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Assistance to the Development of the Mykolaiv Masterplan

Potential of Solar Energy Sources in Power and District Heating Sectors, Report

Final

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COWI

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BIPV	Building-integrated Photovoltaics
CAPEX	Capital Expenditures
cm	Centimetre
CSP	Concentrated Solar Power
IRE of NASU	Institute of Renewable Energy of the National Academy of Sciences of Ukraine
kW	Kilowatt
MCHPP	Mykolaiv Combined Heat and Power Plant, Private Joint Stock Company
MOTE	Mykolaivoblteploenergo, a Municipally Owned Heat Supply Company
MWth	Megawatt Thermal
NEURC	National Energy and Utilities Regulatory Commission
PV	Photoelectric
PVT	Photoelectric Thermal
SAEE	National Agency of Energy Conservation and Energy Saving of Ukraine
SDH	Solar District Heating
USS	Universal Service Supplier
VAT	Value Added Tax

Introduction

This report has been developed within the framework of the project “Mykolaiv - Denmark partnership – Technical Support Unit” financed by the Danish Ministry of Foreign Affairs (MFA). COWI has been entrusted the development of contributions to the masterplan regarding water, energy, and solid waste. The masterplan concerns the Mykolaiv City and its development in the period till 2050 (throughout this report Mykolaiv City and Mykolaiv as well as City of Mykolaiv are used synonymously). Box 1-1 below provides further information about COWI’s contribution to the Mykolaiv Masterplan.

Box 0-1 COWI’s contribution to Mykolaiv Masterplan in a nutshell

Mykolaiv Masterplan, which has been requested by the Mayor of Mykolaiv City, has a time horizon till 2050. It provides a compass for actions to be taken by the Mykolaiv City to ensure that it will develop into a thriving city attractive to its citizens and business community.

COWI and One Works assist Mykolaiv City Administration in developing the masterplan. In this work, COWI focuses on three sectors:

- Water and wastewater
- Energy, including power, district heating and renewable energy sources
- Solid waste management.

Mykolaiv City Administration meets every week with COWI and One Works to ensure proper coordination.

COWI has established a project organization consisting of a project management team and three sector teams of professionals, each headed by a Discipline Leader. Three sectoral Focal Points are responsible for monitoring cross-cutting activities, ensuring coordination between the parties and maintaining consistency in the deliverables.

To enhance transparency in the development of the Mykolaiv Masterplan, given its significant public interest and exposure, COWI has established three sector-specific Sounding Boards inviting all potentially interested parties to take part in these.

The report addresses the issues related to the use of solar power in Mykolaiv City and Mykolaiv Oblast for improving and enhancing the quality of life of their residents, strengthening the security of energy (electricity and heat) supply, and future achieving climate neutrality in Mykolaiv city and the region.

It takes into consideration solar power potential and, the current status of power and HD sectors including the challenges and feasibility of using solar power technologies for HD and power sectors in urban environments.

The report consists of 4 chapters in addition to the current. They are:

Chapter 2 focuses on existing solar energy technologies for DH and power sectors focusing on those suitable for urban environments.

Chapter 3 provides an overview of solar power potential in Mykolaiv City and Mykolaiv Oblast

Chapter 4 gives a brief overview of possible investment projects to untap the potential

Chapter 5 describes the current legal and regulatory framework and required changes in the legal and regulatory framework to untap the potential.

Existing solar energy technologies for DH and power sectors suitable for urban environments

The global energy crisis, triggered by russia's invasion of Ukraine, has sparked unprecedented momentum for renewables. The russia's energy war against Europe, russia's missile and drone attacks on Ukraine's power infrastructure have highlighted the importance and benefits of renewable energy in achieving energy security and independence. Meanwhile, higher fossil fuel prices worldwide have improved the competitiveness of solar PV and wind generation against other fuels.

In response to the hardships and global energy market disruption caused by russia's invasion of Ukraine, on May 18, 2022, the European Commission presented the REPowerEU[1] plan. REPowerEU emphasizes the acceleration of green technologies, from solar photovoltaic, wind, and heat pumps to green hydrogen.

In 2022, the world added 239 GW of new solar capacity, making it another record. That's 45% more solar power capacity than the year before. The positive market developments in the first months of 2023 promise another solar boom year, expected to result in 341 GW of newly-added solar to the grid, by the end of the year – equal to 43% growth. The EU's grid-connected solar capacity additions in 2022 reached 41.4 GW, up 47% from the previous year.

Integrating solar technologies in urban development provides a pathway for building resilient communities and a sustainable future that can effectively adapt and respond to challenges.

Two main types of solar technologies exist for harvesting solar resources to produce energy: photovoltaics (PV) to generate electricity, and solar collectors to produce thermal energy. Both can be applied at various scales and can operate via a standalone or grid-connected configuration. While solar PV provides only electricity, solar thermal has many different applications suitable for urban areas.

This chapter describes the existing technological solutions often used for urban areas, such as PV systems, building-integrated PV, various solar thermal technologies (including concentrated solar thermal systems), and solar photovoltaics-thermal.

2.1 Rooftop solar systems

Within cities, solar PV systems are usually installed on the roofs of buildings. These systems are generally smaller in scale than ground-mounted systems located in the fields. The typical size of installed residential PV systems in Ukraine ranges between 5 and 10 kW. The key technical advantage of residential systems is their proximity to the load, which avoids the energy losses and charges associated with long-distance transmission.

Despite the many advantages that solar PV systems bring to cities, the main challenge to scaling up PV applications in urban areas is the land constraint. For this reason, solar rooftop installations have already been and will continue to be the preferred practice. Commercial buildings, residential complexes, and industrial facilities can all benefit from PV rooftop systems, transforming them into energy-generating powerhouses.

