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FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ENVIRONMENTAL SCIENCE

APPROVED TO DEFENCE
Head of the Graduate Department
_____ T. V. Dudar
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BACHELOR THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 "ECOLOGY",
EDUCATIONAL AND PROFESSIONAL PROGRAM:
"ECOLOGY AND ENVIRONMENT PROTECTION"

Theme: «Use of individual installations based on alternative energy sources in urban conditions»

Done by: student of the Ek – 411 group, Yelyzaveta Burlo
(student, group, surname, name, patronymic)

Supervisor: PhD, Ass. Prof. Radomska M. M.
(academic degree, academic rank, surname, name, patronymic)

Standards Inspector: _____ Andrian A. Iavniuk
(signature) (S.N.P)

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МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_____ Т. В. Дудар
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ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ БАКАЛАВРА

ЗА СПЕЦІАЛЬНІСТЮ 101 «ЕКОЛОГІЯ»
ОПП «ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

Тема: «Використання індивідуальних установок на основі альтернативних джерел енергії в міських умовах»

Виконавець: студентка групи ЕК-411**,** Бурло Єлизавета Віталіївна
(студент, група, прізвище, ім'я, по батькові)

Керівник: Радомська М. М., к.т.н., доц
(науковий ступінь, вчене звання, прізвище, ім'я, по батькові)

Нормоконтролер: _____ Явнюк А. А.
(підпис) (П.І.Б.)

КИЇВ 2022

NATIONAL AVIATION UNIVERSITY

Faculty of Environmental Safety, Engineering and Technologies

Department of Environmental Science

Specialty, Educational and Professional Program: specialty 101 "Ecology", Educational and Professional Program: "Ecology and Environment Protection"

(code, name)

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Head of the Department
_____ Dudar T.V.
«____» _____ 2022

BACHELOR THESIS ASSIGNMENT

Yelyzaveta V. Burlo

1. Theme: «Use of individual installations based on alternative energy sources in urban conditions» approved by the Rector on April 18, 2022, № 388/ст.

2. Duration of work: from 23.05.2022 to 14.06.2022.

Output work: analitic data of perspective of solar power generator parameters for private house.

4. Content of explanatory note: the renewable energy sources of in Ukraine were analyzed, the solar power potential investigate was, the variant of energy provision from solar power generation for private house was proposed, practical recommendations to power supply for a private house was made.

5. The list of mandatory graphic (illustrated materials): figures.

6. Schedule of thesis fulfillment

№ з/п	Task	Term	Advisor's signature
1	Receive themes task, search the literature and legislation	23.05.2022	
2	Preparing the main part (Chapter I)	01.06.2022	
3	Preparing the main part (Chapter II)	03.06.2022	
4	Preparing the main part (Chapter III)	05.06.2022	
5	Formulating conclusions and recommendations of the thesis	06.06.2022	
6	Making an explanatory note to the previous presentation of the department, consultation with the norms controller	07.06.2022	
7	Presentation of the work at the department	10.06.2022	
8	Taking into account the comments and recommendations and training to protect	12.06.2022	
9	Thesis defense at the department	14.06.2022	

7. Date of task issue: «23» May 2022

Qualification Paper Advisor: _____ Radomska M. M
(advisor's signature) (S.N.P.)

Task is taken to perform: _____ Yelyzaveta Burlo
(graduate's signature) (S.N.P.)

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет екологічної безпеки, інженерії та технологій

Кафедра екології

Спеціальність, освітньо-професійна програма: спеціальність 101 «Екологія», ОПП «Екологія та охорона навколишнього середовища»

(шифр, найменування)

ЗАТВЕРДЖУЮ
Завідувач кафедри
_____Дудар Т. В.
«____» _____ 2022 р.

ЗАВДАННЯ
на виконання дипломної роботи
Бурло Єлизавети Віталіївни

1. Тема роботи «Використання індивідуальних установок на основі альтернативних джерел енергії в міських умовах» затверджена наказом ректора від «18» квітня 2022 р. № 388/ст.
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3. Вихідні дані роботи:: аналітичні дані перспективи параметрів сонячного генератора для приватного будинку.
4. Зміст пояснювальної записки: проаналізовано відновлювані джерела енергії в Україні, досліджено потенціал сонячної енергії, запропоновано варіант енергозабезпечення приватного будинку від сонячної генерації, надано практичні рекомендації щодо електропостачання приватного будинку.
5. Перелік обов’язкового графічного (ілюстративного) матеріалу: таблиці, рисунки.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Отримання теми завдання, пошук літературних джерел та законодавчої бази	23.05.2022	
2	Підготовка основної частини (Розділ І)	01.06.2022	
3	Підготовка основної частини (Розділ ІІ)	03.06.2022	
4	Підготовка основної частини (Розділ ІІІ)	05.06.2022	
5	Формулювання висновків та рекомендацій дипломної роботи	06.06.2022	
6	Оформлення пояснювальної записки до попереднього представлення на кафедрі, консультація з нормоконтролером	07.06.2022	
7	Представлення роботи на кафедрі	10.06.2022	
8	Урахування зауважень, рекомендацій та підготовка до захисту	12.06.2022	
9	Захист роботи на кафедрі	14.06.2022	

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Керівник дипломної роботи : _____ Радомська М.М.
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: _____ Бурло Є.В.
(підпис випускника) (П.І.Б.)

ABSTRACT

Explanatory note to thesis «Use of individual installations based on alternative energy sources in urban conditions»»: 47 pages, 22 figures, 1 tables, 44 references.

Object of research – generation and supply of energy at urban territories.

Aim of work – to assess the perspectives of distributed energy systems for Ukrainian cities.

Mehods of research: analysis, data comparison, statistical data processing, mathematical modeling.

RENEWABLE ENERGY, SOLAR POWER, SOLAR GENERATOR, ENERGY SAVING, ENVIRONMENT

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INTRODUCTION

Relevance of the topic: alternative energy is increasingly attracting the attention of potential investors. The relevance is due to the fact that now in Ukraine the issues of energy efficiency and energy independence have come to the fore and in the near future will remain the subject of increased attention of the Government. And this gives reason to expect an increase in the production of electricity from alternative sources and to hope for the creation of favorable conditions for investment.

Energy systems with alternative energy have a number of undeniable advantages, including: ubiquity of location, minimal environmental impact, zero emissions, inexhaustibility, operational safety and a fairly profitable investment.

Aim and tasks of the diploma work

Aim of the work – to assess the perspectives of distributed energy systems for Ukrainian cities;

Tasks of the work:

1. To study the structure of urban energy economy;
2. To compare the advantages and disadvantages of centralized and distributed energy systems;
3. To study the types of renewable energy sources applicable for urban distributed energy systems;
4. To estimate the prospects of distributed energy systems for urban areas on the example of Cherkassy.

Object of research is generation and supply of energy at urban territories

Subject of research is renewable sources of energy as a basis for distributed power supply in cities.

Approbation of results.

Publications*:*

1.Radomska M. M., Burlo Ye.V, Kondratyuk V.Ye. Adaptation of urban areas to climate changes: тези доп. Сучасні екологічні проблеми урбанізованих

територій, м. Житомир, 10 грудня 2021 р.

2.Радомська М., Бурло Є. Використання відновлювальних джерел енергії в індивідуальних установках малої потужності у міських умовах : тези доп. II Міжнародної інтернет-конференції «Екологічна безпека – сучасні напрямки та перспективи вищої освіти», (Харків, 25 лютого 2022 року). – Харків: ХНУ імені В. Н. Каразіна , 2022.

CHAPTER 1. ENERGY SYSTEM OF CITIES

1.1. Energy economy of cities

Energy economy in the structure of housing and communal services includes communal heat supply, gas economy, electric networks, water supply and sewerage economy.

Housing and communal services of Ukraine consume more than a third of the total amount of energy resources used in the country. The share of electricity consumption in housing and communal services is almost twice the world average, so reducing the level of consumption of fuel and energy resources by housing and communal services is an urgent task.

Electricity consumers in the city are:

- city electric transport;
- utilities;
- social infrastructure facilities;
- industrial enterprises.

Consumers of thermal energy are:

- housing facilities of the city;
- social infrastructure facilities;
- administrative buildings;
- industrial enterprises.

In heat supply, the main attention is paid to the production of thermal energy at thermal power plants, boiler houses, transportation of thermal energy and distribution among consumers, as well as heating and hot water supply systems.

Municipal thermal energy of Ukraine today is in a state of crisis, which negatively affects the level of environmental, energy and national security of the country. Among the main factors that significantly affect the current situation: unsatisfactory technical condition of thermal energy facilities, which leads to excessive heat loss during production, transportation and consumption [12]. In the

field of municipal heat companies, about 60% of boilers have already met their regulatory deadlines, and 38% of boilers operate inefficient and obsolete boilers with low efficiency (efficiency), which causes significant fuel losses. Almost 40% of heating plants are in an emergency situation, which leads to constant interruptions in hot water supply and overconsumption of energy resources [3].

