

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE



**DESIGNING A CARBON NEUTRAL ENERGY SYSTEM OF UKRAINE:
INCREASING THE UPTAKE OF BIOFUELS AND BIOMASS IN UKRAINE**



31/03/2023

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LIST OF ABBREVIATIONS

BioPP	Bioenergy Power Plant
CBAM	Carbon Border Adjustment Mechanism
CHP	Combined Heat and Power Plant
CIS	Commonwealth of Independent State
DDGS	Distillers Dried Grains with Solubles
EnC	Energy Community
ESU-2035	Energy Strategy of Ukraine until 2035
EU	European Union
FAO	Food and Agriculture Organization
FIT	Feed-in-tariff
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GoO	Guarantee of Origin
GTS	Gas Transmission System
HPP	Hydro Power Plant
IEA	International Energy Agency
IPS	Integrated Power System
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
LLC	Limited Liability Company
MAPF	Ministry of Agrarian Policy and Food
ME	Ministry of Energy
MTBE	Methyl Tert-butyl Ether
NATO	North Atlantic Treaty Organization
NEURC	National Energy and Utilities Regulatory Commission
NG	Natural Gas
NPV	Net Present Value
NREDAP	National Renewable Energy Development Action Plan
OSCE	Organization for Security and Co-operation in Europe
PSPP	Private Solar Power Plant
PFAN	Private Financing Advisory Network
RED	Renewable Energy Directive
RE	Renewable Energy
SAEE	State Agency on Energy Efficiency and Energy Saving of Ukraine
SDG	Sustainable Development Goals
SPP	Solar Power Plant
TPES	Total Primary Energy Supply
TPPs	Thermal Power Plants
UABIO	Bioenergy Association of Ukraine
UES	Ukraine's United Energy System
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
WPP	Wind Power Plant

SIGNS AND MEASURES

CO ₂	Carbon dioxide
bln	Billion
Gcal	Gigacalories
Gcal/h	Gigacalories per hour
GW	Gigawatt
GWh	Gigawatt hour
ha	Hectares
km ²	Square kilometers
ktoe	Thousand tons of oil equivalent
kW	Kilowatt
kWh	Kilowatt hour
m ³	Cubic meters
mln	Million
Mtoe	Million tons of oil equivalent
MW	Megawatt
MWel	Output power obtained as electricity
thsd	Thousand
thsdtoe	Thousand tons of oil equivalent
TWh	Terawatt hours

CURRENCIES

EUR	Euros
UAH	Ukrainian Hryvnia
USD	United States dollar

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EXECUTIVE SUMMARY

Biomass refers to one of the most perspective sources of renewable energy (RE) coming from carbon containing organic materials of plant or animal origin (wood, agricultural residues, manure, specially grown energy crops and organic portion of solid waste).

Using various transformation processes such as combustion, gasification, pyrolysis the biomass is either transformed into biofuels, bio heat, bioelectricity, animal feed, bio fertilizers and bio chemicals.

Ukraine has a good chance and enough potential for dynamic development of bioenergy.

The main drivers of the bioenergy development are considered to be:

- Agricultural and agro industrial production become the main source for the country and will be developing in the near perspective;
- Energy dependence on import and constantly growing prices on natural gas force to look for alternative fuels;
- Necessity of upgrading and increasing of energy efficiency of the obsolete heat and power utilities infrastructure;
- EU sustainability and energy saving targets – increasing demand for biofuels from Ukraine;
- Favorable taxation and recent legislative initiatives;
- Incentives for electricity and heat produced from agricultural residues.

As part of promoting energy security and efficiency, Ukraine has sought to increase its share of renewables by adopting policies. Energy sector reform remains major to promoting Ukraine's sustainable growth.

Efforts to advance energy reforms require an understanding of this sector architecture and the reform processes in order to identify potential challenges ahead. This study contains a general assessment of the energy sector of Ukraine, the current state of development and potential of bioenergy, existing legislative framework and valuable initiatives for the bioenergy sector development.

INTRODUCTION

This study is linked to the following UNECE activities:

- “Addressing the compounded food and energy crisis in Ukraine through innovative technologies and adaptive agricultural practices” within the SDG Fund project and implemented by FAO, UNEP, and UNECE. The activity is developed in response to the request of the Ministry of Agrarian Policy and Food (MAPF) for support to address fuel shortages in the agriculture sector
- “UNECE early development response: reconstruction of Ukraine – restoring connectivity and rebuilding infrastructure.” The activity supports efforts of the national and local governments for planning of and preparations related to redesigning and rebuilding energy system in Ukraine that suffered significant damage in the war to support achieving the SDGs and are based on the “building back better” principle.

This work is contributing to a comprehensive analysis on the current energy aspects of the crisis in the country to support a better knowledge of the situation and, therefore, to lead an informed decision on a suitable biofuel strategy for Ukraine.

The objective of this study is to assess the role of bioenergy for ensuring energy resilience in Ukraine, including analysis of normative and legislative frameworks to increase the renewable energy uptake.

Within the current global energy crisis, the development of renewable energy (RE) represents one of the main ways of solving problems related to instability of the supply of fossil energy resources.

For Ukraine, bioenergy is one of the strategic directions for the development of the sector of renewable energy sources, taking into account the country's high dependence on imported energy sources, primarily natural gas, and the great potential of biomass available for energy production. Unfortunately, the rate of development of bioenergy in Ukraine is still significantly behind the European ones.

Ukraine has a significant potential of biomass available for energy production - in total more than 20 Mtoe per year. The main components of the energy potential of biomass are waste and by-products of agriculture and energy crops (altogether about 80 per cent), which is collectively defined by the term agro biomass. At the same time, the largest shares of the potential of agricultural residues fall on the straw of cereal grain crops and by-products/waste from the production of grain corn.

The contribution of wood biomass to the energy potential is relatively small (about 12 per cent of the total volume). The remaining components of the energy potential of biomass in Ukraine (about 10 per cent) are liquid biofuels (biodiesel, bioethanol) and biogas obtained from various types of raw materials (waste and by-products of the agricultural industry, industrial and municipal wastewater, solid household waste).

The situation with the consumption of biomass for the production of energy and biofuels in Ukraine is actually the opposite in accordance to the existing potential. Currently, wood biomass is most actively used (more than 90 per cent of the economic potential), and the use of waste and by-products of agricultural origin remains at a low level. On average, the energy potential of Ukraine's biomass is used approximately for 11 per cent.

This study offers a deep analysis of challenges and solutions for bioenergy sector deployment in Ukraine.

CHAPTER 1 COUNTRY OVERVIEW

Located at the crossroads of the European Union, the Black Sea and Caspian regions, Ukraine has abundant mineral resources including oil, natural gas, coal and great renewable energy potential.

Population	41.3 million people (2021)
Total area	603 628 square kilometers (km²)
Nominal gross domestic product (GDP)	UAH 5460 bln in 2021 (USD 200 bln)

The country is divided into 27 administrative units. The capital is Kyiv – a vibrant city with dynamic environment and rich history.

Ukraine is a member to numerous world and regional international bodies, including UN, OSCE, and the Commonwealth of Independent States (CIS). The country is currently taking steps to accede to EU and NATO, and has submitted requests for partnership with both organizations.

Ukraine cooperates with the European Union through the Eastern Partnership, which aims to foster political association and economic integration between the European Union and the Eastern Neighborhood countries (Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine).

The country became an Observer to the Energy Community Treaty in November 2006 and a full Member in September 2010, and has begun adopting and implementing the energy acquis, namely the legislative frameworks for the electricity and gas sectors with requirements in the areas of renewable energy, competition and the environment.

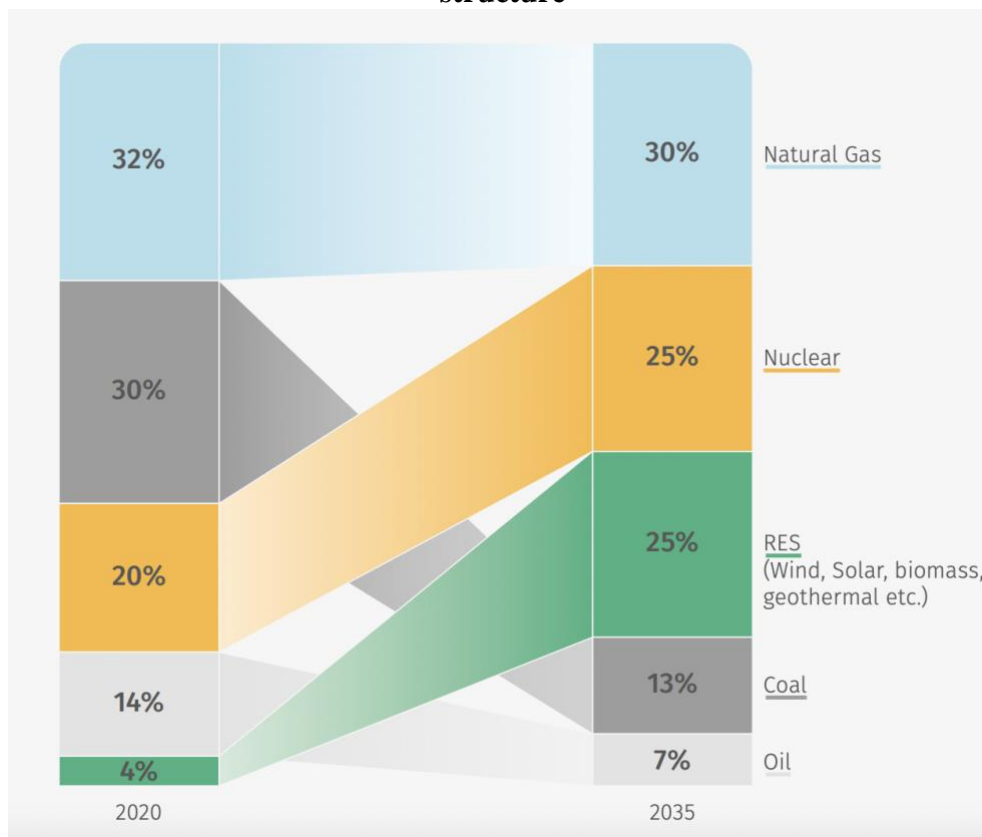
The government of Ukraine also signed and ratified the Association Agreement with the European Union in 2014, and the Deep and Comprehensive Free Trade Agreement between Ukraine and the European Union entered into force on 1 January 2016.

On 23 June 2022, the European Parliament adopted a resolution calling for the immediate granting of candidate status for EU membership to Ukraine. On the same day, the European Council granted Ukraine the status of a candidate for accession to the EU.

UKRAINE'S ENERGY SECTOR

To navigate the recovery of economy and implement vital reforms, on 12 January 2015, the President approved the Strategy for Sustainable Development “Ukraine 2020”. The main goal is to achieve European standards and help Ukraine earn its rightful place in the world. The strategy includes more than 60 reform objectives and programs, including the energy sector reform, energy independence program, environmental protection and energy efficiency program that seek to enhance Ukraine’s energy security and move towards energy efficiency and innovative technologies. The list of energy sector reforms needs to be finalized in a single document outlining the government energy policy both in short and long-term perspective. As of today, the updated Energy Strategy of Ukraine until 2035 (ESU-2035) represents such a systemic document.

Figure 1. Forecasts for substitution of fossil fuels with RE by 2035, primary energy supply structure



Source: Energy Strategy of Ukraine

According to ESU-2035, key objectives of the government’s energy policy until 2035 include:

- developing conscious and energy efficient society;
- ensuring Ukraine’s energy independence with reliable and stable functioning of its fuel and energy complex;
- developing energy markets;
- creating favorable conditions for investment;
- integrating Ukraine’s power grids and energy markets in the EU;
- updating management system in line with the present-day challenges and global energy trends.

KEY ENERGY DATA

Policy frameworks for clean energy and carbon neutrality of Ukraine is determined by the:

- **The Law of Ukraine “On Alternative Energy Sources”** defines the legal, economic, environmental and organizational framework for the use of alternative energy sources and the promotion of their use in the fuel and energy complex. It provides for the establishment of a “green” tariff to stimulate the production of electricity from alternative energy sources (except blast furnace and coke gases, and with the use of hydropower – produced only by micro-, mini- and small hydropower plants).
- **The Law of Ukraine “On Alternative Fuels”** introduces the framework for financial mechanisms to stimulate biofuels and other alternative fuels in order to save energy

resources and reduce dependence on imports. It aims at reducing environmental impact by using various kinds of waste as raw material for the production of alternative fuels.

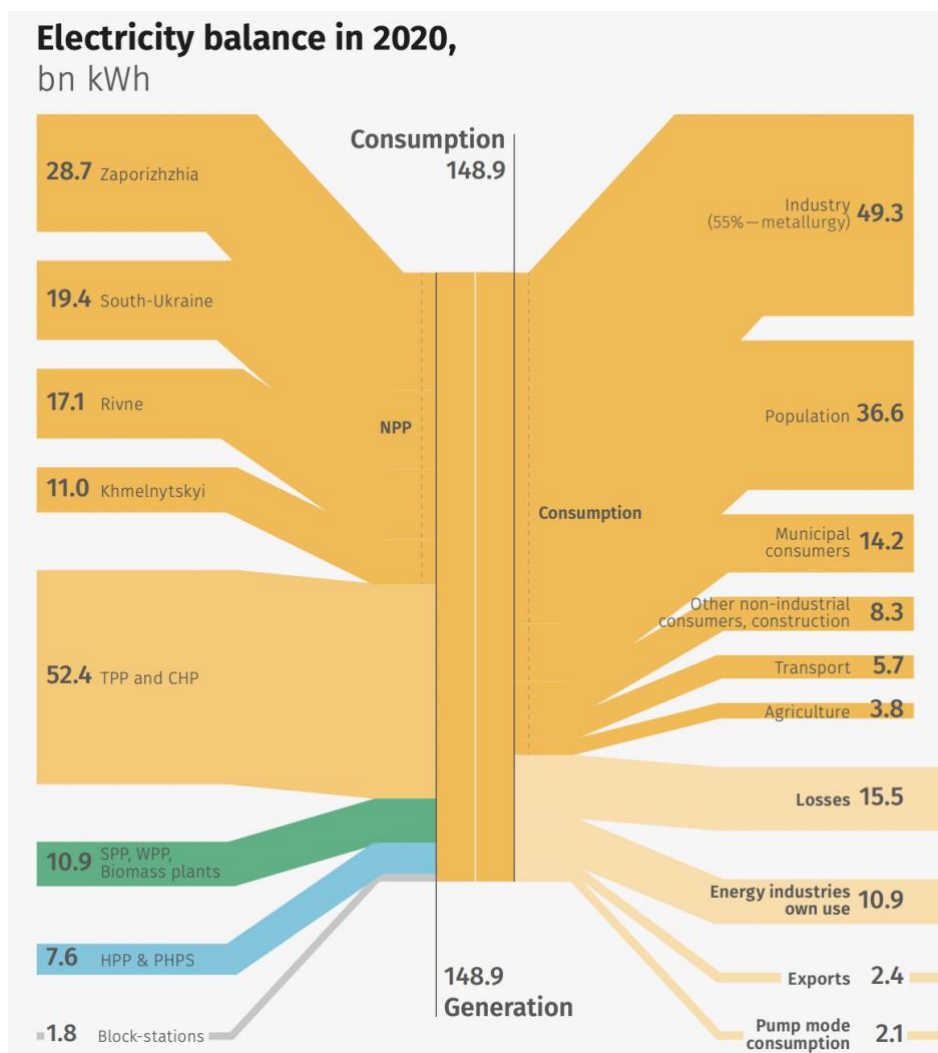
- **The Law of Ukraine “On Electricity Market”** specifies the legal, economic and organizational framework for the functioning of the electricity market, regulate relationships related to the production, transmission, distribution, purchase and sale, supply of electricity to ensure reliable and safe supply of electricity to consumers, taking into account the interests of consumers, the development of market relations, minimizing the cost of electricity supply and minimizing the negative impact on the environment.
- **The Law of Ukraine “On Heat Supply”** defines the main legal, economic, and organizational bases of activities at heat supply facilities and regulates relations related to the production, transportation, supply, and use of heat energy to ensure the energy security of Ukraine, improve the energy efficiency of heat supply system operation, create and improve the thermal energy market and protect the rights of consumers and employees in the field of heat supply.
- **The Law of Ukraine “On Energy Efficiency”** establishes the legal, economic and organizational framework of activities in the field of energy efficiency, ensuring the implementation of energy efficiency measures that will be carried out during the production, transportation, transmission, distribution, supply and consumption of energy.
- **“Concept of State Policy Implementation in Heat Supply”** aims to develop and determine the methods facilitating effective implementation of the state policy focused to ensure reliable provision of heat supply services, Ukraine's energy independence and security; reduce adverse effects on environment, improve financial and economic situation of enterprises, to introduce transparent efficient system of payments between consumer and service suppliers, and to establish conditions and incentives geared to attract investment in heat supply sector.
- **The policy document of Ukraine “National Economic Strategy until 2030”** defines strategic steps for the development of industry, agriculture, mining, infrastructure, transport, energy, information and communication technologies, creative industries and services. The Strategy also takes into account important cross-cutting areas such as digitalization, the green course, entrepreneurship development and balanced regional development.
- **The policy document of Ukraine “National Energy Strategy until 2035”** encapsulates a whole range of far-reaching reforms in the energy sector. The essential task of the energy strategy is to reduce energy consumption of Ukraine's economy by half until 2030 and to boost the Ukrainian production of both traditional and alternative energy sources. The document stipulates for the new structure of energy needs, thus nuclear power will provide 50% of the country's electricity by 2035, renewable sources - 25%, hydropower - 13% and the rest will be covered by thermal electric power stations.

