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Mykolaiv

Assistance to the Development of the Mykolaiv Masterplan

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

Final

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COWI

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List of Abbreviations

CfD	Contract for Difference
CMU	Cabinet of Ministries of Ukraine
CPPA	Corporate Power Purchase Agreement
DH	District Heating
FIT	Feed-in Tariff
GO	Guarantee of Origin
GB	Guaranteed Buyer
HAWT	Horizontal-axis Wind Turbine
IRE of NASU	Institute of Renewable Energy of the National Academy of Sciences of Ukraine
Minenergo	Ministry of Energy of Ukraine
MCHPP	Mykolaiv Combined Heat and Power Plant, Private Joint Stock Company
MOTE	Mykolaivoblteploenergo, a Municipally Owned Heat Supply Company
R&D	Research and Development
RES	Renewable Energy Sources
VAWT	Vertical-axis Wind Turbine
WT	Wind Turbine

1 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). The project, which has been entrusted to COWI, is a framework contract, which, among others, includes assistance to the Mykolaiv City Administration (MCA) in developing the Mykolaiv Masterplan in close cooperation with an Italian company, One Works.

Box 1-1 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 wind power in Mykolaiv City and Mykolaiv Oblast in DH and power sectors, 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 wind power potential and opportunities for using wind power in urban environments. It should be noted that usage of wind technologies in the built environment is quite restricted due to the WT size, turbulent urban wind profiles, socio-environmental issues, etc. Nevertheless, this report aims to provide some possible "wind power-based" solutions for "greening" the power system of Mykolaiv City and improving the quality of life of its residents. With the development of technologies, there are more and more opportunities to use wind energy technologies in urban environments.

The report consists of 4 chapters in addition to the current, including:

Chapter 2 examines wind power technologies for DH and power sectors focusing on those suitable for urban environments.

Chapter 3 provides an overview of wind 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.

2 Wind power technologies for DH and power sectors for urban environments. Challenges and advantages

The global wind power industry has been experiencing a huge boom over the last decade. Climate change issues drive the transformation from a fossil fuel-based economy to a sustainable clean economy with RES at the core. Russia's full-scale invasion of Ukraine made many governments increase their RES targets and improve development plans amid spiking fossil fuel prices and security concerns about relying on fossil fuel imports. Wind technologies are one of the main tools in resolving the above-mentioned problems. Wind power drives reductions in emissions for other sectors, and is a reliable, already-proven instrument to build clean power more quickly.

In the now more than 40 years of modern wind turbine history, not only have installations grown exponentially, but the technology has also progressed enormously. Twenty years ago, turbines with a rated capacity of 1 MW were common; today, the largest wind turbines are in the range of 5-6 MW.

In 2021, the largest wind turbine in the world was Vestas V236-15.0 MW with a unit capacity of 15 MW.

In 2023, the world's largest wind turbine with a unit capacity of 18 MW was manufactured by CSSC Haizhuang for the Dongying City Offshore Wind Power Industrial Park in Shandong Province, China.

Despite the accelerated deployment of utility-scale onshore and offshore wind worldwide, application of the urban-designed wind turbine models is not so common. With the emergence of innovative turbine designs, the ability to harness wind power in the built environment is progressing, yet urban wind deployment in actual practice remains marginal and rare.

The main barriers to the implementation of wind technologies in city conditions can be grouped as follows:

- Technological barriers: lack of wind turbine models with efficient operation in a typical urban environment.

- Specific climate conditions not favorable for wind technologies: low wind speeds and high turbulence. The variability and unpredictability of the wind conditions is one of the main challenges of using wind turbines in urban settings. Buildings, streets, and other structures create turbulence and changes in wind speed and direction that can reduce the efficiency and reliability of wind turbines.

- Socio-environmental barriers include visual and noise impacts, and to some extent vibrations in buildings, therefore quite a little social acceptance. Noise and vibration can affect the comfort and health of the residents and workers in the vicinity of the wind turbines, as well as the acoustic quality of the urban space. Therefore, noise and vibration mitigation measures are essential for ensuring the acceptability and compatibility of wind turbines in cities. WTs can have a significant visual impact on the skyline, the streetscape, and the identity of the city. They can also create shadows, reflections, and flickering effects that can interfere with the natural light and views of the buildings and spaces. Therefore, the shape, size, colour, and placement of the wind turbines need to be carefully considered and coordinated with the existing or planned urban fabric and character. Ornithological and chireptorological studies are required to understand the impact on birds and bats.