Heat supply of individual objects of the city can be carried out both from the centralized system of heat supply, and from local sources. The centralized heat supply system consists of energy sources, where chemical energy is transformed into heat energy, from the transport network, hot water supply system and home heating system, which provide comfortable conditions for consumers of heat supply services.

The most economical source of thermal energy is the system of combined heat and power (for example, a thermal power plant that produces combined heat and power). This process reduces the cost of generating heat by an estimated 1.4-1.6 times. Therefore, it is very advantageous to connect the heat load to the CHP by disconnecting it from the boiler room or completing the boiler room to the CHP (installation of steam boilers and small turbines, installation of gas piston machines with utilizers for heating mains water).

The fuel component has a great influence on the price of heat energy. Coal is much cheaper than gas, but requires additional fuel costs. Solid waste incineration requires pre-sorting of waste, removal of non-combustible substances and plastic, which are raw materials for the production of any product.

A certain reserve for reducing energy consumption is contained in the field of increasing the efficiency of boilers, if it is below 92%. A typical measure is the replacement of boilers. But it is much cheaper and more efficient to upgrade existing boilers, usually by installing economizers that reduce flue gas losses.

In the supply of electricity, the main task is the production of electricity (mostly occurs simultaneously with the production of thermal energy), transmission and distribution of electricity between consumers. Ukraine's electricity industry has sufficient generation capacity and a well-developed

network to supply electricity to consumers, but today this industry is approaching a crisis, which is determined by technological backwardness and depreciation of its fixed assets [16], and therefore its further operation carries significant risks performing the main function - providing the population with electricity, but also on the occurrence of man-made accidents, uncontrolled increase in electricity costs, increase in specific fuel consumption and exacerbation of environmental problems [4].

In addition to the operation and technical obsolescence of the main and auxiliary power and electrical equipment of power plants and networks, the power system is characterized by problems of lack of voltage control and reactive power compensation, lack of telemechanics; imperfections of control systems, low level of provision of electric power facilities with modern means of monitoring, diagnosis and protection [5].

1.2. Sources of energy for Ukrainian cities

The integrated energy system includes nuclear power plants, thermal power plants, hydroelectric power plants, combined heat and power plants, as well as power plants operating on alternative (renewable) sources of electricity (solar, wind). They are interconnected by main electrical networks.

Shares of various sources in the structure of electricity generation in Ukraine:

- Nuclear power plants account for 51%, they have a uniform work schedule andl create an energy base throughout the day. The rate of decrease and increase in power is very low and therefore the danger of sharp maneuvers is great. As a result, nuclear power plants cannot increase production during the evening peaks and decrease it at night, when there is a "night dip" in electricity consumption.
- Thermal power plants - 27%, these are flexible capacities with a quick response to changes in consumption, most often such plants operate on the combustion of coal, gas or fuel oil.

- Combined heat and power plants - 9%, stations of this type produce not only electrical energy, but also thermal energy. Most often it is used in cities for hot water and heating.
- Hydro power plants and hydro storage power plants - 5%, plants of this type are most often used to cover peak demand in the country's energy system. Typically, hydroaccumulative power plants pump water at night, when consumption is minimal and there is an excess of electricity, and they are discharged during peak demand hours - in the morning and evening hours. They are also a reserve that can quickly compensate for a sudden power shortage in the power grid.
- Solar power plants - 5%, environmentally friendly generation of electricity is carried out thanks to sunlight.
- Wind farms - 2%, also environmentally friendly generation, which uses wind energy to generate electricity.
- Biostations - 1%, for the generation of electrical energy, these stations use biological waste from production and biogas. A feature of "green" generation is the complete dependence on weather conditions and the seasonality of its generation [10].

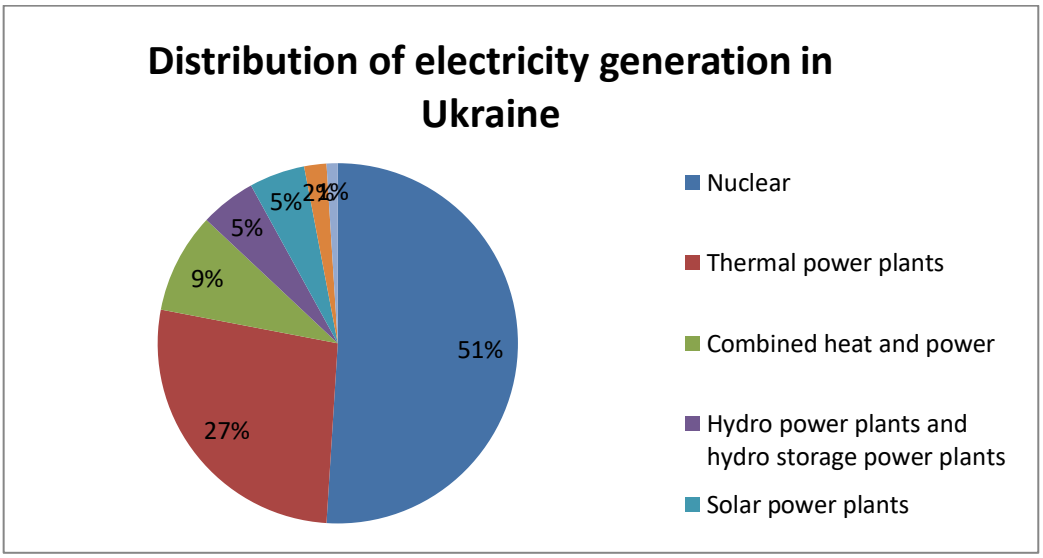

Fig. 1.1 - Distribution of electricity generation in Ukraine

Over time, we can observe a steady trend to change the overall development of energy. We can talk about the dominant establishment of a progressive ideology - the sustainable energy genetation. Thus, analyzing the change in generating capacity United Energy System of Ukraine in recent years, we can see that along with the almost constant value of the total installed capacity power plants, significantly increased the capacity of power plants using renewable energy sources [9].

Over the next 10 years, a significant increase in the capacity of power plants running on alternative energy sources is planned. The structure of generating capacities of the United Energy System of Ukraine from the point of view of ensuring effective regulation of frequency and power in the power system is suboptimal, due to the following main factors:

- a significant share of nuclear power plants, which, according to the technological regulations of their operation, are used to cover the basic part of the consumption schedule and are not involved in regulation;

- reduction of maneuverability of power units of thermal power plants running on solid fuel (wear and aging of equipment, deterioration of fuel quality);

- development of generating capacities that generate electricity using alternative sources is limited [11].

Today in Ukraine the cheapest electricity is nuclear and hydro, the most expensive is "green" - from the sun, wind. At the end of 2008, in our country, to stimulate the development of renewable energy, the state adopted a "green tariff". According to it, electricity obtained from alternative sources is purchased by the state at tariffs that are an order of magnitude higher than the market value. Such a program is designed until 2030 with a gradual reduction in the cost of 1 kW, and after its completion, the cost of green electricity will become standard. It is expected that in 2030 the share of electricity generation from renewable sources (including large hydroelectric power plants) will be about 25-30%. The ratio of generation sources and the balance of the energy system are extremely important for the energy security of the state and must guarantee a stable power supply to the

country under various natural, man-made, managerial, socio-economic conditions and foreign policy factors [10].

The dynamics of development of solar electricity is the largest among renewable energy sources in Ukraine. In Ukraine, there is a tendency to increase the annual capacity of solar energy. In 2016, the installed capacity of solar power plants increased by 23%. Their rapid development in Ukraine is associated primarily with short deadlines and relative ease of implementation, as well as a significant collapse in equipment prices (the cost of 1 kW of power is about 900-1000 USD). Although the production of electricity by solar power plants increased by an average of 3.5% during 2014-16, the average number of operating hours at full capacity over the past three years decreased to 928 hours per year, as shown in Figure 2, which corresponds to the utilization rate installed capacity at the level of 10.6% [9].

Fig. 1.2 - Electricity generation by solar power plant [12]

The dynamics of growth of wind energy capacity was insignificant. As renewable energy sources are quite expensive and require a long time to implement the project, about 2-3 years, it was difficult to implement projects of economic crisis and reduce the attractiveness of Ukraine in the investment sector over the past 3 years. Electricity generation at wind farms has somewhat decreased over the last 3 years and as of the end of 2016 amounted to 925 million kWh, as shown in Fig.1.6, which corresponds to 2,117 hours work at full capacity (24.2% - utilization factor installed capacity) [9].

Fig. 1.3 - Electricity production of wind power [12]

1.3. Types of energy systems by structure

Based on the structure of the energy generation and supply, the energy system of settlements can be built on a centralized or distributed pattern.

