential, million tons	Potential available for energy (economic potential)	
		Share of the theoretical potential, %	Mtoe
Straw of grain crops	32.8	30	3.36
Rapeseed straw	4.9	40	0.68
By-products of grain maize production (stalks, cobs)	46.5	40	3.56
By-products of sunflower production (stalks, heads)	26.9	40	1.54
Secondary agricultural residues (sunflower husk)	2.4	100	1.00
Wood biomass (fuel wood, felling residues, wood processing waste)	8.8	96	2.06
Wood biomass (deadwood, wood from shelterbelt forests, biomass from APPR)	8.8	45	1.02
Biodiesel (from rapeseed)	-	-	0.39
Bioethanol (from maize and sugar beet)	-	-	0.82
Biogas from waste and by-products of agro-industrial complex	2.8 bln m^3 CH_4	42	0.99
Landfill gas	0.6 bln m^3 CH_4	29	0.14
Sewage gas (industrial and municipal wastewater)	0.4 bln m^3 CH_4	28	0.09
Energy crops:			
- willow, poplar, miscanthus (1 mln ha*);	11.5	100	4.88
- maize for biogas (1 mln ha*).	3.0 bln m^3 CH_4	100	2.57
Total	**-**	**-**	**23.10**

** Provided that 1 million hectares of unused agricultural land is used for growing the energy crops.*



a) Total potential of biomass *b) Potential of agricultural residues*

Fig. 5.16. Structure of the biomass potential in Ukraine (2018), Mtoe

Expert estimation shows that in 2050 this potential may increase to more than **47.5** Mtoe/yr that is practically double as compared with 2018 (**Table 5.2**). Thus, the level of biofuel consumption in 2050 (about **20** Mtoe) envisaged in the Roadmap will come to only **43%** of the biomass potential available at that time.

Table 5.2. Forecast for the energy potential of biomass in Ukraine in 2050

Type of biomass	Theoretical potential, million tons	Potential available for energy (economic potential)	
		Share of theoretical potential, %	Mtoe
Straw of grain crops*	49.2	30	5.04
Rapeseed straw	4.9	40	0.68
By-products of grain maize production (stalks, cobs)*	58.1	40	4.45
By-products of sunflower production (stalks, heads)	26.9	40	1.54
Secondary agricultural residues (sunflower husk)	2.4	100	1.00
Wood biomass (fuel wood, felling residues, wood processing waste)*	12.3	96	2.88
Wood biomass (deadwood, wood from shelterbelt forests, biomass from APPR)	8.8	45	1.02
Biodiesel (I and II generation)*	-	-	1.10
Bioethanol (I and II generation)*	-	-	2.33
Biogas from waste and by-products of agro-industrial complex*	8.4 bln m^3 CH_4	83	5.92
Biogas from MSW*	0.7 bln m^3 CH_4	70	0.42
Sewage gas (industrial and municipal wastewater)*	0.4 bln m^3 CH_4	31	0.11
Energy crops*:			
- willow, poplar, miscanthus (2 mln ha**);	34.5	100	14.65
- maize for biogas (2 mln ha**).	7.5 bln m^3 CH_4	100	6.43
Total	**-**	**-**	**47.57**

** Components of the biomass potential, the growth of which is expected by 2050. Other components are left at their level estimated for 2018 according to the conservative approach.*

*** Provided that 2 million hectares of unused agricultural land are used for growing the energy crops.*

Main factors for the growth of energy potential of biomass until 2050 include:

- *Increase in the yield of crops, first of all, cereals.*

Analysis of the current state and current trends in agriculture of Ukraine, as well as data on grain

crops yield in Ukraine and the EU countries (FAOSTAT statistics[45]) shows that the yield of wheat and maize in Ukraine may increase 1.5 and 1.4 times by 2050, respectively.

- Significant increase in the economic potential of biogas obtained from different types of feedstock due to the following factors:

- expansion of feedstock types for biogas production by including crop residues;
- growth of main products output by various industries;
- consolidation of livestock enterprises;
- switch from MSW landfilling to the mechanical and biological treatment technology.

- Doubling of areas under energy crops and an increase in their yield.

It is assumed that in 2050 the area under energy crops will be 2 million hectares for willow, poplar, miscanthus and another 2 million hectares for maize for biogas.

- Growth of the level of the net annual forest increment fellings.

Analysis of the current state and current trends in forestry in Ukraine, as well as data on the level of felling of the net annual forest increment in Ukraine and the EU countries (Bioenergy Europe Statistical Report on Biomass Supply 2019[46], fig. 13) shows that this figure may increase by1.4 times (from ~ 51% to ~ 71%) in Ukraine[47].

- Switchover to II generation biofuels and new types of feedstock for I generation biofuels.

Assessment of the potential of liquid biofuels for 2018 is based on I generation biodiesel (from rapeseed) and I generation bioethanol (from sugar beet molasses and maize grain). Estimation of the potential for 2050 considers the production of II generation biofuels (from lignocellulose feedstock) and the use of new types of feedstock (for example, waste cooking oil, animal fats) for the production of I generation biofuels.

5.3. Suggested use of bioenergy potential by types of biomass and obtained energy carrier until 2050

The structure and directions of using bioenergy potential envisaged in the Roadmap are presented in **Fig. 5.17, 5.18.** The covered types of biofuels include wood biomass, primary and secondary agricultural residues, energy crops, biogas from different types of feedstock and liquid biofuels (biodiesel and bioethanol), the total amount of consumption in 2050 being about **20** Mtoe. Directions of biofuels use include the production of heat, power, biomethane and motor biofuels. Biomethane will be used for power and heat production and also as gaseous motor fuel.

