GREEN ENERGY COURSE FOR KHMELNYTSKYI REGION

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ХМЕЛЬНИЦЬКИЙ
ЕНЕРГЕТИЧНИЙ
КЛАСТЕР

Green energy course for Khmelnytskyi region

This study was prepared by the non-governmental organization "Khmelnytskyi Energy Cluster" in order to propose solutions for the transition of communities to green types of energy, which in war and post-war times will be able to ensure their energy independence.

This information will be useful for business representatives who are looking for investment projects and partners among local self-government bodies.

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CONTENT

LIST OF ABBREVIATIONS

APFSEDC - an action plan for sustainable energy development and climate
CC - a class of consequences
CwAL - a company with additional liability
EU - European Union
Feasibility Foundations - technical and economic justification
HAPP - a hydro-accumulating power plant
HPP - a hydroelectric power plant
IDPs - internally displaced persons (internal refugees)
JSC – joint-stock company
LLC - a limited liability company
LSGBs - is a local self-government body
NPP - a nuclear power plant
PE - a private enterprise
PrJSC - a private joint-stock company
RB - rechargeable battery
RES - renewable energy sources
SBR - state building regulations
SE - a state enterprise
SPP - a solar power plant
UAH – Ukrainian hryvnia
VAT - value added tax
WD - working documentation
WPP - a wind power plant
WP - a working project

INTRODUCTION

With the beginning of the great war, the sphere of energy became a means of influence of the aggressor country, so the energy front can be considered part of the struggle for Ukraine's independence. Before the full-scale invasion, Ukraine's dependence on russian energy sources grew and reached about 80%[1].

Energy security and post-war energy recovery is an important task for Ukraine. It is important to plan and implement energy measures even in wartime, in order to prevent the possibility that the population will be left without electricity and heat supply due to russia's destruction of critical infrastructure facilities.

The urgency of the topic of energy security, forces us to rethink the approach to the development of renewable energy sources (RES). If until February 24, 2022, the development of green energy in Ukraine was built mainly on the green tariff, now RES are considered as reserve or main sources of safe energy supply.

The RES potential in Ukraine is one of the highest among the countries of Central and Southeastern Europe. The total potential of solar electric power generation for Ukraine is 416 GW, which is three times higher than the current installed European capacity, and the technical potential of onshore wind generation is 134 GW - about 60% of the current installed capacity in the entire European Union (EU). In addition, the export of renewable electricity is recognized as an extremely important element of Ukraine's post-war recovery in the "30 GW to 2030 Initiative."[2]

Taking into account the above, we invited the territorial communities of the Khmelnytskyi region to submit proposals for green and energy-efficient projects that they consider appropriate to implement within their territories. Responses from 25 communities that proposed their initiatives were processed, in particular:

- replacing gas and electric heating in communal facilities with biomass heating;
- installation of solar power plants at important infrastructure facilities for self-consumption;
- cultivation of energy crops and processing of grain straw for heating needs.

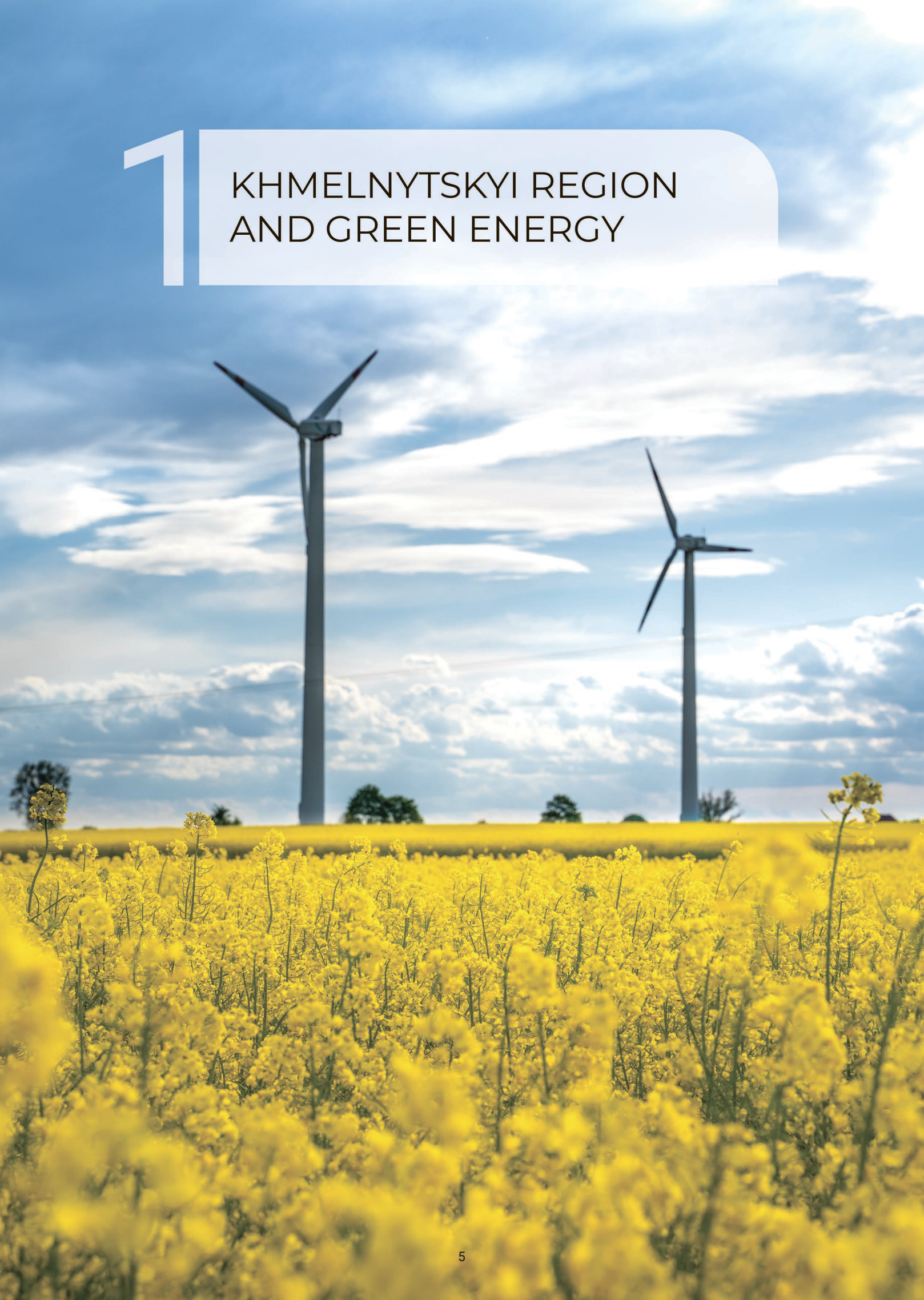
We believe that this information will be useful for business representatives who are looking for investment projects and partners among local self-government bodies.

For the convenience of information perception, we have developed an interactive map that allows you to see the location on the ground and the necessary initial data about the objects, as well as to familiarize yourself with the preliminary calculations for the implementation of the projects. We recommend that you follow the links and QR codes to familiarize yourself with the complete information. In addition, each project offered by the communities has a phone number of a contact person with whom you can discuss the details of the possibility of cooperation.

The general goal of the Khmelnytskyi energy cluster is to create a convenient database of promising projects in the field of RES and to find resources for their implementation together with interested communities. The cluster is ready to become a platform for the communication of interested parties within the framework of work on the proposed projects.

[1] Economic truth - Energy is falling into the abyss. Will the war erase everything? -https://www.epravda.com.ua/columns/2022/08/12/690358/

[2] Economic truth - Ukraine is a paradise for RES without guarantees of origin -https://www.epravda.com.ua/columns/2022/08/9/690175/



1 KHMELNYTSKYI REGION AND GREEN ENERGY

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Khmelnytskyi region has an area of 20,629 km² and consists of three districts: Shepetivskyi, Khmelnytskyi and Kamianets-Podilskyi. They consist of 60 territorial communities, which differ in size, population, financial capacity and challenges in the energy sector.

As of February 1, 2022, 1,227,400 people live in Khmelnytskyi Oblast[3]. After February 24, the population increased by more than 100,000 thanks to internally displaced persons (IDPs). According to the government's plans to evacuate residents of dangerous areas, Khmelnytskyi region is preparing to welcome more than 50,000 forced migrants closer to the winter of 2022/2023[4]. Accordingly, the communities of the region must ensure a warm winter both for the local population and for IDPs.