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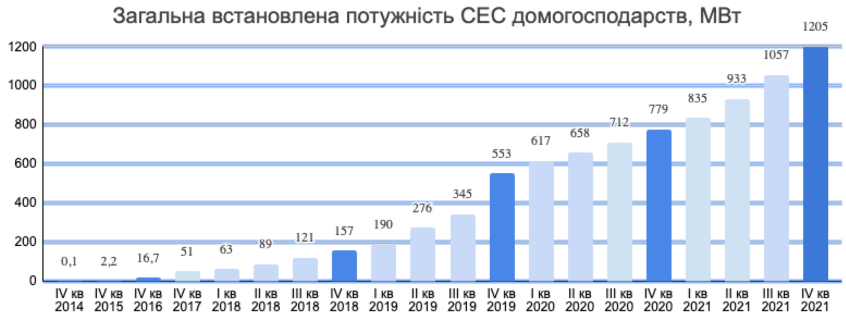
1 REPowerEU (europa.eu)

Ukraine has already made good progress in installing small-scale solar systems for private households. Quite attractive green tariff introduced for small PV boosted deployment of this technology in Ukraine. The below figures from the SAEE show the dynamics of household solar installations' growth in Ukraine.

Figure 0-1 Total number of PV systems in private households, 2014-2021, units, SAEE

Figure 0-2 The installed capacity of PV systems in private households, 2014-2021, MW, SAEE



In general, the leaders in rooftop solar installations for private households in Ukraine are not sunny regions. The top five in terms of the number of rooftop PV in private households include Dnipro, Ternopil, Kyiv, Zakarpattia, and Ivano-Frankivsk regions. According to the NEURC data dated November 2021, the total installed capacity of rooftop PV in Mykolaiv city amounted to 0.67MW.

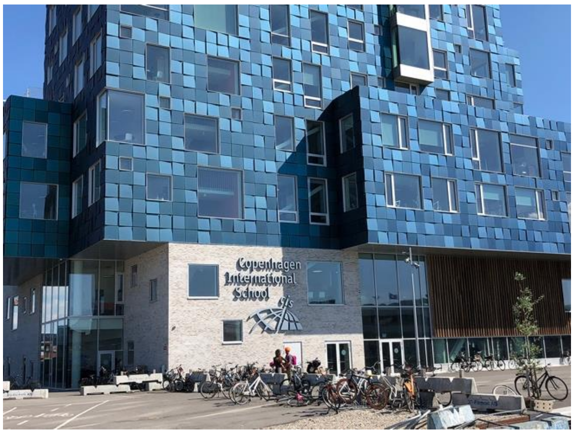
2.2 Building-integrated photovoltaics

BIPVs are solar power plants that are integrated into buildings and structures. Thus, technology involves two major product categories: façade-integrated (such as PV wall/façade) and roof-integrated (such as PV shingles and tiles). BIPV offers the dual functionality of both generating electricity and serving as building materials complementing or completely replacing traditional building materials (facade and roof structures). In the coming years, BIPV solutions will be most actively developed in comparison with other types of solar power plants.

Modern BIPV systems provide added value to a building's needs, not only from the free energy generated viewpoint but also from the multifunctional properties inherent to the smart design. In this sense, by using PV active glazing as a constructive material in buildings, thermal and acoustic insulation will be provided.

The beautiful design of Copenhagen International School is a nice illustration of using PV active glazing as a constructive material in buildings.

Figure 0-3 Copenhagen International School, Denmark, Open Access Government



Installation of BIPV modules instead of traditional roof materials allows to minimize CAPEX during the construction or modernization of buildings. Rooftop installations allow to increase in specific power generation per sq. m in comparison to facade one. However, the available area of roofs is usually significantly lower than the area of the facade in the case of city installation. Rooftop BIPV solutions are more suitable for commercial buildings when a roof is big (stores, factories, logistic centers, etc). The below photograph illustrates the rooftop BIPV solution.

Figure 0-4 Building in Svendborg, Denmark

In a city with high buildings, it would be better to combine several BIPV technologies.

2.3 Solar water heating system

In general, solar thermal systems can be used for heat as well as electricity supply. The sun's heat is typically converted to electricity through concentrated solar power technology, which usually operates at a large scale to make it economically viable, thus requiring a large land area. Therefore, most CSP plants are installed far from cities in locations that have excellent direct solar irradiance.

In contrast, non-concentrated solar thermal systems are used primarily for supplying heat. They can be used at smaller scales that demand less space, and therefore are often installed in urban areas. This technology comprises solar thermal collectors that absorb and convert solar radiation to heat. Solar water heating systems have a high efficiency in the summer, converting up to 80 percent of the energy that contacts the system into heat. In the winter, around 20 – 25 percent of the energy is converted.[2]

Solar collectors for a water heating system can be mounted on a roof, on outside walls, or on the ground. One common form is the glazed flat-plate collector in which the water or anti-freeze circulates through a network of copper piping attached to a flat black plate inside a glass-covered frame. An evacuated tube collector system consists of a series of insulated glass tubes that are arranged in parallel rows. The below photos demonstrate different types of CSP plants installed on the building's roof.

Figure 0-5 Solar evacuated tube collector

Figure 0-6 Solar flat plate collector

Flat-plate collectors perform better on days in which the ambient temperature is similar to the collector temperature, whereas evacuated tube collectors perform better on days when there is a larger temperature difference. For cold and cloudy climate regions evaporated tubes can perform better than flat plate collectors. Therefore, for Mykolav City and Mykolaiv Oblast with their sunny and warm climate, it's better to use flat plate collectors. So far, solar water heating systems have been less popular in Ukraine compared to solar rooftop systems.

[2] Ministry of Agriculture, Food and Rural Affairs, Ontario https://omafra.gov.on.ca/english/engineer/facts/sol_wat.htm#:~:text=Solar%20water%20heating%20systems%20have,of%20the%20energy%20is%20converted.

2.4 Solar district heating

SDH is a large field of solar thermal collectors supplying solar energy to the heat network in urban quarters, smaller communities, or large cities. The solar collector fields are either installed on the ground or integrated into building roofs.

This field is supplemented by a heating center, which provides additional energy to meet all the heating needs of connected residential, public, or office buildings. The heat network can likewise be supplied with surplus energy from collectors installed on the roofs of those buildings. In most cases, solar energy contributes up to 20 % to annual heat demand. Using seasonal storage can increase this solar fraction to 60 % or more.[3]

The solar collector fields are either installed on free ground or integrated into building rooftops. During warmer periods they can replace other sources, usually fossil fuels, used for heat supply. The system can be configured in combination with a storage facility (such as seasonal thermal storage) to provide heat whenever needed. Solar heat can also meet a share of the heating demand during the winter. Typically, shares of the solar thermal plant are 10–50% of the total heat supply of the DH system.