The relevant policies of Ukraine are shaped and implemented in accordance with international obligations, in particular the Association Agreement with the EU, the new European Green Course, the Treaty establishing the Energy Community and the Paris Agreement.

Supply

- Ukraine produces all fossil fuels (in 2020: 14.7 million tons of oil, 16.2 Mtoe of natural gas and 1.7 Mtoe of crude oil), but in quantities insufficient to meet total energy demand.

Figure 2. Electricity generation and consumption in 2020



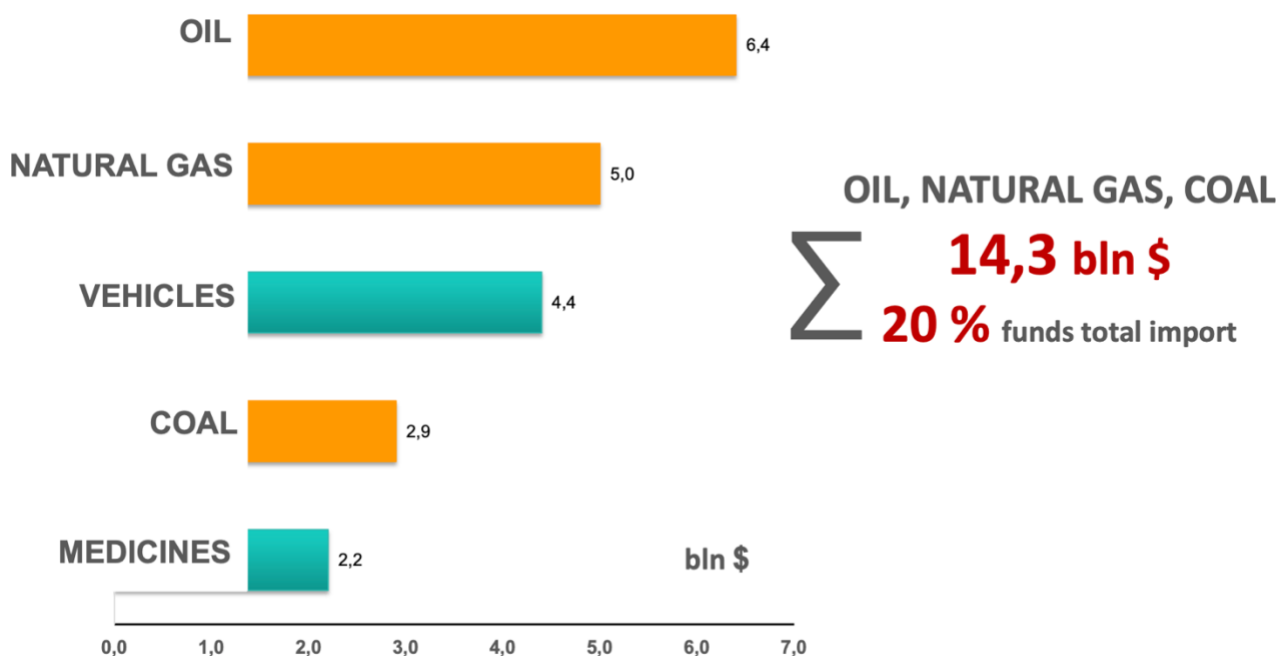
Source: Energy Strategy of Ukraine

- Still, nearly 65 per cent of Ukraine's total energy demand is covered by domestic production. This high self-sufficiency is explained by nuclear energy production, as Ukraine is the world's seventh-highest producer (72 TWh in 2020). Over half of the country's electricity is produced with nuclear power.
- Ukraine is the top energy consumer among EU4 Energy focus countries. Its primary energy supply was 86,5 Mtoe in 2020 (State Statistics Service of Ukraine)¹. Ukraine's energy mix is relatively diversified, with no fuel representing more than 30 per cent of the energy mix. In 2020, the share of natural gas was 27.6 per cent, followed by coal (the country's primary fuel) - 26.4 per cent, followed closely by and nuclear 23.1 per cent.

Import/Export

According to the State Customs Service, the leading positions in the structure of Ukrainian imports are occupied by fossil energy resources - oil products, gas and coal. During 2021, 20 per cent of the total amount of imports was spent on oil, gas and coal, namely -USD 14.3 bln.

Figure 3. Top 5 items of Ukrainian imports in 2021²



Source: State Customs Service of Ukraine

The Unified Power System of Ukraine had a total installed capacity of 54.5 GW as of December 2020. Thermal power plants had the highest capacity in the country, measured at approximately 21.8 GW. According to the data of State Statistics Service of Ukraine the electricity and heat installed capacities are the following:

Figure 4. Installed capacity in electricity for the end of 2020³

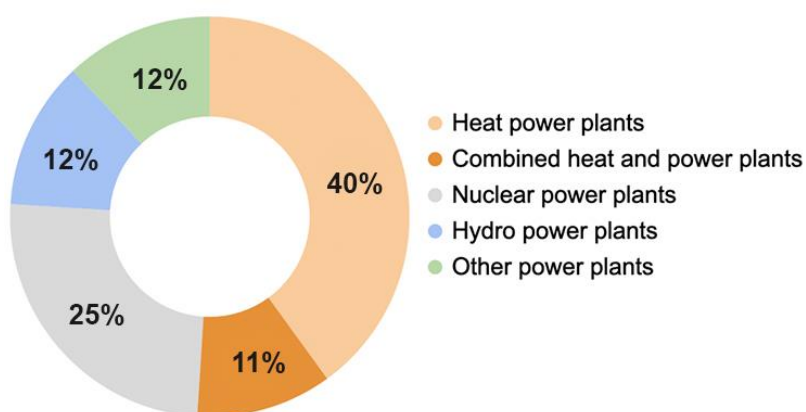


Figure 5. Release of electricity in 2020

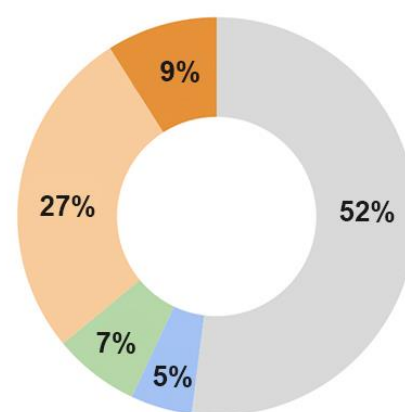


Figure 6. Installed heat capacity for the end of 2020

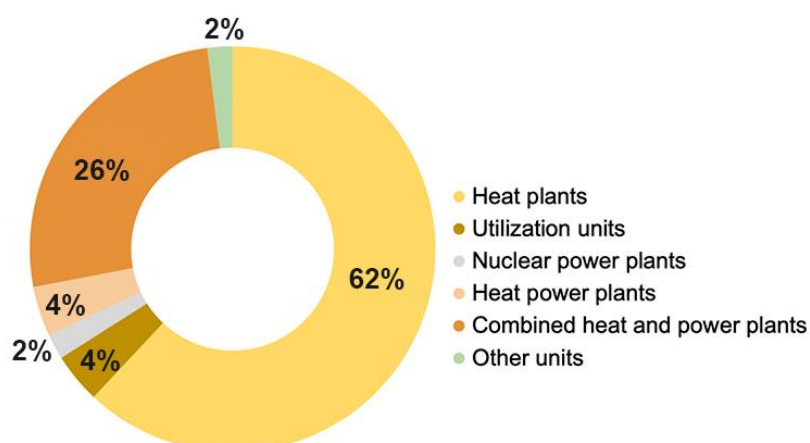
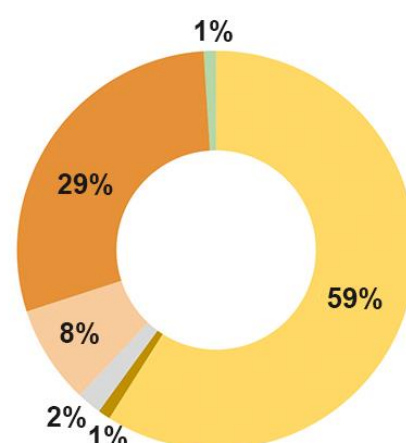


Figure 7. Release of heat in 2020



Source (figures4-7): State Statistics Service of Ukraine

Table 1. Installed capacity of power plants and release of electricity, by type of power plants

Types of generating enterprises	Power plants capacity by year-end, thsd kW		Electricity output, mln kW*h	
	2019	2020	2019	2020
Total	51444	55138	141213	137197
<i>including</i>				
heat power plants	22265	22311	141213	137197
combined heat and power	5855	5890	10738	12837
nuclear power plants	13835	13835	77948	71249
hydro power plant*	6326	6335	7712	7415
other power plants	3163	6767	3906	9396
<i>of which</i>				
wind power plants	795	1110	1760	3271
solar power plants	1953	5194	1883	56084

*Including pumped hydro power plants

Source: State Statistics Service of Ukraine

Table 2. Installed capacity of heat producers and release of heat, by type of power plants

Types of generating enterprises	Power plants capacity by year-end, Gcal/h		Output heat, thsd. Gcal	
	2019	2020	2019	2020
Total	129045	113384	91009	88954
<i>including</i>				
heat power plants	4240	4207	1241	1125
combined heat and power	31959	29896	26733	25517
nuclear power plants	2596	2596	1443	1387
heat plants	83974	70485	53954	52954
utilization units	4138	4358	6656	7088
<i>other units</i>	2138	1843	983	883

Source: State Statistics Service of Ukraine

The development of renewable energy shows a stable upward trend. In recent years, there has been a steady increase in the number of commissioned renewable energy facilities. These dynamics of renewable energy development leads to an increase in the forecast electricity output from renewable energy sources in the Integrated Power System (IPS) of Ukraine. In 2019, electricity generation from RE in the overall production mix reached 3.6 per cent or 5.5 billion kWh. The overall export of electricity to countries of Eastern Europe from the IPS of Ukraine in 2019 made up close to 5.8 billion kWh. In 2020, the generation reached 10.1 billion kWh or 6.8 per cent, in 2021 – 12.5 billion kWh or 8 per cent. It is expected that in 2022 the generation will reach about 14 billion kWh, which will make at least 9 per cent of the total electricity output by all power plants in the IPS of Ukraine.

Demand

Table 3. Final energy consumption for 2016 – 2021¹

№	Sectors	Unit	2016	2017	2018 ²	2019 ³	2020 ⁴
1	Total final energy consumption	thsdtoe	51649	49911	51408	49665	47821
of which							
2	Industry	thsdtoe	14955	15098	16487	16122	15961
3	per cent of total	per cent	29,0	30,2	32,1	32,5	33,4
4	Transport	thsdtoe	9165	9624	9453	10026	8045
5	per cent of total	per cent	17,7	19,3	18,4	20,2	16,8
6	Residential	thsdtoe	17588	16487	16201	14007	13601
7	per cent of total	per cent	34,1	33,0	31,5	28,2	28,4
8	Commercial and public services	thsdtoe	4856	4337	4742	4831	4864
9	per cent of total	per cent	9,4	8,7	9,2	9,7	10,2
10	Agriculture, forestry and fishing	thsdtoe	2143	1847	1880	1882	1671
11	per cent of total	per cent	4,1	3,7	3,7	3,8	3,5
12	Other activities	thsdtoe	31	0	0	0	0
13	per cent of total	per cent	0,1	0,0	0,0	0,0	0,0
14	Non-energy use	thsdtoe	2910	2515	2645	2786	3679
15	per cent of total	per cent	5,6	5,0	5,1	5,6	7,7

¹2014-2020 Excluding temporarily occupied territories of Autonomous Republic of Crimea, Sevastopol and part of the temporarily occupied territories in Donetsk and Luhansk region.

²Final data.

³Updated data.

⁴Operative data.

Note. In some cases, components may not be equal to the total due to the data rounding.

Source: State Statistics Service of Ukraine⁴

ENERGY SECTOR GOVERNANCE

The Cabinet of Ministers, the ultimate decision-making body, is responsible for policy coordination and the oversight of state energy companies. Energy policy is high on its political agenda, with the Parliament and the President also involved in decision-making. Seven main national-level institutions have energy policy responsibilities:

- The Ministry of Energy (ME) is responsible for energy supply policies, sustainable energy policy, climate change policy and for coordinating energy policies across the government and advising the Parliament.
- The Ministry of Finance is responsible for taxation relevant to the energy sector.
- Ministry for Communities, Territories and Infrastructure Development of Ukraine develops local-level policies and programs for reconstruction of Ukraine.
- The State Agency on Energy Efficiency and Energy Saving (SAEE), is the central government body responsible for advancing and promoting energy efficiency and renewable energy developments and technologies.
- The National Energy and Utilities Regulatory Commission (NEURC), established by Presidential Decree No. 715/2014 in September 2014, supervises the natural gas and electricity markets as well as the heat sector. The NEURC is subordinate to the President and accountable to the Parliament.
- The Anti-Monopoly Committee is responsible for preventing excessive concentration of market power.
- The State Nuclear Regulatory Inspectorate has regulatory responsibility for the operation of nuclear facilities, including uranium mining, radioactive waste storage and decommissioning at Chernobyl.

OVERVIEW OF THE RENEWABLE ENERGY UPTAKE

In recent years, trends in the development of renewable energy are going upward (the peak of investment in the construction of renewable energy facilities was in 2019). According to available information, in 2019, the capacity of power facilities that use renewable energy sources for electricity production reached 4,722 GW. During 2020, renewable energy facilities with a capacity of 1.95 GW were additionally put into operation, and in 2021 – another 1.45 GW. However, because of quarantine restrictions due to the spread of COVID-19 pandemic and for a number of economic reasons, not all facilities scheduled for commissioning during the year were put into operation. As expected, renewable energy facilities with a total capacity of about 1.54 GW or more will be additionally put into operation in 2022.

As of 31 December 2021, the installed capacity of RE plants in the IPS of Ukraine, which are directly connected to the grid and deliver electricity, is:

- WPP – 1,529 MW;
- SPPs – 6,365.3 MW (including 1,205.3 MW of household SPP);
- BioPP – 254.2 MW;
- Micro-, mini- and small HPP – 192.9 MW.

Ukraine should expect a sustainable expansion of all renewable energy sources, which are to become an instrument for achieving the energy security of the state. The ESU-2035 forecasts that

renewables will account for 12 per cent of total primary energy supply in the short and medium-term perspective (until 2025), and no less than 25 per cent by 2035 (including all hydropower capacities and thermal energy).

Moreover, growth of renewable energy among consumers shall not be subject to energy system restrictions and should facilitate a dynamic local development. The state policy needs to encourage the initiative of private market players. Efforts to decentralize renewable energy (e.g. photoelectrical systems and solar collectors on the roofs of residential buildings) with an estimated capacity of about 5 per cent of electricity consumption by the population need also to be promoted.

The electricity and heat generation sectors are expected to increase the use of biomass and biogas, which results from a relative production stability and local generation development.

Preference is given to simultaneous production of thermal and electric power in co-generation facilities and substitution of fossil fuels.