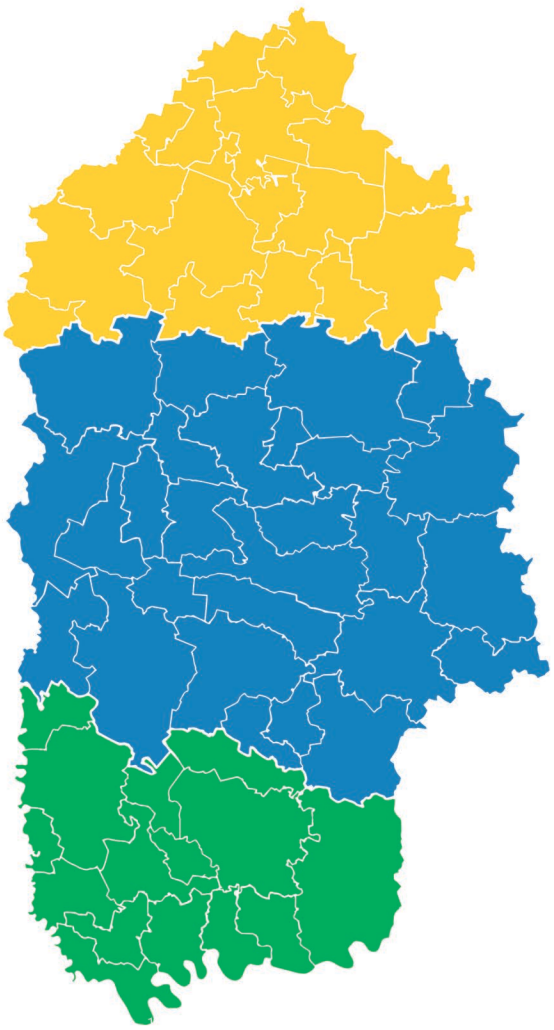
In general, the electricity supply of the Khmelnytskyi region is provided by power plants and substations of the South-Western electric power system, located both on the territory of the region and outside its borders. The main sources of electricity supply include the Khmelnytsky NPP, the Dniester HPP, and the Dniester HPP - a hydro-accumulating power plant.

JSC "Khmelnytskgaz" and JSC "Naftogaz of Ukraine" are one of the main gas suppliers in Khmelnytskyi region. On the territory of the region, centralized heat supply services are provided by 16 communal heat energy enterprises and 1 enterprise of the Netishyn NPP (as of 2017). In total, more than 700 boiler houses are in operation in the region, of which about a quarter are communal. The vast majority of communal boiler houses operate on gas[5].

Renewable energy sources continue to develop in Khmelnytskyi, among which the most dynamic sector is solar energy[6]. In general, the potential of solar energy is most actively realized within the Khmelnytskyi region. The average annual amount of total energy of solar radiation, which enters the territory of Khmelnytskyi region every year, is 1070 kWh/m².

Khmelnytskyi region:

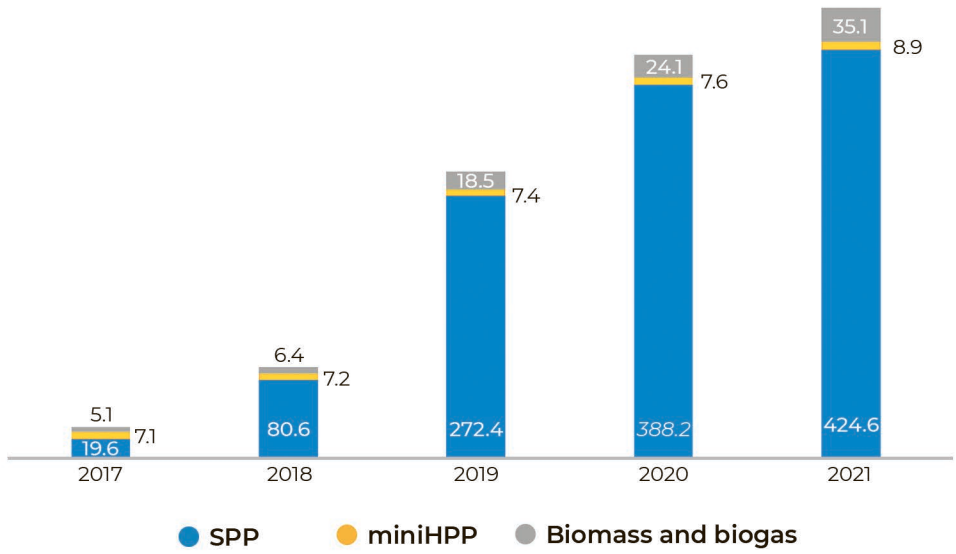
Area: 20 629 km²
Consists of three districts
Consist of 60 territorial communities
Population: 1,227,400 people



- Shepetivskyi district
- Khmelnytskyi district
- Kamianets-Podilskyi district

[3] The main statistics office in Khmelnytskyi region -https://www.km.ukrstat.gov.ua/
[4] The website of the city of Shepetivka - Khmelnychina is preparing to shelter another 50 thousand forced migrants from the cold -https://shepetivka.com.ua/novyny/suspilstvo/11113-khmelnychychna-hotuietsia-prykhystyty-z-kholodamy-shche-50-tys-vymushenykh-pereselentsiv.html
[5] Development strategy of Khmelnytskyi region for 2021-2027 -https://www.minregion.gov.ua/wp-content/uploads/2020/04/strategiya-rozvytku-hmelnyczkoyi-oblasti-na-2021-2027-roky.pdf
[6] Energy Map - Installed electrical capacity of "green" energy producers -https://map.ua-energy.org/uk/resources/699855af-945a-477a-93e7-d479b56f8e2c/

Installed renewable energy capacity in Khmelnitskyi region, MW



In 2021, the total installed capacity of RES facilities in the region was:

- **424,6 MW – SPP;**
- **8,9 MW – mini hydroelectric power plants;**
- **35,1 MW – biogas and biomass.**

As of the beginning of 2022, there are 31 small hydroelectric power plants, 99 SPPs, and 8 biogas and biomass facilities operating in the Khmelnytskyi region. In general, the territorial communities of Khmelnytskyi have great potential for the development of green projects.

Potential green projects in Khmelnytskyi region

During the work on this document, all territorial communities of the region were asked to fill out questionnaires related to bioenergy (solid fuel boilers, cultivation of energy crops, biogas production) and solar energy.

According to the results of the survey, responses were collected from 25 communities that offer:

88
potential projects in the field of bioenergy (transition to solid fuel boilers);

18
potential sites for growing energy crops;

11
potential projects in the field of biogas;

30
potential projects in the field of solar energy.

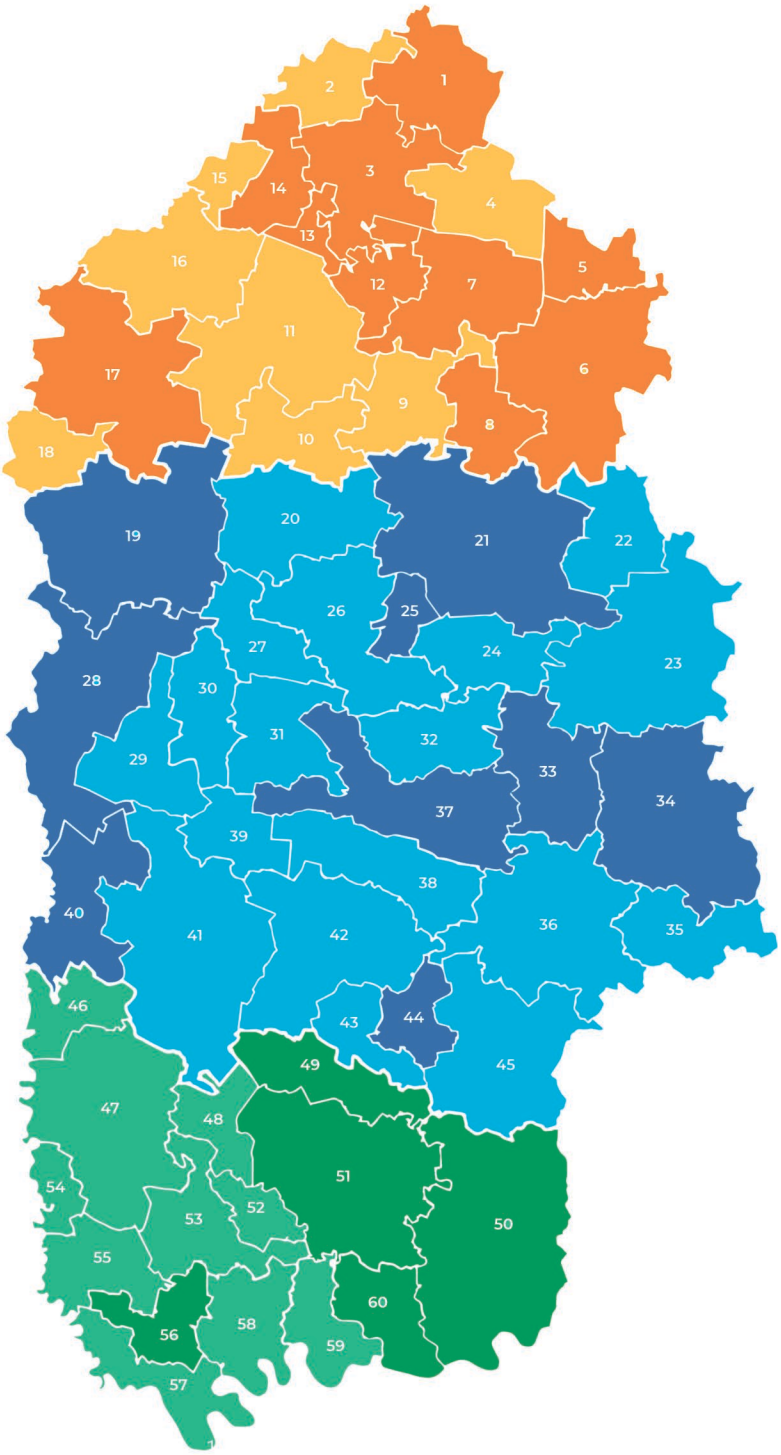
Territorial communities that provided information on potential green projects*