[45] FAOSTAT. Crops http://www.fao.org/faostat/en/#data/QC
[46] Bioenergy Europe Statistical Report on Biomass Supply 2019
https://bioenergyeurope.org/article/178-biomass-supply-report.html
[47] Justification can be found in UABIO's Position Paper N 19 (2018)
"Opportunities for wood fuel harvesting in forests of Ukraine"
https://uabio.org/wp-content/uploads/2018/01/position-paper-uabio-19-en.pdf

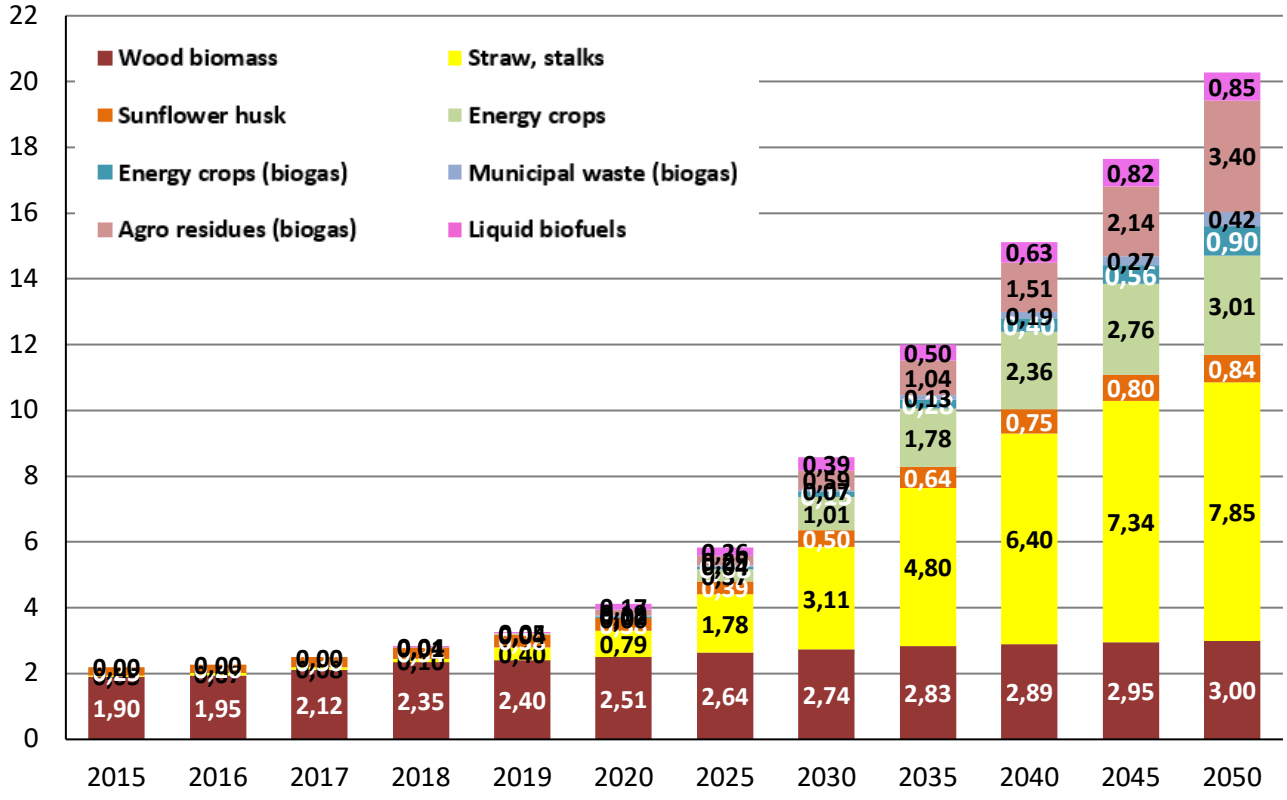


Fig. 5.17. Suggested structure of using biofuels in Ukraine until 2050, by type, Mtoe