Centralized or Unified Energy System is a set of power plants, electric and thermal networks, other power facilities, united by a common mode of generation, conversion, transmission and distribution of electric and thermal energy under the centralized management of this mode [8].

Centralized or Unified Energy System is a set of power plants, electric and thermal networks, other power facilities, united by a common mode of generation, conversion, transmission and distribution of electric and thermal energy under the centralized management of this mode [8].

Distributed power generation is the concept of building a power generation system, which stimulates the production of energy by consumers themselves - individual farms, communities, enterprises. Energy is generated for own needs, but with the possibility of transferring its surplus to the general network at a " Feed-in tariff" or other support mechanism. Distributed generation facilities use local resources, primarily renewables, creating jobs in communities, bringing in investment and profits [6].

Distributed Energy Technologies are technologies that enable interaction

with electrical installations connected to the distribution system (or the implementation of which is part of such electrical installations) and provide the technical ability to produce and / or accumulate electricity energy in order to supply it to the grid and / or provide demand management services [7].

Modes of distributed generation systems are divided into categories according to the level of influence of environmental factors:

- Renewable sources with weakly controlled generation - use renewable resources, but the generation is significantly different depending on the time of day and weather conditions (wind power plants, solar power plants);
- Renewable sources with controlled generation - use renewable resources, have a stable generation during the established period of time (small hydroelectric power plants, geothermal, biogas plants, etc.);
- Non-renewable sources with controlled generation - use mostly traditional energy sources, but have a completely controlled generation process (cogeneration units, steam and gas turbines) [9].

Each such power plant must have installed equipment that will allow the network operator to see it in the central control system and, if necessary, limit its production if there is a risk of an emergency in a particular section of the network.

1.4. Characteristics of distributed energy systems

Growing population and living standards have accelerated the global consumption of energy so, that almost 30% of the world's total energy is now consumed by residential needs. By 2035, the International Energy Agency predicts the cost of the world's energy needs to reach $2 trillion a year [45]

None of the existing centralized power systems is able to address these needs, thus, a decentralized approach.

The availability of renewable energy sources, smart metering technologies, and energy conservation strategies reshapes the energy sector from a traditional and centrally regulated to a complex system with multiple participants and diverse

energy sources.

Advantages of distributed power generation

- Energy independence

With distributed generation, citizens themselves generate electricity for their own consumption. Thus dependence on obsolete inefficient energy systems is reduced, no need to constantly spend money on gas or other fossil fuels with volatile prices. The only costs for distributed generation RES are the costs of maintenance, and they are relatively small and stable.

- New jobs in communities

Distributed generation facilities are based on local energy sources and are installed directly near the consumer, that is why local companies usually build and maintain such systems. These jobs are long-lasting and, as the world practise shows, well paid. Many types of this work do not require professional skills, and can be mastered while working.

- Increase investment in one's own communities

By generating energy yourself from renewable sources, it is possible to lmake profit on the "green tariff" by selling excess electricity to the grid. Also through cooperatives, condominiums or other forms of community organization, citizens can become co-owners of small energy production systems, and attract credit financing for their projects. The typical form of associations of this type are energy cooperatives - legal entities organized by citizens for the common investing in various types of power generation systems or other types of energy supply for the own consumption by the members of the cooperative or for the sale of the product of the activity.

- Reducing negative health effects

According to a study by a group of scientists from the World Health Organization, the death rate from air pollution in Ukraine is among the highest in Europe with 120 deaths per 100,000 population [7]. The main sources of air pollution are coal power plants and cars. Small RES-based power plants (as well as large wind and solar power plants) for power generation will not produce

emissions into the atmosphere.

- Reduction of electricity losses

The greater the distance from the place of power generation to the consumer, the greater the loss of electricity during transmission through networks. At the same time, in Ukraine the losses of electricity in the networks exceed 1.5 - 2 times the average of such losses in EU countries [7].

- Improving the reliability of the power grid

Distributed power generation systems increase the reliability of the entire network by reducing system vulnerabilities. Centralized energy production system based on large power plants is vulnerable to natural disasters and anthropogenic factors (extreme weather conditions, war, terrorism, etc.). Widespread implementation of distributed systems provides facilities or communities with electricity even after major power outages or system damage power transmission [7].

Disadvantages of power generation

Small generation sources have the main disadvantage - low values of the efficiency factor. The most possible direction for the development of such mini-generation sources is the use of cogeneration technology [2].

- Dependence on weather conditions

When installing solar panels on the roof, designed to supply electricity to the whole house, you need to remember that the amount of energy generated will depend on how sunny the weather is. And on average, the power will be reduced by about 50% of the rated power of the batteries. Also, energy production is significantly reduced at night.

- Formalities

Making endless paperwork and permits is something that every owner of a private power plant, who invests a lot of money in his own project, tries to avoid. However, the decision to install a personal power plant and purchase the necessary equipment is still not enough to start enjoying the gifts of nature without hindrance. In order to avoid lengthy trials and disappointments, before starting

work, it is necessary to obtain permission from the local authorities for the construction, familiarize yourself with the list of conditions and requirements, such as the maximum permitted height of the windmill, the need to obtain the consent of neighbors, etc. The paperwork process requires additional financial and time costs.

- High cost of equipment and maintenance

Despite the fact that the use of natural resources can save significant amounts on energy generation, the production of the equipment itself is a rather time-consuming and very expensive process. The main component of solar batteries is a photocell developed on the basis of silicon. And although silicon itself is of little value, its purification and transformation is expensive [1].

1.5. Analysis of the experience in implementation of the decentralized energy systems

Certain problems in the development of distributed generation in Germany were initially caused by the lack of a requirement for such equipment - "smart inverter", but from 2014 all new plants over 100 kW must be equipped with such equipment. In Ukraine, it is not yet mandatory to install such devices for power plants.

Growing dynamics of solar energy use. Demand for the installation of solar panels on the roofs of houses and land is increasing, as well as solar collectors are used for water heating. In 2017, investment in small rooftop solar and ground systems increased by 15% worldwide, to an additional $ 49.4 trillion [6].

Germany

In Germany, the share of small generation systems installed by consumers has reached almost 20% of all installed capacity in the country. The country focused on the development of small solar stations in the early 1990s, and created a state program to support small SPP "Thousand Solar Roofs", which after success was transformed into the program "One Hundred Thousand Solar Roofs". The program has proven that the roofs of ordinary private homes are well-suited for

decentralized photovoltaic production [6].

A good example of German experience is the village of Feldheim - it is the only settlement in Germany that is fully self-sufficient in renewable energy. For several years now, all houses in this village have been supplied with heat and electricity from renewable sources. Wind farms and two biomass biogas plants provide the town southwest of Berlin with heat, electricity and additional jobs. The transformation of a typical Brandenburg small village into a mode for the use of renewable energy sources began in 1995, when five wind turbines were built here. The number of turbines gradually increased until the village, together with the town of Troienbritzen, to which it belongs, and the energy company Energiequelle GmbH built their own power grid. Most of the villagers took part in financing the project, which cost 0.5 million euros. Each family bought a 3,000-euro stake in the company, which co-owns the grid [13].

43 wind turbines and biogas plants heat and light houses, as well as provide 30 jobs for the local population. Another 20 jobs are provided by a local factory for the production of photovoltaic cells. In a village with 145 inhabitants unemployment is now zero! By 2020, Germany plans to receive up to 35% of all energy consumed from renewable resources such as wind and solar. By 2050, this share should be 80%. Thus, Feldheim, which provides itself with 100% renewable energy, has become a model for the future of Germany [13].

Denmark

In recent decades, Denmark has developed a system where heat supply is successfully integrated with electricity balancing. Half of Denmark's electricity is generated by small combined heat and power plants! This system is quite flexible and allows to change the proportions of heat and electricity production, and has a built-in heat storage system that allows to continue heat supply while reducing electricity production at CHP when the system has enough wind energy (Danish Energy Agency, 2014) [6].

USA

In the first half of 2015, distributed generation systems accounted for 40% of

all installed during this period generating capacity of the United States, and the number of panels on the roofs increased 16 times compared to 2008. The country also actively uses small generation of RES in military industry to reduce refueling time fuel in combat, providing safer conditions for servicemen. Both infantry and navy infantry use technologies such as solar panels and backpacks that generate electricity [6].

France

France is also implementing 2 projects in the field of smart grid or Smart Grids. The first is smart meters integrated with network management tools (under disconnection of certain power sources) in Lyon. The second project is the creation of a separate regional system of distributed generation with integrated facilities of renewable energy sources (wind and solar generators) and smart-network management [13].

Fig. 1.4 – Development pover generation in word [13]

Ukraine

Today the RES market in Ukraine is in a state of rebirth. Among other things, there has been a transition from the construction of large industrial RES power plants to smaller projects. This is due to reforms in the field of state regulation of the industry, as well as due to such purely market factors as continuous improvement of technology, which entails lower prices and, consequently, expanding the scope of economic feasibility of various projects. I am

sure that in 10-15 years we will stop talking about state support for the industry and will evolutionarily move to the practical implementation of the idea of distributed generation using RES.