Shepetivskyi district:
1. Berezdiv territorial community
2. Hannopil territorial community
3. Ulashanivka territorial community
4. Myhaylyuchka territorial community
5. Poninka territorial community
6. Polonne territorial community
7. Sudylkiv territorial community
8. Hrytsiv territorial community
9. Lenkivtsi territorial community
10. Sahnivtsi territorial community
11. Izyaslav territorial community
12. Shepetivka territorial community
13. Slavuta territorial community
14. Krupetsk territorial community
15. Netishyn territorial community
16. Pluzhne territorial community
17. Biloghirya territorial community
18. Yampil territorial community

Khmelnytskyi district:
19. Teofipol territorial community
20. Antoniny territorial community
21. Starokostyantyniv territorial community
22. Staryi Ostropil territorial community
23. Stara Synyava territorial community
24. Myrolyubne territorial community
25. Shchyborivka territorial community
26. Krasyliv territorial community
27. Zasluchne territorial community
28. Volochysk territorial community
29. Viytivtsi territorial community
30. Narkevychi territorial community
31. Chornyi Ostriv territorial community
32. Lisovi Hrynivtsi territorial community
33. Medzhybizh territorial community
34. Letychiv territorial community
35. Vovkovyntsi territorial community
36. Derazhnya territorial community
37. Khmelnytskyi territorial community
38. Rozsosha territorial community
39. Hvardiyske territorial community
40. Sataniv territorial community
41. Horodok territorial community
42. Yarmolyntsi territorial community
43. Solobkivtsi territorial community
44. Zinkiv territorial community
45. Vinkivtsi territorial community

Kamianets-Podilskyi district:
46. Zakupne territorial community
47. Chemeryvtsi territorial community
48. Smotrych territorial community
49. Novodunayivtsi territorial community
50. Nova Ushytsia territorial community
51. Dunayivtsi territorial community
52. Makiv territorial community
53. Humentsi territorial community
54. Hukiv territorial community
55. Orynyn territorial community
56. Kamianets-Podilskyi territorial community
57. Zhvanets territorial community
58. Slobidka Kulchiyevetska territorial community
59. Kytayhorod territorial community
60. Stara Ushytsia territorial community

*** territorial communities, which gave their proposals – marked bold**



You can familiarize yourself with the projects by following the link to the Google map, where all the proposed projects are marked with markers. Clicking on the mark opens a link to the raw data and calculations. This information will be presented later in this study, in the section on territorial communities in the context of each individual community.

Map with potential RES projects:
https://bit.ly/RES_Khmelnytskyi

2 BIOENERGY

2 BIOENERGY

This section provides information that will allow you to better understand the process of preparing projects for the replacement of natural gas with biomass in public sector buildings. The following calculations and explanations will be useful for representatives of local governments and for potential investors who are looking for opportunities for cooperation in the field of biomass heating.

In order to calculate the possibility of replacing natural gas with biomass in public sector buildings in Khmelnytskyi region, we present a list of potential premises provided by 25 communities.

List of potential facilities for replacing natural gas with biomass: https://bit.ly/biomass_khm_en

The topicality of replacing natural gas with biomass

Since 2021, there has been a significant increase in the price of natural gas, including for organizations financed from the state and local budgets. The price of gas for the population is largely subsidized and is currently within the range of UAH 8.0-8.2/m^3 for household consumers and for heat supply organizations that produce thermal energy for this category of consumers. On the other hand, for budget, and especially for commercial consumers, natural gas prices have increased several times. In 2021, budget organizations had the opportunity to conclude gas supply contracts until the end of 2022 at a price of UAH 16,500-16,700 for 1000 m^3 including VAT. But, given that the market price of natural gas currently exceeds UAH 30,000 for 1000 m^3, no one can say for sure whether budget consumers will not have to pay for gas at the market price in the future. Fluctuations in world natural gas prices in 2021-2022 were quite significant. Also, as a result of full-scale aggression of the russian federation, there is a potential threat of a shortage of natural gas. Therefore, reducing dependence on natural gas is an urgent task for budget consumers.

For this purpose, Ukraine has been implementing projects for many years to improve the energy efficiency of public institutions and transition to alternative types of heating, including projects for the implementation of biomass boilers. Currently, hundreds of public institutions - kindergartens, clubs, educational institutions and hospitals in various regions of Ukraine - have switched to biomass heating.

As a rule, the implementation of biomass energy use projects also solves the issue of improving the quality, reliability, efficiency of thermal energy production and ensuring consumer access to services in the field of heat supply.

Non-compliance with sanitary requirements of indoor air temperature and lack of hot water is one of the key problems of consumers in the municipal sector. Another problem is the lack of sufficient funds from consumers to cover the costs of fuel and thermal energy to provide facilities of the municipal sphere. It is worth noting that, depending on the direction, the project for the construction of a biofuel boiler house may aim to solve technical, organizational, economic or environmental issues. Rejection of the use of expensive fuel and transition to the use of biofuel will simultaneously solve these problems.

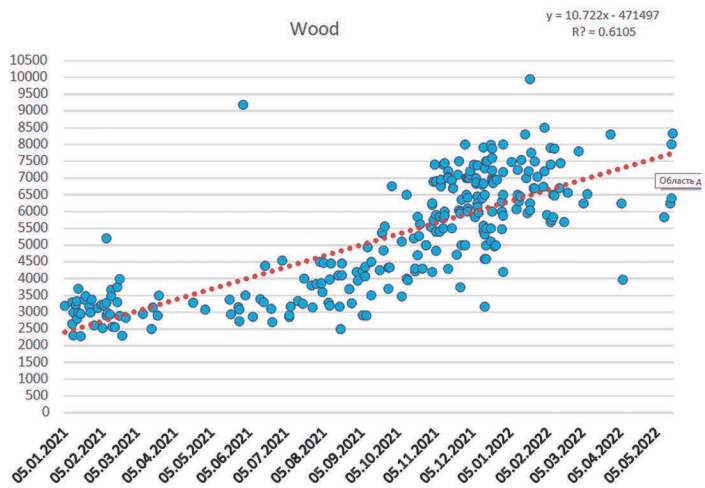
When making a decision to install a boiler that runs on biofuel or to build a boiler house that runs on biofuel, it is worth setting tasks that will be specific, measurable, realistic, expedient and determined in time.

Types and price of fuel

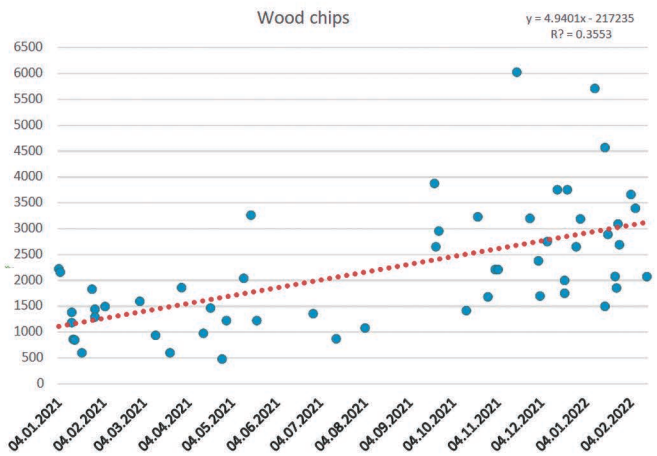
For the production of thermal energy from biomass, different types of fuel can be considered, in particular, firewood, wood chips, pellets and briquettes from various types of vegetable raw materials, baled straw, corn stalks or cobs, etc. In addition, according to the experience of many energy communities in Europe, thermal energy for heating local consumers can be obtained from biogas cogeneration plants operating on waste supplied by local farmers.

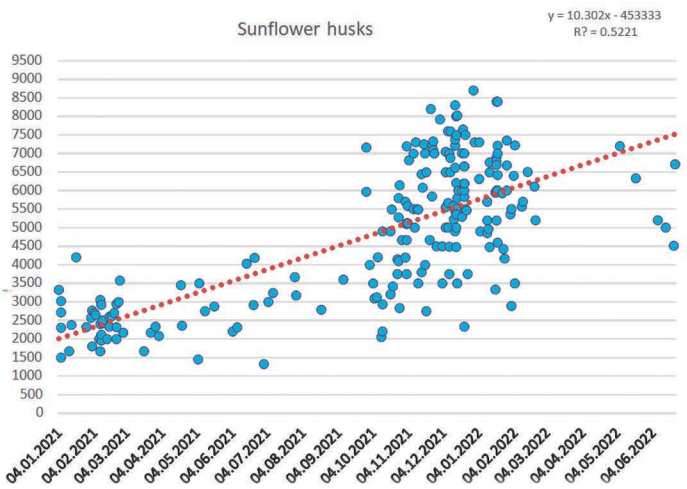
The first thing to consider as a source of biomass is local resources and local suppliers of biofuel. Although the purchase of fuel by budget organizations should take place on a competitive basis through tenders, in order to choose the direction of transferring the heating of budget institutions with biomass, it is worth analyzing the possible types of biomass and their prices in one or another region, as well as the dynamics of their changes. This will make it possible to focus on those types of fuel that have more or less stable prices in the region. Of course, the price of fuel biomass is significantly affected by fluctuations in the price of natural gas. In the heating season of 2021/2022, significant price fluctuations were observed for fuel biomass, especially wood pellets and sunflower husks.