The main benefits of solar district heating are that the system can be installed with low solar resources, provides a stable cost for at least 25 years[4] since no fuel price influences the expenses, and uses already mature and available technology with zero emissions.

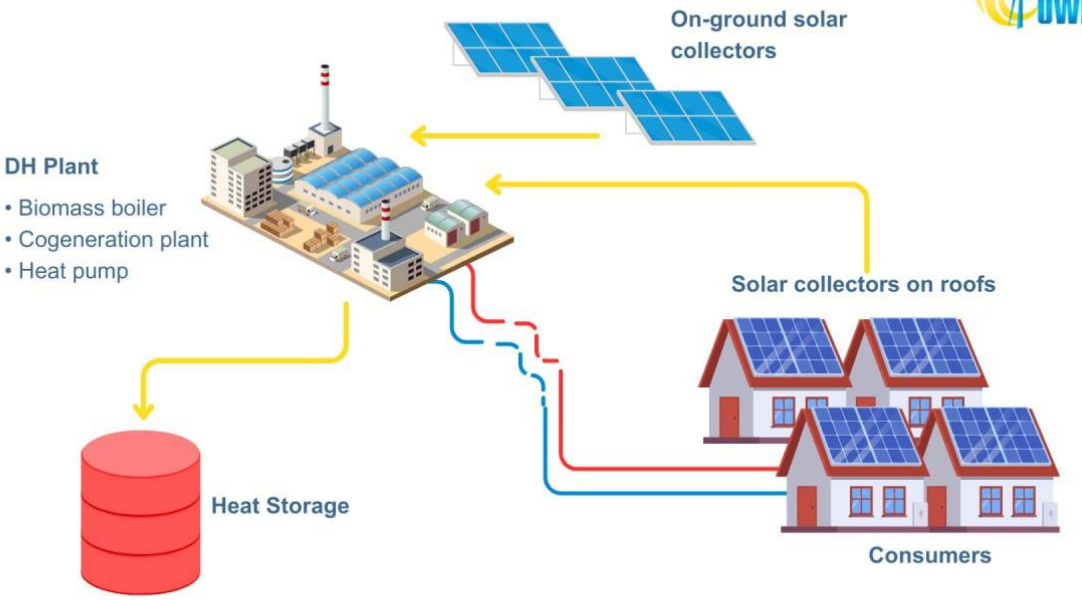
In 2023, the total number of District Heating networks existing in the EU reached 17,000. Out of the 20 biggest SDHs in operation in the world, 16 are in Denmark, totalling an installed capacity of 394 MWth.

The scheme of SDH networking in the urban environment is presented below. This SDH system combines on-ground and rooftop solar collectors, a heat storage facility, and additional RES energy sources (a biomass boiler/cogeneration plant/heat pump).

[3] Task 55 Integrating Large SHC Systems into District Heating and Cooling Networks www.task55.iea-shc.org https://eu-mayors.ec.europa.eu/en/solar-district-heating-resources

[4] Solar District Heating, https://www.solar-district-heating.eu/en/benefits/

Figure 0-7 Scheme of Solar District Heating Network

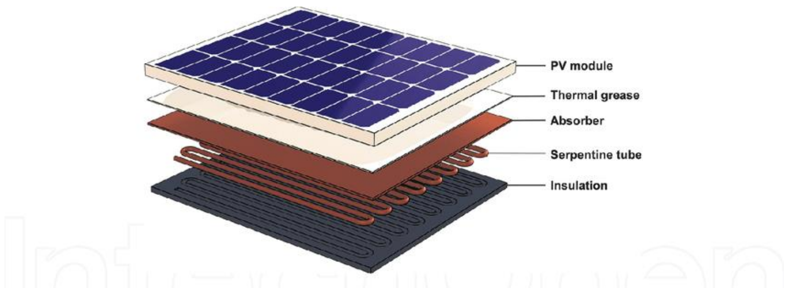


2.5 Photovoltaic thermal solar collectors

PV-thermal technology is a hybrid system with an integrated design to provide both electric power and heat. The aim is to achieve higher overall energy conversion efficiency of solar radiation and address the challenge of limited available land area in cities.

PVT collectors comprise PV cells (often arranged in solar panels) that convert sunlight into electricity with a solar thermal collector which transfers the otherwise unused waste heat from the PV model to a heat transfer fluid. By combining electricity and heat generation within the same component, these technologies can reach a higher overall efficiency than solar PV or solar thermal alone. The contacting fluid can cool the PV panels for better electrical efficiencies during high summer temperatures, while the absorbed heat is used for direct heating. A schematic of the PVT collector is presented in Figure 0-8.

Figure 0-8 Schematic of PVT collector, ResearchGate



PVT collectors utilize more of the solar spectrum while another advantage is space saving through a combination of the two structures to cover a lesser area than two systems separately. On the other hand, the high investment costs and the lack of knowledge (the technology is still in the development/research phase) remain the major barriers to potential market growth. The widespread use of this technology in Mykolaiv City and the region currently seems to be appropriate for the mid-term (2040) and long-term (2050) perspectives depending on the technology being matured.

3. Solar power potential

To understand the efficiency of solar technologies in a region, it is necessary to understand the climate of the region and its solar potential. Therefore, this chapter presents a brief description of the climatic conditions and focuses on solar potential available in the Mykolaiv Oblast and Mykolaiv city.

Ukraine has favourable conditions for the use of solar energy. According to the Institute of Renewable Energy of Ukraine of the National Academy of Sciences of Ukraine, the average annual amount of total solar radiation falling on 1 m^2 of surface ranges between 1070 kWh/m^2 in the northern regions and 1400 kWh/m^2 in the south of Ukraine.

The radiation regime in the territory of Ukraine is characterized by an annual variation in the average sunshine duration between 1690-1850 hours in the western regions of Polissya and Forest-Steppe and 2150-2450 hours in Crimea and on the coasts of the Black and Azov Seas. The amount of solar radiation that reaches the territory of Ukraine (isolation level) ranges from 1064.9 kWh/m^2 per year in the west (Carpathian region) to 1551.7 kWh/m^2 in the south of the Crimean Peninsula. Average annual values of the radiation balance vary throughout the territory from 330 kWh/m^2 in Volyn to 580 kWh/m^2 on the coasts of the Black and Azov Seas and in Crimea.