- Economic barriers: some implementations are quite expensive, while electricity output is quite low or poor.

Despite these challenges, using wind turbines in urban environments also offers some benefits and opportunities. Wind turbines can provide a clean and renewable source of energy thus reducing the dependence on fossil fuels and saving greenhouse gas emissions. The implementation of wind turbine technologies in city areas eliminates the need to expand the high-voltage electricity network to provide electricity for consumers located in the city area. They can also create a visual and symbolic expression of sustainability and innovation that can enhance the image and attractiveness of the city.

Though some efforts have been made in the last few decades to explore wind energy and improve wind energy application technologies to optimize performance and increase electricity generation in turbulent urban wind profiles, the use of wind turbines in urban environments is mainly in the research and development phase.

Until now, two main approaches to using WTs in urban environments include either locating a wind farm in the town outskirts or a specially allocated territory like an innovation industrial park or integrating WTs into the building design. It should be noted that the deployment of smaller-scale wind farms or just a few wind turbines in suburban areas prevails nowadays, particularly in wind-abundant regions.

2.1 VAWTs vs HAWTs in built-up areas

In general, there are two types of wind turbines: horizontal-axis wind turbines and vertical-axis wind turbines. Both are presented in Figure 2-1.

VAWTs are considered to be better suited in built-up areas than the HAWT as VAWTs are relatively quieter than HAWT and operate efficiently in urban environments with variable wind directions.

The vertical design of VAWTs allows for easy installation in various locations. VAWTs are compact and take up less space compared to horizontal axis turbines. Due to their vertical design, VAWTs can be placed closer together, maximizing the use of limited spaces thus making them ideal for urban environments, where space is limited and highly valued. Due to their more appealing designs, their social acceptance is higher compared to HAWTs. The main disadvantage of this technology is that VAWTs tend to stop operating under gusty conditions.

Figure 2-1 Types of wind turbines

Vertical-axis wind turbine *Horizontal-axis wind turbine*

The average rated capacity of a vertical-axis wind turbine is around 7 kW.

VAWTs show better results on rooftops than in open fields. The efficiency of HAWT decreases rapidly with the increasing turbulence of the wind which is common for urban environments.

VAWTs are suitable for both residential and commercial applications. The rapid growth of electric vehicles calls for a robust charging infrastructure. VAWTs can be integrated into charging stations, providing a renewable source of energy to power EVs. Integrating wind power into public transportation systems reduces the reliance on fossil fuels and promotes sustainable urban mobility.

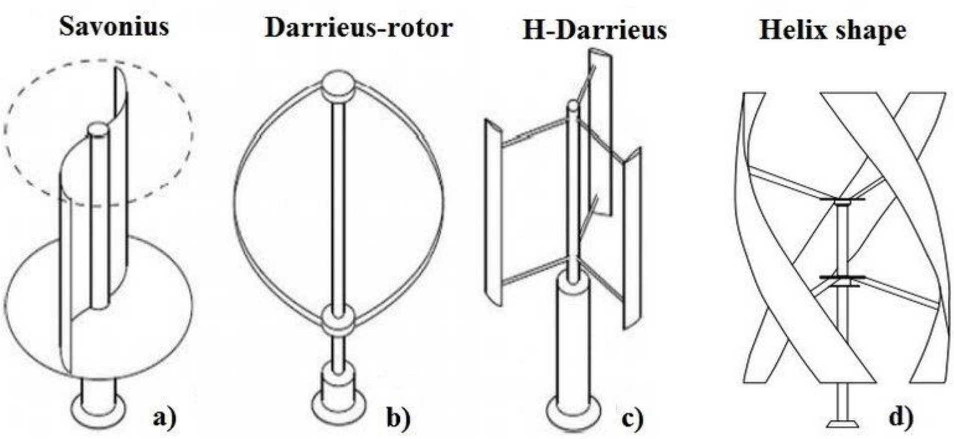
Table 2-1 compares the performance of VAWTs and HAWTs in urban environments.