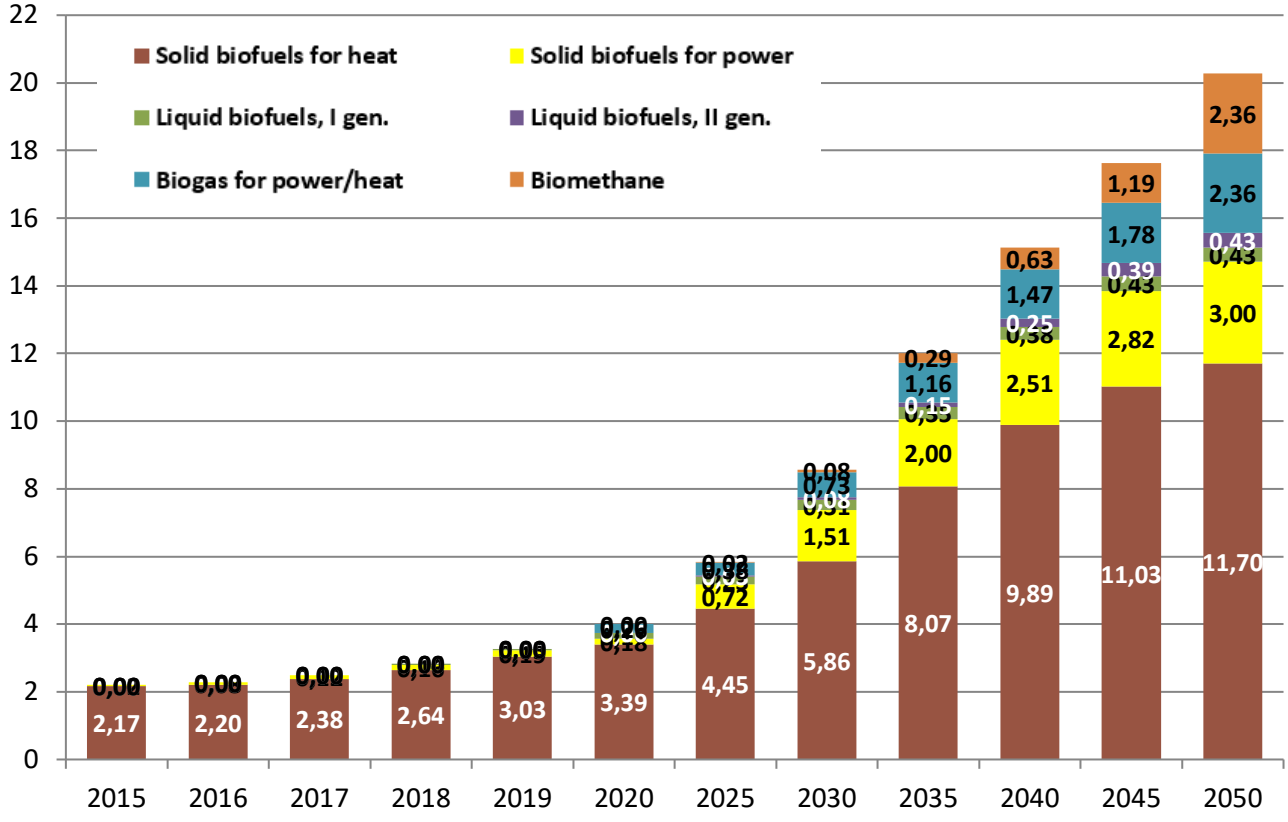


Fig. 5.18. Suggested structure of using biofuels in Ukraine until 2050, by type of the obtained energy carrier, Mtoe

The suggested structure of production and consumption of biofuels takes into account and reflect ***the key trends*** that, according to the expert prediction, will take place in the bioenergy sector of Ukraine during 2020-2050:

- *Increase in the share of agrobiomass, namely agricultural residues and energy crops, in the structure of solid biofuels consumption up to 60% and 20% of the total in 2050, respectively.*

Currently, the main components of the energy potential of biomass in Ukraine are primary agricultural residues (straw of cereals and rapeseed, by-products of maize for grain and sunflower production) and energy crops (willow, poplar, miscanthus for solid biofuels and maize silage for biogas production). The share of primary agricultural residues is almost 40% of the total potential (hereinafter data for 2018), and that of energy crops is 32%. However, in the structure of energy production from biomass in Ukraine, the primary agricultural residues and energy crops rank last as their potential is used only by 0…3% depending on the type of biomass. The Roadmap envisages a significant increase in the energy production from agrobiomass, primarily stalks and other by-products of maize and sunflower production.

- *Minimal growth in the use of wood biofuels, namely 1.2 times in 2050 (against 8 times for agricultural residues during 2020-2050).*

The share of wood biomass in the structure of bioenergy potential in Ukraine is only about 13%; however, the utilization of the potential exceeds 80%. Based on the principles of sustainable development, the Roadmap envisages the minimum growth in the energy production from wood biofuels required to meet the 2050 targets. This growth can be achieved through the involvement of felling residues, deadwood, wood from the reconstruction and renewal of shelterbelt forests, residues from pruning and removal of orchards and vineyards in energy production. It is also planned to increase the level of felling of the net annual forest increment from the current ~ 51% to ~ 71%[47], which is in line with European experience[46].

- *Significant increase in the production of biogas and liquid biofuels: up to 4.7 Mtoe/yr and 0.85 Mtoe/yr, respectively, in 2050.*

Ukraine has the necessary prerequisites and opportunities for a significant increase in the production of liquid and gaseous biofuels. Feedstock for biogas production can be agricultural residues (primary residues such as straw; secondary residues such as spent grain in beer production, sugar beet pulp; manure), energy crops (maize silage), as well as MSW and some other types of biomass. Liquid motor biofuels include bioethanol and biodiesel. In Ukraine, traditional feedstock for the production of liquid biofuels of the first generation is maize grain, sugar beet molasses for bioethanol and rapeseed for biodiesel.

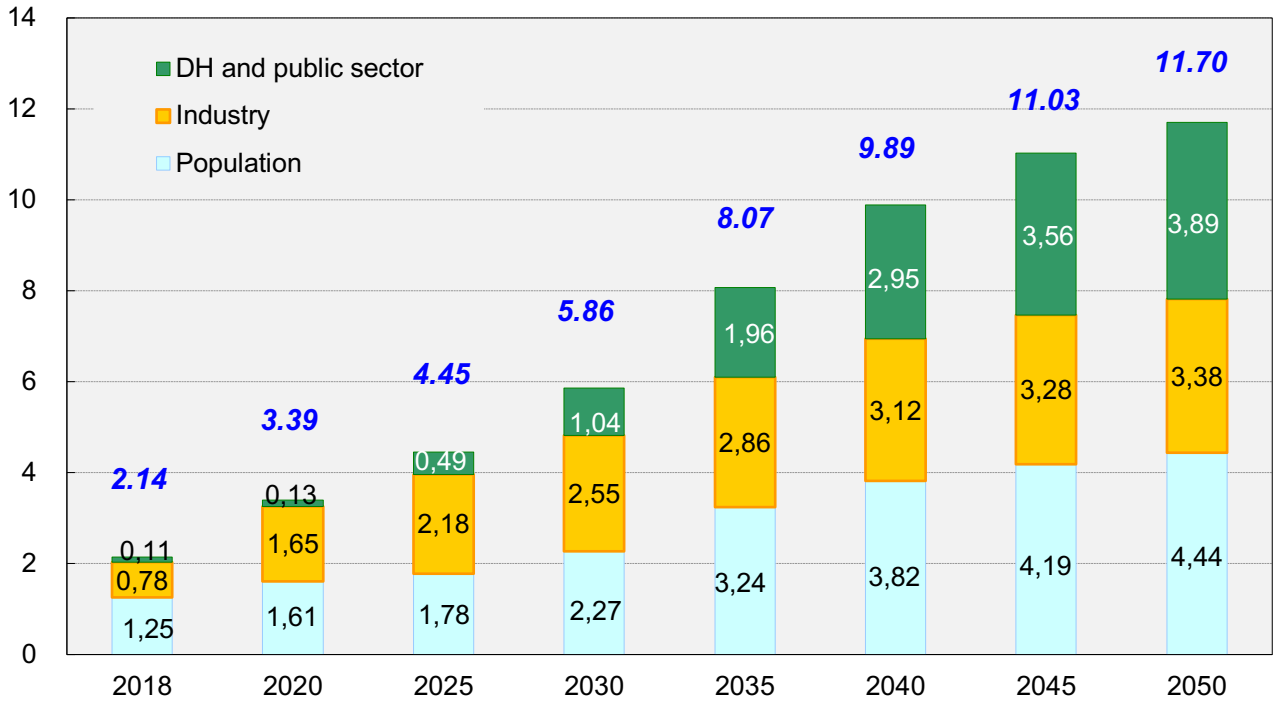
- *The launch and growth of the production of biomethane and motor biofuels of the second generation: up to 2.4 Mtoe/yr and 0.43 Mtoe/yr in 2050, respectively.*