Ukraine has the first village to operate on wind and ground energy. Progressive residents of Severinivka create projects and win international and Ukrainian grants. Severynivka, in the Zhmerynskyi district of Vinnytsia, is the first energy-efficient, energy-independent village in Ukraine. Almost all available types of clean energy were tested here: from biofuels to wind, solar and subsoil energy [13].

1.6 Conclusion to chapter 1

The introduction of renewable generation sources based on the use of renewable energy sources helps to reduce the solution of problems related to waste from electricity generation and reduce the environmental impact on the environment.

This, in turn, will significantly increase the efficiency of natural resources and reduce the cost of electricity in the future. Another important aspect is that such implementation will solve the problem by unloading the system of generating and distributing electricity networks, as well as advance the process of modernization and improvement of power facilities, which in turn will increase reliability of power supply.

CHAPTER 2. DISTRIBUTED ENERGY GENERATION SYSTEMS

The introduction of modern distributed energy generation systems requires a careful analysis of the advantages and disadvantages of the proposals available on the market, as well as the conditions in which they are expected to operate. At this stage, cogeneration units, systems with alternative energy sources, in particular solar and wind installations, heat pumps can be considered promising.

2.1 Systems based on cogeneration units

The development of integrated technologies based on low-power cogeneration units demonstrates their efficiency, due to the possibility of sharing different energy sources, adapted to changes in economic and environmental factors and the structure of energy consumption. An important advantage of such energy supply systems is also the ability to optimize their operation by integrating with alternative energy sources, heat pumps, the use of trigeneration, etc. [20-22].

As a rule, cogeneration systems used for autonomous supply of household consumers with electricity and heat consist of such basic elements as: engine, electric generator and heat recovery and control systems.

The advantages of using cogeneration systems can be divided into four interrelated groups, namely:

a) increase the reliability of energy supply, which is carried out by eliminating interruptions possible in the centralized energy supply from high-power sources and increase security, as the installation is located directly in the area of responsibility of the consumer;

b) the possibility of heat recovery and the use of up to two thirds of fuel energy, the loss of which is typical for most primary heat engines;

c) economic benefits, which are a significant reduction in the cost of electricity production, the cost of which may be several times lower than existing tariffs and eliminate the cost of energy transmission, as well as losses in the distribution and transportation of energy, ranging from 12 to 30 % [24, 25], as

cogeneration units are built at places of electricity consumption;

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d) environmental benefits are the ability to use methane from urban landfills and sewers, reducing up to 20 times the pollution compared to its combustion.

As the main source of electricity and heat for utilities, it is advisable to use cogeneration units based on gas-piston engines-generators up to 3-4 MW.

2.2. Systems with alternative energy sources

Taking into account energy resources, domestic infrastructure, climatic and

geological conditions and given the world level of energy technologies, in our country it is advisable to large-scale development and implementation of modern technologies for renewable and unconventional energy sources [26, 27]. The advantage of renewable resources over non-renewable ones is their higher level of environmental friendliness, as the use of non-combustible renewable energy resources in modern conditions does not cause emission of greenhouse gases and other pollutants (the main share of pollution from these resources).

Another advantage of renewable resources is the fact that they are renewable, which in the case of rational use does not lead to the threat of their depletion and guarantees long-term availability of these resources. In fact, replacing imported non-renewable energy with renewables is a clear example of resource efficiency and environmentally sound management, which will to some extent neutralize the risks of fluctuations in non-renewable energy prices, increase the competitiveness of utilities and reduce the burden on nature.

Solar energy is considered to be the most natural and available of renewable energy sources. The most mastered and simple in terms of technical implementation is the use of solar energy to meet the needs of thermal energy [31-34], so solar installations are a promising source of heat for hot water and heating systems of local facilities. Solar installations are built on the basis of solar collectors with coolant circulation. The choice of composition and layout of the elements of the solar heating system in each case is determined by the climatic conditions of the region, seasonality of the solar system, daily and seasonal schedule of thermal and electrical loads of the energy supply facility. The main advantages of solar installations are:

- reduction of costs for hot water supply and heating;
- saving of organic fuels (coal, oil, gas);
- reduction of carbon dioxide emissions;
- public availability and inexhaustibility of the source.

According to climatic conditions, Ukraine belongs to the regions with medium intensity of solar radiation. The use of solar collectors in the heating

systems of buildings will make it possible to use this radiation for hot water supply systems [35]. To meet the heat needs during the heating period, it is not advisable to use solar collectors, because during this period the supply of solar radiation in most of Ukraine is insufficient. This will allow large areas to be allocated for the absorption panels of the solar system, which is not profitable [36]. Therefore, it is advisable to combine a solar collector and a heat pump in one installation.

Small household *wind turbines* can be an additional source of power for single-family homes or even for small farms. Their main advantage is partial or complete independence from electricity supply from the general grid. A domestic wind turbine can supply electricity for the needs of a stand-alone receiver (dedicated line), for example: a yard lighting scheme or power for underfloor heating or home heating.

In an individual house it is enough to use "micro" wind turbines with a capacity of less than 100 watts (W). Installation of wind turbines with a capacity of more than 100 kW may require special permits. The most popular wind generators are with the capacity of 3 to 5 kW. The energy produced with their help and accumulated in the batteries is enough to power lighting, pumping systems, household appliances and equipment.

It is necessary to consider at installation of wind generators the noise factor from their work. Low-noise are wind turbines with a vertical axis of rotation. Prior to construction, it is necessary to check the rules and standards for such work.

Heat pumps operate without the use of fuel and do not emit harmful emissions into the atmosphere. Therefore, the introduction of heat pump technologies for heat production is one of the effective energy-saving means of saving fossil fuels and reducing environmental pollution.

One of the conditions for the rational use of heat pump stations is the availability of low-temperature heat sources with a sufficiently high temperature during the year, which do not require significant pumping costs and do not lead to corrosion of equipment. Heat produced by heat pumps is used for heating and hot water supply of residential and public buildings [38, 39].

Advantages of using heat pumps:

- high efficiency of electricity conversion in comparison with electric heating devices;
- environmentally friendly technology;
- minimum operating costs compared to other heat generating systems;
- long service life without major repairs (10-20 years, 45-60 thousand hours);
- reliable automatic operation of the installation, which does not require constant monitoring;
- relatively small size and light weight.

2.3. Combined power supply systems

Analysis of the results of operation of energy supply systems, which use only alternative energy sources or only cogeneration units, showed that each of them has certain limitations that do not allow to achieve maximum indicators of energy and economic efficiency of the system [40, 41].

During the operation of systems with alternative energy sources, the limitations are mostly determined by the following factors:

- low energy potential of the source;
- daily and seasonal unevenness of electricity and heat supply;
- the presence of a significant stochastic component when forecasting the energy efficiency of the source at a given time interval;
- the need to use additional and backup energy sources for ensuring the smooth operation of the system;
- long payback period of the system.

Cogeneration plants are also characterized by limitations due to [42]:

- non-compliance of the schedules of thermal and electrical loads of the KU with the corresponding schedules of the consumer;
- significant daily and seasonal unevenness of electrical and thermal load;

- environmental component available when using fossil fuels.

The transition to energy supply systems based on cogeneration technologies and alternative energy sources opens up additional opportunities to create more flexible systems that use different energy sources, adapt to changes in economic, environmental factors, energy structure [43].

2.4. Analysis of the preconditions for solar energy sector development

The solar industry has weathered a devastating global pandemic despite COVID-19 taking longer than expected. And the solar energy market has set a new annual growth record of 18%, with 138 GW of solar plants installed worldwide in 2020.

The global success of solar energy is due to many factors. One of them is the lead in power generation costs, which continues to improve indefinitely. Another of its versatility: solar energy covers a wide range of electricity consumption at different levels - from very small residential complexes to large companies, from stand-alone systems to BIPV and integrated solar solutions in sheds, apartment buildings or agricultural greenhouses. There are also mobile photovoltaic systems and off-grid solutions for rural electrification. More and more attention is paid to off-grid systems - small photovoltaic systems, autonomous systems and mini-grids. In the coming years, they will remain GW-sized markets with double-digit growth rates. After all, no other power plant can be planned and built as quickly as a solar photovoltaic system [18].

Despite the fact that in 2010 Ukraine has had a "green" tariff (FIT) for renewable energy support schemes, the intensive development of solar energy has only recently begun, in 2018-2019. The main trigger for the development of solar power generation in Ukraine was significant reduction in device costs in 2018/2019 [18], which enhanced the positive effect of the subsidy program through the "green" tariff (FIT). "Green" tariffs in Ukraine are protected by the laws "On the Electricity Market" and "On Alternative Energy Sources" and guarantee an average payback period of 5.5-7 years for new solar systems.