Table 2-1 Comparison of VAWT and HAWT models for urban utilisation

VAWT	HAWT
technology is still quite new with design development in progress	matured technology, receives much more R&D.
can operate in variable wind directions	must face wind
easy installation in various locations	require proper location
more efficient in built-in areas	less effective within cities as compared to open areas
compact and take up less space	require more space
relatively quiet	noisy
sometimes more vibration	create vibration
tend to stop operating under gusty conditions	less appealing design compared to VAWT

The most well-known vertical-axis technologies are the Savonius and Darrieus turbines. The Savonius turbine appears to be well suited for urban applications, as it has a simple microturbine design and works with relatively low start-up wind speeds. The rotor of Darrieus WTs can assume different configurations, such as “egg beater”, H-shape, or helical shape. The Darrieus turbine is well suited for rooftop installations as it has low noise and vision disturbance.

Figure 2-2 Different kinds of VAWT: a) Savonius; b) Darrieus with "egg beater" design rotor; c) Darrieus with H-shape blades; d) Darrieus with Helis shape blades, ResearchGate[1]



The following sections of the report brief on WTs' main applications in urban environments.

2.2 WT integrated with building

Such applications of HAWT are intended mainly for skyscrapers. They can be placed in the corners of the facades of the buildings or between building blocks. The first building with three WTs integrated into the architectural design of the building was the Bahrain World Trade Center, which was completed in 2008. Three HAWTs with a diameter of 29 m were integrated with the building taking advantage of the narrow pipe effect between the two branch buildings to provide up to 35% of the electricity required by the BWTC[2].

Figure 2-3 Bahrain World Trade Center, Wikipedia

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1 *https://www.researchgate.net/figure/Different-kinds-of-vertical-axis-wind-turbines-VAWT-a-Savonius-b-Darrieus-with_fig1_333316757*

2 *Study on the operation of small rooftop wind turbines and its effect on the wind environment in blocks, https://www.sciencedirect.com/science/article/abs/pii/S0960148121016438*

WTs integrated with buildings are placed on the highest building in the area, usually with skyscrapers. Integration of WTs into skyscrapers gives a possibility to reach the layers of high wind speed without turbulence, which means having the more efficient operation of WT and higher electricity generation compared to the other WTs designed for urban environments. In such case, there is no need for a tower, since the building "acts as a tower" itself, plus the aerodynamic structure of the building can direct and concentrate the wind towards the turbine. These WTs not only give a building a modern design and make the WT less visible, i.e. solving negative visual impact, but having on-site generation reduces losses that are linked to transmitting electricity for a long distance.

One of the main disadvantages of such WT implementation is its quite high cost. Moreover, the use of WTs integrated with buildings in Mykolaiv City seems to be unrealistic from short-term and medium-term perspectives, first of all from a cultural viewpoint. So far, there are no skyscrapers in the city, and their construction is not expected in the short and medium terms perspectives.

2.3 Rooftop WTs

In recent years, there has been a growing interest in the use of rooftop WTs for distributed generation. Rooftop WT is a typical example of urban wind power. However, knowledge gaps still exist in the understanding of the wind resources of an urban district. Generally, the rooftop wind turbines are referred to as mini- or micro-turbines with small rotor diameters of less than 5–10 m and rated capacities below 50 kW. It's typically cheaper to install a roof-mounted turbine than a standalone one, although their small size means "they are less powerful". They normally generate around 1–2 kWh of electricity. The advantages and disadvantages of the rooftop WT models are presented in Table 2-2.

Table 2-2 Pros and Cons of Rooftop WT

Pros	Cons
Do not require any special modification to the building. Such WT can be installed on existing or newly built buildings	Not all turbines are suitable for all types of roofs. Depending on the roofing material, turbine vibrations can cause fatigue
Self-generation reduces losses caused by electricity transmission for a long distance	Low electricity output
Self-consumption: The energy generated is consumed directly at the installation site	
The typical background noise of cities covers most noise emissions from turbines.	Could be quite noisy
Affordable for individuals and small business	

Such environment-friendly and cost-effective small rooftop wind turbines are ideal for lighting, small telecommunication centers, and mobile homes.

2.4 Free-standing WT

Unlike the previous models, these types of WT act as an autonomous system. Figure 2-4 shows a hybrid wind–solar system coupled to a streetlight. Such a hybrid wind-solar system is very popular nowadays and could be easily implemented in Mykolaiv City in the short-term perspective (up to 2030).