Production and consumption of biomethane not only for power/heat production but also as motor fuel and second-generation motor biofuels are relatively new but very promising sectors of bioenergy. In Ukraine, unlike Europe, these areas, unfortunately, have not begun to develop yet. The Roadmap envisages the launch and growth of the production of these types of biofuels. This is in line with European trends and offers some clear benefits for the country's energy and transport sectors.

5.4. Biofuels in the sectors of heat production, power production and transport

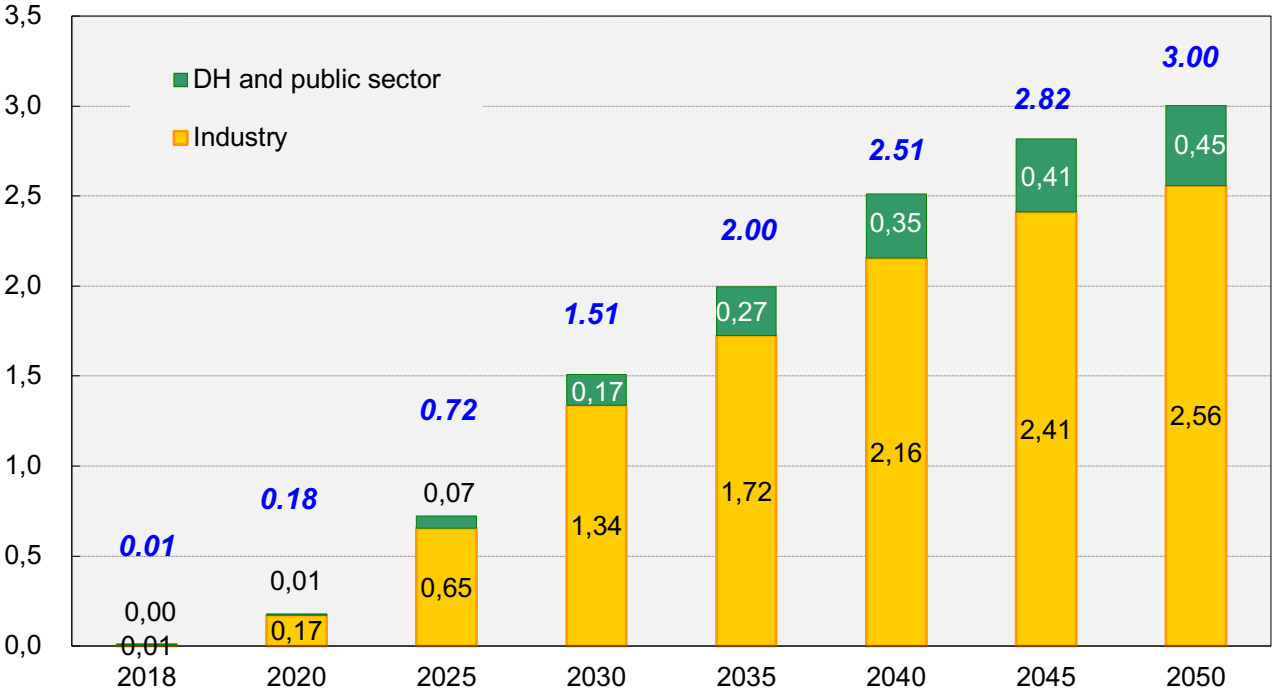
In Ukraine, more than half of the final energy consumption is accounted for heat (see **Fig. 3.2**). Taking this into consideration, according to the Roadmap, about a half of the total consumption of biofuels will fall to solid biofuels used for heat production (11.7 Mtoe) in 2050 (see **Fig. 5.18**). The rest will be divided into relatively comparable proportions between solid biofuels for electricity production (3.0 Mtoe), biogas (2.36 Mtoe), and biomethane (2.36 Mtoe). The smallest share of the total biofuel consumption in 2050 falls to liquid biofuels (0.85 Mtoe); of them, the second generation biofuels (the production of which has not started yet in Ukraine at all) account for 0.43 Mtoe.

Forecast for the structure of the use of solid biofuels for the production of heat and power in different sectors in Ukraine is presented in **Fig. 5.19, 5.20**. These data show that the volume of heat production from solid biomass will be comparable in DH/public sector, industry and individual heating closer to 2050, while power production from biomass will be concentrated more in the industrial sector during the whole period until 2050.



Notes: The upper figures are sums total by sectors

Fig. 5.19. Forecasted structure of using solid biofuels for heat production in different sectors in Ukraine, Mtoe



Notes: The upper figures are sums total by sectors

Fig. 5.20. Forecasted structure of using solid biofuels for power production in different sectors in Ukraine, Mtoe

5.5. Envisaged bioenergy equipment to be introduced until 2050

It is estimated that the total installed capacity of bioenergy equipment will be about **50** GW_{th} and **5.2** GW_{el} in 2050. The total consumption of biofuels will be over **20** Mtoe/yr, which actually corresponds to almost entire current potential of biomass in Ukraine (see **Table 5.1**).

Table 5.3 presents the distribution of equipment by sectors in 2050: household sector (domestic boilers and stoves on solid biofuels), DH/public sector (boilers and CHP plants on solid biofuels), and industry (boilers, CHP plants, TPPs, ORC TPPs on solid biofuels, CHP plants on biogas/biomethane, CHP plants on biogas obtained from waste).