Based on non-fuel technologies, hydropower will continue to play an important role in stable functioning of Ukraine's United Energy System (UES) since it provides the energy system with highly flexible capacities for regulating daily load schedules covering peaks and filling night gaps. Moreover, it performs an important function of emergency capacity reserve.

Major activities aimed at implementing strategic goals in the renewable energy sector include pursuing consistent and predictable policy as regards facilitation of SPP and PSPP construction; arranging international communication campaigns to attract international strategic and financial investors to Ukraine's renewable energy market; constructing and putting into operation of 5 GW RE capacity (excluding high-power HPP); increasing the use of biomass in electric and thermal generation by:

- promoting the use of biomass as a fuel by companies generating biomass as a residual product;
- informing about possible use of biomass as a fuel in individual heating;
- promoting competitive biomass markets.

Feed-in tariff (FIT) was introduced in 2008 and by 2019 the amount of RE was rising steadily. However, on 25 April 2019 the new law No. 8449-d was adopted in Ukraine, which partly cancels FIT and introduces green auctions. As a result, in order to secure FIT in the first half of 2019 alone, renewable energy facilities with a capacity of more than 1.5 GW were connected to Ukrainian electrical grid. In 2019, which has been a record-breaking year so far, numbers were almost 50 per cent more.

Ukraine also has commitments under different agreements with international organizations such as Energy Community (EnC) and International Renewable Energy Agency (IRENA), which also gives some benefits and leads Ukraine to the right regulatory decisions.

IRENA predicts that Ukraine has the potential to increase its share of renewables by up to 20–25 per cent by 2030. The highest potential is in expanding the country's utilization of biomass because of the abundance of fertile black soil there, further to extensive agricultural and forestry waste too.

The country has set a goal of sourcing 25 per cent of its total energy mix from renewables by 2035. At the beginning of 2020, the share of energy generated from renewables by wind, solar, biomass, biogas, and small hydro, including large hydropower projects over 10MW reached – 11 per cent and by the end of the year - 12.4 per cent.

In order to achieve a more ambitious share of RE in Ukrainian power generation in 2030, investments in new capacities and flexible generators to balance fluctuations will be needed.

The introduction of a fixed FIT for RE generation acted as the initial driver for investment into this sector, with around EUR 8 bln invested until 2020. However, the eligibility of new plants for

FIT support ended in 2019 and FIT levels were retroactively restructured in 2020. From 2020, support for new plants is determined via competitive auctions.

In August 2017, the Government adopted the new Energy Strategy of Ukraine (ESU) till 2035⁵. It replaced the Energy Strategy till 2030, which was already outdated at the time of its adoption in July 2013.

ESU implementation is divided into three stages:

- The first stage (2018-2020) aims to create the liberalized, competitive energy markets and minimize state interference in their performance.
- The focus of the second stage (2021-2025) is on developing energy infrastructure, integrating it with the European system and attracting necessary energy sector investments.
- Finally, the third stage (2026-2035) is concerned with sustainable development: meeting the greenhouse gas (GHG) emissions reduction commitments; rapidly developing renewables; ensuring energy security by further boosting gas production, including unconventional gas and offshore drilling, after achieving gas self-sufficiency in the second stage.

The National Renewable Energy Development Action Plan (NREDAP)⁶ was adopted in 2014 in accordance with Ukraine's Energy Community commitments. According to the SAEE the NRDEAP's ambitious goals required investment from USD 3.5 bln to USD 4.3 bln in order to raise the installed capacity (excluding large hydro) by more than five times, from 1 024 MW to 5 700 MW.

In order to enforce the renewable energy development in Ukraine, the Ministry of Energy mutually with SAEE has developed a draft National Renewable Energy Action Plan till 2030⁷, which defines 27 per cent of energy consumption from renewable sources in 2030.

Currently, Ukraine has the following mechanisms for supporting renewable energy:

- FIT support scheme or auction price for 20 years for energy production from RE (Law on Alternative Energy Sources);
- Generating facilities that produce electricity from biomass and/or biogas will be entitled to a feed-in tariff if they were put into operation before the 1-st of January 2023;
- the tariff for production of heat energy from RE at the level of 90 per cent cost of heat from natural gas (Law on Heat Supply).

In summer 2020, the EU approved the Hydrogen Strategy for a climate-neutral Europe until 2050, in which it identified Ukraine as one of the priority partners. In this Strategy, the EU declared an initiative to create 80 GW of electrolyze production capacity in EU and in neighboring countries by 2030, of which 10 GW is assigned to Ukraine.

CHAPTER 2

BIOENERGY IN UKRAINE

CURRENT STATUS OF BIOENERGY SECTOR

Over the past years, Ukraine has been often spotlighted as one of the significant areas for expanding and consolidating renewable energy production for the European energy market, particularly bioenergy. This owes to the massive yet largely untapped sustainable biomass potential, extending on more than 600.000 sq. km, of which about 70 per cent are very fertile agricultural lands and 17 per cent of forests.

Most of the detailed biomass assessments date back some years now (or build on the past statistical data), yet there is some convergence in estimating that agricultural and forestry residues for energy production could deliver about 10-15 per cent of total primary energy supply (TPES) in the future energy mix. Bioenergy is currently approximately 4 per cent of TPES, where the overall target for renewables is 17 per cent in 2030. However, most of current usage refers to heating at the household level and biogas production in verticalized agri-businesses, while biofuels contribution to the transport sector is still very marginal. Most ambitious scenarios would imply significant efforts in the modernization of the primary sector, accompanied by appropriate investment. Among factors that could foster positive developments are the need to secure more energy self-sufficiency vis-a-vis the perduring tensions with Russia, formerly the primary provider of energy products.

The long-lasting conflict in the Eastern regions and confrontation with Russia are cyclically destabilizing society and the economy since almost a decade, impacting the energy market. Economic crises, demographic changes, long-term effects of the transition to market economy, decline of obsolete industries combined with limited investment capacity brought to a 20 per cent drop in domestic energy production in the past two decades. According to IEA, while TPES fell by 30 per cent and the final consumption of electricity is back to the year 2000 values. Since the COVID-19 pandemic and related impacts on the economy, the feed-in tariff system is stalling, thus affecting the overall outlook for both ongoing and planned investments. On the other hand, the current scenario could represent a real opportunity for the bioenergy take-off, particularly in the heating and transport sectors. So that biomass could play an important role, even though the current contribution to the energy mix is limited.

The field of bioenergy in Ukraine has a great development potential. This is due to the peculiarities of the climate, the potential of the agricultural sector and the availability of necessary workforce. The greatest energy potential in Ukraine is provided by such types of biomass as agricultural residues (primary - formed in the field during harvesting, secondary - formed at enterprises during crop processing, animal manure) and energy crops (for obtaining solid biofuel and biogas).

The dynamics of electricity production from biomass lag behind the generation based on other renewable energy sources - the installed electric power on biomass and biogas at the beginning of 2021 was 212 MW⁸.

One of the ways to develop biogas technologies is the production of biogas from solid household waste, of which about 10 mln tons are produced annually in Ukraine. In Ukraine, there are almost 5,500 landfills and solid waste landfills. The largest number of them are in the Vinnytsia (741), Poltava (675) and Chernihiv (659) regions⁹.

In addition, at the beginning of 2021, there are 22 TPPs and CHPs with a total electric capacity of 109 MW operating in Ukraine, which produce energy from biomass and operate at a feed-in tariff. During 2019-2020, there was a rapid increase in the capacity of such facilities, from 51 MW of electrical capacity at the end of 2018 to 109 MW at the end of 2020.

Taking into account the significant underachievement of the goals of the National Action Plan for the Development of Renewable Energy for the period until 2020 in terms of bioenergy development and the projected generation profile of this segment of renewable sources, the Action Plan envisages the intensive development of electricity generation using biomass and biogas.

At the same time, a potential direction for increasing the share of renewable energy sources in electricity is the use of bioenergy at existing facilities of traditional generation, through their conversion. In addition, a potential direction for the use of bioenergy is the use of biomethane in highly maneuverable generation that consumes natural gas.

PROSPECTS FOR BIOENERGY DEVELOPMENT

The potential for obtaining first generation liquid motor biofuels in Ukraine is estimated at 580 ktoe/year of biodiesel and 860 ktoe/year of bioethanol (UABIO's estimate based on biomass potential 2021 data).

According to the draft National Renewable Energy Action Plan until 2030,¹⁰ the share of renewable energy in the transport sector should be 14 per cent in 2030. The expected consumption reaches 238 ktoe for bioethanol/ETBE and 87 ktoe for biodiesel in 2030. Over the past 20 years, several relevant programs have been developed and approved in the country, including the Ethanol Program (2000)¹¹ and the Diesel Biofuel Development Program (2006)¹², but their implementation has not been successful.

The prospect of increasing the volume of the second generation (2G) biofuel in the EU is enshrined in the EU directives on the mandatory consumption rate of 2G biofuels in fuel mixtures. The main protocol of RED II to the EU Directive on alternative fuels (June, 2018) stipulates that the overall increase in annual use of biofuels in fuel mixtures for road transport should occur only due to the increase in the use of 2G biofuels, the share of which should be half by 2030 from the fixed at the level of 7 per cent of the volume of use of biofuel of the first generation according to the schedule - 0,2 per cent in 2022; 1 per cent in 2025; 3.5 per cent in 2030.

By 2030, the amount of 2G biofuel to offset the need for 3.5 per cent of the EU's transport fuel needs should be 10.5 Mt. Eurostat predicts that the total consumption of transport fuel (automobile and railway) in 2030 will be 306,567 Mt.

Ukraine has a great advantage over other biofuels exporting countries, having huge reserves of cellulose-containing raw materials in the form of wheat straw, corn stalks, etc. In 2019, Ukraine harvested 65 million tons of grain. There is 0.5 tons of straw per 1 ton of wheat, so Ukraine has 32 million tons of straw where 5.5 tons of wheat straw are needed for 1 ton of 2G biofuels. This number of raw materials is enough for 6 million tons of 2G biofuels. As of today, no enterprise in Ukraine has been certified for 2G biofuel production.

Table 4. Estimated potential of Ukraine's bioenergy sector

Technology	Current volumes of production (2021)	Development potential 2035	Investment potential 2035, B Euro 2050, B Euro (long term scenario)
Biomethane/biogas	150 mln m3 CH4 (biogas) 125 ktoe (biogas)	2012 mln m3 (biometane) 1719 ktoe (biomethane)	4.0-5.4 33-44
Bioethanol	81.1 kt (2020) 51.1 ktoe (2020)	555 kt 350 ktoe	0.87 3.9
Biodiesel	-	322 kt 300 ktoe	0.62 2.3
Solid biomass	16.2 Mt 4.2 Mtoe	37.1 Mt 10.1 Mtoe	10.3 16.4

Source: Estimates according to the basic modelling scenario, with the support of 100RE UA and UABIO

Biomethane

According to the data of LLC "Gas TSO of Ukraine" in 2021, the total annual volume of natural gas consumption amounted about 27 bln m³¹³, imports - almost half of this amount (general expenses USD 5 bln)¹⁴. This is the second place in the commodity structure of Ukraine's imports after oil and petroleum products.

At the same time, Ukraine can replace its annual needs in natural gas due to the use of biological fuels and, in particular, the development of the biomethane market.

In addition, Ukraine has a well-developed natural gas supply system. The total length of distribution networks is 246,000 kilometers¹⁵. More than 75 per cent of the population of Ukraine has access to the gas network.

As of 1 January 2022, there are 60 plants in Ukraine that produce energy from biogas and operate at a feed-in tariff (NEURC)¹⁶.

The total electrical capacity of these plants is 124 MW, of which 30 units with a capacity of 92 MW are based on agricultural waste and another 30 units with a capacity of 32 MW are based on solid household waste.

These plants produced 553 mln kWh of electricity in 2021, which is equivalent to 280 mln m³ of biogas or 150 mln m³ of biomethane.

According to UABio experts¹⁷, it is possible to produce in Ukraine approximately 1 bln m³ of biomethane per year by 2030¹⁸. Biomethane production potential by region and type of raw material is shown in the Figure 8.

According to the decision of the Council of Ministers of the Energy Community dated 30 November 2021 № 2021/14/MC-ЕпС¹⁹ as part of the implementation of the fourth energy package "Clean Energy for Europeans", Ukraine has to implement the EU Directive 2018/2001 "On the promotion of the use of energy from renewable sources" (hereinafter - RED II) by the end of 2022. One of the requirements of RED II is the implementation of a mechanism for issuing guarantees of origin (GoO) of biomethane.

Until 2021, the term "biomethane" was absent in the Ukrainian legislation. Accordingly, there was no possibility to verify biomethane for its further injection into the gas grid, and as a result, there were no conditions for its production.

In order to solve the mentioned problem in Ukraine, on 21 October 2021 the Verkhovna Rada of Ukraine adopted the Law "On Amendments to Certain Laws of Ukraine Regarding the Development of Biomethane Production" No. 1820-IX²⁰, which aims to provide an opportunity of:

- verification of purified biogas (biomethane), the physical and technical characteristics of which meet the requirements of legal acts on natural gas;
- issuance of a GoO for the volumes of such gas;
- implementation of the Biomethane Register.

Pursuant to the requirements of Law No. 1820-IX, Resolution No. 823 of the Cabinet of Ministers of Ukraine dated 22 July 2022 "On Approval of the Procedure for the Operation of the Biomethane Register" was developed and adopted²¹. It provides:

- implementation of the general principles of functioning of the Biomethane Register;
- determination of the Register holder duties (State Agency on Energy Efficiency and Saving of Ukraine) and Register users;
- procedure for creating a Register user account;
- procedure for formation of biomethane GoO, their transfer, distribution or cancellation and provision of biomethane GoO;
- the procedure for conducting an independent audit of activities related to biomethane production.

In accordance with paragraph 2 of the aforementioned Resolution No. 823, the SAEE must ensure within six months from the date of adoption of the Resolution the creation and operation of the Biomethane Register, i.e. by 22 January 2023. It is expected that the first GoO of biomethane will be issued at the beginning of next year.

This will become a prerequisite for Ukrainian biomethane to enter the European market.

In the future, after the introduction of a carbon tax at the border with the European Union as part of the Carbon Border Adjustment Mechanism (CBAM), the demand for biomethane, confirmed by GoO, will increase among producers for export.

According to UABio estimations²², the full cost of commercial biomethane, taking into account the raw materials, installation capacity and the logistics to the final consumer costs, can reach 313-1136 €/1000 m³¹⁷. The most important component of biomethane cost is raw materials cost. As of 14 September 2022, the average cost of natural gas in the European hubs was about 2,100 EUR/1000 m³²³. The historical maximum of gas prices was observed in the end of August 2022 and reached almost 3400 EUR/1000 m³.

Therefore, in the conditions of the energy gas crisis caused by the Russian military aggression and the price policy on the gas market, biomethane is totally competitive comparing to traditional mined methane.

Regarding the injection of biomethane into the gas transmission system, Article 19 of the Law of Ukraine "On the Natural Gas Market"²⁴ provides that producers of biomethane and other types of gas from alternative sources have the right to obtain access to gas transmission and gas distribution systems, provided that this gas according to its physical and technical characteristics meet the standards for natural gas. In this way, it is already technically possible to supply biomethane to the gas transmission or gas distribution system without their technical re-equipment.

In addition, the NEURC adopted Resolution No. 847 dated 2 August 2022 "On Amendments to

the Code of the Gas Transportation System and the Code of Gas Distribution Systems"²⁵, which regulates the issue of biomethane supply in the gas grid, namely, it provides for an increase in the molar fraction of oxygen in natural gas from 0.02 molar percentages:

- up to 0.2 molar percentages for access of biomethane to the gas transmission system;
- up to 1.0 molar percentages for access of biomethane to gas distribution systems.

This issue was a barrier for potential biomethane producers, as the average oxygen content in biomethane is 0.2-1 molar percentages and bringing it to 0.02 molar percentages requires the use of complex technologies and expensive absorption equipment.

Therefore, during 2021-2022, Ukraine created a significant regulatory framework for establishing biomethane production. Currently, the Biomethane Register is expected to be launched for the issuance of relevant GoO (the deadline set for this by the Government is 2023).