Figure 2-4 Hybrid wind-solar light system

Such a system integrates a battery to store energy. The system's "potential" is pretty clear; solar and wind work well in a complementary fashion. Solar only generates during the sunniest hours, wind can be 24 hours, but it is dependent on conditions. The great advantage of such a system is its grid "independence": if there is grid interruption, the lighting of the area is not affected. The positioning of WT depends on the wind conditions (not on buildings, as it is independent of buildings).

2.5 MW-class WT

implemented in the surroundings of technical institutions or on the territory of an innovative industrial park. As a proposed According to the Invest Passport of Mykolaiv District for 2021 (available at official website of Mykolaiv District State Administration) an innovative industrial park was planned for Mykolaiv City. A wind project consisting of 1-3 MW-class WTs (the number of WTs depends on the unit capacity and expected electricity consumption) can be installed on its territory and become part of its "green" electricity supply solution.

From the medium perspective, another application for the MW-class wind project can be considered the Mykolaiv Sea Port.

As turbine performance depends on positioning and obstacles that can cause turbulence, future surrounding buildings have to be part of the installation project.

To increase electricity output and energy security a hybrid wind-solar system backed up with energy storage is recommended for projects that are not connected to the grid.

At the same time noise and vibrations can cause social non-acceptance. Therefore, it's recommended to conduct measures aimed at engaging the local community at the early stage of the project implementation. It's also should be noted that wind speed in the city is lower than in rural areas, and thus, the wind turbine performance will become lower.

2.6 Wind farms for community

With the emergence of innovative turbine designs, the ability to harness wind power in the built environment is progressing fast. The deployment of smaller-scale wind farms or just a few wind turbines in peri-urban areas is growing, particularly in wind-abundant regions. By generating electricity closer to where it is consumed, wind farms reduce transmission losses and increase overall system efficiency. It allows communities, businesses, and institutions to have greater control over their energy supply.

Community wind projects are getting more and more popular nowadays. While most wind power projects are owned by companies with limited local ties, community wind projects are owned by the local community. Since wind energy requires minimum amounts of water, community wind energy can become part of the solution when examining energy production and potential water savings.

Usually, a community wind project comprises one to three wind turbines with a unit capacity of around 2 MW depending on the community population and electricity consumption. Community wind projects generally operate on a smaller scale than utility-scale wind farms, so they may not require transmission upgrades. Most community wind projects can be easily connected to the distribution grid or just to consumers. In places where no transmission lines exist or where no distribution lines can be used, a dedicated line could be economically justified to connect the wind farm with consumers, given the limited transmission distance.

Community wind projects have multiple applications and can be used by schools, hospitals, businesses, farms, or community facilities to supply local electricity. They enhance the community’s grid resilience and help in reducing the risk of widespread power outages. Localized energy sources can continue to operate during disruptions, ensuring reliable electricity supply to critical infrastructure, emergency services, and residential areas.

3 Wind power potential

Mykolaiv is situated in southern Ukraine, near 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. Coastal areas boast sandy beaches and the region's geography is characterized by agricultural activities, including grain farming and viticulture. Due to the relatively flat land and the proximity to the Black Sea coast the wind potential can be expected to be high.

The climate of the Mykolaiv Oblast and Mykolaiv City is temperate continental, characterized by dry hot summers and moderately cold winters with unstable snow covers influenced by the maritime climate of the Black Sea.

3.1 Average annual air temperature

The average annual air temperature in Mykolaiv City 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.

The average temperature of the warmest month in Mykolaiv City is +24.6°C with an absolute maximum of +40.1°C. In general, in Mykolaiv City, 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 City 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 first decade of March with an average daily high temperature below 6.5°C. The coldest month of the year in Mykolaiv City is January, with an average low of -6°C and a high of 1.1°C.

3.2 Wind direction

The wind regime of the territory is characterised by wind direction and speed. The wind direction depends on the relative position of high- and low-pressure areas, and the speed depends on the difference in atmospheric pressure between the interacting areas.

According to the Atlas of the Energy Potential of Renewable Energy Sources in Ukraine by IRE of NASU (developed in 2020), west winds are prevalent in the western, central, and northern regions of Ukraine, while east and north winds are prevalent in the eastern and southern regions and the Autonomous Republic of Crimea (Figure 3-1).