Thus, in 2018, the total capacity of solar photovoltaics reached 1,545 MW. The largest increase occurred in 2019, when the installed capacity increased 3.5 times compared to last year. In 2020, the Ukrainian solar sector added 1,169 MW of commercial solar photovoltaic capacity and 226 MW in the private sector. A total of 6,873 MW of solar energy was installed in Ukraine by January 1, 2021, with 779 MW or 11% of this capacity consisting of private home photovoltaic plants up to 30 kW (ac).

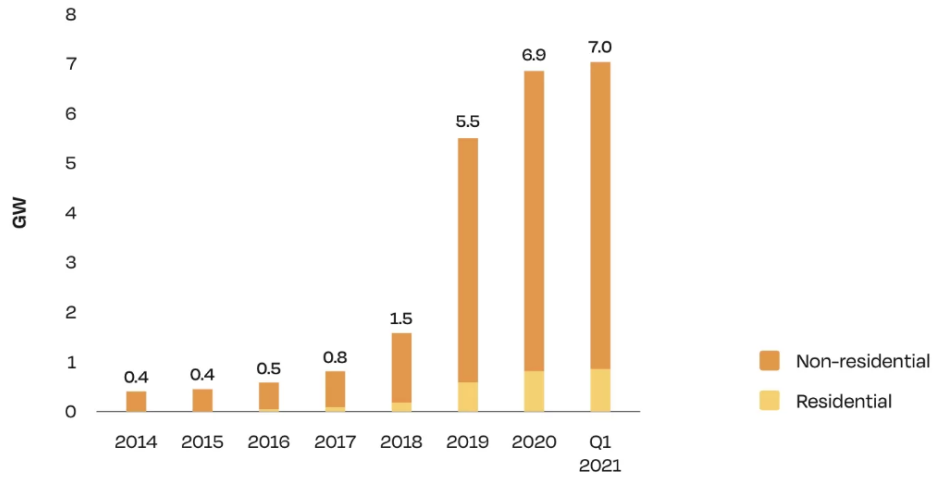

Fig. 2.1 - Installed capacity of commercial and private solar power plants in Ukraine (SolarPowerEurope, ACEU) [18]

The main problems of the Ukrainian solar sector are a lack of investor confidence in the government's RES activities, huge debts for purchased electricity, current international arbitrations on retrospective reduction of the “green” tariff and the possible introduction of additional excise taxes on renewable energy sources at the end of 2021. In addition, the impact of COVID-19 on the economic context of Ukraine and the high cost of borrowing private photovoltaics create significant new obstacles for the development of the industry and reduce the investment climate [18]. However, solar panels become increasing popular in Ukraine. They are used both for private Ukrainian production and for owners. Today, solar modules are used all over the world in the military and aerospace industries, in the automotive industry, in the aircraft industry, in many industries

and in daily life [19].

It turns out that in some hard-to-reach corners of the world, modern power lines are still not available. For some locations, connecting to power stations is an extremely disadvantageous and expensive option. But getting power from a solar panel is a real salvation. Their installation here is a cost-effective, reasonable and justified solution [19].

Thus, with the help of solar panels and solar energy, the problem of energy supply is solved where houses are cut off from civilization. From the other side, apartments in high-rise buildings can also be equipped with solar panels [19].

To date, the installation of 6 types of solar panels is practiced in Ukraine:

• Polycrystalline silicon. Since the execution of such batteries is not too complicated and expensive, the panels are of low cost. They are less resistant to high temperatures.

• Monocrystalline silicon. Their installation is simple. These panels are durable and highly efficient. They have a complex manufacturing technology.

• Multicrystalline silicon. Against the background of single crystals, their price is more affordable, since the manufacturing process is simpler.

• Thin film solar modules. These panels are used to build solar stations. They can be installed not only on the roof, but also on the walls of buildings.

• Amorphous silicon. A distinctive feature of such panels is their low efficiency. These panels produce cheap electricity.

• CIGS semiconductors. These panels are made using film technology. They occupy a small area [19].

In Ukraine, some manufacturers can offer a full cycle of solar module production – from growing silicon to assembling the solar modules themselves [44]. There are two factories in Ukraine where you can perform all stages of creating a solar panel: from growing and cutting silicon to assembling a finished photomodule.

Kvazar, Kyiv, was once the most powerful Ukrainian company for the production of solar panels – under the Kvazar brand. Kvazar has equipment for

cutting silicon, equipment for assembling ready-to-use photomodules, as well as all the equipment necessary for production quality control. The production capacity is around 30 MW/year.

However, due to the removal of the mandatory "local component", the plant ceased operations in 2015. After some time, restructuring was carried out.

After the restructuring, the subsidiary Kvazar-7 sells the panels. To date, the company both supplies solar panels made in China under its own brand and assembles panels in Ukraine from imported elements.

At the same time, the company promises that if there is an order for a large batch, it can launch all existing equipment (including silicon cutting) and supply 50% Ukrainian materials and components – which is enough to meet the “Local component” requirement by the Green Tariff [44].

Prolog Semicor, Kyiv, was established in 1997 as a manufacturer of polished silicon wafers for microelectronics. In 2014, the company launched its own assembly line for solar panels and mastered its own production of polysilicon.

The production capacity is now 12 MW/year. The company has two factories – in Lviv and Kyiv. However, the Lviv plant is more focused on microelectronics.

Under the Prolog Semicor brand, monocrystalline panels with a capacity of 10 to 300 watts are available. The manufacturer guarantees that in 25 years the Prolog Semicor panels will retain at least 80% power.

The manufacturer claims that the share of imported materials and components in the finished photovoltaic solar modules does not exceed 45% [44].

There are other companies working within this sector:

1. "Manufacturers" without production facilities in Ukraine are companies that order ready-made panels from abroad (mainly China), and in Ukraine they only affix a label with a Ukrainian mark.

2. Partial cycle manufacturers are companies that purchase certain items from foreign manufacturers (mainly in China) and in Ukraine they assemble, distribute and provide warranty support [44].

The first category includes, for example, solar panels under the Altek (and

partly Kvazar) brand. These panels are ordered from Chinese factories and sold in Ukraine under their own brand. These companies organize stable deliveries of solar panels to Ukraine and provide warranty support. However, they cannot be categorically classified as "Ukrainian manufacturers" [44].

Kness, Vinnitsa, is equipped with one of the most modern assembly lines in Ukraine – from the Chinese manufacturer Boostsolar. The line is almost entirely automated. The capacity of the first stage is 200 MW of solar panels per year. After the launch of the second stage, the annual capacity of the plant will reach 400 MW. Most components of solar panels are imported from abroad: solar cells, glass and EVA film. So far, only aluminum frames are purchased in Ukraine [44].

ENHOL Energodar, Energodar, has been in the refrigeration and ventilation business for over 25 years. And in 2018, a new assembly line for assembling solar panels was launched. For the production of solar panels, the company buys Chinese solar cells and films. In Ukraine, the company buys glass and frames. In monetary terms, the share of Ukrainian equipment is less than 50%. The maximum annual capacity of the assembly line is 10 MW.

Under the ENHOL Energodar brand, two battery modifications are currently produced – polycrystalline solar panels with a power of 260 W and polycrystalline solar panels with a power of 275 W. For both models, the manufacturer gives a warranty of 25 years that efficiency will not drop by more than 80% [44].

InfoSvyaz, Odessa, launched mass production of solar panels in 2016. Production is located in Odessa on the territory of the Promsvyaz plant. For the production of panels, the company purchases photovoltaic cells from China, and a full-fledged assembly of solar panels takes place in Ukraine.

Ukrainian profiles, glass and dielectrics are purchased for the production of solar panels. The manufacturer claims that the solar panels are made up of 60% Ukrainian-made elements.

To date, the assembly line capacity is approximately 160 kW per month. After the launch of the second stage of the assembly line, the monthly capacity is expected to increase to 550 kW.

The company not only produces solar panels, but also independently develops and manufactures equipment for assembly lines.

The product range is currently limited to 275W polycrystalline panels, which offer a 25-year guarantee that efficiency will not drop below 80% [44].

2.5 Conclusion to chapter 2

Ukraine has its own energy potential in the field of the sale of solar installations. Solar installations are more relevant and cost effective than wind turbines because solar panels can be installed anywhere from the ground to the roofs of different types of houses, both private and local. At the same time, wind turbines should be installed in places where the average wind speed reaches 5-6.5 m/sec, which is not the case for Cherkasy.

CHAPTER 3. DECENTRALIZED ENERGY SUPPLY PROJECT FOR THE CITY OF CHERKASY

3.1. Characteristics of the city of Cherkasy

Cherkassy is a city, regional and district center in Ukraine, the center of the Cherkassy Municipality, the industrial center of the Central Economic District, a significant cultural and educational center. The city's growth after gaining regional center status led to its transformation into a major industrial center and the most important cultural center of the region.