As biomethane is a renewable energy source, it is subject to all relevant government incentive mechanisms described above (FIT or auction price for electricity production, a tariff of 90 per cent cost for the production of heat from alternative sources compared to the tariff for heat from natural gas).

The assessment of the energy potential of biomethane production in Ukraine is based on the analysis of the current level of production of main crops by agricultural enterprises, products of the food processing industry, the available livestock of cattle, livestock, pigs and poultry at livestock enterprises, as well as the volume of solid household waste generation and wastewater in the municipal economy (2020).

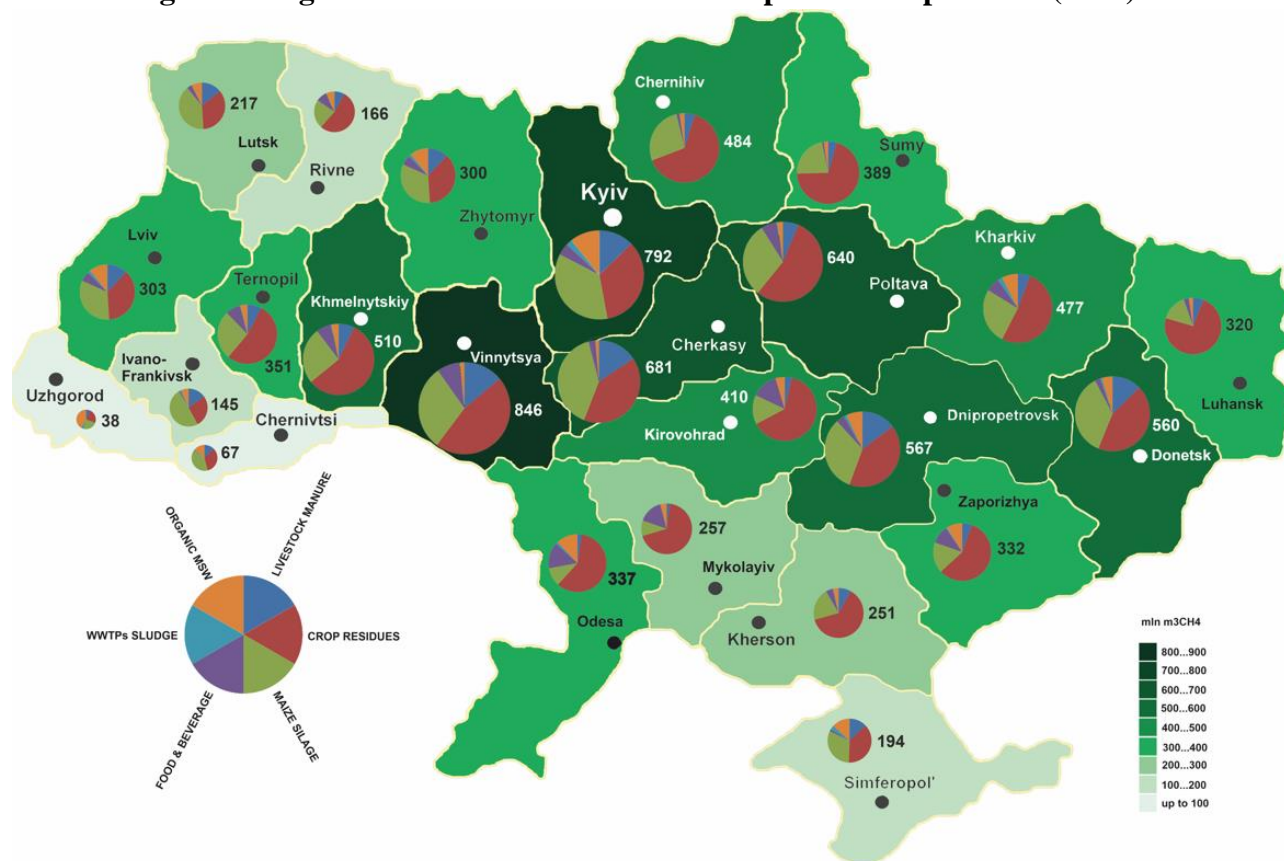
At the regional level, almost half of the methane (CH₄) production potential is concentrated in six regions of Ukraine, namely: Vinnytsia, Kyiv, Cherkasy, Poltava, Dnipropetrovsk, and Donetsk regions (Figure 8).

The highest potential was assessed in the Vinnytsia region, the lowest in the Zakarpattia region. The potential for CH₄ production by region ranges from 38 to 846 million m³/year.

It should be noted that the estimated potential of CH₄ production is not an absolute value and can change both to a greater and to a lesser extent. The key factors that can affect the potential are:

- variations in the volume and structure of gross production of plant and animal products;
- changing the area and structure of arable land use for growing food, fodder, technical and energy crops;
- population variation.

Figure 8. Regional distribution of biomethane production potential (2020)



Source: Bioenergy Association of Ukraine

The actual production potential of commercial biomethane is smaller by the amount of physical losses of CH₄ during purification and upgrading of biogas (up to 3 per cent, depending on the upgrading technology) and by the amount of energy consumption of biogas for the biomethane plant's own needs (as a rule, up to 15-20 per cent, if not other energy sources are used).

Bioethanol

Upon joining the Energy Community Secretariat, Ukraine assumed international obligations regarding the implementation of the European legislation. In particular, the requirements of RED II, which provide not less than 14 per cent share of energy from renewable sources in the gross final volume of energy consumption in transport in 2030. This is also foreseen by the project of the National Action Plan for the Development of Renewable Energy of Ukraine for the period until 2030⁷.

According to the Energy Balance of Ukraine for 2020¹, the share of energy from renewable sources in transport was only 2,5 per cent.

The import of oil and oil products in 2020 took the first place in the commodity structure of Ukraine's imports and amounted to USD 3,8 bln²⁶.

At the same time, Ukraine has sufficient resource potential for the production of motor fuel components based on bioethanol and a number of industrial capacities for this. The existing raw material base of the agro-industrial sector can provide raw materials for the country's need for liquid biofuels production. Also, Ukraine is one of the world leaders in the export of grain crops, part of which goes to the production of bioethanol in the EU countries and China.

According to the Bioenergy Association of Ukraine, the production potential of bioethanol today is about 0.8 mln toe and will amount about 2.3 mln toe until 2050¹⁸.

One of the promising options for bioethanol production is the construction of bioethanol facilities on the basis of sugar plants.

After the production of sugar, molasses remains, and this is the source of a significant amount of greenhouse gas emissions into the environment and creates an environmental problem.

In Europe, the experience of sugar production with the accompanying production of bioethanol and biogas is quite developed. The latter goes to further production of thermal and electrical energy for the company's own energy supply. Thus, there is an increase in the environmental friendliness of production, reduction in energy consumption and an increase in the level of profitability.

According to the fuel market experts²⁷, 90 per cent of all gasoline produced in Ukraine or imported to its territory contain methanol oxygenates of petroleum origin, in particular, about 10-12 per cent of methyl tert-butyl ether (MTBE).

Unlike low toxic oxygenates based on bioethanol, methyl oxygenates are produced on the basis of a number of by-products of petroleum processing. They are toxic in nature and accumulate in the soil and plants after burning gasoline, cause corrosive processes in engines when burned and emit 30 per cent more greenhouse gases than when using gasoline with bioethanol additives.

In this regard, the USA, Canada and some European countries, such as Spain, Portugal, France, Finland, Poland, Slovakia, Switzerland and others, refused to use MTBE²⁸. Therefore, in order to decarbonize the economy and improve environmental indicators, it is expedient to introduce amendments to the Ukrainian legislation regarding the ban on the use of MTBE.

According to the Ministry of Agrarian Policy²⁹, the total installed bioethanol production capacity of the subsidiaries of SE "Ukrspirt" is 111.4 thousand tons/year. However, for today these capacities are out of use and bioethanol is not produced. In particular, this is due to the lack of an effective legislative mechanism for the development of bioethanol production.

To date, only stable bioethanol is used in the EU countries to ensure the fulfilment of quotas regarding the content of biocomponents in fuel.

Bioethanol that does not meet sustainability criteria has a lower price on the EU market and is not in significant demand³⁰. This is one of the barriers to the development of production and further export of Ukrainian bioethanol to EU countries.

The creation of a clear state procedure for confirming bioethanol's compliance with sustainability criteria will enable Ukrainian producers to make their products competitive on the EU market and meet international requirements.

Therefore, the issue of creating a domestic market for the production and use of liquid biofuel, which can replace a part of imported petroleum products, is pressing today. For this, it is necessary to make changes to the Ukrainian legislation regarding the introduction of a mandatory share of liquid biofuels in transport that meet sustainability criteria, as well as to introduce by-laws on the approval of the procedure for confirming that biofuels meet to sustainability criteria.

The technical requirements for automobile gasoline with a bioethanol content of up to 10 per cent for conventional engines are determined by the Technical Regulations on Requirements for Automobile Gasoline, Diesel, Marine and Boiler Fuel, which was approved by the Resolution of the Cabinet of Ministers of Ukraine dated 1 August 2013 No. 927³¹. There is no Technical Regulation for alternative fuel with a bioethanol content of more than 10 per cent by volume in Ukraine. And therefore, this issue needs further legal adjustment.

As for the tax policy in the field of development of bioethanol production, according to subsection 229.1.1 of the Tax Code of Ukraine³², the excise tax for bioethanol, which is used by enterprises

for the production of motor gasoline, as well as bioethanol, which is used for the production of biofuels is UAH 0.

According to clause 215.3.3 of the Tax Code of Ukraine, the excise tax for alternative motor fuel with a bioethanol content of more than 30 per cent is 162 EUR/1000 liters.

As for state plans for the development of bioethanol, the draft of the National Action Plan for the Development of Renewable Energy until 2030 envisages - 238 thousand toe of bioethanol in achieving mandatory indicative targets for transport by 2030(SAEE)⁷.

Biodiesel

According to the Ministry of Agrarian Policy, Ukrainian farmers sowed 1,029 million hectares of winter rapeseed for the 2022 harvest. This is 20 thousand hectares more than the year before, and 615 thousand hectares more than in 2016, when 415 thousand hectares were sown. In 2019, the record area of winter rapeseed was 1,292 million hectares. At the same time, Ukrainian agrarians set aside a small amount of land for rapeseed - within 40 thousand hectares every year³³.

According to the State Customs Service², Ukraine exports up to 3 million tons of rapeseed annually. From this rapeseed, about 1 million tons of biodiesel is produced outside of Ukraine every year (according to the "Alternative Fuels Research Institute" estimates, about 1 ton of biodiesel is obtained from 3 tons of rapeseed)³⁴. This is about 20 per cent of the total annual consumption of diesel in Ukraine.

This happens because domestic enterprises do not have the opportunity and incentives to process rapeseed into biodiesel in Ukraine.

It is worth noting that a number of oil and fat plants that process oilseeds can be used in the field of biodiesel production, which is currently not produced in Ukraine. These possibilities open up prospects for the use of self-produced biodiesel in transport.

According to the information of specialized associations³⁵ and state authorities, by 2013 there were 55 enterprises engaged in the production of biodiesel in Ukraine. One of the main reasons for the cessation of their activities was the introduction of an excise tax on biodiesel at the level of 48 EUR/1000 liters in 2013. In 2014, the corresponding excise duty was increased to 98 EUR/1000 liters, in 2015 to 102 EUR/ton, and in 2017 to 106 EUR/1000 liters (subsection 215.3.4 of the Tax Code of Ukraine)³².

The presence of an excise tax on biodiesel makes it uncompetitive compared to diesel fuel of petroleum origin.

The technical requirements for diesel fuel with a biodiesel content of up to 7 per cent for conventional diesel engines are determined by the Technical Regulations on Requirements for Automotive Gasoline, Diesel Fuel, Marine Fuel and Boiler Fuel, which was approved by Resolution No. 927 of the Cabinet of Ministers of Ukraine dated 1 August 2013³¹. There are no technical regulations for alternative diesel fuel with a biodiesel content of more than 7 per cent by volume in Ukraine. This issue needs further legal adjustment.

According to the project of the National Action Plan for the Development of Renewable Energy for the period until 2030, which provides total expected contribution of biodiesel to achieve mandatory indicative targets for its consumption in transport in the amount of 87 thousand toe of biodiesel until 2030 (SAEE)⁷.

In order to develop the production of biodiesel, it is necessary to make changes to the current legislation of Ukraine regarding the abolition of the excise tax on the production of biodiesel.

It is also necessary to adopt the technical regulation on alternative diesel fuel with a biodiesel content of more than 7 per cent by volume.

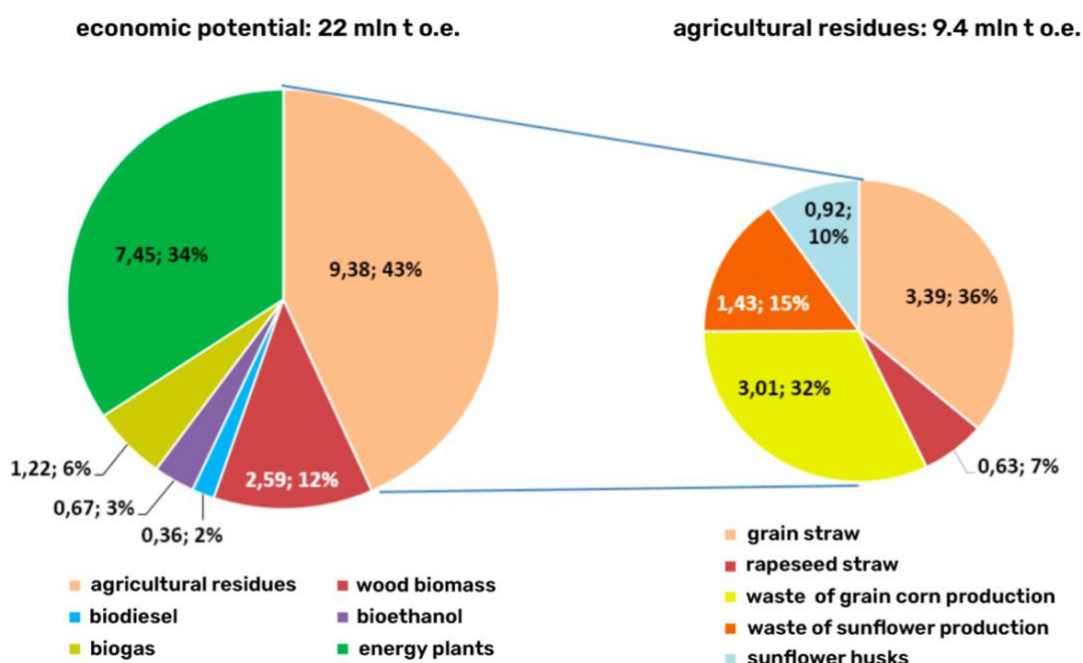
Solid Biomass

According to the Bioenergy Association of Ukraine, the production potential of solid biomass for today is about 22Mtoe and may almost double by 2050 (Bioenergy Association of Ukraine)¹⁸.

The main components of the potential are primary agricultural residues (43 per cent) and energy crops (34 per cent)³⁶, but the potential of these types of biomass is realized in Ukraine at a very low level. A greater share of biofuels and energy is produced from woody biomass, although its resources are limited compared to the agricultural residues and energy crops. Thus, there is a discrepancy between the structure of the biomass potential itself and the structure of its consumption.

In Ukraine, about 94 million tons of agricultural crop waste is generated annually. Out of them, 37 per cent (34 million tons) is the share that is actually available and can be used in the energy sector. Thus, the annual potential of natural gas substitution from agricultural waste is 9,3bln m.³

Figure 9. Components of the energy potential of biomass in Ukraine, Mtoe (2020)



Source: Bioenergy Association of Ukraine

At the same time, the solid biofuels market has a number of problems that inhibit the development of bioenergy sector. They include:

- instability of biofuel prices;
- unreliability of biofuel supply;
- low biofuel quality.

The solution to these issues can be in creation of a single competitive and transparent solid biofuels market. This is evidenced by the international experience of biofuel trade. In particular, there is a trend of transition of biofuels trade to specialized platforms that provide transparency, openness and competitive conditions for the formation of market prices on biofuel.

In particular, Lithuania introduced the Baltpool biofuel exchange in 2012. The share of biomass purchased through it increased from 1 per cent in 2013 to 95 per cent in 2017(SAEE)³⁶.