The peculiarity of atmospheric circulation in the Mykolaiv oblast is the stable position of the Siberian anticyclone spur in the cold half of the year, which causes the predominance of winds from the north and east. Based on the average annual data of long-term observations at the Mykolaiv meteorological station, north wind with a frequency of 20.2 % out of the total, prevails in the areas around Mykolaiv city (Table 3-1Table 3-1 Main Wind Directions).

At the same time, it should be noted that observations were made at the height of 10 m which is insufficient for assessing wind potential but still gives a general understanding of the existing wind patterns in the region.

Figure 3-1 Wind directions prevail in Ukraine

Table 3-1 Main Wind Directions

Wind Direction	Wind frequency as a percentage of the total, %
North	20.2
North East	15.7
East	15.2
South East	7.1
South	11.4
South West	8.2
West	9.8
North West	12.4

3.3 Wind speed

Wind speed depends on the difference in atmospheric pressure between the interacting areas.

In Mykolaiv Oblast strong winds (15 m/s and more) are observed throughout the year, but more often in the winter and transitional seasons, when winds increase due to the emergence of large baric gradients.

In summer, winds increase due to the passage of cold fronts and intense thunderstorm activity and are of a short-term squally nature. Often, winds are accompanied by July rains, thunderstorms, hail, dust storms, and blizzards.

The results of the wind measurement campaigns conducted in the Mykolaiv oblast by several companies engaged in implementing wind projects in the region support the initial assumption that the wind potential in the region is high. Based on several studies conducted, for example, on behalf of the company “Wind Parks of Ukraine,” the average long-term wind speed at 120 m above ground was found between 6,9 – 7,7 m/s, resulting in full load hours of 3800 – 4200 h per year depending on the turbine type and specific site.

The map of the average wind speed developed from Global Wind Atlas (a product of a partnership between the Department of Wind Energy at the Technical University of Denmark (DTU Wind Energy) and the World Bank Group) shows an average wind speed of 6.35 m/s at the height of 100 m in the area around Mykolaiv City (Figure 3-2), while mean energy density amounts to 240 w/m2 (Figure 3-3). But for sure, it’s just approximate figures, it’s necessary to assess wind potential for each concrete site/project.

Figure 3-2 Map of the average wind speed in Mykolaiv oblast, Global Wind Atlas

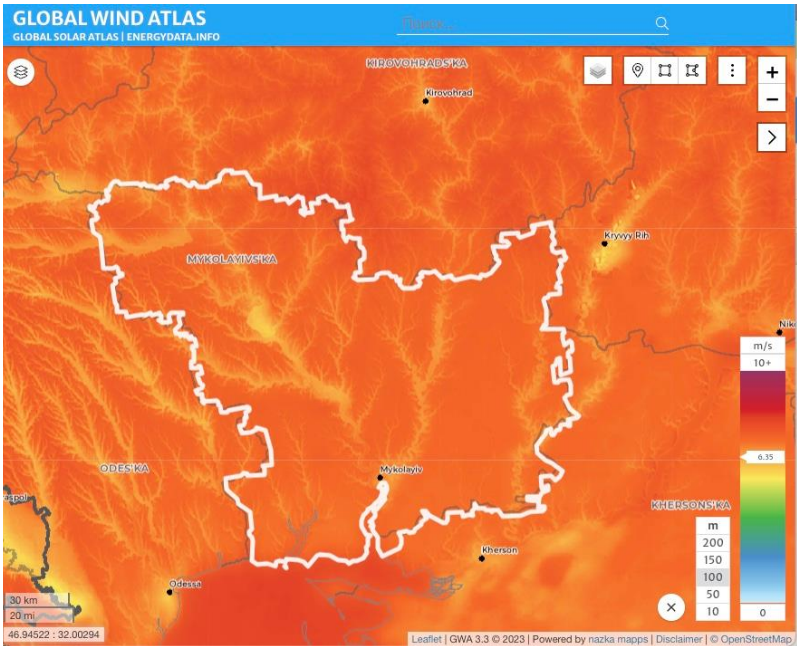
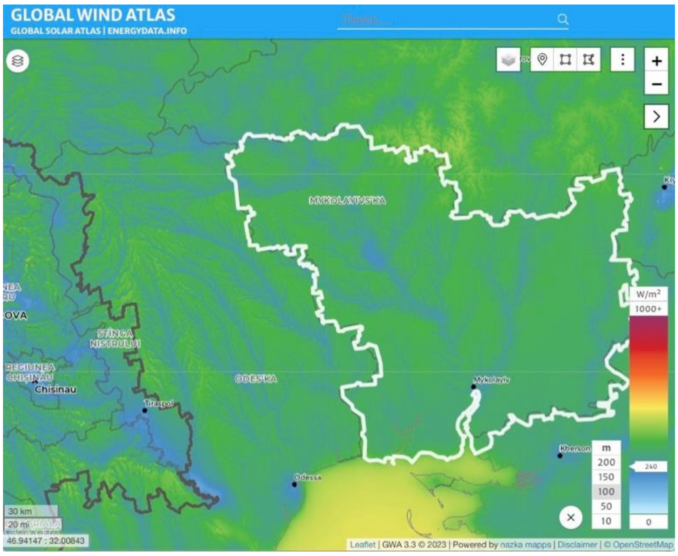