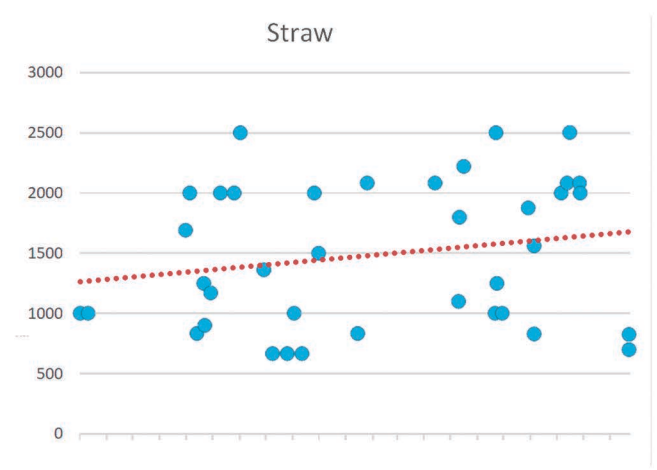
Price changes for fuel pellets (pellets)

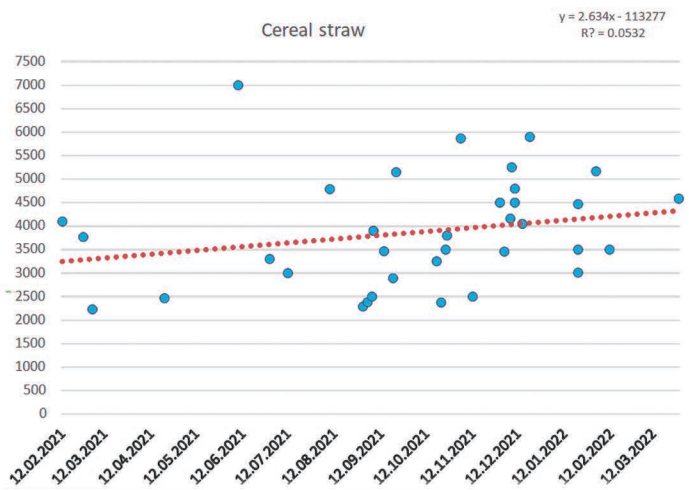


Change in prices for other types of fuel biomass









According to the results of the analysis of fuel biomass purchases on the electronic platform "Prozorro", the average price of fuel biomass in the heating season of 2021/2022 was:

Wood pellets

UAH 7,000 t without VAT;

Sunflower husk granules

UAH 6,500 t without VAT;

Granules from grain straw

UAH 4,500 t without VAT;

Grain straw in bales

UAH 1,500 t without VAT;

Wood chips

UAH 3,000 t without VAT;

Frewood

UAH 2.500 t without VAT;

Comparison of the price of energy in fuel

The main factor that determines the possibility of obtaining an economic effect from the introduction of a biomass boiler house is the lower cost of the fuel component in the cost of energy for the project option compared to the basic option, that is, with the type of fuel used. A comparison of the price of energy in fuel according to fuel prices in the heating season of 2021-2022 is shown below.

Fuel energy price comparison

Type of fuel or energy carrier	Average price with transport, without VAT (heating season 2021/2022)		Lower calorific value		Cost of a unit of energy, UAH/Gcal
	А		Б		А/Б*4.19
Natural gas for the population (annual tariff)	8000	UAH/thousand m^3	33.5	MJ/m^3	1001
Natural gas for the budget sector	16554	UAH/thousand m^3	33.5	MJ/m^3	2070
Natural gas for industry	26000	UAH/thousand m^3	33.5	MJ/m^3	3252
Coal	6250	UAH/ton	25	MJ/kg	1048
Oil fuel	19200	UAH/ton	42	MJ/kg	1915
Electricity for the population	1.68	UAH/kWh	-		1955
Electricity for non-household consumers	3.5	UAH/kWh	-		4074
Electricity for non-household consumers through a heat pump with coefficient of performance = 2.3	3.5	UAH/kWh	-		1771
Wood chips	3000	UAH/ton	12	MJ/kg	1048
Not chopped firewood	2500	UAH/ton	13.4	MJ/kg	782
Wood pellets	7000	UAH/ton	17	MJ/kg	1725
Pellets from husk	6500	UAH/ton	17.5	MJ/kg	1556
Straw pellets	4500	UAH/ton	18.5	MJ/kg	1019
Bales of straw or corn stalks	1500	UAH/ton	14.6	MJ/kg	430

The given information demonstrates that not all types of fuel biomass can compete with natural gas for the budget sector: wood pellets and sunflower husks have almost the same energy value in fuel. Straw pellets, wood chips, firewood and straw bales are more competitively priced. As for natural gas for industrial consumers, almost all types of fuel biomass can compete with it in terms of price.

Making a decision on the construction of a boiler house on biofuel

The implementation of municipal projects, including those with the involvement of budget funds, is primarily aimed at solving social issues and may not always have the goal of making a profit or be economically expedient. Unlike municipal projects, commercial projects are aimed at obtaining profit from planned activities. Although such municipal facilities as schools and hospitals may have their own boiler houses, their main activity should remain the provision of the educational process and the treatment of the sick, and their managers should not be engaged in the preparation and implementation of construction projects. Thus, it is recommended to involve qualified specialists in the preparation of the project, and the projects themselves must meet the following criteria: technological feasibility, viability after their implementation, efficiency, economic feasibility, environmental safety.

When deciding on the construction of a biofuel boiler house, special attention should be paid to fuel raw materials and technological equipment. The choice of fuel should be based on long-term availability, economic feasibility and environmental safety. The most common types of biofuels currently used are firewood, pellets and briquettes. More and more biofuels from agricultural waste and by-products of agriculture are beginning to be used in the budgetary and communal spheres for the production of thermal energy. Information about the availability of biofuel producers in the region can be obtained from district and regional administrations and from open Internet sources. Existing suppliers of fuel for existing heat supply facilities can be a valuable source of information.

When choosing fuel and evaluating potential suppliers, special attention should be paid to the availability of current quality certificates, compliance of the product with standards, the possibility of ensuring the necessary volumes of supply, compliance with the requirements for containers and packaging. The available amount of fuel must exceed the need by at least 50%, and the available number of potential suppliers must be at least three.

Depending on the type of fuel chosen and its fuel characteristics, it is necessary to choose equipment of the appropriate power, efficiency and emission class. There are more than 100 manufacturers of biofuel boilers and another 100 brands of foreign production operating in Ukraine. In addition to the price and power of the heating equipment, it is worth paying attention to its configuration and level of automation, to evaluate the quality of materials from which it is made, dimensions, availability of guarantees and service. By contacting the manufacturers of boilers, you can get comprehensive information about the characteristics and requirements for the operation of the equipment. It is also useful to obtain information about objects that use similar equipment. It will not hurt to personally verify the correctness of the choice and the validity of the decisions made by visiting the implemented objects.

In addition to the costs of the equipment itself, additional funds are needed for the development of project and estimate documentation, the purchase of auxiliary equipment and materials, the execution of works and the provision of services. For small-capacity projects, the cost of additional costs, as a rule, exceeds the cost of the equipment itself several times, which should be taken into account when preparing projects.

The capacity of a biomass boiler house when replacing natural gas should, as a rule, correspond to the capacity of the existing boiler house, if this capacity meets the conditions for reaching the required temperatures in the heated rooms in the entire range of outdoor air temperatures. The power of the boiler room usually depends on the heating needs of the premises, which in turn depends on the geometric dimensions of the premises and the thermal resistance of the enclosing building structures.

Usually, the required capacity of boiler houses of budgetary institutions is within the following limits:

Kindergartens:
50-350 kW

Schools, lyceums:
100-500 kW

Clubs, premises of village councils:
50-500 kW

Hospitals:
100-10 000 kW

Different types of boilers can be used for heating public sector facilities, depending on the size of the facility and the capacity of the boiler room.

Types of boilers

Image	Type of fuel	Typical boiler capacity, kW	Boiler type
	Firewood, briquettes	20-800	With a fixed grid, manual loading
	Granules (pellets)	20-1500	With pellet burner or retort, mechanical loading
	Cod	200-10 000	With a retort furnace or various types of moving grates, mechanical loading
	Straw bales	200-800	Intermittent action, burning of whole bales Continuous operation, burning of bales with partial or complete grinding, various types of moving grates

When implementing a biomass boiler house, existing gas boilers can be used as a backup in case of interruptions in the supply of fuel biomass. Therefore, they should be left in operation, providing the opportunity to work if necessary instead of biomass boilers or in parallel with them.

Requirements for the placement of biofuel boilers

According to the requirements of SBR V.2.5-77:2014 "Boilers", for public buildings and structures, administrative and household buildings, it is allowed to design attached, built-in and rooftop boiler rooms when using water heating boilers, heat generators with a water heating temperature not higher than 115 °C. Rooftop boiler rooms are expected to run on natural gas. The operation of attached and built-in boiler rooms is allowed on natural gas, solid and liquid fuel with a vapor flash point not lower than 61 °C.

The productivity of attached and roof boiler rooms for public buildings, which is accepted taking into account the heat loads of the main buildings and, if necessary, the supply of coolants to other consumers from the internal heat networks of the main building, should not exceed 5.0 MW (with a unit capacity of a boiler that does not have drums,, no more than 1.25 MW).