Table 5.3. Envisaged installed capacity of bioenergy equipment in Ukraine in 2050

Type of equipment	Total installed capacity in 2050	
	MW_{th}	**MW_{el}**
Household sector		
Domestic boilers and stoves on wood biomass (firewood, pellets, briquettes)	5285	
Domestic boilers on agrobiomass (pellets, briquettes, small bales)	7500	
Domestic boilers on energy crops (pellets, chips)	6000	
DH + public sector		
Boilers (wood biomass)	600	

Boilers (primary agricultural residues)	12750	
Boilers (secondary agricultural residues)	900	
Boilers (energy crops)	2750	
CHP plants (wood biomass)	225	75
CHP plants (primary agricultural residues)	1500	500
CHP plants (energy crops)	2250	750
Industry		
Boilers (wood biomass)	1400	
Boilers (primary agricultural residues)	3000	
Boilers (secondary agricultural residues)	300	
CHP plants (wood biomass)	240	80
CHP plants (primary agricultural residues)	1520	475
CHP plants (secondary agricultural residues)	300	100
CHP plants (biogas, biomethane)	2870	2040
TPPs (primary agricultural residues)		380
TPPs (secondary agricultural residues)		160
TPPs (wood)		55
TPPs (energy crops)		340
TPPs ORC (primary agricultural residues)		25
CHP plants on biogas obtained from waste (landfills, mechanical and biological treatment of waste, wastewater)	265	250
Total	**49655**	**5230**

5.6. Assessment of investments required for implementing Roadmap until 2050

Preliminary expert estimates indicate that the implementation of the Roadmap requires investments in the range of **21…33.5** billion EUR, depending on the cost of the equipment to be installed. Approximate distribution of the investments by type of bioenergy equipment/technologies is given in **Table 5.4**.

Table 5.4. Assessment of investments required for the implementation of the Roadmap

Types of bioenergy equipment/technology	Specific capital costs*	Expected investments, bln EUR
Individual boilers and stoves on solid biomass.	50…100 EUR/kW_{th}	0.9…1.9
Boilers on solid biomass.	200…300 EUR/kW_{th}	4.3…6.5
CHP plants/TPPs on solid biomass.	2500…4000 EUR/kW_{el}	7.4…11.8
CHP plants on biogas/biomethane (agricultural residues, landfill gas, mechanical and biological treatment of waste, wastewater).	2500…4000 EUR/kW_{el}	5.7…9.1
Production of biomethane (motor fuel).	10000…16000 EUR/(m^3 CH_4/hr)	1.1…1.8
Production of liquid biofuels of I generation.	837…1648 EUR/ktoe	0.4…0.7

Production of liquid biofuels of II generation.	2346…4246 EUR/ktoe	1.0…1.8
Total		**20.8…33.5**

** These are some average figures as the specific capital costs depend on type/capacity of an installation, type of applied technology and used biomass. They will be gradually decreasing during the period until 2050.*

Expected sources of funding include private investments, loans/grants from Ukrainian and international financial institutions and programs (Ukrgasbank, EBRD, GEF, IFC, USAID, GIZ, NEFCO, UNDP etc.) as well as state funds under the relevant support programs.

5.7. Economic impacts of implementing the Roadmap

Implementation of the Bioenergy Roadmap will have positive economic impacts such as reduced import of fossil fuels, GDP growth, development of national economy, creation of new jobs and some others.

Based on the Roadmap data for 2050 on the consumption of biofuels, the possible currency saving caused by the reduced imports of natural gas and petrol/diesel to Ukraine is estimated as **2.31** bln USD/yr and **0.77** bln USD/yr respectively[48], the total sum being **3.08** bln USD/yr.

The total number of created new jobs may be over 162,000 by 2050. They include direct jobs (connected with servicing bioenergy equipment) and indirect jobs (connected with harvesting and supply of biomass for energy).

Replacement of coal, heavy oil, petrol and diesel by biofuels in the energy sector and in transport leads to a reduction of pollutant emission, which makes a generally positive impact on people's health.

5.8. Roadmap summary

Roadmap summary indices by benchmark years are presented in **Table 5.5**. According to the forecast presented in the Roadmap, by 2050, the development of bioenergy in Ukraine may lead to:

- replacement of nearly **20** bln m^3/yr of natural gas and more than **1** Mt of petrol and diesel;
- reduction of GHG emissions by over **54** Mt $CO_{2\text{-eq}}$/yr;
- creation of over **162,000** jobs.

Table 5.5. Bioenergy Roadmap summary indices.

Year	Installed capacity of bioenergy equipment		Consumption of biofuels*, Mtoe	Replacement of NG, bln m^3	Replacement of petrol and diesel, Mt	Reduction of CO_2 emission Mt/yr	Required investments, bln EUR		Creation of new jobs, number
	MW_{th}	MW_{el}					min	max	
2020	8206	202	3.77	4.34	0.17	8.90	1.52	2.52	16914
2025	12276	844	5.83	6.35	0.25	14.31	3.73	6.06	31438

[48] Data on the amount and cost of natural gas, petrol and diesel imported to Ukraine in 2019 are taken according to the Statistical Yearbook "Ukraine's Foreign Trade" issued by the State Statistics Service of Ukraine, 2020.

2030	19087	1846	8.57	9.11	0.39	21.35	7.07	11.44	54302
2035	30237	2804	12.01	12.62	0.50	30.37	10.78	17.43	86237
2040	39338	3609	15.13	15.77	0.67	38.66	14.15	22.85	115439
2045	45351	4299	17.64	17.98	0.96	45.79	16.94	27.38	139013
2050	49655	5230	20.28	19.92	1.23	54.40	19.70	31.81	162710

** Including liquid and gaseous biofuels for transport.*

Of these, the solid biomass segment makes the biggest contribution accounting for 17.9 bln m^3/yr of natural gas, 35 Mt CO_2/yr and over 107,000 new jobs in 2050 (**Table 5.6**). Another 2.1 bln m^3/yr of natural gas and 0.4 Mt/yr of petrol and diesel will be replaced at the expense of the production and consumption of biogas/biomethane (**Tables 5.7, 5.8**). The contribution of liquid biofuels to Roadmap indexes in 2050 will lie in the replacement of 0.83 Mt/yr of petrol/diesel, reduction of almost 2 Mt CO_2/yr of GHG and creation of over 8,500 new jobs (**Table 5.9**).