3.1 Climate

Mykolaiv Oblast is located in the Southern part of Ukraine, alongside the Black Sea. The region features a mix of flat plains and lowlands, with the Dnieper River playing a significant role in the local geography. The climate of the Mykolaiv Oblast and the city of Mykolaiv is temperate continental, characterized by dry hot summers and moderately cold winters with unstable snow cover.

To characterize the climate of the region and the city of Mykolaiv, information provided in 2019 by the Mykolaiv Meteorological Station and information available at the Weather Spark website[5] (is used. Sub-chapters 3.1.1. – 3.1.4. brief on the main climate indicators that are directly related to the efficiency of solar installations.

3.1.1 Average annual air temperature

The average annual air temperature is +8 - +10°C, the average temperature in July is +21.2 - +22.9°C, in January - -3.2 - -5.0°C; the absolute maximum is +38 - +39°C, the absolute minimum is -29 - -33°C. The frost-free period lasts 160 - 205 days. Coastal areas boast sandy beaches and the geography of the region is characterized by agricultural activities, including grain farming and viticulture.

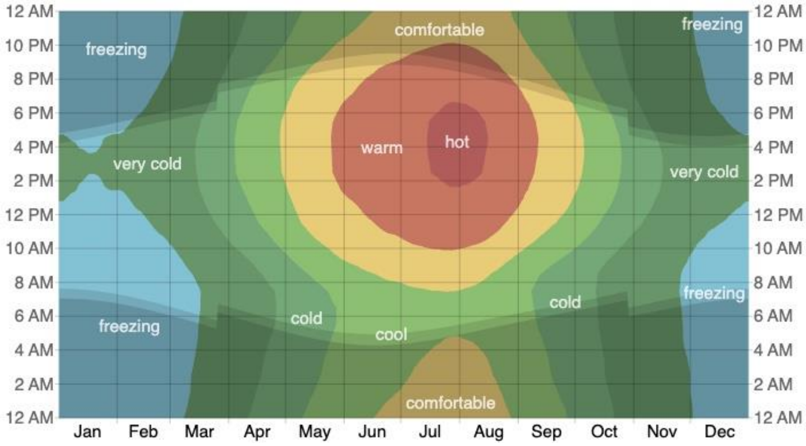
The average temperature of the warmest month in Mykolaiv is +24.6°C with an absolute maximum of +40.1 °C. In general, in Mykolaiv, the summers are warm and mostly clear and the winters are long, freezing, snowy, windy, and partly cloudy. The hot season lasts for 3 and half months from the last decade of May to the first decade of September with an average daily high temperature above 25°C. The hottest month of the year in Mykolaiv is July, with an average high of 30.5°C and a low of 16°C. The cold season lasts for almost 4 months – from the middle of November to the

[5] (https://weatherspark.com/y/97047/Average-Weather-in-Mykolayiv-Ukraine-Year-Roundsite

first decade of March with an average daily high temperature below 6.5°C. The coldest month of the year in Mykolaiv is January, with an average low of -6°C and a high of 1.1°C.

The figure below shows a characterization of the entire year of hourly average temperatures. The horizontal axis is the day of the year, the vertical axis is the hour of the day, and the color is the average temperature for that hour and day.

Figure 0-1 Hourly average temperatures in Mykolaiv City, per month, Weather Spark



3.1.2 Clouds

Clouds are another important climate indicator for the efficiency of solar technologies

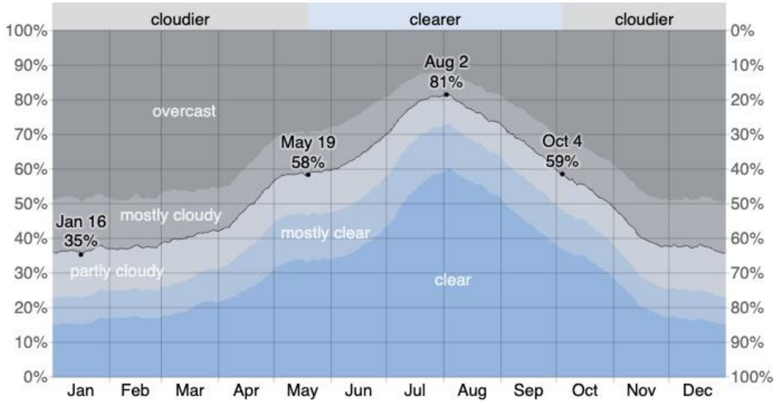
In Mykolayiv, the average percentage of the sky covered by clouds experiences significant seasonal variation over the year.

The clearer part of the year in Mykolayiv begins around the third decade of May and lasts for almost 4.5 months, ending around the beginning of October.

The clearest month of the year in Mykolayiv is July, during which on average the sky is clear, mostly clear, or partly cloudy 78% of the time. The cloudiest month of the year in Mykolayiv is January, during which on average the sky is overcast or mostly cloudy 63% of the time.

The figure below describes the cloud cover categories in the summer in Mykolaiv, with the percentage of time spent in each cloud cover band categorized by the percentage of the sky covered by clouds. It should be noted that the summer months have been selected on purpose, as solar power generation is the highest in the summer in Ukraine.

Figure 0-2 Cloud cover categories in the summer in Mykolaiv City, Weather Spark



3.1.3 Precipitation

The annual precipitation is 380-500 mm, with the bulk of it (65-70%) falling in the warm season in the form of showers (the daily amount can reach 60-70 mm). Autumn and winter periods are usually characterized by prolonged, low-intensity rains. The snow cover appears in November-December and disappears in late February - early March. Its height varies from 10-12 cm in the central and southern regions to 50 cm in the northern regions.

The average annual rainfall ranges between 24.4 mm and 55.2 mm. Mykolaiv experiences monthly variation in precipitation level with the highest amount of precipitation falling in summer.

The wetter season lasts 2 months – from May to July. The month with the most wet days in Mykolayiv is June, with an average of 6.6 days. The month with the fewest wet days in Mykolayiv is August, with an average of 4.2 days. The average precipitation in mm experienced in 2019 in Mykolaiv city is presented in Table 0-1.