The total productivity of boilers, heat generators installed in built-in boiler rooms for public buildings and structures, administrative and household buildings should not exceed:

a) 5.0 MW during the operation of boilers and heat generators on natural gas and liquid fuel (with a unit capacity of a boiler that does not have drums, no more than 1.25 MW);

b) 1.7 MW during the operation of boilers, heat generators on solid fuel (with a total maximum yield of ash and slag in the boiler room of no more than 150 kg/h).

It is not allowed to design boiler rooms (including separate boilers, equipment and facilities) attached, built-in, roofed for the following buildings and structures of public purpose:

- preschool educational institutions;
- schools;
- health care and recreation (treatment-preventive and sanitary-preventive institutions, sanatoriums and sanatoriums-prophylactics);
- physical culture and health and sports;
- houses and leisure facilities, cultural and entertainment and cult institutions;
- institutions of social protection of the population (except population employment centers);
- buildings and transport facilities intended for direct public service;
- household service enterprises (except dry cleaners and laundries);

- houses and structures with atriums.

It is also not allowed to design boiler rooms that are directly adjacent to or located directly above and below the following premises of buildings and structures:

- premises designed for the simultaneous permanent or temporary stay of more than 50 people;
- premises of categories A and B in terms of explosion and fire hazard, warehouses of combustible materials, flammable and combustible liquids.

It is not allowed to install boilers, heat generators on liquid fuel with a vapor flash point lower than 61°C, as well as boilers and heat generators on gaseous fuel - in basement (underground) floors, and on liquefied gases - in underground and basement floors.

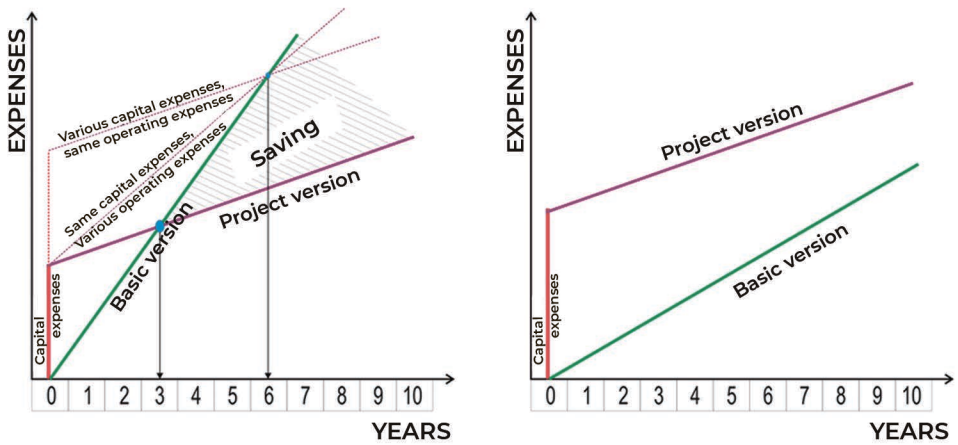
It is allowed (in the case of impossibility of applying other solutions) the design of reconstruction and technical re-equipment of existing boiler rooms gasified with natural gas, built into the basement floors of industrial, administrative, domestic, public, residential buildings.

Thus, the main technical solution for the implementation of solid fuel boiler rooms for the vast majority of institutions financed from state or local budgets is a separate boiler room (new or converted on the basis of an existing gas boiler room).

The specific cost of introducing biofuel boilers

The use of biomass for the production of thermal energy allows to reduce the fuel component in the cost of thermal energy by 40-65%. At the same time, for the implementation of the construction project, it is necessary to attract investments, which causes an increase in financial and amortization deductions by increasing the value of fixed assets. Thus, the economic effect of the production of thermal energy from biomass can be achieved if the reduction of fuel costs, compared to gas, exceeds the total increase of all other costs.

Economic effect of heat energy production from biomass



а) an acceptable payback period is guaranteed **б) an acceptable payback period is not guaranteed**

According to existing practice, cheap domestic equipment is mainly used for the needs of the municipal sector. The average cost of such equipment is up to 1500 UAH/kW including VAT. At the same time, the cost of turnkey projects varies in a very wide range and depends on both the cost of equipment and the volume of construction work. For boiler house reconstruction projects with the installation of domestic biofuel boilers, specific investments are up to 3500 UAH/kW, for the construction of new boiler houses, including with the use of imported equipment and infrastructure – from 3500 to 7500 UAH/kW. As a rule, for boilers and boiler houses of the same type, the specific cost (that is, the cost per unit of installed capacity of the boiler house) decreases as the installed capacity increases.

Capital costs for the implementation of construction projects include: equipment and materials, works and services, organizational costs, taxes and fees. Pricing during project development and construction is based on regulatory and calculation indicators and current prices of labor and material and technical resources.

The cost of project works for the boiler room depends on the capacity of the object and, according to the average estimate, is about 5% of the total estimated cost of construction.

The number of design stages depends on the class of consequences of construction objects. For boiler plants with class of consequences - CC1, design is performed in one (working project), for CC2 - in two (Feasibility Foundations + work project (WP)) or three stages of design (Feasibility Foundations + project + work documentation (WD)). Expenditures for the design stage of the Feasibility Foundations make up 20-25% of the total design costs, the stage of the working project (WP) - 75-80%, the project (P) - 30-35%, and the stage of the working documentation (WD) - 40-50% .

Stages of implementation

Typical stages of implementation of a biomass boiler house are as follows:

- selection of a plot of land for construction;
- acquisition of property rights to a land plot;
- performance of preparatory works. Engineering searches;
- obtaining technical conditions and town-planning conditions and land plot development restrictions, development of a design task;
- development and approval of project documentation;
- project development in terms of environmental impact assessment;
- obtaining permits and carrying out construction works and putting the facility into operation;
- registration of ownership of the construction object;
- registration of boilers, preparation of mode maps;
- usual operation of the boiler room.

Implementation of construction projects or their reconstruction can be carried out both on existing and on new land plots that require appropriate registration. The right to develop a land plot is exercised by its owner or user, provided that the land plot is used in accordance with the requirements of urban planning documentation. The main difficulties associated with the allocation of a plot of land for construction are the need to develop a detailed plan of territories, conduct public hearings, develop land documentation and obtain cadastral numbers. It is prohibited to change the intended purpose of a land plot that does not correspond to the zoning plan of the territory and/or the detailed plan of the territory.

For objects that will be financed with state capital investments and/or credits (loans) raised by the state or under state guarantees, the design task is drawn up on the basis of an investment project approved or selected in accordance with the procedure established by law, which substantiates the feasibility of such construction.

The development of a preliminary feasibility study makes it possible to assess the possibility of achieving the desired economic efficiency of the project when using different equipment options and different types of fuels. In this way, the general concept of the project is substantiated, the requirements for the cost of implementing the boiler house, the type and marginal price of fuel biomass are worked out, and the impact of the main factors on the economic efficiency of the project is analyzed.

The basis of the economic efficiency of projects to replace expensive natural gas with cheaper biofuel is the cost savings that occur in the project variant compared to the basic one and can be aimed at returning investments. For projects that are financed with own funds and are implemented to meet one's own needs for heat energy, it is possible to use the method of economic assessment of projects, which is based on the use of saved funds as the difference between the full cost of heat energy from gas and biofuel. For projects that involve the attraction of investments and the sale of thermal energy to third-party consumers, the evaluation of projects should be performed based on the analysis of investment indicators - simple and discounted payback period (SDPP), net present value (NPV) and internal rate of return (IRR).

Sources of funding

The success of the implementation of any project depends on the availability of sufficient funds and their timely receipt. Preparation for the financing of municipal projects with the involvement of budget funds is a long process and requires significant efforts and high-quality preparation. As a rule, such projects are prepared in advance and implemented no earlier than in the next budget year, which is related to the peculiarities of the formation of state and local budgets. At the same time, projects financed by private investors can be implemented in the shortest possible time.

Funding sources are divided into internal and external, among which we can highlight next:

- self-financing, which involves the financing of the project exclusively with the own funds of utility companies;
- budget financing – project financing with budget funds;
- credit financing - financing with loans;
- project financing (grant funds);
- attraction of private investments;
- other

Mixed financing involves the receipt of funds from various considered sources.

The main sources for financing projects in the field of municipal heat supply are budgetary and self-financing. As experience shows, the role of budget financing from planned to implemented projects is significantly exceeded, while the role of private investors and bank loans is underestimated by project initiators. The most common source of financing municipal projects in the field of heat supply is the State Fund for Regional Development, international projects (project financing) and technical assistance.

Project financing involves the use of various financial instruments. In such projects, the source of debt repayment is the cash flows generated by the project, and the debt is secured by the assets of the financing participants. The company's or municipality's own contribution to the implementation of the project, as a rule, is at least 10% and can be provided not only in monetary form.

In conditions of limited access to funding sources and in order to improve the efficiency of management and use of state or communal property, balance-holders and local self-government bodies (LSGBs) often consider the possibility of involving private companies for the implementation of projects. Currently, there are several main forms of attracting private companies to invest in the heat supply sector, including lease, concession, public-private partnership, ESCO and others. Until recently, it was through the involvement of private companies that the majority of projects on the construction/reconstruction of boiler houses with the use of biofuel in the budgetary sphere were implemented.