Cherkassy is located on the right bank of the Kremenchug reservoir, which arose in the middle reaches of the Dnieper. The population of the city is 269,836 people (January 1, 2022).

The relief of the historical part of the city was formed by the castle hill, on which the Cherkassy castle was located, and numerous gorges in Sosnivka. But most of the city is on the plains. Intensive urbanization has distorted the historical natural landscape of the Dnieper Hills in Cherkasy. The actions of the Soviet city planners were particularly destructive.

The area of the city of Cherkasy in 2010 was 69 km2. The city stretches along the shore of the Kremenchug reservoir for 17 km ², and the city is only 8 km wide. In the north-west and north, the city is surrounded by the Cherkassy forest, which is the largest (28.5 thousand hectares) in the country pine forest of natural origin. Cherkasy is a city famous for its green beauty [15].

The structure of the city's land fund is mainly represented by land for housing and public buildings, there are about 2150 hectares of undeveloped land. The city is surrounded by fertile farmland. Green plantations occupy about 2070.8 hectares, which is almost 30% of the city's total area. They are characterized by a great variety of species. The territory of Cherkasy covers about 38 hectares of landscaped plantations of oak and pine.

The state of the environment in the city is generally described as stable. The annual air quality index for the city ranges from 8.2 to 27.5, which is considered to

be good and better than in many oblast centers in Ukraine. The decrease in the pollution index is due to a decrease in the concentrations of ammonia and nitrogen oxides in the atmosphere. The most polluted districts are Dniprovskyi and Tsentr. The condition of the former is due to its proximity to OAO Azot and the center is more congested with vehicles. A further reduction in the content of harmful gases in the air is due to the closure of the chemical plant "Khimvolokno" and the reduction in the capacity of other plants [15].

3.2. Renewable energy potential of Cherkassy

Cherkassy has significant potential for the development of alternative energy sources, primarily wind and solar. The average annual solar radiation per 1 m2 of area in the region is up to 1300 kWh/m^2, which is considerable enough to develop the solar power plants.

Under the climatic conditions of the Cherkassy region, it will be effective to use flat and concentrating solar collectors for solar heat supply, using direct and scattered solar energy.

Apartment or small house owners can join forces to generate solar energy, especially, with the help of panels on the roofs of high-rise buildings.

In Cherkassy, there is an experience of generating power using the photovoltaic power plant on the roof of the building by the Gromova street, 138/6 (power 30 kW), and in 2017 the second stage of the photovoltaic power plant on the roof of the building facing the Gromova street, 138/6 (power 30 kW) was introduced, as well as on Patsayeva street, 99 (power 100 kW) and photovoltaic power plant on the roof of the building at Chemists Avenue, 8 (power 50 kW),

The region also has solar power plants in the village Gordashivka of Talniv district – Gordashivska SPP (capacity 102.5 kW), and in Zvenigorodka – SPP "Ozirna" (capacity 150 kW), photovoltaic power plants on the roof of the building on the Shevchenko street, 47 in Zolotonosha, (power 60 kW) [17].

The data obtained from Cherkassy district Energy Company (Fig. 3.1) demonstrate high level of solar generation potential implementation, which creates

favorable conditions for further development of this renewable energy system.

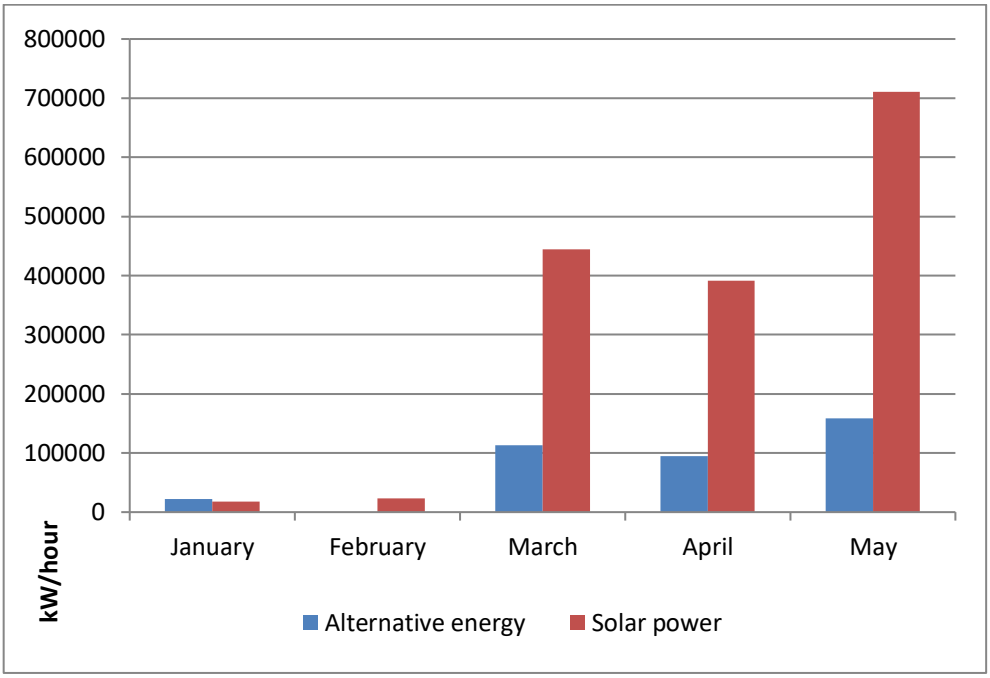

Fig. 3.1 – Power generation from renewable sources in Cherkassy in 2022

3.3 Selection of objects for the pilot project

The choice of houses for individual power plants was based on the following criteria:

1. The absence of shading of the panels, which leads to a decrease in their actual power during operation.

2. The presence of a flat roof, which has a useful area larger than hipped roofs, for horizontal installation of panels.

Properly chosen characteristics and placement of photovoltaic modules primarily affect the efficiency of an individual power plant. The first thing to focus on when choosing is the type of crystals.

In individual power plants, polycrystalline modules are more common. They work well at any inclination to the Sun, producing electricity even from reflected light. All panels from which the array is assembled are standardized in size and face value. At 260-290 W of power, their area varies about 1.5 - 1.7 m^2.

The panels will be installed horizontally on the roofs of buildings, as this

solves the problem of shading the panels and reduces the cost of their installation and further maintenance.

Table 3.1

Standart	
S (m²)	Power, kW
1,5	**0,260**

Number	Address	Nature of the building (number of floors)	S roof	Type of installations and their number	Approximate power, kW
1.	Gagarin 17	1	1609,29	1072	278
2.	Gagarin 21	10	2002,37	1334	346
3.	Gagarin 23	11	471,86	314	81
4.	Gagarin 25	9	798,31	532	138
5.	Gagarin 27	9	798,31	532	138
6.	Gagarin 29	12	1731,61	1154	300
7.	Gagarin 33	10	2245,76	1497	389
8.	Gagarin 35	10	1211,03	807	209
9.	Gagarin 37	10	1012,56	675	175
10.	Gagarin 39	10	1054,55	703	182
11.	Heroes of the Dnieper 81	10	3587,17	2391	621
12.	Heroes of the Dnieper 83	10	1048,64	699	181

13.	Heroes of the Dnieper 85	10	779, 62	519	134
14.	Sergeant Zhuzhomi 6	10	834, 76	556	144
15.	Sergeant Zhuzhomi 8	11	2157 ,81	1438	373
				14223	**3689**