Table 0-1 Average precipitation level, mm, 2019, Mykolaiv Meteorological Station

Month	1	2	3	4	5	6	7	8	9	10	11	12	Year
Average precipitation	39.8	24.4	30.2	35.6	55.2	38.4	40.9	16.5	26.6	34.0	33.2	29.4	404.2

3.1.4 Day length

The length of the day in Mykolayiv varies significantly over the year. In 2023, the shortest day is December *22*, with 8 hours, and 31 minutes of daylight; the longest day is *June 21*, with 15 hours, and 54 minutes of daylight.

3.2 Photovoltaic power generation potential in Mykolaiv Oblast

The Global Horizontal Irradiation map of Ukraine (Figure 0-3) prepared by the Solargis under contract to The World Bank, represents the average daily/yearly sum of global horizontal irradiation (GHI) covering a period of 25 years (1994-2018).

Figure 0-3 The Global Horizontal Irradiation Map of Ukraine, Solargis

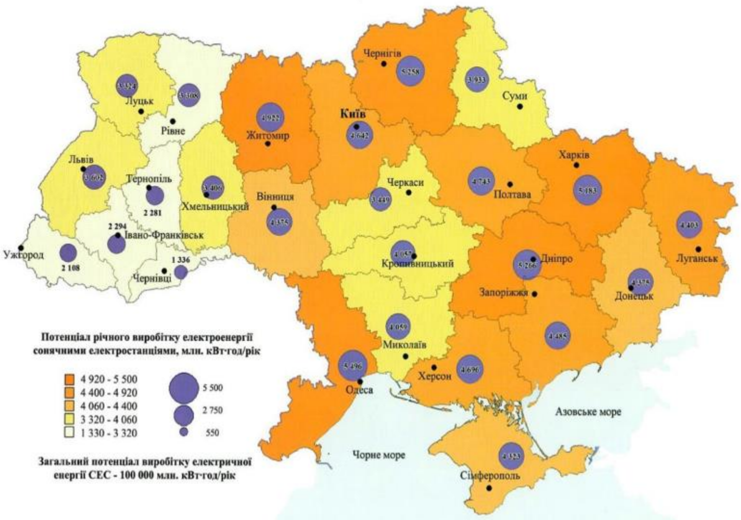
According to the map, Mykolaiv oblast is located in the zone with GHI values ranging between 1250 and 1275 kWh/m^2. Table 0-2 shows GHI values related to the Mykolaiv Oblast. For easy perception, the table is shaded in different colours according to the colours of the map. With a GHI of 1329.0 kWh/m^2 Mykolaiv city is mid-table, while the south of Mykolaiv Oblast (cities of Ochakiv and Luparevo) has the highest indicators.

Table 0-2 GHI values in Mykolaiv Oblast

City	GHI, kWh/m2	Potential Yield kWh/kWp
Bashtanka	1302.5	1263.9
Nova Odesa	1304.9	1264.9
Stepove	1312.4	1272.6
Shihurivka	1322.4	1284.2
Kryva Balka	1326.8	1290.7
Mykolaiv	1329.0	1287.0
Schaslyve	1330.3	1294.9
Schevchnkove	1339.9	1302.7
Novofedorivka	1345.6	1312.1
Prybuzke	1350.7	1315.8
Lupareve	1356. 5	1319.5
Solonchaky / Ochakiv	1369.8	1340.4

Based on NASA data[6], scientists from the IRE of NASU calculated the average yearly totals of solar insolation per region of Ukraine. To make their assessment visual, the map of the photovoltaic power generation potential in Ukraine was developed. It should be noted that to calculate the theoretical installed capacity of SPPs, the following components were used: solar insolation value, an area available for the construction of SPPs, a capacity factor that depends on the type and location of PV panels, the distance between rows of panels, etc.

Figure 0-4 The photovoltaic power generation potential in Ukraine, kWh/year, IRE of NASU



The scientists from the IRE of NASU also calculated a potential electricity output by a 1 kW PV module, south-oriented, in the Mykolaiv Oblast. The results of their calculations are shown in Table 0-3.

Table 0-3 Potential 1 kW PV module electricity output, per month

Month	Incoming solar energy, kWh/m^2	1 kW PV module electricity output, south orientation, kWh
January	1,21	47,3
February	1,94	72,9
March	2,80	129
April	4,04	152
May	5,47	174
June	5,66	166
July	5,85	175
August	5,14	170
September	3,72	136
October	2,40	109
November	1,21	59,5
December	0,95	42,2
	Annual average 3,37	*Total 1432,9*

Summarising the above, it can be concluded that there is a high potential for the efficient use of solar technologies in the Mykolaiv Oblast. According to the NEURC data dated November 2021,

[6] The Power project. NASA prediction of worldwide energy resources; https://power/larc/nasa/gov/data-access-viewer

the total installed PV capacity in the Mykolaiv Oblast, including rooftop PV systems for private households amounted to 879.65 MW.

4. Brief overview of the potential investment project

In this chapter, we give some examples of projects that have been successfully implemented in other regions of Ukraine and that can be implemented in the short-term perspective in the city of Mykolaiv. These are primarily rooftop solar projects for municipal social facilities such as schools, kindergartens, and hospitals.

For such types of projects, the following equipment is required:

- PV modules;
- Inverter;
- Electricity battery storage (preferably);
- Support structures;
- Cable and wire products (DC), connectors etc.

Project implementation phases include:

- Design / Preparatory work;
- Installation of structures and PV modules;
- Cable installation on the side of DC, AC;
- Installation of inverters and protection equipment;
- Start-up and adjustment works.

The approach to the capacity of the rooftop solar system is calculated based on the following data:

- Annual and monthly electricity consumption of the object;
- Rooftop type and available place considering the south side;
- Internal technical engineering plan;
- Weather conditions (summer and winter).

The capacity of the energy storage is calculated taking into consideration the following data:

- Usual duration of the blackouts in the region;
- Capacity of the inverter;
- Necessary capacity to cover the critical needs of the object.

Cost breakdown structure of such a project:

- Cost of equipment (PV panels, inverter, electricity battery storage);
- Installation works;
- Logistics;
- General and administrative expenses.

The project implementation period is 2-3 months.