Table 5.6. Forecast for the development of bioenergy until 2050 in terms of solid biofuels

Year	Installed capacity		Consumption of biofuels, Mtoe	Replacement of NG, bln m^3	Reduction of CO_2 emission Mt/yr	Required investments, bln EUR		Creation of new jobs
	MW_{th}	MW_{el}				min	max	
2020	8103	105	3.57	4.33	8.49	1.14	1.85	13334
2025	11955	552	5.18	6.29	12.32	2.74	4.39	23284
2030	18465	1295	7.36	8.94	17.53	5.24	8.39	39853
2035	29173	1908	10.06	12.22	23.95	7.90	12.64	64023
2040	37854	2421	12.40	15.06	29.51	10.28	16.41	85987
2045	43307	2738	13.85	16.82	32.97	11.75	18.75	99755
2050	46520	2940	14.71	17.86	35.01	12.63	20.15	107543

Table 5.7. Forecast for the development of bioenergy until 2050 in terms of biogas

Year	Installed capacity		Consumption of biofuels, Mtoe	Replacement of NG, bln m^3	Reduction of CO_2 emission, Mt/yr	Required investments, bln EUR		Creation of new jobs
	MW_{el}	MW_{th}				min	max	
2020	97	104	0.03	0.00	0.11	0.24	0.39	1843
2025	292	321	0.40	0.06	1.46	0.73	1.17	5547
2030	551	622	0.80	0.16	2.96	1.38	2.21	10474
2035	896	1064	1.39	0.35	5.13	2.24	3.58	17026
2040	1188	1484	1.94	0.59	7.16	2.97	4.75	22564
2045	1561	2044	2.61	0.91	9.63	3.90	6.24	29655
2050	2286	3135	3.89	1.54	14.36	5.72	9.14	43434

Table 5.8. Forecast for the development of bioenergy until 2050 in terms of gaseous biofuels

Year	Production		Replacement of motor fuels including:			Reduction of CO_2 emissions Mt/yr	Required investments, bln EUR		Creation of new jobs
	Mt	Mtoe	NG, bln m^3	Diesel and petrol, Mt	Total, Mtoe		min	max	
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
2025	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	8
2030	0.01	0.01	0.01	0.00	0.01	0.05	0.02	0.03	47
2035	0.05	0.06	0.05	0.02	0.06	0.21	0.08	0.12	224
2040	0.14	0.16	0.12	0.06	0.16	0.58	0.21	0.34	609
2045	0.32	0.36	0.24	0.15	0.36	1.31	0.47	0.76	1377
2050	0.75	0.83	0.52	0.40	0.83	3.05	1.10	1.76	3195

Table 5.9. Forecast for the development of bioenergy until 2050 in terms of liquid biofuels

Year	Production of biofuels				Replacement of petrol and diesel		Reduction of CO_2 emission Mt/yr	Required investments, mln EUR		Creation of new jobs
	Total, Mt	Including II-gen biofuels, Mt	Total, Mtoe	Including II-gen biofuels, Mtoe	Mt	Mtoe		min	max	
2020	0.27	0.00	0.17	0.00	0.17	0.17	0.29	145	286	1737
2025	0.39	0.04	0.26	0.03	0.25	0.26	0.52	257	496	2599
2030	0.58	0.11	0.39	0.08	0.38	0.39	0.82	447	851	3928
2035	0.70	0.20	0.50	0.15	0.48	0.50	1.08	640	1205	4965
2040	0.85	0.31	0.63	0.25	0.61	0.63	1.41	905	1687	6280
2045	1.09	0.49	0.82	0.39	0.80	0.82	1.88	1285	2382	8227
2050	1.12	0.53	0.85	0.43	0.83	0.85	1.98	1359	2516	8538

6. Improvement of the legal framework required to implement the Roadmap

The legislative basis for the development of Ukraine's bioenergy sector consists of the Laws of Ukraine "On Alternative Energy Sources"[49], "On Alternative Fuels"[50], "On Heat Supply"[51] and some other laws and regulations.

The Law of Ukraine "On Alternative Energy Sources" defines the basic concepts of the renewable energy sector, contains rules for establishing and applying a feed-in tariff ("green" tariff) for the electricity produced from AES, as well as rules for auctions to distribute support quotas for the electricity production from AES to relevant business entities. According to this Law, energy from biomass and biogas belongs to renewable energy sources, which, in turn, are a component of alternative energy sources. Another mechanism to support the development of Ukraine's bioenergy sector is a stimulating tariff for heat from AES introduced in 2017[52] and included in the Law of Ukraine "On Heat Supply".

At one time, these incentive tools played a significant role, but now they need some improvement. For example, the existing values the feed-in tariff for electricity from biomass/biogas and the stimulating tariff for heat from biomass are insufficient to ensure the profitability of the respective low-scale installations. In addition, there are no mechanisms of state support for such important areas of bioenergy as production/consumption of biomethane and growing of energy crops.

Other barriers to the sector include the underdevelopment of the biofuel and organic fertilizer markets, difficult access of private companies to logging residues, low investment attractiveness and problems with the practical implementation of bioenergy projects. Recommendations for overcoming the main barriers of the bioenergy sector are presented in **Table 6.1**. Almost all the recommendations are supported by draft laws, some of which have already been included in the plans to be considered by the Government of Ukraine.

Table 6.1. Barriers in Ukraine's bioenergy sector and recommendations on how to overcome them

Main barriers in the bioenergy sector	Recommendations for overcoming the barriers taking into account European experience
1. Underdeveloped biofuel market.	• Introduction of a system for electronic trade with biofuels following the example of the Lithuanian biofuel exchange Baltpool.
2. Low investment attractiveness of bioenergy projects.	• Introduction of auctions for state support of projects producing electricity from RES, including biomass and biogas. • Creation of the competitive heat market.