Figure 3-3 Map of the mean energy density in Mykolaiv oblast, Global Wind Atlas



3.4 Wind power generation potential in Mykolaiv Oblast

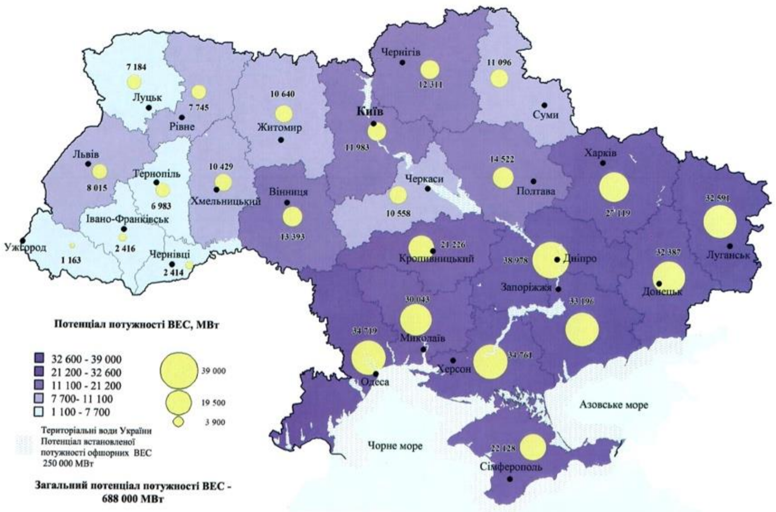
GEO-NET Umweltconsluting GmbH (hereinafter GEO-NET), the UWEA member company, has been working as a consultant for wind energy projects in Ukraine since 2008 and has conducted more than 200 studies, assessments, and wind measurement campaigns across Ukraine for local and international clients and investors including accredited wind measurement campaigns and energy yield assessments for more than 10 planned wind farm sites in Mykolaiv oblast.

The assessed wind farm sites are largely distributed across the region. Some of them are located near the Dnieper River on farmland as well as along the Black Sea coast. All work has been carried out in accordance with the state-of-the-art and international standards IEC61400-50-1 and MEASNET and includes wind conditions determined for each turbine site at hub height for a 20-year average. Because of GEO-NET's extensive experience and expertise in assessing wind potential for different wind sites located in Mykolaiv oblast, for this report, we refer to GEO-NET's assessment of wind power generation potential in Mykolaiv oblast. Based on several studies conducted by GEO-NET on behalf of MC “Wind parks of Ukraine” LLC the average long-term wind speed in 120m above ground ranges between 6.9 – 7.7 m/s, resulting in full load hours of 3800 – 4200h per year depending on the turbine type and specific site.

The potential energy yield can even be increased by using modern turbine technology with larger rotor diameters and greater hub heights of more than 120m. The open and sparsely populated areas outside the city support the planning and operation of wind farms. To give a rough estimate based on the existing data, a planned wind farm with 200 WTs of each 5 MW, which is 1GW installed capacity, an annual energy yield of 3.9 GWh could be produced in the region. As the area is sparsely populated and the existing agricultural areas in no way exclude their use as wind potential areas from a technical point of view, even larger wind farms or several wind farms of that size seem feasible.

According to the assessments made by the IRE of NASU, the potential of wind farms that could be installed in the Mykolaiv Oblast exceeds 30,000 MW (Figure 3-4).