4.1 Possible solar solutions for schools

The main schools that provide a full-scale educational process (from the 1st to 11th grade) are secondary schools (or general educational schools). The capacities of such schools are around 2000 pupils and kids from different settlements of the communities go to such schools. The duration of the educational process in the school is from 8:30 am to 19:00 pm.

The main source of electricity supply in schools is the distribution grid. Diesel generators if available, are usually around 3-5 kV which is not enough to cover the consumption of the school or at least some parts of it. In addition, such energy source harms the environment (CO_2 emission) and is quite expensive (cost of diesel). In regions such as Mykolaiv Oblast, schools quite often are not operational due to the high risks of military attacks and interruption of electricity supply.

The proposed solution to ensure the electricity supply to schools during the blackouts is rooftop solar systems. Such a system provides for installing rooftop solar PV modules, electricity battery storage, and a hybrid inverter.

According to NGO Energy Act for Ukraine Foundation that performed several rooftop solar projects for schools and hospitals in different regions of Ukraine in 2022 -2023, the typical capacity of the PV system proposed for a school is 20 kW, which comprises 58 PV panels; while the typical capacity of energy storage is around 40 kW/hour (typically covering up to 6-8 hours of blackouts in school).

Consumption of the critical consumers as requested by the school: basement, light inside and outside, some classes, kitchen).

4.2 Examples of implemented rooftop solar projects for schools

The below projects have been implemented by NGO Energy Act for Ukraine Foundation.

Hybrid solar power plant installed at Chernihiv School No. 3

Chernihiv school No. 3 – capacity up to 2000 pupils.

The PV rooftop project implemented in 2023 (Figure 4-2-1) includes:

- 22 kW solar modules – 58 solar panels
- 40 kWh energy storage – 4-6 hours of blackouts – lithium-ion storage
- 20 kW inverter – hybrid 3-phase invertor

Positive impact:

- Up to 4 hours cover the blackout
- Up to 35% to cover yearly consumption of the school
- Yearly economy – 2336 EUR per year
- 637 CO_2 emission decreased during the 25 years
- Yearly generation - 28 MW/hour

Figure 4-2-1. PV project at Chernihiv school No. 3

Irpin Liceym Mriya in the Kyiv region

The PV rooftop project for Irpin school (Liceym Mriya) in the Irpin city Kyiv region was implemented in 2022 (Figure 4-2-2)

Figure 4-1-2. PV project at Liceym Mriya, Irpin

Information about the project:

- 20 kW solar modules - 52 solar panels 385 Wp
- 49kWh energy storage - lead-gel batteries, 48 pieces
- 20kW inverter - PV inverter STP 20000 TL-30 plus 3 battery inverters.

Positive impact:

- Up to 4 hours covers the black out
- Up to 35% to cover yearly consumption of the school (in practice the storage covered 8 hours)

4.3 Possible solar power projects for hospitals

The electricity consumption of the hospitals is big, and the efficient solution can be the solar power plant which is capable of guaranteeing the supply of electricity to intensive care and surgery units.

Typically, one hospital needs at least 50 kW of solar power plant with electricity battery storage. The main sources of electricity consumption are the relevant medical equipment, computer and office equipment, climate control, and lighting. Monthly consumption of the hospital depends among others on the type and amount of the relevant medical equipment.

According to the NGO Energy Act for Ukraine Foundation, the positive impact from the implementation, for example, 150 kW of solar power plant project for the hospital may be as follows:

- Generation of around 150 000 kWh per year of clean electricity which can partly or fully cover the needs of the hospital depending on the amount of its electricity consumption
- Saving the health and lives of people
- The reduction of CO_2 emissions is just under 80 tons per year. Over the entire operational life of the plant, the reduction of emissions is thus over 1,450 tons.
- Annual savings of around 22,000 EUR, with a payback period of around 6,2 years.

4.4 Solar Power Plant System for Business

The proposed project provides for installing 832 kW solar power plant. It can be implemented to supply electricity to a production facility.

Proposed project main data:
Solar system installed capacity - 832 kW;
Estimated annual electricity generation amounts to around 881 552 kWh;
Number of hours of maximum generation – 1060 hours.

The solar power plant will be composed of:
- solar panels –PV models JA Solar 540 - 1540 pieces
- inventers - Huawei SUN2000-100KTL-M1-400Vac - 7 pieces

The area required for installing such solar system is appr. 4024 m^2.

The business model of such type of a project is based on providing an electricity supply to an enterprise/production facility through the implementation of the construction of a solar power plant that is integrated into the internal grid of the enterprise/production facility. Thus, the electricity supply from the SPP maximizes the consumption schedule of the facility and reduces the cost related to purchasing electricity from external power grids.

Cost of works under the EPC contract – appr. 750 USD / per 1 kW (including VAT). The EPC cost is indicative; for an accurate determination, it is necessary to visit the facility.

5. RES legal and regulatory framework

The war unleashed by the russian federation against Ukraine demonstrates the vulnerability of Ukraine's power sector dominated by fossil fuel generation, nuclear, and thermal. The invasion highlights the urgency for Ukraine to reduce its dependence on fossil fuels.

The different approaches to RES development can be illustrated by different targets for RES deployment that have been set before and after russia's invasion. The Energy Strategy of Ukraine until 2035 adopted in 2017 set a goal of sourcing 25% of Ukraine's power from renewables by 2035, while the National Economic Strategy of Ukraine approved in March 2021, clarifies the 25% share of RES in electricity generation by 2030. The Energy Strategy until 2050 presented at the Ukraine Recovery conference in June 2023 in London, UK, has defined the goals of fundamental transformation of the Ukrainian energy sector, according to which Ukraine should become a widely electrified country and achieve NetZero goals through the development of carbon-free generating capacities. According to Ukraine's Energy Strategy until 2050, Ukraine's wind power sector should deliver 140 GW of wind capacity while installed solar capacity should reach +94 GW.

It is worth noting that there are some inconsistencies between different strategies approved in Ukraine. For sure, a complete understanding of the damages to the power system of Ukraine caused by the war unleashed by the russian federation against Ukraine (after the war ends) will affect the set goals.

The destruction of the power system by russia's missile and drone attacks has unveiled one more urgency for Ukraine's power sector - a distributed generation: when the consumer is as close as possible to the energy source.