After the creation of biofuel exchange, the biomass market in Lithuania began to function more efficiently and transparently. There was a reduction in the cost of biomass by up to 40 per cent in

2015 (compared to 2012), and the price difference between neighboring areas has almost disappeared. In addition, a number of biomass suppliers has increased due to the possibility of easy access to trading on the exchange. The same result is expected to become in Ukraine after the introduction of the appropriate mechanism into the legislation.

A similar biofuel trading platform, BiomassPool, was introduced in Denmark in 2018. The consumption of wood chips in Denmark is 4 million tons. A positive example of a biofuel trading organization is the Graceful Globe Biomass Exchange. It is an electronic platform designed for B2B trade between consumers, producers and wholesalers of biomass from all over the world.

A similar exchange operates in the USA - Minneapolis Biomass Exchange, which since 2009 has been providing online biomass trading for buyers and sellers of biomass from different countries.

Therefore, today it is necessary to make changes to a number of legislative acts of Ukraine regarding the implementation of a single electronic platform for solid biofuel trade.

This will facilitate:

- creation of a transparent biofuel market in Ukraine;
- reduction of biofuel prices (up to 40 per cent);
- construction of new generating capacities on biofuel;
- increasing the number of biofuel suppliers and buyers;
- expansion of activities for producers of solid biofuel of wood and agricultural origin;
- increasing the volumes of raw materials suitable for the production of solid biofuel;
- provision of generating capacity with biofuel;
- increasing revenues to the budget of all levels with creating additional jobs.

Also, Ukraine has a significant potential for growing energy crops on unproductive and marginal lands that are not suitable for growing agricultural crops. There are about 1 million hectares of such land (according to the State Geocadastre), however, as of today, energy plant plantations totaled about 6 thousand hectares³⁷.

Unproductive and marginal lands often remain vacant and do not bring income to local budgets due to their rent.

Cultivation of energy crops on such lands is the optimal solution, which will simultaneously make profit from unproductive lands and gradually restore their fertility without additional budget costs.

Perennial energy crops cultivation for 20 years on such lands will be able to significantly improve their quality characteristics, in particular:

- protect soil from various types of erosion;
- improve biological diversity and microclimate;
- contribute to the accumulation of organic matter and humus, as well as the development of soil fauna;
- serve for phytoremediation,
- minimize the use of herbicides, pesticides and mineral fertilizers, and can also be used to reduce water pollution during wastewater and landfill treatment.

This is noted by scientists from the Institute of Bioenergy Crops and Sugar Beet of the National Academy of Sciences of Ukraine³⁸ and other scientific institutions.

Biomass is considered in many countries as one of the main renewable energy sources to substitute fossil fuels and reduce greenhouse gas emissions in the context of the Paris Agreement goals. Energy crops are one of the sources of biomass grown to ensure a stable supply to businesses that produce energy or fuel.

According to the European Bioenergy Association “Bioenergy Europe”, almost all EU countries

consider energy crops as a promising direction of bioenergy and already have a total of about 104,401 hectares of plantations on their territories, both tree (≈ 55 per cent) and grass (≈ 45 per cent) of energy crops. Poland (17,824 ha), Germany (15,800 ha), Sweden (11,623 ha) and Greece (11,010 ha) are the leaders among the EU countries in terms of the total area under energy crops³⁹.

Currently, there are a number of barriers to the development of the cultivation of energy crops in the current legislation of Ukraine:

- absence of the term "energy crops" in the legislation;
- complicated procedure for renting state and communal land;
- dependence of the amount of rent for land plots on the normative monetary valuation of the land and wide limits of the coefficient of the land payment;
- short terms of the land lease agreement.

The implementation of such projects has its own specifics:

- require significant capital investments at the initial stages of planting (lack of soft loans);
- have a long payback period (6-9 years).

To ensure the possibility of using the above-mentioned potential, it is necessary to make appropriate changes to a number of current legislative acts in Ukraine.

Also, the norms of the Law of Ukraine dated 30 November 2021 No. 1914-IX "On Amendments to the Tax Code of Ukraine and Some Legislative Acts of Ukraine on Ensuring the Balance of Budget Revenues"⁴⁰, which entered into force on 1 January 2022, increased the tax rate for atmospheric emissions CO₂ from 10 to 30 UAH per ton.

Taxpayers for CO₂ emissions are the business entities and other legal entities defined in the Article 240 of the Tax Code of Ukraine, which emit polluting substances into the atmosphere by stationary sources of pollution, if such emissions exceed 500 tons per year, and this is more than 1,500 such facilities that produce thermal and electrical energy. Out of them, about 500 economic entities are those that burn biofuel. They are also taxpayers for CO₂ emission.

This does not correspond to the world practice. According to the Clean Development Mechanism Methodology of the UN Framework Convention on Climate Change, carbon dioxide emissions from burning biomass are not taken into account because biofuel is considered a CO₂-neutral fuel.

In all EU member States, taxes on carbon dioxide emissions during the production of energy from biofuels are also not applied.

In view of the above, it is necessary to make changes in the Ukrainian legislation regarding the establishment of a zero-tax rate on CO₂ emissions for plants burning biofuel

CHAPTER 3

INCREASE OF RENEWABLE ENERGY UPTAKE THROUGH BIOENERGY

For Ukraine, bioenergy is one of the strategic directions for the development of the sector of renewable energy sources, taking into account the country's high dependence on imported energy sources and the great potential of biomass available for energy production. Unfortunately, the rate of bioenergy development in Ukraine is still significantly behind the European ones. Therefore, the Parliament, the Government, specialized organizations, international experts and other stakeholders are currently developing legislative mechanisms for the development of this specified area.

Regarding the biomethane market, during 2021 and 2022, the necessary legislative regulation for the development of biomethane production was implemented in Ukraine. The launch of the biomethane registry for issuing of GoO is planned for 2023. The first biomethane plant in Ukraine "Hals Agro" is already put into operation in Chernihiv region, the annual production volume of which is about 3 million m³. Also, several more biomethane plants are currently under construction.

However, today there is no legislative base in Ukraine regarding the development of use in the transport sector. In view of the above, it is suggested to develop an appropriate act that would take into account the best world experience in the development of an effective regulation.

In order to develop the market of liquid biofuels, the Parliament of Ukraine, together with the government and other stakeholders, have developed a draft law "On Amendments to Certain Legislative Acts of Ukraine Regarding Mandatory Use of Liquid Biofuels (Biocomponents) in the Transport Industry" (Reg. No. 3356-d dated 5 November, 2020)⁴¹.

On 30 June 2021, at session of the Verkhovna Rada of Ukraine, the draft law was adopted in the first reading as a basis. The main goal of the draft Law is to create an effective legislative mechanism for the development of a competitive market for the production and use of bioethanol and other biocomponents in transport sector of Ukraine. Its adoption is an important step on the way to replace oil.

In addition, Ukraine annually imports up to 80,000 tons of bioethanol as part of gasoline, which it could produce and consume on its own territory.

The bill envisages to:

- establish a mandatory share of liquid biofuel (quota) in the total annual volume of gasoline sales of at least 5 per cent by volume;
- introduce accounting and control of the content of biocomponents in gasoline;
- establish liability (fines) for non-compliance with quotas by business entities engaged in the production, import and sale of gasoline in the customs territory of Ukraine;
- introduce requirements for compliance with sustainability criteria for biofuels.

At the same time, the technical characteristics of fuel with biocomponents must necessarily meet the requirements of technical regulations, harmonized with European standards and other legal acts.

In general, the adoption of the draft law will allow to:

- attract investments in the production of liquid biofuel;
- stimulate the construction of new capacities for the production of bioethanol;
- activate agricultural holdings and distilleries in the production of liquid biofuels;
- increase the utilization level of distilleries and the production potential of adjacent areas;

- contribute to the fulfillment of international obligations before Energy Community in achieving a share of 14 per cent in transport from renewable sources.

In addition, the draft law provides introduction of sustainability criteria for bioethanol used in transport.

The mechanism of imposing fines for non-fulfillment of mandatory quotas for the addition of bioethanol, which is also proposed by draft law No. 3356-d, is used in more than 20 of the 27 EU member states, in particular in: Austria, Sweden, Portugal, Poland, Netherlands, Germany, Italy, Czech Republic, Finland and others.

In view of the above, the adoption of draft law No. 3356-d is extremely important for the development of the domestic energy market, reduction of import dependence, establishment of bioethanol export to EU countries and development of the use of Ukraine's agricultural potential in the energy sector.

Therefore, the adoption of the draft law will allow to reduce emissions of harmful substances and the amount of CO₂ emissions in the transport sector.

In accordance with the requirements of the Law of Ukraine "On Standardization"⁴², the state policy in the field of standardization is based on the principle of voluntary application of national standards and codes of established practice, unless otherwise provided by regulatory legal acts.

Also, according to the provisions of the current legislation of Ukraine, in particular Article 1 of the Law "On Technical Regulations and Conformity Assessment"⁴³, a technical regulation is a legal act that defines the characteristics of products or related processes and production methods, including relevant administrative regulations, compliance of which is mandatory.

That means the state standards for motor fuel in Ukraine are not mandatory, and the Technical Regulation on requirements for automobile gasoline, diesel, marine and boiler fuels, approved by the Resolution of the Cabinet of Ministers of Ukraine dated 1 August, 2013 No. 927³¹, applies only to gasoline with bioethanol content up to 10 per cent and diesel fuel with biodiesel content up to 7 per cent.

Therefore, in order to establish clear procedures for the use of alternative motor fuel and biocomponents in transport, ensure their quality, environmental friendliness and safety, it is necessary to develop and approve relevant technical regulations taking into account the requirements of European and international standards in this area.

Another effective step for the development of the liquid biofuels market could be the reduction of excise taxes on biodiesel and alternative fuels (with a content of biocomponents over 30 per cent), which currently amount to 103 EUR/ton and 162 EUR/ton, respectively. During the period of martial law, these excise tax rates are set at the same level as petroleum gasoline and diesel – 100 EUR/ton.

The mechanism for the development of the solid biofuel market in Ukraine can be the use of a single electronic platform where all interested producers and consumers will trade biofuel.

In order to solve this issue, the Members of Parliament of Ukraine developed a package of draft laws:

1. The draft law "On Amendments to Some Legislative Acts of Ukraine Regarding the Development of Electronic Trade in Alternative Fuels" (reg. No. 8052 dated 19.09.2022)⁴⁴;
2. The draft law "On Amendments to the Code of Ukraine on Administrative Offenses Regarding Liability for Offenses in the Field of Electronic Trading of Alternative Fuels" (reg. No. 8053 dated 19.09.2022)⁴⁵.

The bills propose to introduce a single electronic platform in Ukraine, where all interested

producers and consumers will trade biofuels.

In order to fill the electronic trading system of biofuel with real transactions, it is proposed to provide for the obligation gradually, from 40 per cent of the total annual volume of production or consumption of solid biofuel to 100 per cent (the introduction is planned to be made within 4 years), to trade through the exchange for individual enterprises:

- traders of biofuel - state and communal enterprises that produce solid biofuel;
- buyers of biofuel - economic entities that obtained FIT or an auction price for the production of electricity and economic entities that received an incentive tariff of 90 per cent (cost from the gas tariff) for the production of thermal energy from alternative sources.

The electronic platform plans to provide biofuel trade in accordance with the quality classes to be determined by the Ministry of Energy and internal documents of the electronic trade system based on European standards.

Administrative liability is provided for failure to comply with obligations regarding trading in the electronic biofuel trading system.

The adoption of the specified legislative changes will contribute to:

- creation of a transparent biofuel market in Ukraine;
- significant reduction of biofuel prices;
- construction of new biofuel generating capacities;
- increasing the number of biofuel suppliers and buyers;
- expansion of activities for producers of solid biofuel of wood and agricultural origin;
- increasing the volumes of feedstock suitable for the production of solid biofuel;
- provision of generating capacities with biofuel.

The raw materials for the production of solid biofuel are mostly waste from forestry and the woodworking industry (sawdust, wood chips), grain straw, sunflower husk, etc. However, the supply of such raw materials is seasonal and not always stable.

Therefore, the cultivation of perennial energy crops is another option for providing solid biofuel producers with raw materials. This is the way to the faster decarbonization of energy production, reduction of greenhouse gas emissions and achievement of energy independence.

In order to ensure the possibility of using the potential of unproductive lands for the cultivation of energy crops with the aim of their further use in the energy sector, the Members of Parliament of Ukraine developed a package of bills:

1. The draft law “On Amendments to Some Legislative Acts of Ukraine Regarding Promotion of the Development of the Field of Growing Energy Crops” (reg. No. 5227 dated 12.03.2021)⁴⁶;
2. The draft law “On Amendments to Article 288 of the Tax Code of Ukraine regarding rent for land plots on which energy crops are grown” (reg. No. 5228 dated March 12, 2021)⁴⁷;

The main provisions of the draft laws are:

- establishment of the maximum amount of rent for land plots of state and communal property at the level of 5 per cent of the normative monetary assessment;
- introduction of a minimum lease term for land plots provided for the cultivation of energy crops - 20 years;
- lease of unproductive and marginal land plots of state and communal property (without conducting land auctions);

- providing a definition of the term "energy crops" and introducing state support for the cultivation of energy crops.

Cultivation of energy crops on marginal lands is the optimal solution, because it will allow to simultaneously earn a profit and gradually restore their fertility without additional budget costs.

However, currently there is one more legislative barrier to the development of bioenergy sector in Ukraine. As mentioned above, according to the requirements of the current legislation, a tax of 30 UAH/ton is levied in Ukraine for carbon dioxide emissions that occur when biofuel is burned⁴⁸ (at the same level as fossil fuel). However, this is contrary to international practice.

The coefficient of greenhouse gas emissions for biomass is zero in accordance with the provisions of Annex IV of Directive 2003/87/EC on the establishment of a trading system of quotas for greenhouse gas emissions within the EU and amending Council Directive 96/61/EC. Therefore, taxes on carbon dioxide emissions during the production of energy from biofuels are also not applied in all EU member states.

Therefore, according to SAEE, the Government of Ukraine is developing a package of bills⁴⁸ to solve the above-mentioned issue, namely:

1. The draft law "On amendments to the Tax Code of Ukraine regarding the establishment of a zero-tax rate for carbon dioxide emissions for installations that produce such emissions as a result of burning biofuel"⁴⁹;
2. The draft law "On Amendments to the Law of Ukraine "On Alternative Fuels" regarding the creation of a Register of installations that use biofuel as the only type of fuel"⁵⁰.

The adoption of these draft laws will contribute to the:

- exemption from taxation of biofuel installations in order to create conditions for further stimulation of energy production from biofuel;
- attraction of investments in the field of biofuel usage;
- increase in projects that directly substitute fossil fuels.

CHAPTER 4

EXISTING BIOENERGY PROJECTS

Biogas

In Ukraine, the list of raw materials used for biogas production is limited to 5 main types, namely⁶²: pig manure, cattle manure, chicken manure, sugar beet pulp and maize silage (Figure 10). The total consumption of these types of raw materials is about 97 per cent by fresh weight, and the total share of produced biogas from them is about 92 per cent. The largest volume of biogas is currently produced from sugar beet pulp (39.8 per cent) and maize silage (38.4 per cent) (Figure 11). Grain chaff, molasses, fatty sludge and some other types of raw materials are also used in relatively small quantities.