Fig. 3.2 - Sergeant Zhuzhomi 6

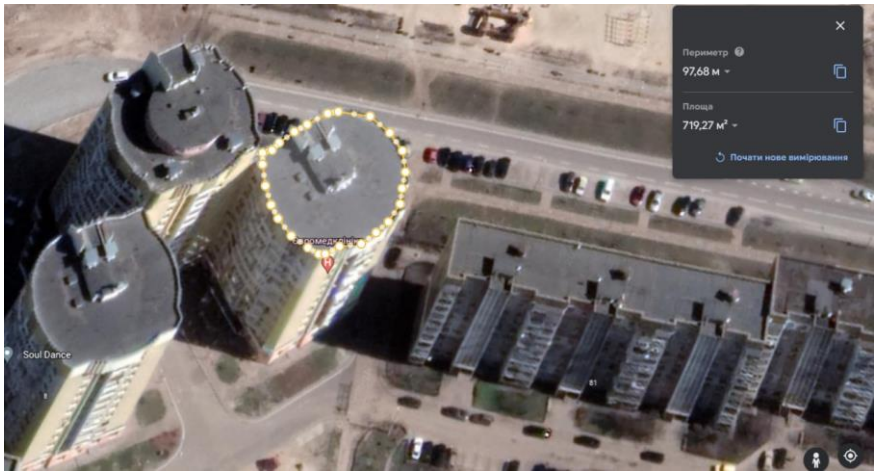

Fig. 3.3 - Sergeant Zhuzhomi 8

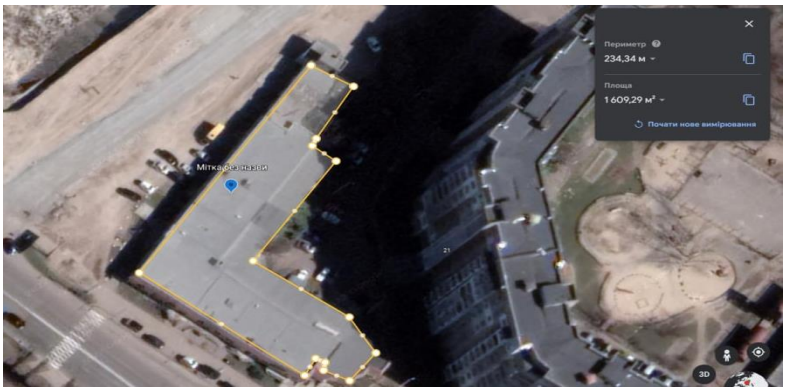

Fig. 3.4 - Gagarin 17

Fig. 3.5 - Gagarin 21

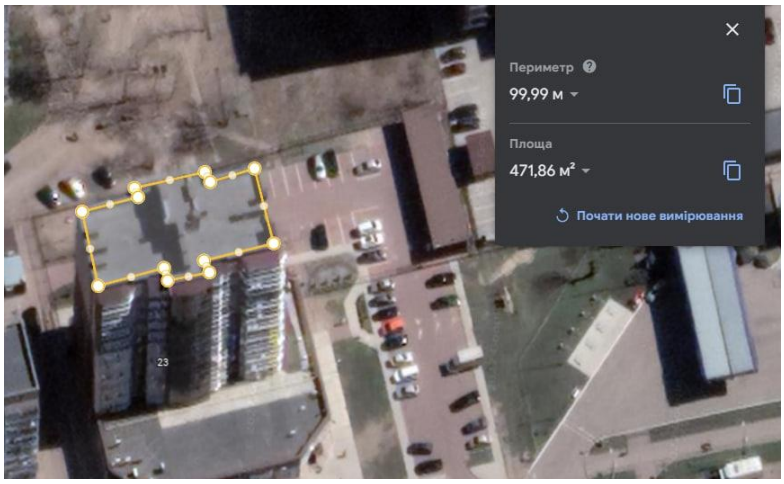

Fig. 3.6 - Gagarin 23

Fig. 3.7 - Gagarin 25

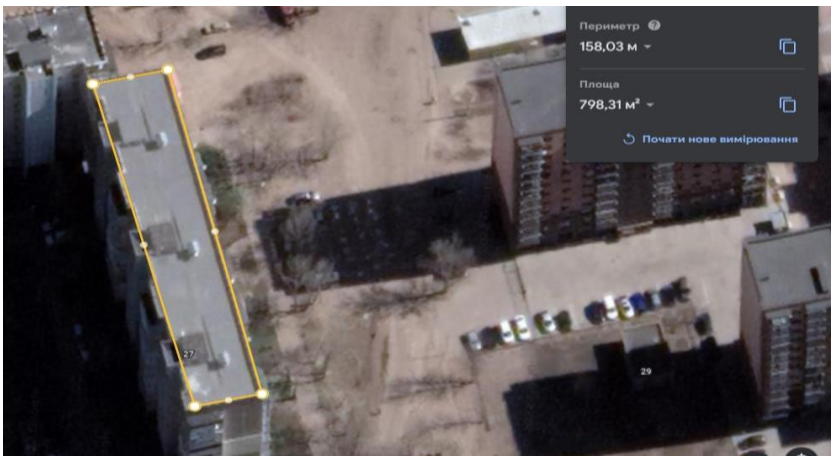

Fig. 3.8 - Gagarin 27

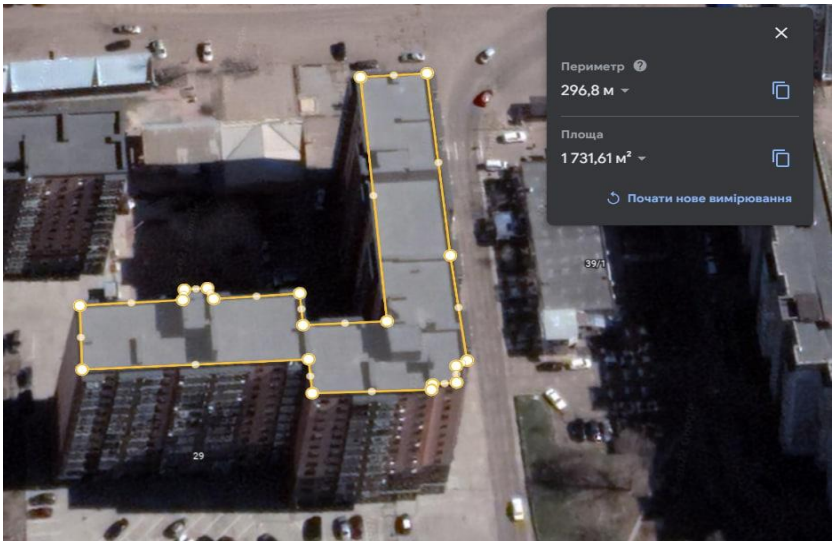

Fig. 3.9 - Gagarin 29

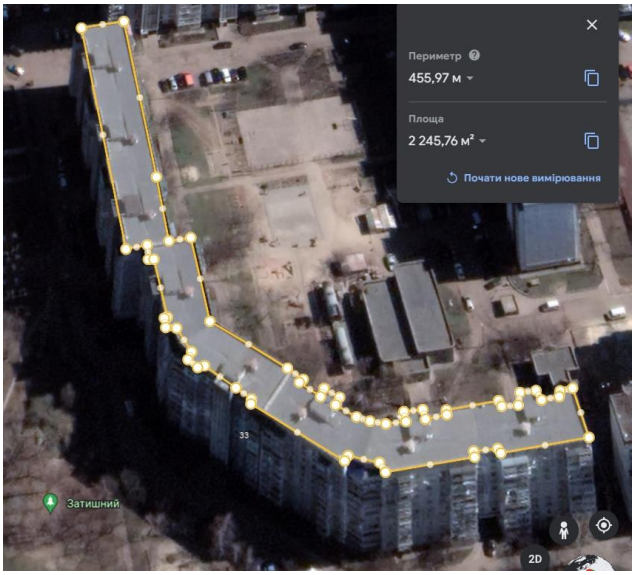

Fig. 3.10 - Gagarin 33

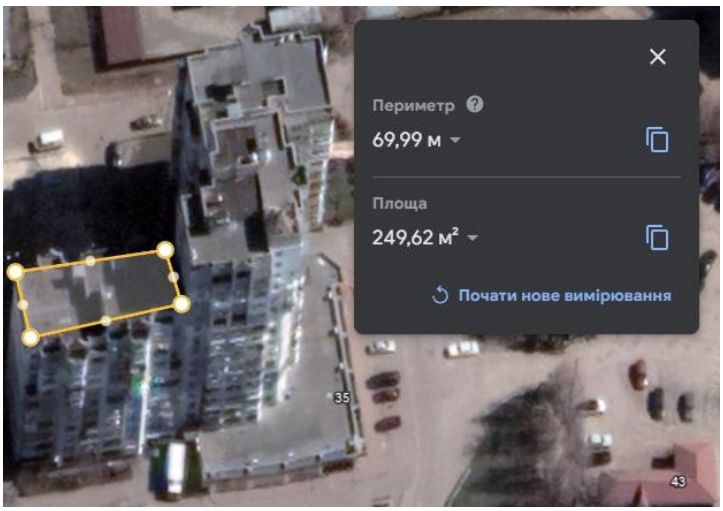

Fig. 3.11 - Gagarin 35/1

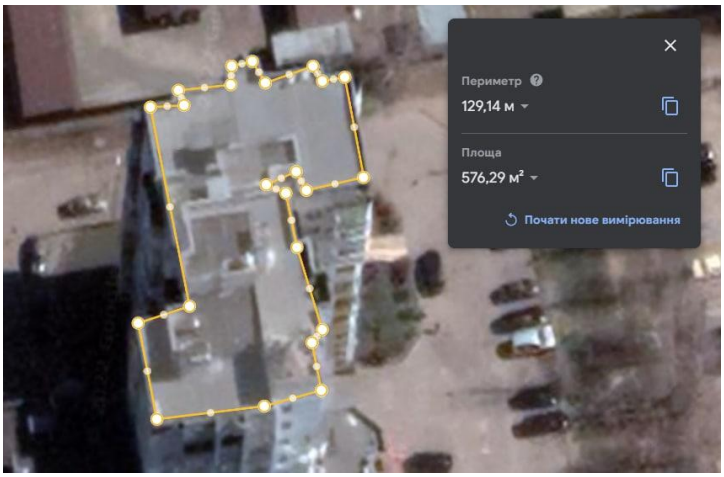

Fig. 3.12 - Gagarin 35/2

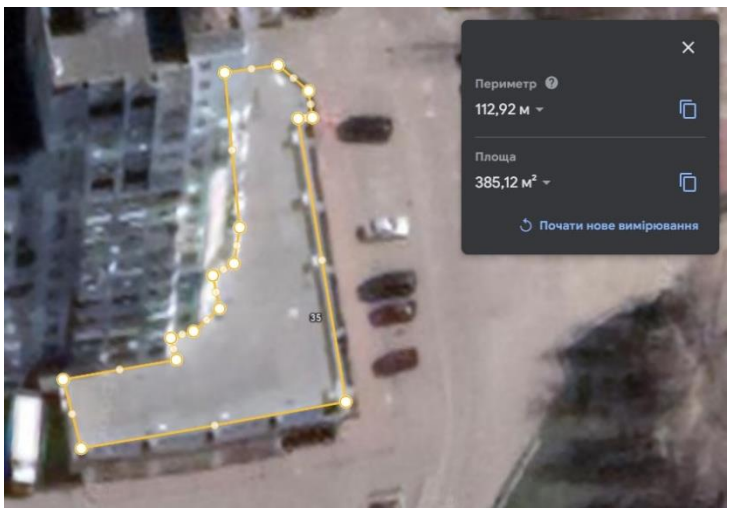

Fig. 3.13 - Gagarin 35/3

Fig. 3.14 - Gagarin 37

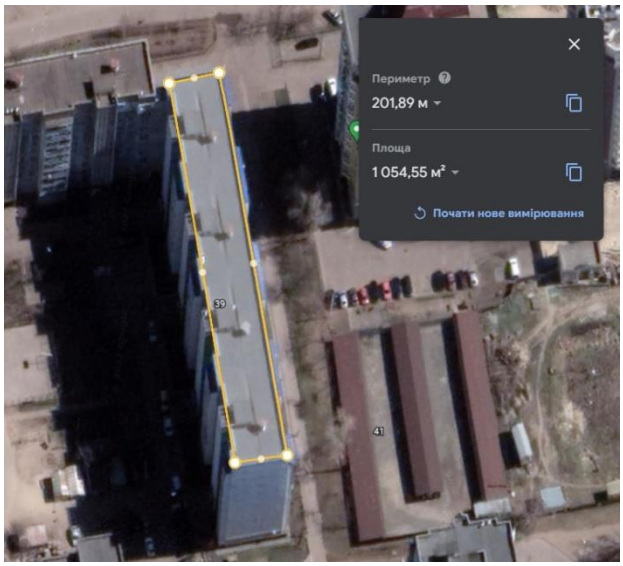

Fig. 3.15 - Gagarin 39

Fig. 3.16 - Heroes of the Dnieper 81/83/85

Power, generated by the roof top solar station, should be used for the common utilities provision – illumination of stairways and stair cases, work of

elevators and pumps etc. The cost of the power, supplied to the centralized network by green tariff, could be used for the maintenance and rehabilitation works at the building. Thus, the maximal efficiency of the project will be obtained by condominiums (ACMH).

3.4 Evaluation of project effectiveness

Thus, by installing solar power plants people are investing in their energy independence, as home SPP is an opportunity to meet their own energy needs, be autonomous, gain some additional income after the payback period and develop the local economy.

In Ukraine, the law "green tariff" allows individuals to sell electricity to the state at a very favorable rate. This tariff determines the amount that the owner of the SPP (up to 30 kW) must receive from Oblenergo for the difference between produced and consumed energy. Oblenergo is also obliged to purchase all the remaining energy in accordance with the law. The payback of the network solar station under the green tariff with a capacity of up to 30 kW is about 4-6 years.

In home power plants, polycrystalline modules are more common, they work at any angle to the sun and also generate electricity even from reflected light, and these modules have the lowest threshold for automatic start.

In Ukrainian latitudes, SPP rarely provides more than 50% of the nominal value, only if the sunny weather clear skies in summer one can get the most out of the solar system. It should also be understood that all panels, regardless of type and characteristics are standardized in size and face value, and in this thesis for calculations to install SPP used only the usable area of the roof.

So, even though in Ukrainian latitudes it is rare that SPP gives more than 50% of its potential, and the average payback period is from 4 to 6 years. We can say with confidence that solar systems are profitable to install, because the first is energy efficient, and the second energy obtained does not cause any harm to the environment, we can say with confidence that the energy obtained from solar

panels is the future.

If we consider a solar power plant only on the factor of economic efficiency without its application under the "green tariff", the payback of such SPP will be about 20-30 years.

Let's analyze one of the proposed houses for our project

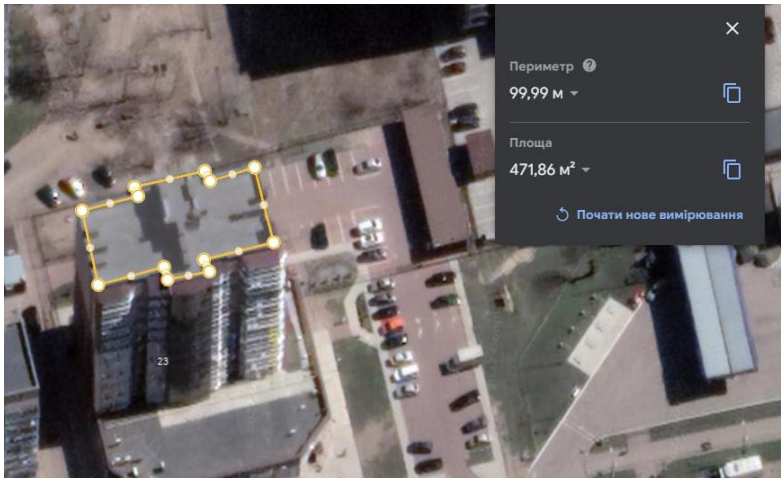

Fig. 3.17 - Gagarin 23

Property: residential new building in 2014