The institutional analysis report (D2) developed within the framework of the project "Mykolaiv - Denmark partnership – Technical support unit" addresses the existing legal and regulatory framework for energy production and consumption in Ukraine. This chapter is devoted to the latest legislative updates (2022-2023) focusing on the utilisation of solar technologies in urban environments.

5.1 Promoting self-generation and self-consumption

Understanding the urgency for improving renewable sector legislation and delivering the set targets, on June 30, 2023, the Verkhovna Rada of Ukraine adopted the Law of Ukraine "On Amendments to Certain Laws of Ukraine on the Restoration and Green Transformation of the Energy System of Ukraine" (hereinafter – the Law No. 3220-IX) which entered into force on July 27, 2023.

Law No. 3220-IX aims to change the paradigm of Ukraine's renewable energy policy towards a free market and is expected to give a new impetus to the development of renewable energy, primarily wind and solar. It introduces amendments to 18 laws in Ukraine (most importantly to the Law on Alternative Energy Sources and the Law on the Electricity Market) governing guarantees of origin, self-consumption contracts for difference for green auctions, a market premium system for producers operating under the green tariff, improved mechanisms for corporate PPAs.

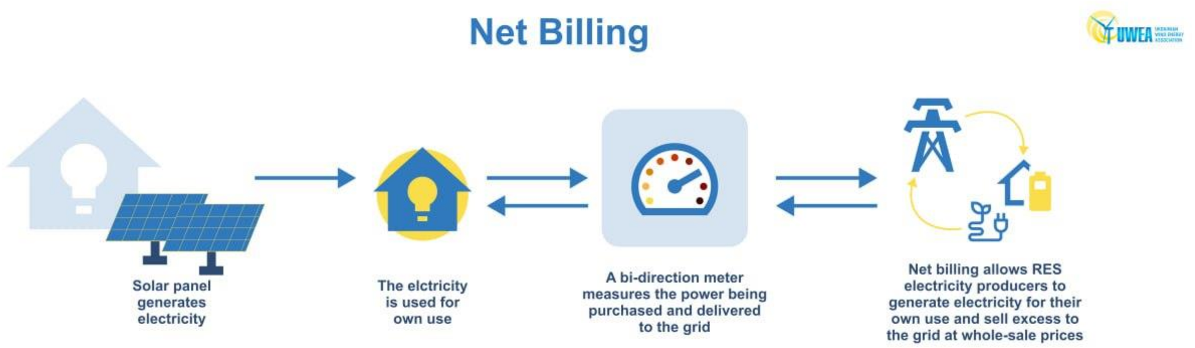
5.1.1 Net Billing

Considering that the present report focuses on the utilization of wind and solar energies in urban environments (Mykolaiv City), the most relevant instrument to untap the wind and solar potentials and decentralize power and heating systems out of those introduced by the Law is a net-billing mechanism. By enabling net-billing, Ukraine allows self-consumers to actively participate in the market, i.e. consumers can install generation for their own needs, and surplus electricity can be sold to the grid at free market prices.

Such a support system is established for consumers whose generating facilities are connected to consumption facilities, provided that the installed capacity of such facilities does not exceed the permitted (contractual) capacity of the consumption facilities of a consumer, namely:

- solar and wind generating facilities of private households with an installed capacity of up to 30 kW;
- solar and wind-generating installations of small non-household consumers with an installed capacity of up to 50 kW;
- installations of other non-household consumers generating electricity from solar, wind, biomass, biogas, hydropower, and geothermal energy, provided that their installed capacity does not exceed the permitted (contractual) capacity of such consumer's electrical installations intended for electricity consumption.

Figure 0-1 Net Billing mechanism in Ukraine



The electricity capacity of an active consumer (except for household and small non-household consumers) allowed to be supplied to the grid may not exceed 50 percent of the permitted (contractual) capacity of the electrical installations of such consumer. After fulfilling specific technical requirements of the distribution system operator/transmission system operator (which should additionally be set), the permitted power to be supplied to the grid may be increased.

To implement such a support system, active consumers enter into a self-generation electricity purchase and sale agreement with a supplier of universal service (this option is only available to private households and small non-household consumers) or an electricity supplier (all active consumers) by the model form approved by the NEURC.

The remuneration of self-consumers depends on the market price, imbalances, network tariffs, and VAT. Feeding electricity into the grid at times of high wholesale electricity prices incentivizes self-consumers to support the system in periods of peak demand.

If private households and small non-household consumers enter a contract with a USS, electricity supplied by consumers is sold at the day-ahead market price in the relevant hour, while in all other cases, free prices are applied to electricity supplied by an active consumer. The electricity purchase and sale agreement under the self-generation mechanism provides for mutual settlements between the electricity supplier or universal service provider and the active consumer in terms of hourly balancing of the cost of electricity supply to the electricity grid and the cost of electricity withdrawal from the electricity grid, taking into account the cost of electricity transmission and/or distribution services during the relevant billing period (month).

The electricity supplied and consumed is offset in the respective month, which results in the obligation of the consumer or supplier to make payment based on the offsetting results.

5.1.2 Active consumer

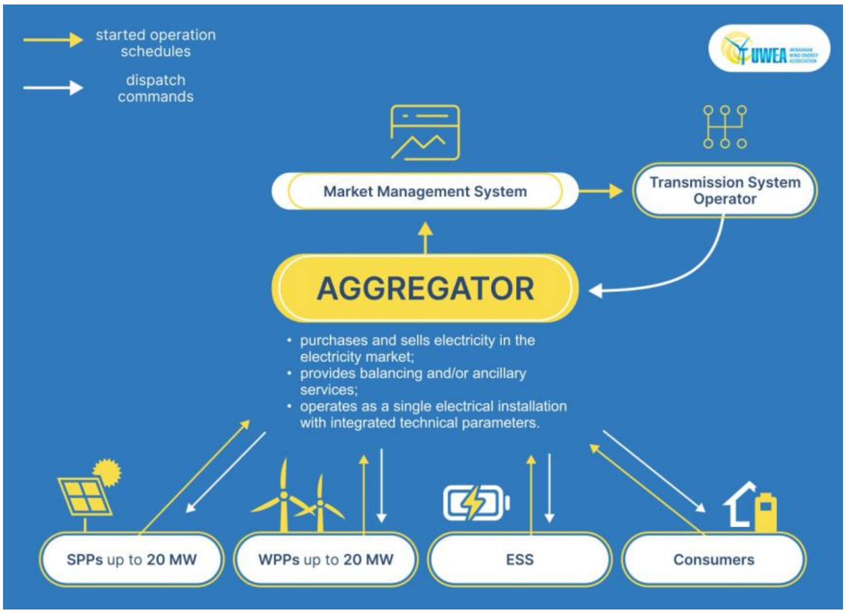
The Law No. 3220-IX introduces a new notion - an active consumer. The active consumer is a customer of an energy service that consumes and produces electricity, and/or carries out energy storage activities, and/or sells surplus produced and/or stored electricity, or participates in energy efficiency and demand management activities, provided that these activities are not professional and/or economic activities.