Figure 10. The structure of raw materials consumption for biogas production, 2020

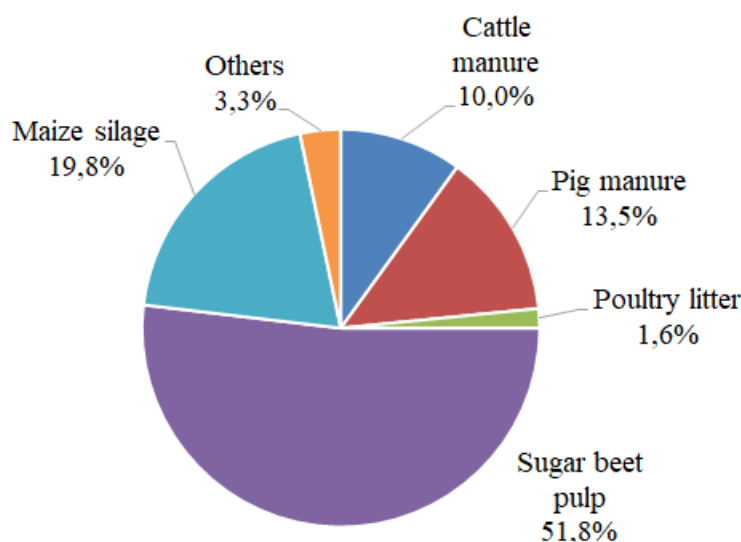
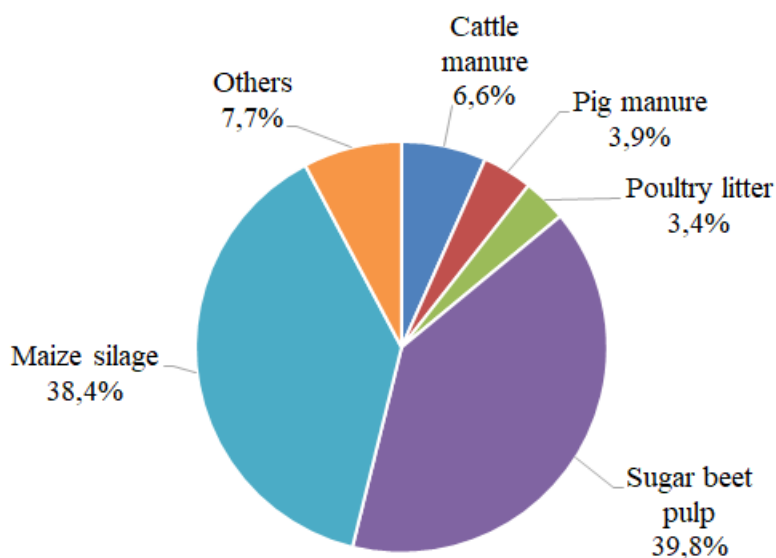


Figure 11. The structure of biogas production by types of raw materials, 2020



Source: UABIO Position Paper 29 "Prospects for biomethane production in Ukraine"⁶²

Recently, there have been examples of cereal straw and maize stalks use, which is a promising direction. There are also examples of biogas production from wastewater of industrial enterprises (wastewater from the production of chips, yeast, beer, cardboard). Sludge from municipal sewage treatment plants is partially used only at the Bortnychy WWTP, although biogas production projects are also being developed at a number of other large WWTPs (for example in Kharkiv and Lviv). Currently, there are still no examples of using the organic fraction of MSW for the production of biogas or biomethane.

The total potential of cattle manure is used by approximately 4 per cent, pig manure by 6 per cent, manure by 1 per cent in comparison to sugar beet pulp for 20 per cent. The use of the potential of other types of raw materials for biogas production does not exceed 1-2 per cent and most types are still not used at all. Thus, there is a fairly significant potential to increase the use of almost all types of raw materials for the production of biogas and biomethane.

By the end of 2021, 29 biogas plants were built and operating in Ukraine's agricultural sector, producing about 180 million m³ of biogas in total⁵¹. At the vast majority of these plants, biogas is used for the combined heat and power production in cogeneration units, the total installed electrical capacity of which was 86.4 MW_{el} (Table 5). At some plants biogas is used only for heat production.

Table 5. Biogas plants in Ukraine's agricultural sector (2021)

N	Plant owner	Argo/industry sector	Biogas utilization	Main feedstock for biogas production	Capacity, MW _{el}
1	LLC "Agroenterprise "Zeleny Gai"	Plant breeding	CHP/GT	Maize silage	0.125
2	LLC "Vinnytsia Poultry Farm"	Animal and plant breeding	CHP/GT	Chicken litter, silage, cattle manure	12
3	HOPAK Linyvitsa	Animal and plant breeding	CHP/GT	Sugar beet pulp (SBP)	2.406
4	HOPAK Zhuravka	Animal and plant breeding	CHP/GT	Pig and cattle manure, maize silage	3.906
5	HOPAK Hor. Pustovarivka	Animal and plant breeding	CHP/GT	Pig manure, maize silage	2.406
6	"Goodwelly Ukraine" LLC	Animal and plant breeding	CHP/GT	Pig manure, maize silage	1.166
7	LLC "Demetra Bioenergy"	Animal and plant breeding	CHP/GT	Pig manure, maize silage	0.527
8	"Ekokoshet" LLC	Animal and plant breeding	CHP/GT	Pig manure, maize silage	1.064
9	PJSC "Ekoprod"	Animal and plant breeding	CHP/GT	Cattle manure, maize silage	1.487
10	LLC "Kyiv Bio Center"	Animal and plant breeding	CHP/GT	Cattle manure, maize silage	0.33
11	"Komertsbudplast" LLC	Animal and plant breeding	CHP/GT	Poultry litter, maize silage	3.12

12	PrJSC "Oril-Leader"	Animal and plant breeding	CHP/GT	Chicken litter, silage	5.692
13	LLC "Rokytnian sugar plant"	Food and beverage production	CHP/GT	Sugar beet pulp, cattle manure	2.382
14	SPRAT "Ukraine"	Animal and plant breeding	CHP/GT	Cattle manure, maize silage	0.401
15	Vimexim Trading House LLC	Plant breeding	CHP/GT	Maize silage	1.203
16	LLC "Theofipol Energy Company" phase 1	Food and beverage production	CHP/GT	Sugar beet pulp	5.109
17	LLC "Theofipol Energy Company" stage 2	Animal and plant breeding	CHP/GT	Maize silage	10.5
18	LLC "Theofipol Energy Company" phase 3	Food and beverage production	CHP/GT	Maize silage, SBP, chicken litter	6.004
19	LLC "Theofipol Energy Company" phase 4	Plant breeding	CHP/GT	Stillage, straw, maize silage, SBP	4.503
20	Yuzefo-Mykolaiv Biogas Company LLC	Food and beverage production	CHP/GT	Sugar beet pulp, straw	5.2
21	"Korsun Eco Energy" LLC	Food and beverage production	CHP/GT	Sugar beet pulp	7.5
22	Agricultural firm named after Chkalova I&U Group Kapitaniv sugar factory	Food and beverage production	CHP/GT	Sugar beet pulp	6.004
23	Ukrainian dairy company	Animal breeding	CHP/GT	Cattle manure	1.053
24	"Demis-Agro"	Animal breeding	CHP	Pig manure	0.125
25	PP "Sigma"	Animal breeding	CHP	Pig manure	0.315
26	Pig farm of "Agro-Oven" corporation	Animal breeding	CHP	Pig manure	0.16
27	Elite	Animal breeding	CHP	Pig and cattle manure	0.25
28	Dionis Biogas Energy	Food and beverage production → paper industry	CHP→BM	Waste from alcohol production, sugar factories and elevators, waste from the paper industry	1.501 (20 mln m ³ CH ₄ /yr)
29	Subacon (Organic D)	Animal breeding	Heat	Pig manure	0.2 mln m ³ CH ₄ /yr
30	Zaporizhstal PJSC pig farm	Animal breeding	Heat	Pig manure	0.05 mln m ³ CH ₄ /yr

31	Globin sugar factory "Astarta-Kyiv"	Food and beverage production	Heat	Sugar beet pulp	6.8...27.4 mln m ³ CH ₄ /yr
32	Rubizhne cardboard packaging plant, Rubizhne	Food and beverage production	Heat	Industry waste water	n/d
33	Rohan Brewery, Kharkiv	Food and beverage production	Heat	Industry waste water	n/d
34	Desna Brewery, Chernihiv	Food and beverage production	Heat	Industry waste water	n/d
35	Yantar Brewery, Mykolaiv	Food and beverage production	Heat	Industry waste water	n/d
36	Pivzavod Slavutych, Kyiv	Food and beverage production	Heat	Industry waste water	n/d
37	Slavutych Brewery, Zaporizhzhia	Food and beverage production	Heat	Industry waste water	n/d
38	Company Nadiya (production of yeast), Kryvyi Rih	Food and beverage production	Heat	Industry waste water	n/d
39	Kraft Foods (production of chips), N. Petrovtsi	Food and beverage production	CHP	Industry waste water	0.5
40	Enzym Plant (yeast production), Lviv	Food and beverage production	Heat	Industry waste water	n/d
<p><i>CHP/GT – production of electricity and thermal energy in cogeneration unit (CHP), with the sale of electricity at a "green" tariff</i> <i>CHP - production of electric and thermal energy in CHP for own consumption.</i> <i>CHP→BM – transition from the production of electric and thermal energy in CHP to biomethane</i> <i>BM – biomethane</i> <i>n/d – no data</i></p>					

Source: UABIO statistics based on NEURC data

Biomethane

One of the main restraining factors for the development of biomethane production is that the procedure for exporting biomethane from Ukraine to the EU and the mechanism for issuing guarantees of biomethane origin have not been established. However, it is expected that within this year the first GoO for biomethane will be issued in Ukraine.

It is also known about the intentions of a number of other operating biogas plants to switch from electricity production at CHP to biomethane production, in particular Yuzefo-Mykolaiv Biogas Company LLC, MHP-Ekoenergo, Dionis Biogas Energy and others.

To date, more than 30 potential biomethane producers have applied to LLC "Operator GTS of Ukraine" to obtain technical conditions for connection to the gas network⁵² among which, in

particular, a number of agricultural holdings: Pro-Energy, Gals-Agro, MHP, Astarta-Kyiv, Vit-Agro and others.

The Regional Gas Company also issued technical conditions for connecting the biomethane plant of Hals Agro LLC in the Chernihiv region. It is assumed that the connection to the gas grid is taken place by the end of 2022.

The raw material for production of biomethane can include a long list of organic materials. In general, 12 separate categories of raw materials can be distinguished:

1. Livestock manure (Cattle (dairy) farms, Pig farms, Poultry farms and other farms).
2. Harvest residues of agricultural crops - plant growing enterprises.
3. By-products and waste of the food processing industry (sugar factories, distilleries, breweries, starch and molasses production, flour and grain mills, oil extraction plants, meat processing plants, slaughterhouses, canneries, winemaking enterprises and other production).
4. Bioethanol and biodiesel production waste (bioethanol plants and biodiesel plants).
5. Energy crops - plant growing enterprises.
6. Phyto-biomass (natural water bodies, artificial water sources and systems).
7. Waste from horticultural and park farms (communal park, airports, and large sports fields with a natural surface).
8. Trade and catering waste (communal and private catering, food markets and shops).
9. Municipal solid waste (sorting stations, mechanic-biological processing plants, garbage cans with separate collection of organic waste).
10. Municipal wastewater and its sediments (municipal treatment facilities, local sewage treatment plants of industrial enterprises).
11. Sequential crops (green fertilisers) plant growing enterprises.
12. Vegetation of meadows - natural meadows that are not used for farming and which are not included in the nature reserve fund.

The expediency and potential scale of involving certain types of raw materials for the production of biomethane is determined by a number of factors. Among the main factors of influence are the specific cost of energy in raw materials, taking into account delivery to the biogas station (UAH/MJ), the level of technological complexity of processing into biogas, availability within a reasonable delivery radius.

When producing biomethane for export to countries where renewable biofuels guarantee of origin have been implemented in transport, the type of raw material from which it will be produced can affect the contract price for biomethane. In this case, it will be appropriate to use those types of organic materials, which according to the approved lists, are set for 2-fold crediting of the produced energy. At the EU level, such a list of materials is provided in Annex IX of the EU RED II Directive.

From the point of view of raw material sustainability, the first priority in biomethane production should be given to wastes that by their nature have no other alternative use than final disposal, incineration, conversion to energy or use as organic fertilizers or soil improvers. Such types include, for example, manure waste, substandard food products, the organic fraction of solid waste, sewage sludge, grass clippings of artificial lawns, by-products of animal origin that are not suitable for human consumption, etc.

One of the promising types of raw materials for biogas, which does not compete with food and fodder products, are sequential crops grown in the interval between two annual food crops. The use of such crops for biogas with the subsequent return of the digestate to the same fields, allows

to significantly expand the potential of attracting arable land resources to the energy sector without harming agricultural production. According to EBA, more than a quarter of the biomethane production potential can be ensured by using cover crops for this purpose.

Next priority should be given to by-products of various industries, which have either lost their commercial properties for alternative use, or for which there is currently no alternative demand in a certain place as food or animal feed. The list of such products can include, for example, sugar beet pulp, grain processing waste, fuzz and meal of oil crops, etc.

The use of specially grown energy crops for the production of biomethane in the EU countries is given less and less priority. Starting from 2018, no new biomethane plants were built in Europe, the main raw material for which would be maize silage. Therefore, when producing biomethane in Ukraine for export from maize silage, it should be borne in mind that the contract price for it may be limited.

The main possible applications of biomethane and the corresponding potential markets are:

- Replacement of NG with biomethane. Biomethane can be used for any purpose as a substitute for NG. In this way, it is possible to replace imported natural gas and liquid petroleum products, as well as fulfil Ukraine's obligations to reduce GHG emissions within the framework of the Paris Agreement.
- Use of biomethane as motor fuel for road transport, agriculture, aviation and marine transport. This option allows you to replace fossil motor fuel like gasoline, diesel, aviation fuel, CNG, LNG, and LPG. This is an excellent opportunity for agricultural producers to obtain fuel from waste and secondary products of their own production. The use of biomethane as a fuel for public transport can significantly reduce air pollution in large cities. The use of biomethane in passenger cars is also possible, it is popular in some, including developed countries (a European example is Italy).
- Biomethane export to the EU using the national register of biomethane production and consumption. Using the capabilities of Ukraine's gas transportation system, which is connected to the European NG system, through the virtual export mechanism can increase the economic attractiveness of biomethane production in Ukraine.
- Production of electricity and heat from biomethane using the NG grid. This option makes it possible to produce electricity and thermal energy in the immediate vicinity of the consumer and, thus, to increase the efficiency of fuel use due to the efficient use of thermal energy, at least in urban district heating systems. Currently, biogas in Ukraine is used with an efficiency that does not exceed 50 per cent.
- Storage of biomethane in the NG system for electricity production at peak load. This option allows to use biomethane in periods of maximum load on the power system and thereby reduce the need for regulation of electric power, which in Ukraine is mainly provided by coal-fired power plants. The use of biomethane for this purpose can largely compensate for the limited possibilities of regulation of rapidly developing renewable energy sources – solar PV and wind energy.
- Biomethane as a renewable feedstock for the chemical and other industries. The consumption of NG in the chemical industry is related to the production of derivative products, such as nitrogen mineral fertilizers, methanol, ammonia, etc. Possible export restrictions on products using fossil fuels, in particular due to the carbon border adjustment mechanism (CBAM), in the long run may stimulate domestic producers to switch to the consumption of renewable raw materials, which in the chemical industry can replace NG with biomethane.

Liquid Biofuels

One of the ways to use biomass is processing it into liquid biofuels: biodiesel and bioethanol.

Bioethanol and biodiesel are both environmentally friendly fuels. They are manufactured from organic sources like corn, wheat, rapeseed etc. Sugar beet is also used as source materials for bioethanol and its ancillary alternative fuel products.

Ukraine has the necessary conditions for liquid biofuels generation both in terms of land resources and plant potential, and in terms of the availability of its own production facilities.

According to the State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEE), bioethanol production in 2020 amounted to 51.1 ktoe, in 2019 – 88.1 ktoe (Table 6). Biodiesel production in 2014-2020 was not recorded.

Table 6. Production of bioethanol and biodiesel in Ukraine⁵³

Type of biofuel	2014	2015	2016	2017	2018	2019	2020
Bioethanol, ktoe	42.4	35.1	38.4	47.0	37.2	88.1	51.1
Biodiesel, ktoe	-	-	-	-	-	-	-

Source: Reports on the Promotion and Use of Energy from Renewable Sources in Ukraine in 2014–2020, SAEE

Bioethanol

In Ukraine, there are 22 small bioethanol (BE) plants, which in total can produce about 500,000 m³ BE/y⁵⁴ (~400,000 t/y) (Table 7). Out of them, 7 plants are new private factories, the rest is reconstructed old state factories.