[49] Law of Ukraine "On Alternative Energy Sources» (No 555-IV of 20.02.2003, amended) https://zakon.rada.gov.ua/laws/show/555-15

[50] Law of Ukraine «On Alternative Fuels» (No 1391-XIV of 14.01.2000, amended) https://zakon.rada.gov.ua/laws/show/1391-14

[51] Law of Ukraine «On heat Supply» (No 2633-IV of 02.06.2005, amended) https://zakon.rada.gov.ua/laws/show/2633-15

[52] Law of Ukraine "On Amending Law of Ukraine" On Heat Supply" to Stimulate the Production of Heat from Alternative Energy Sources" (No 1959-VIII of 21.03.2017) https://zakon5.rada.gov.ua/laws/show/1959-19

	• Introduction of support for growing energy crops. • Abolition of CO_2 tax for bioenergy plants.
3. Problems with practical implementation of bioenergy projects, in particular, connection to power grid, access to heat network.	• Ensuring transparency, conciseness and efficiency of the connection to power grid, so that this procedure does not deter investors from implementing new projects. • Introduction of non-discriminatory criteria for the access to heat network for independent producers of heat from biomass.
4. Complicated access of private companies to felling residues.	• Development, implementation and optimization of technologies for collection and harvesting of felling residues with use of modern specialized equipment. • Obliging forest owners and forest users to haul felling residues to the nearest roads for the production of solid biofuels.
5. Problems with practical use of agrobiomass as fuel and feedstock for biofuel production.	• Use of agro-biofuel only in specialized equipment. • Compliance with the requirements of boiler equipment for fuel and ensuring optimal operating modes of the equipment. • The use of grain maize production by-products for energy.
6. Underdeveloped organic farming; no application of digestate.	• Development of the market of organic fertilizers. • Effective implementation of provisions of the Law of Ukraine “On Basic Principles and Requirements for Organic Production, Circulation and Labeling of Organic Products” (No 2496-VIII of July 10, 2018).
7. Absence of state support for the production and consumption of biomethane.	• Setting strategic goals for biomethane production. • Development of legal framework to support the production and consumption of biomethane: introduction of the concepts of biomethane, guarantee for biomethane origin of, FIT for biomethane; development and adoption of the Procedure for functioning of the register of production and consumption of biomethane; introduction of FIT for electricity from biomethane.

Implementation of the proposed legislative changes will help to create a favorable environment for significant growth in the production of energy and biofuels from biomass, which will ensure the realization of the goals and tasks of the Roadmap for the development of bioenergy in Ukraine until 2050.

Conclusions

Renewable energy sources are playing an increasing role in Ukraine's energy sector. According to the Energy Balance for 2018, the amount of renewable energy in the final energy consumption was **3582** ktoe, which is equivalent to **7.0%** of the total final energy consumption. Of these, the largest contribution is made by bioenergy – **77.3%.**

In Ukraine, there has been a steady trend of increasing energy production from alternative fuels, in particular, from biomass. According to the Energy Balance of Ukraine for 2018, the total supply of primary energy from biofuels and waste amounted to **3195** ktoe, which is equivalent to the replacement of **4 bln m^3/yr** of natural gas. The share of biofuels in the total supply of primary energy is **3.4%** (over **70%** of the total supply of renewable energy). The growth of the sector in 2010-2018 averaged **31%** per year.

The Roadmap for the development of bioenergy in Ukraine until 2050 is a necessary document, as it provides an action plan to achieve existing goals for the development of bioenergy until 2035, outlines the goals and prospects of the sector until 2050, contains materials for developing a number of strategic documents in the energy sector. For example, the Roadmap data can be used in the development of NREAP until 2030 as well as a new Energy Strategy of Ukraine with the extension of the covered period until 2050. In addition, the Roadmap is the first step towards preparing a more comprehensive document – a long-term strategy for the development of bioenergy in Ukraine.

The proposed Roadmap covers the period of 2020-2050 and has several reference points. One of them takes into account the goal of bioenergy development set by the Energy Strategy of Ukraine for 2035 – **11** Mtoe of biomass, biofuels and waste in the total supply of primary energy.

The Roadmap corresponds to the scenario of achieving over **60%** of RES in the energy balance of Ukraine in 2050, including the individual sectors:

- power production – **70%** of RES;
- heat production – **65%** of RES;
- transport – **35%** of RES.

Preliminary expert estimates indicate that the implementation of the Roadmap requires investments in the amount of 21…33.5 billion EUR, depending on cost of the equipment to be introduced.

According to the forecast presented in the Roadmap, the development of bioenergy in Ukraine may lead to the replacement of almost **20** bln m^3/yr of natural gas and create over **162,000** jobs by 2050. Of these, the solid biomass segment makes the biggest contribution accounting for 17.9 bln m^3/yr of natural gas, 35 Mt CO_2/yr and over 107,000 new jobs in 2050. Another 2.1 bln m^3/yr of natural gas and 0.4 Mt/yr of petrol and diesel will be replaced at the expense of the production and consumption of biogas/biomethane. The contribution of liquid biofuels to Roadmap indexes in 2050 will lie in the replacement of 0.83 Mt/yr of petrol/diesel, reduction of almost 2 Mt CO_2/yr of GHG and creation of over 8,500 new jobs.

Based on the Roadmap data for 2050 on the consumption of biofuels, the possible currency saving caused by the reduced imports of natural gas and petrol/diesel to Ukraine is estimated as **2.31** bln USD/yr and **0.77** bln USD/yr respectively, the total sum being **3.08** bln USD/yr.

With the purpose of achieving the goals and tasks of the proposed Roadmap, some recommendations have been developed to overcome the main barriers to the bioenergy sector. Almost all of the suggested recommendations are supported by draft laws, some of which have already been included in the plans for consideration by the Government of Ukraine.

Annex 1. What it roadmap?