Notably, an active consumer with generating facilities of more than 1MW may lose this status for one year if the volume of electricity generated and supplied to the grid by its facilities exceeded 50 percent of its consumption in the previous year. The Regulator will determine the consequences of cancelling the status of active consumers.

5.1.3 Aggregation

By amending clause IV^2 of the Law of Ukraine on Electricity Market, Law No. 3220-IX introduces a new electricity market participant, the licensee — the aggregator and regulates a new type of market activity – aggregation, which is related to the association of electrical installations (with unit capacity less than 20 MW intended for production, consumption, and storage of electricity), operates in the electricity market as a single electrical installation. Aggregation activities are carried out based on an agreement on participation in an aggregated group essential terms of which shall be determined by the Market Rules.

Figure 0-2 Aggregation activities under the Law No. 3220-IX



5.2 Improving the functioning of the electricity market

Law No. 3220-IX contains provisions aimed at improving the functioning of the electricity market. Thus, the Law has been supplemented with exceptions to the direct line regulation. From now on, RES electricity producers may supply electricity to their enterprises located on the same land plot as the electricity generating facility and to the facilities of other owners located on adjacent land plots, provided that the connection is organized and the necessary metering is performed. In this case, the line connecting the producer and the consumer is not considered a direct line, i.e. it does not require the Regulator’s approval for its construction and operation.

The distribution of electricity by small distribution systems is recognized as a licensed activity. In addition, the Law regulates the procedure for the creation and use of small distribution systems within industrial parks during their construction and operation.

The definition of an energy cooperative is harmonized with the terms of the Law of Ukraine “On Cooperation” and the Law of Ukraine “On Consumer Cooperation”, making it possible to establish cooperatives for the production, procurement, transportation, or storage of fuel and energy resources to meet such a cooperative’s energy demands.

5.3 Developing energy storage legislation

Energy storage is an important component of the energy system, as it provides an increase in its flexibility, and therefore, allows integrating more RES generation into the energy system.

Energy storage technology is especially relevant to the proposed development of Mykolaiv City given the growth of “green” energy capacities, which could lead to a significant imbalance in the power system.

The legislative changes allowing the functioning of the energy storage facilities came into effect on 16 July 2022. The Law of Ukraine “On Amendments to Certain Laws of Ukraine on the Development of Energy Storage Facilities” No. 2046-IX provides for amendments to the Laws of Ukraine “On the National Energy and Utilities Regulatory Commission” and “On the Electricity Market” and has adopted a wide definition of energy storage activities which include, among other things, activities related to the operation of energy storages and the reconversion by energy storages to electricity to consume such electricity or store and transmit such electricity to the grid.

If the installed capacity of energy storage does not exceed the one stipulated in the license and separate commercial electricity metering for the energy storage facility is established (conditions for RES electricity production and operating of energy storage facilities), the installation of such a facility is not a basis for reviewing the established feed-in tariff.

By its Resolution No. 798 dated 22.07.2022, the NEURC approved the licensing conditions for conducting economic activities in energy storage. Since July 2022, the NEURC supplemented the Transmission System Code and Distribution System Code with regulations applicable to energy storage facilities. These include the procedure for connecting the energy storage facility to the grid, requirements to contracts applicable to the facility, a mechanism for calculating the distribution services fee, peculiarities of distribution system operators owning, using, and managing the facilities, etc.

5.4 Required changes in the legal and regulatory framework to untap the wind and solar potential

By harnessing the power of the sun, cities can reduce their carbon footprint, improve air quality, and improve the quality of life for their residents by creating a more sustainable and liveable environment for them. To accelerate the deployment of sun technologies in Ukraine’s cities, more strict RES requirements by imposing, for example, specific obligations on using PV and/or thermal solar systems in new residential buildings should be introduced in Ukraine.

Law No. 3220-IX stipulates, that the Cabinet of Ministers of Ukraine shall additionally stimulate the installation of RES electricity generating system and/or energy storage (with a total capacity of up to 10 kW) by private households through the State Target Economic Program for Stimulating the Deployment of Small Distributed Generation from RES (the State Targeted Economic Program). The development and control over the implementation of the relevant State Targeted Economic Program is carried out by the Ministry of Energy of Ukraine.

According to Law No. 3220-IX, the State Targeted Economic Program may provide for measures aimed at reimbursing some percentages of the loan amount or refunding some bank interests for the purchase and installation of a RES electricity generating facility and/or an energy storage facility by private households.

So far, it’s unclear when the State Targeted Economic Program will be developed and approved. We consider that its soonest drafting and approval will speed up the deployment of distributed power generation.

In addition, the State Targeted Economic Program should be expanded to also cover the installation of generating facilities that produce electricity from RES and/or energy storages at critical infrastructure facilities (centralized water supply, sewage, heat supply systems; medical facilities, and critical consumers of apartment buildings).

From a short-term perspective, the direct effect of the program is a functioning critical infrastructure in terms of emergency/hourly outage schedules and decentralized generation, which is technically difficult and economically inexpedient to disable with missile and drone attacks.

From the medium perspective, implementation of the State Targeted Economic Program will result in the installation of small-scale renewable energy facilities by municipal institutions to cover their basic needs. Co-benefits include: the development of own equipment production; reduction of the financial burden on state and municipal property for electricity consumption, replacement of fossil fuel generators, and reduction of carbon emissions.