Table 7. Producers of bioethanol in Ukraine

Name of plant	Design capacity, m ³ /day	Actual production capacity (increased capacity), m ³ /day
Operational private plants		
Hnidavskyi plant, «Biopek» Ltd	46	64
Teofipolskyi plant	100	100
Kozhanskyi plant, «Fazor» Ltd	46	62
Uzynskyi sugar plant	32	43
Budytskyi plant, «Eco-energy» Ltd	48	64
Kramatorskyi plant, «Olimp» Ltd	24	32
Total, private plants	296	365
Operational state plants		
Zarubynskyi alcohol plant	48	64
Haisynskyi plant, «Intercite» Ltd	63	74
Trostianetskyi alcohol plant	24	32
Popivskyi experimental plant	24	32
Total, state plants	159	202

Source: UKRSPYRT⁵⁵

Bioethanol factories are included in the system of local clusters of beet and corn processing and organically complement the ecosystem of creating high added value — field → sugar factory → bioethanol factory → biogas plant → fertilizer production or field → bioethanol plant → poultry farm → biogas plant → fertilizer production.

The exports of bioethanol from Ukraine increased from about 6.1 kt in 2019 (the quota being 70.8 kt) to more than 27.5 kt in 2021 (the quota being 100 kt) (Table 8).

Table 8. Use of the quota for the export of ethyl alcohol (CH2207 and CH2208) from Ukraine to the EU in 2019-2022⁵⁶

Year	Quota, t	Export, t	Average per month, t	Growth, %	Remaining quota, t
2021	100 000	27 518	2 293	11	72 482
2020	85 400	24 786	2 066	307	60 614
2019	70 800	6 083	507	4	64 717

Source: Ukrainian Technological company, (UTC), 2022⁶⁸

Biodiesel

In Ukraine, 14 large biodiesel (BD) plants of 300 kt BD/y total production capacity have been built, however these plants have been actually idle, mostly due to economic factors. Information on the current state of their equipment and possibility to launch the production is not available. In addition, there are about 50 smaller enterprises capable of producing up to 25 kt BD/y, but no reliable information about their functioning is available^{57 58}. Some biodiesel plants ceased their operation, for example “Biodiesel Bessarabii” Ltd, “Biodiesel Group” Ltd.

Solid Biomass

Biomass CHPs/TPPs usually have low maneuverability and are not able to respond quickly to the request of the network operator for changing of power capacity. Usually, in Ukraine and EU, biomass CHPs are used for baseload heat supply in the industrial or the district heating sector.

The installed capacity of typical biomass CHPs/TPPs is usually in the range of 3-10 MW_{el}. In some cases, more powerful biomass TPPs are being built in the EU, but these are the single cases due to special production needs.

Based on analysis of NEURC’s data, 22 CHP plants and thermal power plants (TPPs) of about 152 MW_{el} total installed capacity were operating on solid biomass in Ukraine by the end of 2021 (Table 9). Most of them run on wood chips and 8 plants use sunflower husk as fuel. All the CHP plants/TPPs have feed-in tariff for power generation.

Table 9. CHP plants and TPPs on solid biomass in Ukraine (2021)

N	Company, plant	Location	Biomass type	Start of operation	Installed capacity, MW _{el}
1	"Biogasenergo" Ltd, TPP	Kyiv region	wood chips	21.11.2013	19.0
2	"Ukrainian Black Sea Industry" Ltd, TPP	Odesa region	no data	23.07.2021	16.0

3	"Aiaks Dnipro" Ltd, TPP (1 line)	Dnipropetrovsk region	sunflower husk	05.04.2019	16.0
4	"Bandurskyi OEP" Ltd, TPP	Mykolaiv region	no data	22.09.2021	13.7
5	Private Stock Corporation "Kropyvnytskyi OEP", CHPP	Kirovohrad region	sunflower husk	26.10.2009	12.3
6	Private Stock Corporation "Poez-Kernel Group", TPP	Poltava region	sunflower husk	12.05.2021	10.4
7	"Smilaenergypromtrans" Ltd, CHPP	Cherkasy region	wood chips	18.03.2010	8.5
8	"Combinat Kargill" Ltd, CHPP	Donetsk region	sunflower husk	13.12.2012	2.0
9	"AGL Energy" Ltd, TPP	Kharkiv region	sunflower husk	11.10.2019	7.0
10	"Bio Electrics" Ltd, TPP	Khmelnyskyi region	wood chips, sunflower husk	09.07.2020	6.0
11	"Biotes" Ltd, TPP	Zakarpattia region	wood chips	26.11.2019	6.0
12	"Poliska TPP" Ltd	Zhytomyr region	wood chips	12.07.2018	5.9
13	"Singa Energies" Ltd, CHPP	Mykolaiv region	wood chips	10.11.2017	5.1
14	"APK "Yevgroil" Ltd, CHPP	Mykolaiv region	sunflower husk	19.12.2013	5.0
15	"EPG "Yugenergopromtrans" Ltd, TPP (1 line)	Kyiv region	wood chips	31.10.2017	5.0
16	"Clear Energy" Ltd, TPP	Chernihiv region	wood chips	30.06.2016	4.0
17	"Pivden Bio Energy" Ltd	Mykolaiv region	no data	09.06.2021	3.0
18	"PGS-Energy" Ltd, TPP	Zaporizhzhia region	sunflower husk	19.02.2020	2.7
19	"Mebel-Service" Ltd, CHPP	Lviv region	wood chips	19.06.2018	2.4
20	Communal Enterprise "Miskteplovodenergiya", CHPP (2 line)	Khmelnyskyi region	wood chips	01.07.2019	1.6
21	Individual entrepreneur Peresadko R.V., power plant	Ivano-Frankivsk region	wood chips	19.07.2018	0.10
22	Individual entrepreneur Stelmaschuk V.D., mini-power plant	Ivano-Frankivsk region	wood chips	06.12.2019	0.05
	TOTAL				151.75

CHPP – CHP (combined heat and power) plant; TPP – thermal power plant; OEP – oil extraction plant.

Source: [UABIO statistics based on NEURC data](#)

The volume of electricity production from biomass remains stable in Ukraine – 28 million kWh, and from biogas – 43 million kWh which makes up to 14 per cent of the total monthly production. In general, during 2020, more than 656 million kWh of "green" electrical energy was produced from biomass and biogas, which was 6.8 per cent of the total production of electricity from renewable energy sources that year.

In 2020, three major producers of electricity from biomass were "Aiaks Dnipro" TPP (from May 2020), "Biogasenergo" TPP and "Kropyvnytskyi OEP" CHPP (Fig. 12, 13). The biggest volume of electricity from biomass in 2021 was produced at "Aiaks Dnipro" TPP (117 GWh) followed by "Biogasenergo" TPP (46.7 GWh) and "Kropyvnytskyi OEP" CHPP (44.5 GWh)⁵⁹.

CHAPTER 5

FEASIBILITY OF POTENTIAL BIOENERGY PROJECTS

The feasibility studies of this chapter were carried out by UABIO experts in 2023. The respective projects can be implemented in those regions of the country where the required biomass fuels or feedstock are available.

Results of feasibility studies show that at present the following bioenergy projects are economically feasible (the simple payback period < 5 years) in Ukraine:

Biomethane

Production of biomethane from sugar beet pulp (4 mln m³/y productivity and more)

Feasibility study of biomethane production from sugar beet pulp

Parameter	Production of biomethane (12-15 bar) from sugar beet pulp
Biogas upgrading technology	Membrane separation
Annual production, mln Nm³/year biomethane	4.1
Operation load, hours/year	8300
Annual need for raw materials, kt/year	55
Purchase price of raw materials, EUR/t, incl. VAT	5
CAPEX, EUR million	10.18
OPEX, EUR million/year	1.31
Specific operating costs for the production of biomethane, EUR/kg	0.319
Biomethane sales price, EUR/m ³ , VAT incl.	0.9
Income from biomethane sales, mln euros/year	3.7
The sale price of the digestate solid fraction, EUR/t, incl. VAT	71.9
Income from the sale of digestate, EUR million/year	0.55
Levelized cost of biomethane (LCOE), EUR/m³	0.6
Loan share of CAPEX, %	60
Lending period, years	7
Loan rate in EUR, %	8.5%
Internal return rate (IRR), %	25.9%
Simple payback period, years	4.9

- Production of **biomethane** from a feedstock mix (manure, straw, corn silage) (1000 m³/y productivity and more)

Feasibility study of typical biomethane plant

Parameter	Units	Connection to the gas distribution network	Connection to the gas transport network
Project capacity	m ³ CH ₄ /hour	1000	1000
Feedstocks		15% of cattle manure, 35% of wheat straw/corn stover, 50% of maize silos	
Method of feedstock processing		shredding in a bio-extruder	
CAPEX	million EUR	16.27	17.47
Feedstock price	EUR/t	40	40
Pressure in the gas network at a distance of 0.5 km	bar	up to 8	up to 55
Feedstock component in the cost of biomethane	EUR/1000 m ³ CH ₄	195	
Full cost price of biomethane	EUR/1000 m ³ CH ₄	523	550
Selling price of biomethane	EUR/1000 m ³	900	
NPV	million EUR	32.1	29.9
IRR	%	28.4	25.7

Bioethanol

- Production of **bioethanol** from corn grain (25 kt/y productivity and more)

Feasibility study of typical bioethanol plant

Parameter	Bioethanol from corn grain
Bioethanol output, kt/y	25
Bioethanol output, mln l/y	32
Operational time, h/y	8000
Feedstock consumption, kt/y	76
Feedstock purchase price, EUR/t without VAT	155
CAPEX, mln EUR	17
OPEX, mln EUR/y	17.8
Bioethanol production expenses, EUR/l	0.564
Depreciation charges, EUR/l	0.021
DDG sale price, EUR/t without VAT	112,5
Income from DDG sale, mln EUR/y	2.6
Corn oil sale price, EUR/t without VAT	1145.8
Income from corn oil sale, mln EUR/y	1.1
Bioethanol production cost, EUR/l	0.47
Approximate sale price of bioethanol, EUR/l without VAT	0.65
<i>Economic assessment of the project</i>	
Loan share of CAPEX, %	70
Lending period, years	5
Loan rate in EUR, %	6
Internal return rate (IRR), %	29.8%
Simple payback period, years	4.5

Biodiesel

- Production of **biodiesel** from used cooking oil (20 kt/y productivity and more)

Feasibility study of biodiesel plant

Parameter	Biodiesel from used cooking oil
Biodiesel output, kt/y	20
Operational time, h/y	8000
Feedstock consumption, kt/y	22.2
Purchase price of feedstock, EUR/t without VAT	300
CAPEX, mln EUR	26.7
OPEX, mln EUR/y	11.3
Biodiesel production expenses, EUR/l	0.50
Depreciation charges, EUR/l	0.047
Sale price of crude glycerine, EUR/t without VAT	100
Income from sale of crude glycerine, mln EUR/y	0.20
Production cost of biodiesel, EUR/l	0.54
Approximate sale price of biodiesel*, EUR/l without VAT	1.1
<i>Economic assessment of the projects</i>	
Loan share of CAPEX, %	70
Lending period, years	5
Loan rate in EUR, %	6
Internal return rate (IRR), %	41.1%
Simple payback period, years	3.5

* The price does not take into account the excise tax 100 EUR/1000 l⁶⁰.

Solid biomass

- Production of **heat** from wood chips at *reconstructed* boiler plants (Ukrainian equipment) for *population* and *budget-financed* organisations. Production of **heat** from wood chips at *newly constructed* boiler plants (foreign equipment) for *budget-financed* organisations (about 3.5 MW_{th} installed capacity):

Feasibility study of heat production from wood chips at boiler plants

Indexes	Values	
Capacity, MW _{th}	3.6	
Heat for sale, Gcal	5684	
Purpose	space heating, basic load, sale	
Type of construction	reconstruction	new construction
Capital expenditure, million UAH	<i>Ukrainian equipment</i> 13.5	<i>foreign equipment</i> 29.5
Biomass fuel price, UAH/t with VAT	wood chips, 2200 UAH (60 EUR/t)	
Annual biomass fuel consumption, t	3200	

Weighted average tariff for heat production, UAH/Gcal without VAT	1881 <i>(households)</i>	3070 <i>(budget)</i>	1881 <i>(households)</i>	3070 <i>(budget)</i>
Gross income, million UAH	15.8	24.5	15.8	24.5
Operating expenses, million UAH	10.5	10.9	10.5	10.9
Net cash flow, million UAH	2.6	7.6	3.3	8.3
IRR, %	20%	104%	3%	36%
Payback period, years	4.2	0.9	10	2.5

- Production of **heat** from biomass pellets at *reconstructed* boiler plants (Ukrainian equipment) for *budget-financed* organisations. Production of **heat** from biomass pellets at *newly constructed* boiler plants (foreign equipment) for *budget-financed* organisations (about 3.5 MW_{th} installed capacity):

Feasibility study of heat production from pellets at boiler plants

Indexes	Values			
Capacity, MW _{th}	3.6			
Heat for sale, Gcal	5684			
Purpose	space heating, basic load, sale			
Type of construction	reconstruction		new construction	
Capital expenditure, million UAH	<i>Ukrainian equipment</i> 11		<i>foreign equipment</i> 20.8	
Biomass fuel price, UAH/t with VAT	biomass pellets, 6500 UAH (<i>175 EUR/t</i>)			
Annual biomass fuel consumption, t	1670			
Weighted average tariff for heat production, UAH/Gcal without VAT	1881 <i>(households)</i>	3070 <i>(budget)</i>	1881 <i>(households)</i>	3070 <i>(budget)</i>
Gross income, million UAH	15.8	24.5	15.8	24.5
Operating expenses, million UAH	13.1	13.5	13.1	13.5
Net cash flow, million UAH	0.4	5.5	0.7	6.0
IRR, %	-	87%	-	38%
Payback period, years	-	1.2	-	2.5

- Production of **heat** from wood chips/biomass pellets at *industrial* boiler plants (Ukrainian/foreign equipment) for own needs with partial replacement of natural gas (about 3.5 MW_{th} installed capacity):

Feasibility study of heat production at boiler plants in the commercial sector for own needs with partial substitution of natural gas.

Indexes	Values
Capacity, MW _{th}	3.6
Heat for sale, Gcal	5684
Purpose	industrial, partial replacement of gas, provision of own needs
Natural gas consumption, 1000 m ³	770

Price of natural gas, UAH/1000 m ³	28000			
Natural gas costs, million UAH	21.5			
Type of biofuel	wood chips		pellets	
Capital expenditure, million UAH	<i>Ukrainian equipment</i> 13.5	<i>foreign equipment</i> 29.5	<i>Ukrainian equipment</i> 11	<i>foreign equipment</i> 20.8
Biomass fuel price, UAH/t with VAT	2200 UAH (60 EUR/t)		6500 UAH (175 EUR/t)	
Annual biomass fuel consumption, t	3180		1670	
Biomass fuel costs, million UAH	7.6		10.6	
Operating expenses, million UAH	10.5		13.5	
Annual savings, million UAH	11.0		8.0	
Simple payback period, years	1.2	2.7	1.4	2.6

- **Combined** heat and power production (4.7 MW_{th}+12 MW_{el} CHP plant, *commercial sector*, foreign equipment) from sunflower husk (own residues). **Combined** heat and power production (4.7 MW_{th}+12 MW_{el} CHP plant, *commercial sector*, Ukrainian equipment) from sunflower husk pellets

Feasibility study of heat and power production at CHP plant in the commercial sector

Indexes	Values		
Capacity electric/thermal, MW	4.7 / 12		
Capital expenditure, million EUR (loan 50% of CAPEX, 7% per annum, 5 years)	11 (2300 EUR/kW – <i>Ukrainian equipment</i>)	16 (3300 EUR/kW – <i>foreign equipment</i>)	
Type of biomass fuel	husk pellets	husks	
Biomass fuel price, UAH/t with VAT	6500	1500	
Heat price, UAH/Gcal without VAT (90% of the heat cost from natural gas)	2280		
Electricity tariff, UAH/kWh without VAT	4.12		
Annual consumption of biomass fuel, 1000 t	38.5		
Sale of electricity, 1000 MWh	26		
Heat production, 1000 Gcal	44		
Saving of natural gas, million m ³	6		
Gross income, million EUR	7.6		
Operating expenses, million UAH	6.1	1.8	
Net cash flow, million EUR	-0.8	3.6	
IRR, %	-	39%	26%
Simple payback period, years	-	2.4	3.4

- **Combined** heat and power production (CHP plant of 1.5 MW_{el}, Ukrainian equipment/ European equipment) from wood chips/sunflower husk for *own needs* and for *sale* (budget-financed organisations):

Feasibility study of heat and power production from wood chips at CHP plant for own needs and for sale

Indexes	Option 1 Provision of own needs		Option 2 Sale in the grid	
Installed capacity, MW_{el}	1.5			
Capital expenditure, million EUR	3.75 (2500 EUR/kW – <i>Ukrainian equipment</i>)			
Useful supply/consumption of power, 1000 MWh	10.8			
Useful supply/consumption of heat, 1000 Gcal	24	36	24	36
Type of biomass fuel	wood chips			
Biomass fuel price, UAH/t with VAT	2200 (60 EUR/t)			
Price of natural gas, UAH/1000 m ³	28000			
Purchase price of electricity, UAH/kWh with VAT	4.8			
Electricity sale tariff, UAH/kWh with VAT	-		3.84*	
Heat sale tariff, UAH/Gcal with VAT	-		3024**	
Base costs, million UAH	145.2	176.3	-	-
Planned costs of the CHP, million UAH	90.1	101.0	90.1	101.0
Sales revenue, million UAH	-	-	114.0	138.2
Expected savings / Profit, million UAH	55.0	75.2	23.9	37.2
Simple payback period, years	2.7	2.0	6.3	4.0
Notes: * price of electricity on a Day-Ahead Market; ** weighted average heat tariff for budget institutions.				