Examples of Feasibility Foundations results for different capacities and different types of fuels

Below is an approximate estimate of the payback of projects for the implementation of biomass boilers for different types of fuel for two main levels of the price of natural gas: the current price for budget institutions (13,795 UAH/1000 m^3 without VAT) and the price for industrial consumers (26,000 UAH/100 m^3 without VAT).

Fuel prices were taken at the level of their prices in the heating season of 2021/2022, as shown above.

Estimated cost of implementation of boilers of different capacities

Wood		Wood cod, dry		Cod wood, moist		Pellets (wood or sunflower husk)	
Required installed capacity of the boiler room, kW	Implement ation costs, EUR	Required installed capacity of the boiler room, kW	Implemen tation costs, EUR	Required installed capacity of the boiler room, kW	Implement ation costs, EUR	Required installed capacity of the boiler room, kW	Implement ation costs, EUR
30	10800	200	74600	1000	229600	30	15200
50	13700	300	91100	1500	323300	50	19300
70	16300	400	106000	2000	414100	70	22700
100	19800	600	132900	2500	502900	100	27300
120	22000	800	164900	3000	590200	120	30100
150	25100	1000	188700	3500	676200	150	33900
200	47400	1250	216800	4000	761300	200	71800
300	63600	1500	243500	5000	928900	300	97100
400	78900	2000	294000			400	122000
500	93500	2500	341700			500	141000
750	128200					750	188800
1000	161000					1000	233200

Payback periods (years) for different types of fuel

Wood			Wood pellets		
Required installed capacity of the boiler room, kW	Payback period (years), at the price of natural gas, UAH/1000 m³ without VAT:		Required installed capacity of the boiler room, kW	Payback period (years), at the price of natural gas, UAH/1000 m³ without VAT:	
	13795	**26000**		**13795**	**26000**
30	2,99	1,6	30	-	3,4
50	2,91	1,3	50	-	3,2
70	2,79	1,1	70	-	2,9
100	2,62	0,9	100	-	2,6
120	2,52	0,9	120	-	2,5
150	2,39	0,8	150	-	2,3
200	3,82	1,3	200	-	4,1
300	3,57	1,1	300	-	3,8
400	3,38	1,0	400	-	3,6
500	3,24	0,9	500	-	3,3
750	2,99	0,8	750	-	2,9
1000	2,81	0,7	1000	-	2,7

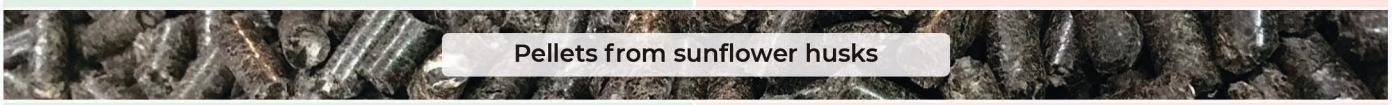
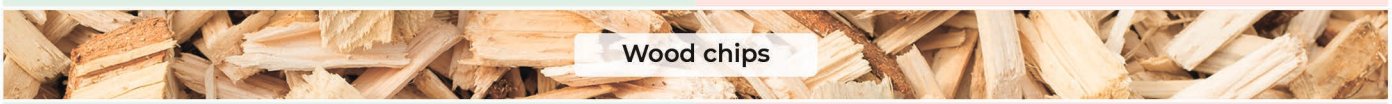
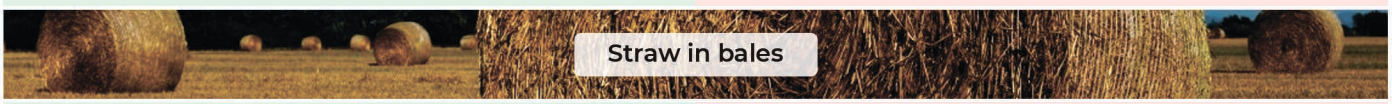
Wood cod, dry			Cod wood, moist		
Required installed capacity of the boiler room, kW	Payback period (years), at the price of natural gas, UAH/1000 m³ without VAT:		Required installed capacity of the boiler room, kW	Payback period (years), at the price of natural gas, UAH/1000 m³ without VAT:	
	13795	**26000**		**13795**	**26000**
200	>15	4,7	1000	>15	2,0
300	>15	3,1	1500	>15	1,8
400	>15	2,4	2000	11,3	1,6
600	11,4	1,7	2500	9,6	1,6
800	9,2	1,5	3000	8,6	1,5
1000	7,7	1,3	3500	8,0	1,5
1250	6,6	1,1	4000	7,6	1,4
1500	5,9	1,0	5000	7,0	1,4
2000	5,1	0,8			
2500	4,5	0,7			

Thus, wood-fired boiler houses have the best return, which is due to both the lower cost of implementing such boiler houses and the acceptable price of this fuel. Compared to the price of natural gas, dry chip boilers for public institutions have an acceptable payback only with an installed capacity of 1,000 kW or more, and wet wood chip boilers only with a capacity of about 5,000 kW. It is clear that such power of the boiler house can only be suitable for some budget institutions (for example, large hospitals). At this price of gas, boiler rooms on wood pellets do not have an acceptable return. But at the price of gas for industrial consumers, the simple payback period for all types of fuel and boiler plant capacities is less than 5 years.

It should be noted that the replacement of electric energy heating with biomass heating has an acceptable payback period even for pellet boilers already for the cost of electricity starting from 2.5 UAH/kWh without VAT. So, for a wood pellet boiler with a capacity of 200 kW, the simple payback period is about 5 years, and at the price of electricity 3.5 UAH/kWh, it is reduced to 2.3 years.

Each type of fuel biomass has its strengths and weaknesses compared to others.

Advantages and disadvantages of different types of biomass

Advantages	Disadvantages
 **Wood**	
Lower price, sufficient availability in forest farms in most regions of Ukraine (except eastern and southern).	A large amount of physical labor for sawing, stacking and feeding into the boiler, which requires the presence of additional personnel. Lower efficiency of boiler equipment. Restrictions on the unit capacity of boilers by labor protection legislation.
 **Wood pellets**	
Sufficient distribution, especially in the northern, central and western regions of Ukraine. Ease of use, the possibility of mechanizing the processes of loading and unloading, storage and feeding into the boiler. Low humidity, stability of fuel characteristics, availability of requirements of standards and practices of obtaining quality certificates. Can be used in all pellet boilers and boilers for fine dry fuel.	The highest price of all types of fuel biomass. There is a great demand abroad, especially for pellets of the highest quality, which causes their high price in the country as well. This is also due to the trend of export of the highest quality pellets.
 **Pellets from sunflower husks**	
Sufficient distribution, especially in the central, eastern and southern regions of Ukraine. Other qualities are practically the same as for wood pellets. Compared to wood pellets, the price is somewhat lower.	Higher ash content compared to wood pellets. The availability of this resource depends on the amount of cultivation and processing of sunflower, which in turn depends on the possibility of exporting sunflower oil.
 **Cereal straw pellets**	
The lowest price among all types of pellets. There is a great potential for procurement of raw materials in almost all regions of Ukraine.	Despite the spread of raw materials, insufficient production volumes, spot spread on the market. Lower fuel characteristics - higher ash content and lower melting temperature, which necessitates the use of boilers adapted to such fuel.
 **Wood chips**	
A fairly low price, the possibility of mechanizing unloading and feeding into the boiler.	Insufficient stability of fuel characteristics due to possible high humidity, possible presence of too massive or small particles. Insufficient supply on the market.
 **Straw in bales**	
The price is quite low, and there is a great potential for harvesting raw materials in almost all regions of Ukraine.	Lower fuel characteristics - higher ash content and lower melting temperature, which necessitates the use of boilers adapted to such fuel. Insufficient distribution, small offer on the market.

The potential of Khmelnytskyi

For the Khmelnytsky region, bioenergy should become one of the strategic directions of the development of the sector of renewable energy sources. This is due to the fact that the Khmelnytskyi region has a large potential of biomass available for energy production. This is a good prerequisite for the development of the bioenergy sector. It should be noted that the energy potential of biomass from the agricultural sector of Khmelnytskyi region varies from year to year and depends on the productivity of the main agricultural crops. The main components of the potential are waste from agricultural production (straw, corn stalks, sunflower stalks, etc.).

The greatest energy potential among all types of biomass in the Khmelnytskyi region is plant waste. Stalks of corn and sunflower stalks, the energy potential of which prevails in most communities, can be briquetted or crushed and burned in appropriate boiler plants. Straw can be burned both in bales and in the form of briquettes or pellets. Sunflower husk is already widely used by oil extraction plants, in particular in Starokostyantinov at the largest plant in the region and at other smaller facilities.

Khmelnytskyi region has the highest yield rate in 2022 among grain crops, and as of August 12 of this year, the harvested crop in the region is 1 million 495 thousand tons[7]. (75% of the planned). It is predicted that this indicator will reach 2 million tons. This will at least ensure the volume of straw at the level of 2 million tons. Even if we subtract 50% of straw for the needs of cattle breeding and other related areas, we can claim the presence of 1 million tons of straw for energy needs. Briquetting of straw allows you to increase its volume density, reduce humidity and thus improve storage capacity, as well as reduce transport costs. The energy contained in the straw has a high concentration, giving the fuel very good energy indicators, calorific value, and also with minimal amounts of ash. Meanwhile, ash from burning briquettes and pellets can be used as mineral fertilizers due to the high content of elements vital for plant growth.