There is no official definition of the concept of "roadmap" and requirements for its structure in the legislation of Ukraine. Usually the "road map" is used as a synonym for "strategy", for example:

STRATEGY for the implementation of the provisions of directives and regulations of the European Union in the field of international maritime and inland water transport ("roadmap") (APPROVED by CMU's order No 747-p of October 11, 2017[53]

STRATEGY for the implementation of the provisions of the European Union directives in the field of postal services and courier services ("roadmap") (APPROVED by CMU's order No 104-p of February 14, 2018[54]

EXPORT STRATEGY OF UKRAINE ("roadmap" of strategic trade development) for 2017-2021 (APPROVED by CMU's order No 1017-p of December 27, 2017)[55]

Analysis of the above and similar regulations shows that they usually consist of the following *parts*: general part, purpose, main directions of implementation, tasks, expected results, monitoring and are accompanied by a *plan of measures* to implement a strategy ("roadmap").

The following definitions and explanations can be found in the literature:

A roadmap is a step-by-step scenario of the development of a management object, clearly presented in the form of a graph of the management process, which reflects the strategically important events that determine the development of the management object and the sequence of their occurrence. ***A roadmap occupies an intermediate position between the strategy and the strategic plan***[56].

A roadmap is a ***strategic plan*** *that defines a goal or desired outcome and includes the major steps or milestones needed to reach it*[57].

A roadmap is a ***strategic planning technique*** *that places a project's goals and major deliverables (tasks, milestones) on a timeline, all grouped in a single visual representation or a graphic*[58].

[53] https://zakon.rada.gov.ua/laws/show/747-2017-%D1%80
[54] https://zakon.rada.gov.ua/laws/show/104-2018-%D1%80
[55] https://zakon.rada.gov.ua/laws/show/1017-2017-%D1%80
[56] https://stud.com.ua/18661/menedzhment/strategichne_planuvannya
[57] https://www.productplan.com/roadmap-basics/
[58] https://www.officetimeline.com/roadmaps

Abbreviations

AES – alternative energy sources
APPR – agrarian plantations pruning and removal
CHP – combined heat and power
CHPP – combined heat and power plant
CMU – Cabinet of Ministers of Ukraine
DH – district heating
HPP – hydro power plant
HAPP – hydro-accumulating power plant
IEA – International Energy Agency
FIT – feed-in tariff
GDP – gross domestic product
GHG – greenhouse gas
MSW – municipal solid waste
NG – natural gas
NPP – nuclear power plant
NREAP – National Renewable Energy Action Plan
ORC – organic Rankine cycle
RES – renewable energy sources
SAEE – State Agency on Energy Efficiency and Energy Saving
SPP – solar power plant
TPES – total primary energy supply
TPP – thermal power plant
UABIO – Bioenergy Association of Ukraine
UPS – Unified Power System
WPP – wind power plant
100 RE UA – Public Union Global 100RE Ukraine
ktoe – thousand tons of oil equivalent
Mtoe – million tons of oil equivalent
bln – billion
mln – million

Previous publications by UABIO

Available by the following link: https://uabio.org/en/materials/uabio-analytics/.

1. *Position Paper № 1* (2012) "Position of bioenergy in the draft updated energy strategy of Ukraine till 2030".
2. *Position Paper № 2* (2013) "Analysis of the Law of Ukraine "On amending the Law of Ukraine "On Electricity" No5485-VI of 20.11.2012".
3. *Position Paper № 3* (2013) "Barriers to the development of bioenergy in Ukraine".
4. *Position Paper № 4* (2013) "Prospects of biogas production and use in Ukraine".
5. *Position Paper № 5* (2013) "Prospects for the electricity generation from biomass in Ukraine"
6. *Position Paper № 6* (2013) "Prospects for heat production from biomass in Ukraine"
7. *Position Paper № 7* (2014) "Prospects for the use of agricultural residues for energy production in Ukraine".
8. *Position Paper № 8* (2014) "Energy and environmental analysis of bioenergy technologies"
9. *Position paper № 9* (2014) "State of the art and prospects for bioenergy development in Ukraine"
10. *Position paper № 10* (2014) "Prospects for the growing and use of energy crops in Ukraine"
11. *Position paper № 11* (2014) "Prospects of biomethane production and use in Ukraine"
12. *Position paper № 12* (2015) "Prospects for the development of bioenergy as an instrument for natural gas replacement in Ukraine"
13. *Position paper № 13* (2015) "Analysis of energy strategies of the EU and world countries and the role of renewables in their energy systems".
14. *Position paper № 14* (2016) "Analysis of tariff setting in the district heating sector of EU countries".
15. *Position paper № 15* (2016) "Analysis of additional sources of wood fuel in Ukraine".
16. *Position paper № 16* (2016) "Opportunities for harvesting by-products of grain corn for energy production in Ukraine".
17. *Position paper № 17* (2016) "Analysis of criteria for the sustainable development of bioenergy".
18. *Position paper № 18* (2017) "Creation of the competitive biofuel market in Ukraine".
19. *Position paper № 19* (2018) "Opportunities for wood fuel harvesting in forests of Ukraine".
20. *Position paper № 20 (2018)* "Analysis of possibilities for the production and use of agribiomass briquettes in Ukraine".
21. *Position paper № 21* (2019) "Analysis of barriers to the production of energy from agribiomass in Ukraine".
22. *Position paper № 22* (2019) "Prospects of energy utilisation of municipal solid waste in Ukraine".
23. *Position paper № 23* (2020) "Analysis of pellets and briquettes production from corn residues".
24. *Position paper № 24* (2020) "Agricultural residues for energy. What you should know about organizational and technical solutions".
25. *Position paper № 25 (2020)* "Prospects of sunflower residues use for energy".

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7 Years

30 Companies

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20+ Experts in Ukrainian Bioenergy

We participate in the development of legislative, state and sectoral strategic documents that contribute to bioenergy development in Ukraine; we provide expert, advisory and information assistance to partners; we monitor national and international legislation in bioenergy, renewable energy, energy efficiency, and climate change; we cooperate with international associations, organizations, business, experts, government representatives; we organize public events: conferences, workshops, and seminars; we raise the Ukrainians level of awareness about the bioenergy benefits through the website, social networks, and digest.

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