Feasibility study of heat and power production from sunflower husks at CHP plant for own needs and for sale

Indexes	Option 1 Provision of own needs		Option 2 Sale in the grid	
Installed capacity, MW_{el}	1.5			
Capital expenditure, million EUR	4.8 (3300 EUR/kW – <i>EU equipment</i>)			
Useful supply/consumption of power, 1000 MWh	10.8			
Useful supply/consumption of heat, 1000 Gcal	24	36	24	36
Type of biomass fuel	sunflower husks			
Biomass fuel price, UAH/t with VAT	1500* (40 EUR/t)			
Price of natural gas, UAH/1000 m ³	28000			
Purchase price of electricity, UAH/kWh with VAT	4.8			
Electricity sale tariff, UAH/kWh with VAT	-		3.84**	
Heat sale tariff, UAH/Gcal with VAT	-		3024***	

Base costs, million UAH	145.2	176.3	-	-
Planned costs of the CHP, million UAH	32.2	36.1	32.2	36.1
Sales revenue, million UAH	-	-	114	138
Expected savings / Profit, million UAH	112	140	81.8	102
Simple payback period, years	1.8	1.4	2.4	1.9
Notes: * nominal price of own waste; ** price of electricity on a Day-Ahead Market; *** weighted average heat tariff for budget institutions.				

CHP plants operation advantages:

1. Earlier, the main incentive for the construction of thermal power plants in Ukraine was a high feed-in ("green") tariff with a much lower price of electricity on the market and a low price of heat. However, now the situation is the opposite.
2. Today, high prices of natural gas for the production of heat and relatively low prices of electricity stimulate the production and substitution of heat.
3. Economic efficiency of CHP projects improves *at the expense of*:
 - increase in annual heat production volumes;
 - reduction of the installed electric capacity and the corresponding decrease of investment costs;
 - switch to the operation according to a thermal heat schedule with a back pressure turbine instead of the use of condensing turbines with extraction for the operation according to electrical energy schedule;
 - lower fuel prices

Therefore, it is currently more efficient to produce heat and power at CHP plants for own needs than for sale.

CHAPTER 6

ECONOMIC PROSPECTS OF BIOENERGY PROJECTS AFTER LEGISLATION IMPROVEMENT

Estimates made in the Roadmap for Bioenergy Development in Ukraine until 2050 (UABIO)¹⁸ show that the installed capacity of bioenergy equipment may reach about 48 GW_{th} and 4 GW_{el} in 2050 (Table 10). Distribution of the envisaged bioenergy equipment by types is presented in Table 11.

Table 10. Summary indices of the Roadmap for Bioenergy Development in Ukraine until 2050

Year	Installed capacity of bioenergy equipment		Consumption of biomass fuels*, 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	8231	225	3.85	4.34	0.17	9.19	1.58	2.62	17342
2025	12385	918	6.09	6.39	0.26	14.35	4.32	7.0	33870
2030	19185	1886	9.13	9.19	0.43	21.20	8.08	13.1	57648
2035	29949	2618	12.74	12.66	0.60	29.37	12.04	19.5	87067
2040	38822	3265	16.10	15.72	0.82	36.91	15.87	25.6	115220
2045	44493	3740	18.73	17.71	1.11	42.62	19.02	30.7	136595
2050	48056	4091	20.70	19.00	1.24	46.71	21.35	34.5	150550

* Including liquid and gaseous biomass fuels for transport.

Table 11. 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)	1536	1151
TPPs (primary agricultural residues)		380
TPPs (secondary agricultural residues)		160
TPPs (wood)		55
TPPs (energy crops)		340
TPPs ORC (primary agricultural residues)		25
Total	48056	4091

- The potential of biogas/biomethane production in Ukraine is assessed as 9.45 bln m³/y in 2030 and 21.8 bln m³/y in 2050 (Table 12).

Table 12. Biogas/biomethane production potential in Ukraine in 2030 and 2050

Biogas/biomethane, billion m³/year	2030	2050
Biogas from animal waste	0.83	0.9
Biogas from crop residues	4.36	5.2
Biogas from by-products of the food processing industry	0.66	0.7
Biogas from household solid waste	0.53	0.5
Biogas from sewage sludge (municipal treatment plants)	0.07	0.1
Energy plants: biogas from maize silage (from 1 million hectares)	3.0	3.8
Biogas from cover crops (20% of arable land)	0.0	9.8
Biogas from biomass obtained by thermal gasification (10%)	0.0	1.0
Biogas/biomethane, total	9.45	21.8

With the improvement of Ukrainian legislation and economic conditions, additional types of bioenergy projects may become feasible:

- Production of heat from wood chips at newly constructed boiler plants (foreign equipment) for population;
- Production of heat from biomass pellets at reconstructed boiler plants (Ukrainian equipment) for population;
- Production of heat from biomass pellets at newly constructed boiler plants (foreign equipment) for population.

Required improvement for the projects above is setting a single commercial price of natural gas for all consumers types (including the population).

- Combined heat and power production (CHP plant of a communal heat supply enterprise, high share of Ukrainian equipment) from sunflower husk pellets;
- Combined heat and power production (CHP plant of a communal heat supply enterprise, foreign equipment) from wood chips;
- Combined heat and power production (CHP plant, commercial sector, Ukrainian/foreign equipment) from wood chips.

Required improvements for the projects above are the following:

- increase in annual heat production volumes;
 - reduction of the installed electric capacity and the corresponding decrease of investment costs;
 - switch to the operation according to a thermal heat schedule with a back pressure turbine instead of the use of condensing turbines with extraction for the operation according to electrical energy schedule;
 - lower fuel prices.
- Production of bio-LNG and liquefied CO₂ from sugar beet pulp;
 - Production of bioethanol from cereal straw, by-products of grain corn production and other lignocellulosic feedstock (advanced bioethanol);
 - Production of biodiesel from rapeseed and rapeseed oil;
 - Production of HVO (hydrotreated vegetable oil) from rapeseed oil.

Required improvements for the projects above are the following:

- finding ways to reduce capital and operating costs;
- using cheap feedstock;
- legal setting of obligatory targets for the share of bioethanol in gasoline and biodiesel in diesel fuel;
- stimulation for those who comply with the targets or penalties for those who do not.

CHAPTER 7

CHALLENGES AND EXISTING BARRIERS

Today, the motor biofuels sector of Ukraine is in stagnation due to the lack of a consistent state policy and incentive mechanisms. The situation is exacerbated by the high excise tax on biodiesel (106 euros/1000 liters) and the tax bill on the full rate of excise duty, required for the bioethanol transportation.

Since the beginning of the war, Ukraine has abolished and then reduced excise taxes on traditional fuels, but this did not affect biofuels. In general, in Ukraine, the excise tax on ecological fuel was higher than on traditional fuel. At the end of 2022, excise duties were equalized however no extra preferences were given to biofuels.

Substantive pressure on biofuel investors is related to institutional superstructure of controllers who are required to check production at all technological stages. Each release of products and production is possible only with the consent of tax inspectors of the excise warehouse, which creates corruption and institutional risks. The movement mechanism using promissory notes for the full rate of excise tax on ethyl alcohol greatly complicates the purchase of the product by fuel companies. Importer lobbies are blocking the incentive taxation of alternative fuels and the introduction of the mandatory addition of bio-components in accordance with European directives.

An important element for the development of biofuels, in particular bioethanol, was the de-monopolization and privatization of the alcohol industry, which is currently continuing. Today, the Government of Ukraine is carrying out an intensive work on deregulation and implementation of incentives for projects implementation. Currently, fuel companies and agricultural holdings are conducting an intensive study of the possibilities for creating their own plants on complex processing of agricultural raw materials, one of the elements of which is bioethanol and biodiesel.

Table 13. Bioenergy sector barriers

Technology	Identified Barriers
Biomethane/ biogas	<ul style="list-style-type: none">• The Register for issuing Guarantee of Origin has not yet been operational; mechanism for issuing a guarantee of origin for biomethane in transport has not been implemented.• Absence of state goals and obligations regarding the share of biomethane use in transport.• Absence of legislation supporting for biomethane producers to connect the gas distribution system (GDS).• Lack of legislation providing incentives for the use of biomethane in the transport and agricultural sectors.• Lack of regulations on technical requirements for the use of biomethane as motor fuel in transport.• Due to Martial law in Ukraine, there are natural gas export limitations.
Bioethanol	<ul style="list-style-type: none">• There is no regulation for mandatory share of bioethanol in gasoline.• Lack of technical regulations for alternative fuel with a bioethanol content of more than 10 per cent by volume to add about 85 per cent vehicles.• High excise tax rate on gasoline with a content of at least 5 per cent by weight of bioethanol – 100 EUR per 1000 litres.

	<ul style="list-style-type: none"> • Requirement for the full excise duty rate tax bill for the transportation of bioethanol.
Biodiesel	<ul style="list-style-type: none"> • High rate of excise tax on biodiesel and its blends – 100 EUR per 1000 litres. • Lack of support for alternative fuel with a biodiesel content of more than 7 per cent by volume. • There is no requirement for a mandatory share of biodiesel in diesel fuel. • There is no export duty on rapeseed. This reduces incentives to process rapeseed inside of the country. • There are no regulations and stimulus for the collection of used cooking oil that can be used for the production of biodiesel.
Solid biomass	<ul style="list-style-type: none"> • The need for biomass and biogas boiler plants, CHP plants/TPPs to pay obligatory CO₂emissions tax. • Lack of regulations on the management of felling forest residues. • Lack of incentives for the production of heat from solid biomass for population due to subsidized natural gas tariffs. • Absence of a biomass exchange in Ukraine. • Monopoly of the district heating operators and lack of incentives for independent producers to access heat networks. • Absence of the “energy crops” definition in Ukrainian legislation. • Expensive and short-term land lease agreements for the cultivation of energy crops. • Imperfect land auctions procedure for land leases to cultivate energy crops. • Production of electricity from biomass is not supported by the mechanism of guarantees of origin. • Absence of auctions for the allocation of state support for bioenergy projects. • Lack of balancing capacities and electricity storage systems to balance the energy system with a high proportion of renewable energy sources.

CONCLUSIONS AND RECOMMENDATIONS

This report provides the analysis of normative and institutional framework in support of increasing the renewable energy uptake with special attention to bioenergy in Ukraine.

There are global trends for the increase of the prices on fossil fuels. This issue is particularly tough for Ukraine, as the country depends on oil supplies from abroad. The fuel shortage endangers the operation of vehicles, machines, and equipment involved in the energy production. Ukraine's dependence on oil supplies from abroad poses a significant challenge to the country's energy production, and investments are required to neutralize the effects of Russian aggression and related economic damages.

The bioenergy sector in Ukraine has great potential for growth and could play a vital role in reducing the country's dependency on fossil fuels. However, to achieve this, there are numerous legislative and normative changes that need to be implemented.

In this context, the study recommends a set of policy changes to utilize the potential of bioenergy products, including adopting legislative acts regarding the development of biogas, liquid and solid biofuel markets, to increase the use of local renewable fuels and substitute fossil fuels. These recommendations will not only support the development of the bioenergy sector in Ukraine but also lay the foundation for the country's post-war reconstruction and economic growth.

Table 14. Recommendations for bioenergy sector development

Technology	Possible solutions/recommendations	Responsible institution
Biomethane/ biogas	<ul style="list-style-type: none"> • Implementation of the biomethane Register¹. • Development of regulatory support schemes for biomethane usage in transport and agriculture. • Regulatory adjustment of GDS with the integration of consumers into larger consumption clusters, determine network operators to create conditions to receive the reverse flow of biomethane. • Inclusion of biomethane consumption goals (5-10 per cent of natural gas consumption in transport by 2030) in the National Energy Strategy and National Renewable Energy Action Plan, as well as goals for the number of gas filling stations. • Development of technical requirements for the use of biomethane as motor fuel (CNG i LNG). • Ensuring the possibility to obtain a guarantee of origin without connecting a biomethane producer to GTS or GDS. • Development of support mechanism enabling export of biomethane. 	<ul style="list-style-type: none"> • Ministry of Energy • Ministry of Infrastructure, State Agency on Energy Efficiency and Energy Saving of Ukraine • Ministry of Agrarian Policy and Food • Ministry of Economy
Bioethanol	<ul style="list-style-type: none"> • Adoption of the draft law on mandatory share of bioethanol in gasoline and the development of the liquid biofuels market. • Creation of regulatory environment for the increase of mandatory share up to 10 per cent for the existing engines and up to 50-85 per cent for flexible fuel vehicles in future. • Reduction or cancellation of excise tax on gasoline with a content of at least 5 per cent by weight of bioethanol. 	<ul style="list-style-type: none"> • Ministry of Infrastructure, State Agency on Energy Efficiency and Energy Saving of Ukraine • Ministry of Agrarian Policy and Food

	<ul style="list-style-type: none"> • Considering introduction of incentives for importing flexible fuel vehicles that can use up to 85 per cent of bioethanol as fuel. • Mitigation of requirements for the full excise duty rate tax bill for bioethanol transportation. 	
Biodiesel	<ul style="list-style-type: none"> • Reduction or cancellation of the excise tax on biodiesel and its blends. • Development and adoption of technical regulations for alternative diesel fuel with a biodiesel content of more than 7 per cent by volume. • Introduction of mandatory share of biodiesel in diesel fuel at the level of 5 per cent. • Introduction of an export duty on rapeseed (10 per cent of the product customs value) similar to the existing duty on flax, sunflower and camelina seeds. • Ensuring gradual transition to the production and consumption of hydrotreated vegetable oil (HVO), which is a complete analogue of diesel fuel and can be used up to 100 per cent in diesel engines. • Development of legislation creating incentives for the collection of used cooking oils. 	<ul style="list-style-type: none"> • Ministry of Infrastructure, State Agency on Energy Efficiency and Energy Saving of Ukraine • Ministry of Agrarian Policy and Food
Solid biomass	<ul style="list-style-type: none"> • Exemption of installations that burn solid biofuel and biogas from CO₂ emissions tax. • Elaboration of regulations in the Forest Code on the prohibition of the burning of felling residues in the forest, obligation of forestry enterprises to clear felling site, simplification of the access of third parties to felling residues. • Development of regulatory incentives for population to produce heat from solid biomass. • Introduction of the centralized electronic system for biomass trading (biomass exchange). • Development of legislation supporting competitive heat energy market and ensuring non-discriminatory access for independent producers to the heat networks. • Introduction of a definition of "energy crops" into legislation of Ukraine. • Regulatory extension of the land lease agreement terms for the cultivation of energy crops up to 20 years (currently it is maximum 7 years). Limit the maximum land lease payments for unproductive and degraded land on which energy crops are grown to 5 per cent of the normative monetary value. • Introduction of change to legislation simplifying the lease of unproductive land for the cultivation of energy crops – without holding land auctions. • Development and implementation of a mechanism of guarantees of origin for electricity produced from biomass. • Launching the implementation of state support auctions to produce electricity from biomass. • Start of auctions for balancing capacities and electricity storage systems. 	<ul style="list-style-type: none"> • Ministry of Infrastructure, State Agency on Energy Efficiency and Energy Saving of Ukraine • Ministry of Energy

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