Use of biogas

Another promising area of bioenergy is the use of biogas. For sugar factories, distilleries and large livestock farms, the possibility of using their own waste for biogas production allows solving the issue of waste disposal and impact on the environment. At the same time, enterprises will receive economic benefits by reducing costs for traditional energy carriers. There are many enterprises in Khmelnytskyi region for which the use of biogas is a relevant alternative. Information about such enterprises was provided by communities of Khmelnytskyi region. Cooperation with them can solve the issue of providing thermal energy to communal institutions and the residential sector. A vivid example can be the Teofipol settlement community, on the territory of which there is a sugar factory that produces biogas (the total installed capacity of the facility, which consists of 4 stages - 26,6 MW*h in the equivalent of electrical energy, which allows the same amount of heat to be produced). This object has the prospect of covering all the needs of Teofipol's heat supply, however, such an initiative requires a dialogue between the authorities, the community and business.

[7] Khmelnytskyi Regional Military Administration - Khmelnytskyi Region is the leader in the yield of grain crops -https://www.adm-km.gov.ua/?p=114553

Energy crops

Considering the favorable soil and climatic conditions for growing plants, growing energy crops is a promising type of bioenergy for the Khmelnytskyi region. Energy crops are special plants that are specifically grown for use as biofuel and/or for further energy production. In particular, they include fast-growing trees (plantations of various types of willow and poplar, paulownia) or other types of plants (sorghum, miscanthus).

Prospects for growing energy crops are available in all communities of Khmelnytskyi region. However, only a few communities provided information to our request for proposals for allocating land for energy crops. This does not indicate a lack of available land or a need, but rather demonstrates a lack of understanding of all the advantages of growing organic crops, which will reduce the cost of biomass due to proximity to facilities where the fuel will be consumed in the community.

According to the assessment of the Bioenergy Association of Ukraine, there are 1,318 plots of unproductive or degraded land in Khmelnytskyi region that are not involved in agriculture. Their total area reaches 31,924.50 hectares. These areas can be found at the following link: https://webgis.bioplat.eu/#/map

In the calculation of the cultivation of 1 hectare of miscanthus (the most productive crop and the best option from the point of view of soil requirements, care and costs for planting), you can get from 18 tons of dry biomass per year. Annually, 1 hectare of plantation absorbs from 2.5 tons of CO2, which is four times more than 1 hectare of forest on average. In addition, 1 hectare of miscanthus per year can replace the use of 9,270 m3 of natural gas, 7.5 tons of crude oil, 31 tons of wood, and 16.2 tons of coal.

If these calculations are scaled to an area of 31,924.50 hectares[8], then you can get:

- collection of dry biomass in the amount of 574,641 tons;
- net accumulation - 79,811.25 tons of CO_2;
- replacement of natural gas use - 295,940,115 m^3;
- replacing the use of crude oil - 239,433.75 tons;
- replacing the use of wood - 989,659.5 tons;
- replacing the use of hard coal - 517,176.9 tons.

To understand the main requirements and characteristics of the growth of energy crops, we provide a comparative table below.

Energy crops for growing in Ukraine[8]

Name	Soil requirements, pH	Amount of precipitation, mm/year	Temperature, °C	Life cycle, years	Periodicity of harvesting	Productivity, ton/hectares/ year
Willow	5-7	650-700	15-26	20-25	1 time in 3 years	12,4-22,7 (fresh)
Miscanthus	5,5-7,5	500-700	25-32, frost-resistant	Until 20	Annually	15-20 (after the 2nd year (W10-15%)
Rod-like millet	5,5-7	380-760	Drought resistant	10-15	Annually	7-14 (W10-15%)
Perennial sorghum	5-8,5	460-760	Drought resistant	8-10	Annually	10-17 (dry)
Silphium piercing-leaved	5,5-7,5	Resistant to floods	5-40, frost-resistant	15-20	Annually	15-20 (dry)
Poplar	6-7	≥600	15-25	20-25	1 time in 2-3 years	10-20 (dry)

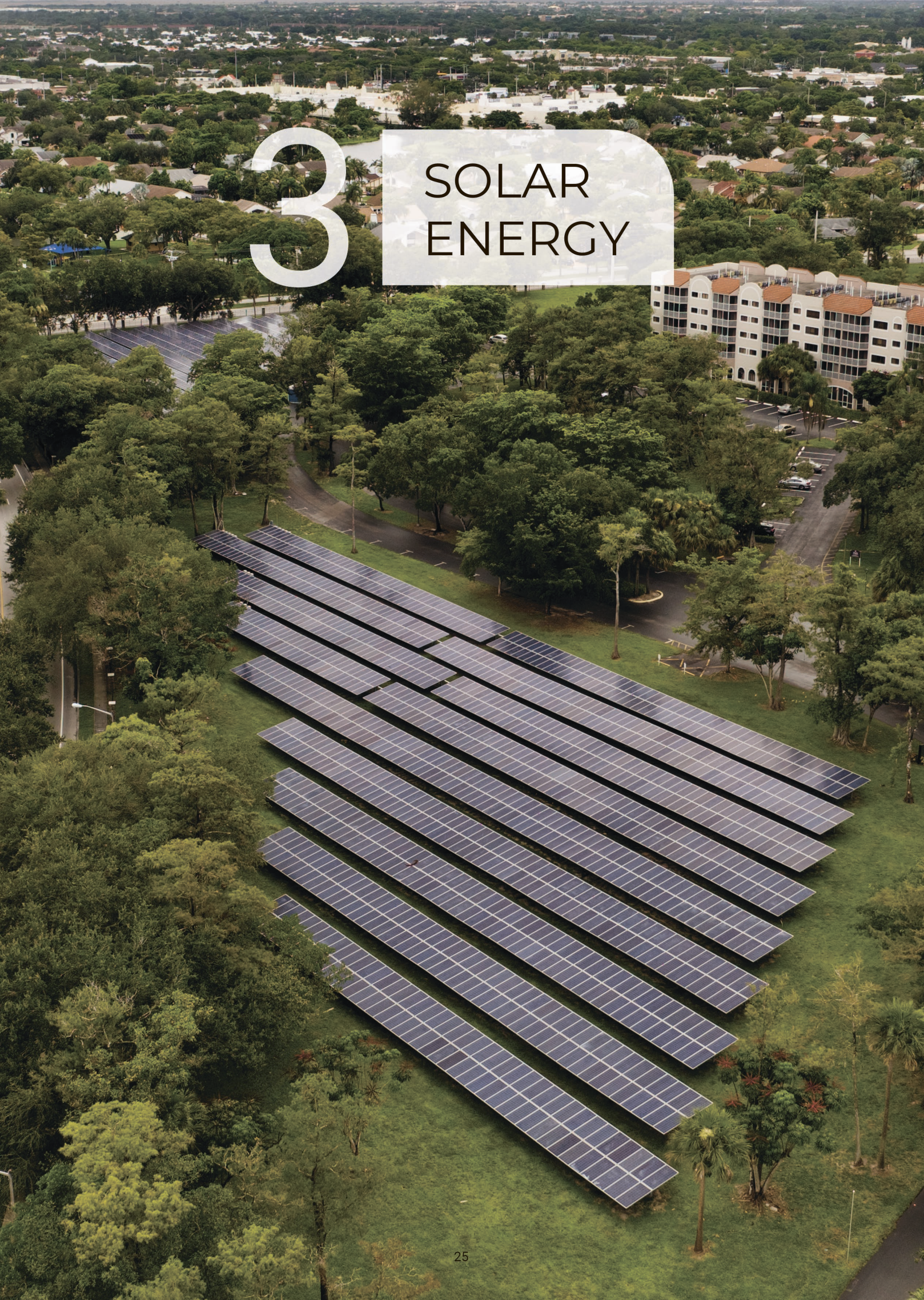
Another type of biomass relevant for the Khmelnytsky region is wood. The total area of forests in the region as of 2020 is 287.6 thousand hectares. At the same time, coniferous forests occupy more than 30% of the area of forested lands of the region.Waste wood and firewood are currently widely used, however, their harvesting volumes cannot fully satisfy demand, which is important to consider when planning potential projects to replace boilers with solid fuel.

[8] Project to promote Ukraine's transition to "green" energy
-https://uabio.org/wp-content/uploads/2021/03/EU4USociety_Tryboi_Energy_Crops_26-02-2021.pdf

Thus, the decision to build a biomass boiler house should be made taking into account all circumstances, in particular, the cost and possibilities of supplying fuel biomass, the cost of natural gas and the prospects for their change, the availability of free space for the construction of a new boiler house or the possibility of reconstruction of an existing one, the possibility of attracting financing.

Currently, the ratio of the cost of biofuels and natural gas for budget institutions can provide acceptable payback periods for boiler rooms on wood, as well as on wood chips, with a boiler capacity of 1000 kW or more. When the price of natural gas rises to the level that industrial consumers currently have, acceptable payback is provided for all considered types of fuel biomass, including for boilers on wood pellets, sunflower husks and others.

Substitution of electric energy heating with biomass heating has an acceptable payback period starting from the cost of electricity of 2.5 UAH/kWh without VAT. With the current price of electricity for public institutions at the level of UAH 3.5-5.5/kWh without VAT, the payback of projects to replace electricity with biomass is much better than when replacing natural gas.