Floors: 11

Sections / entrances: 1

roof type: flat

Coating: ruberoid

Roof area: 471.86 m2

(Roof area was calculated using google earth)

During the year, the station proposed for this house will produce total energy in quantity:

40,5*1200=48600 kWt

The average cost of installing 5 kW - about 4.5 thousand dollars. So, in our case, the installation cost will be

4500 USD * (40,5/5)= 36 450 USD

The average cost of the house for electricity, i.e. lighting stairways and stairwells, floors and adjacent areas, as well as the operation of elevators. In

general, lighting of common areas for houses of this type requires on average

87,6 kWt/h *11 * 1 = 963,6 kW/h per year

The elevator works unevenly and consumes very different amounts of energy, but we can assume that the annual consumption, given the capacity of the elevator and elevator equipment of 6.75 kW, can be determined by the number of floors, which directly determines the number of inhabitants and hence the frequency of elevator use. Thus, for this building we can take the annual amount of electricity consumption by elevators at the level

108 kWt/h *11 * 1=1188 kW / h per year

Thus, the total consumption by these categories

963, 6 kWt/h +1188 kWt/h =2151 kW / h per year, which is

(2151 kWt/h /48 600 kWt) *100% = 4,43 %

Thus, it is possible to fully meet the needs, as well as use energy for other needs or withdraw funds from the sale of the balance in the centralized network. Thus, in monetary terms, the energy produced is about

(48 600 kWt per year – 2151 kWt/h) * 0,18 USD = 8 361 USD per year.

If you compare the data obtained with the cost of installation, the payback period will be

36 450 USD /8 361 USD = 4,4 years

Based on the calculations, we can say that we will definitely get a lot of advantages from solar panels, a good investment, and the greater the capacity of the project, the faster it will pay off, and accordingly it will be more profitable.

3.5 Conclusion to chapter 3

It should be noted that a solar power plant can be both a solution to the problem of electricity supply and a profitable investment that can pay for itself in a few years and bring a fairly stable income during the year.

CONCLUSIONS

1. Ukraine has its own energy potential in the sale of solar installations. Solar installations are more relevant and cost-effective than wind turbines, because solar panels can be installed anywhere from the ground to the roofs of different types of houses, both private and local. At the same time, wind turbines should be installed in places where the average wind speed and stability are higher than in Cherkasy.

2. It is better to install solar panels openly, on roofs, facades, without obstacles. . You will be able to provide your home with an autonomous source of electricity and hot water. On the roof of the house you can install a solar collector, which will provide in winter not only hot water in the tap, but also heating.

3. A study was conducted on the calculation of costs and payback rates of solar panels under the conditions of connection to the "green tariff".

4. It was found that the most optimal system of distributed energy generation for the climate and latitude of the city of Cherkasy is the system of solar installations, its rate of return and the prospect of investment capacity is high.

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