3 SOLAR ENERGY

3 SOLAR ENERGY

Before the full-scale war, the development of solar energy in Ukraine was the most pronounced of all other sources of renewable energy. At the best of times (2019), Ukraine was the third fastest growing solar energy country in Europe and installed almost as much solar generation as Germany. According to informationSolar Energy Association of Ukraine, as of the end of September 2022, solar power plants with a total capacity of about 1 GW were damaged or remain in the territory temporarily not controlled by Ukraine. Payments under the green tariff for commercial objects are only at the level of 18%, which barely covers the operating costs of investors[9]. All these factors destroyed the investment climate and made it impossible to attract private investments for the implementation of solar energy projects.

However, solar power plants can be considered as a backup or permanent power source that will reduce the dependence of important infrastructure facilities on centralized networks that are the target of attacks by the aggressor country. Solar energy remains the most relevant for communal and state facilities, as well as commercial electricity consumers, for whom the cost is market (many times higher than for individuals) and exceeds 5 UAH per 1 kWh.

The collection of information from local self-government bodies was focused specifically on the installation of SPP at those infrastructure objects that the community considers important (health care facilities, educational institutions, administrative buildings, water supply, etc.). Calculations carried out by experts of the Khmelnytskyi energy cluster for 30 potential SPPs predict a payback period for communal SPPs for own consumption - up to 5 years. This is an excellent rate of return of funds, which can be an incentive for establishing cooperation between local self-government bodies and private investors or with other partner organizations that are ready to invest in green energy projects on the terms of credit or grant support.

For the development of solar energy projects, we see the need to coordinate cooperation with JSC "Khmelnytskoblenergo" as a monopolist company in the field of energy supply of electricity for communally owned establishments. The cooperation of local self-government bodies and the energy supply company is necessary for the permission to "mutual netting" of electricity between the facility where the SPP is located and JSC "Khmelnytskoblenergo". This will resolve the issue when the SPP generates more energy than the facility consumes, and the remainder will enter the general network, where the volume of transmitted electricity will be recorded. As much as the facility gives to the network, it will be possible then to receive from the network for free in periods when the SPP will not generate enough to fully cover its needs.

In some cases, the installation of solar power plants on the objects of important infrastructure with the use of energy storage devices (RB) should be considered. According to the results of communication with the communities, only a few objects among those that were submitted to us had a backup power source (generators). Taking into account the threat of damage to the energy infrastructure, we recommend that communities, in addition to the main source, have two backups (for example, a generator + SPP with batteries), which will make the electricity supply more stable. This applies precisely to those objects that must work under any conditions.

It should be understood that the development of solar energy in the communal sphere, in particular depends on the strategic planning of the development of the community. In other words, if the community allocates funds for the reconstruction or capital repair of facilities where it is possible to actually install a SPP, then it is necessary to foresee the possibility of installing a power plant in the future. That is, if the roof is being reconstructed, then it is necessary to plan in advance that the SPP will be installed on it, and this is an additional load on the roof (own weight of the station, wind and snow load). Even if the community does not yet have the funds to install a station, taking into account the requirements for installing a SPP in the future will allow it to be installed faster without damaging the building.

[9] Solar Energy Association of Ukraine - Solar energy sector in Ukraine lost 15% of installed capacity -https://aseu.org.ua/artem-semenyshyn-pv-tech/?fbclid=IwAR3a3P6YnM06YIeUvRIWtCdFZaJpxv2RHjZV1Xv74npgtmE3gAjbMsS6IZA

4 GREEN PROJECTS FOR COMMUNITIES

Nova Ushytsia urban territorial community

Nova Ushytsia

- Nova Ushytsia children's youth sports school
- Department of Youth Education and Sports of Nova Ushytsia territorial community
- Nova Ushytsia vodokanal SPP
- Nova Ushytsia territorial community

Brailivka

- Braylivka gymnasium of Nova Ushytsia territorial community

Pesec

- Pesec elementary school of grades I-III

Kucha

- Kucha elementary school of grades I-III

Otrokiv

- Otrokiv elementary school of grades I-III

Kamianets - Podilsky district
Area: **853 km²**
Number of settlements: **59**
Population: **26 541 people**
Annual budget: **UAH 197 781 539,51 (2021)**

Contacts:
17, Podilska str., Nova Ushytsia
+38 068 84 49 980, +38 0384 72 14 74
gromada_nova_ushytsya@ukr.net
04407388@mail.gov.ua
https://novagromada.gov.ua/

You can find out more about potential community projects by following the link: https://bit.ly/nova-ushytsia

Community representatives provided the following project ideas for implementation:
- 7 potential projects in the field of bioenergy (transition to solid fuel boilers);
- 1 potential project in the field of solar energy.

Nova Ushytsia community is located in the southern part of Khmelnytskyi region, which belongs to the forest-steppe physical-geographical zone. The community is relatively remote from the main highways and railways of Khmelnytskyi region. However, one of the largest water arteries of Ukraine - the Dniester River - flows through its territory.

Among the priority sectors for investment, the Novoushytska community identified the following:
- development of the mineral and raw material base;
- production of new types of energy from renewable sources;
- improvement of the agro-industrial complex and development of animal husbandry;
- development of tourism and recreation .

The total area of land used in agriculture on the territory of the community is more than 55,000 hectares. The largest industrial enterprises of the community include: Nova Ushytsia branch of "Agrobusiness" LLC (production of bread and bakery products) and PE "Jivaldis" (processing of milk and production of dairy products).

[19] Investment passport of the Nova Ushytsia Territorial Community

High-voltage interdistrict power lines pass through the Nova Ushytsia community: 330 kV with a length of 20 km, 110 kV with a length of 40 km, and 35 kV with a length of 38 km.

The state enterprise "Nova Ushytsia Forestry" occupies an area of more than 12,000 hectares. The enterprise includes the Struga, Brailiv, Zelenokurylovetske and Novoushytska forests and the Novoushytska ornamental nursery[20].

The community has potential for growing energy crops, implementing bioenergy projects and projects in the field of solar energy. The production of new types of energy from renewable sources is one of the priorities indicated in the community's investment passport.

Investment passport of the Nova Ushytsia Territorial Community (2022) : https://novagromada.gov.ua/biznes-v-hromadi/investytsiynyy-pasport

Development strategy of the Nova Ushytsia Territorial Community for 2019-2023: https://novagromada.gov.ua/nasha-hromada/stratehiya

[20] Development strategy of the Novoushytsk United Territorial Community for 2019-2023

CONCLUSIONS AND RECOMMENDATIONS

1. During the implementation of the main part of the study, questionnaires were sent to all 60 territorial communities of Khmelnytskyi region to determine which energy projects, in their opinion, the community needs in order to reduce its energy dependence during the war and after victory. As a result, 25 communities got in touch and submitted their proposals for project implementation.

2. A significant share of all proposed projects is in the field of bioenergy - transition to solid fuel boilers - 88 proposed projects. The number of proposed projects in solar energy is 30, and there are also 18 potential sites for growing energy crops and 11 potential projects in the field of biogas.

3. Each potential project contains contact information. If you are interested in this or that project, we recommend contacting the information providers to get answers to questions from the original source.

4. As a result of the russian federation's full-scale aggression, there is a potential threat of a shortage of natural gas. Therefore, reducing dependence on natural gas is an urgent task for budget consumers. For this purpose, Ukraine has been implementing projects for many years to improve the energy efficiency of public institutions and transition to alternative types of heating, including projects to implement biomass boilers. The implementation of biomass energy use projects also solves the issue of improving the quality, reliability, efficiency of thermal energy production and ensuring consumer access to services in the field of heat supply.

5. For the Khmelnytsky region, bioenergy should become one of the strategic directions of the development of the sector of renewable energy sources. This is due to the fact that the Khmelnytskyi region has a large potential of biomass available for energy production. This is a good prerequisite for the development of the bioenergy sector.

6. A promising area of bioenergy is the use of biogas. For sugar factories, distilleries and large livestock farms, the possibility of using their own waste for biogas production allows solving the issue of waste disposal and impact on the environment. At the same time, enterprises will receive economic benefits by reducing costs for traditional energy carriers. There are many enterprises in Khmelnytskyi region for which the use of biogas is a relevant alternative.

7. Considering the favorable soil and climatic conditions for growing plants, growing energy crops is a promising type of bioenergy for the Khmelnytskyi region. According to the assessment of the Bioenergy Association of Ukraine, there are 1,318 plots of unproductive or degraded land in Khmelnytskyi that are not involved in agriculture. Their total area reaches 31,924.50 hectares.

8. The development of solar energy in the communal sphere, in particular, depends on the strategic planning of community development. In other words, if the community allocates funds for the reconstruction or capital repair of facilities where it is possible to actually install a SPP, then it is necessary to foresee the possibility of installing a power plant in the future.

9. Calculations for 30 potential SPPs in communities predict a payback period for communal SPPs for own consumption - up to 5 years. This is an excellent rate of return of funds, which can be an incentive for establishing cooperation between local self-government bodies and private investors or with other partner organizations that are ready to invest in green energy projects on terms of credit or grant support.

10. The post-war energy reconstruction of the region must take into account the rapid transition to renewable sources and adaptation to climate change. Therefore, the implementation of projects in the wartime period should take into account that it is necessary to strive for low-carbon development now.

11. The gradual transition of the region to green energy during the war period will help facilitate the post-war recovery of the whole of Ukraine. Such recovery will be comprehensive and will include aspects of integration into the European Union, where combating climate change and transitioning to renewable energy sources are priority components.

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