Figure 3-4 Map of the wind farm potential per region of Ukraine, Atlas of the Energy Potential of Renewable Energy Sources in Ukraine by IRE of NASU



As of October 2023, 70 wind turbines with nameplate capacities ranging between 2,5 MW and 6 MW totaling 275.7 MW operate in Mykolaiv Oblast.

4 Possible investment projects to untap the potential

This chapter presents several wind projects to be implemented in Mykolaiv City or its suburbs / the territory of the neighbouring community. Due to the martial law currently introduced in Ukraine, it's not possible to get detailed information on power infrastructure objects, locations, etc, therefore only model projects are presented that in the future could be tied to the exact location.

The projects provide for installing wind turbines of different unit capacities depending on the application, wind conditions, and financing. Understanding the energy usage and the associated costs is essential in determining the turbine size needed for a wind project.

In combination with energy storage, it can be used as an autonomous /backup source of electricity.

The wind turbine alone or in combination with the solar system will reduce electricity consumption from the grid (reduce electricity bills) and strengthen electricity supply/independence (backup system). It will also reduce fossil fuel consumption, "green" production, and save CO2 emissions.

The wind installation can operate:

- as an additional source of electricity as part of a separate power grid
- as an additional source of electricity in the general industrial network (synchronized with the network)
- as a source of electricity for specific needs – heating and/or hot water supply

The wind project implementation stages:

- Determination of the purpose/application (stand-alone system, reduced consumption, self-generation, uninterrupted operation)
- Determination of consumption structure (electricity, heating, etc)
- Determination of wind potential
- Assessment of compliance of the selected site with the environmental standards of Ukraine (setback, noise, shadow flicker, ornithology, etc)
- Determination of required generation capacity/output
- Determination of wind equipment / WT
- Ordering equipment
- Foundation construction
- WT installation
- System setting

All the prices are as of the end of 2022, 2023. Delivery costs, VAT, and overhead costs are excluded.

4.1 Model project 800 W (VAWT)

Such type of project provides for installing an 800 W wind turbine (VAWT) of Ukrainian production.

Estimated electricity generation – around 2.5 – 8.0 kWh per day (depending on wind conditions)

Application: top roof installation for electricity supply

Expected timeline: up to 45 days

Estimated investment cost (CAPEX): EUR 3 860.00, where:

- WT cost – EUR 2 970.00 (including 2 kW controller, cables and mast)
- Construction cost - EUR 890.00

4.2 Model project 800 W (HAWT)

Such type of project provides for installing an 800 W wind turbine (HAWT) of Ukrainian production.

Estimated electricity generation – around 250 kWh per month (depending on wind conditions)

Application: stand-alone installation for private households

Expected timeline: up to 45 days

Estimated investment cost (CAPEX): EUR 7 480.00:

- WT cost – EUR 6 390.00 (including 17 m mast, 2.4 kW inventor, 2.4 kW storage battery)
- Construction cost EUR 1100.00

4.3 Model project 45-50 kW Wind Turbine

Such type of project provides for installing a 45-50 kW wind turbine (HAWT), HH 40m of Ukrainian origin.

Estimated annual electricity generation – around 145.000 kWh.

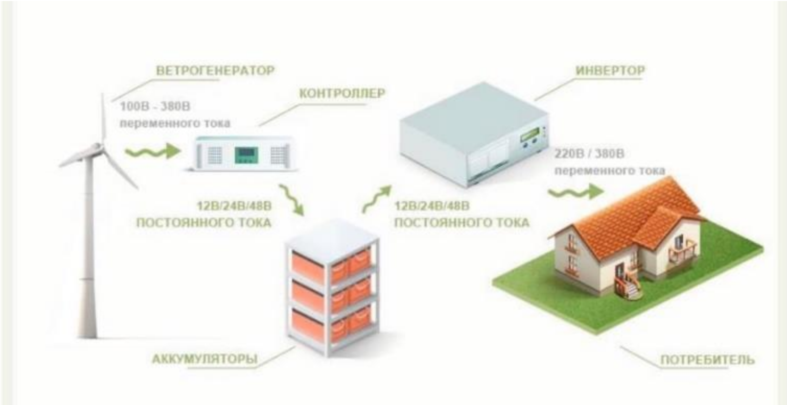
Application: production facility, community municipal facility, utility company (water supply/water treatment), farms

Expected timeline: 90 days

Estimated investment cost (CAPEX): EUR150 000.00:

- WT cost (including 40 m mast, 50 kWh accumulator, cables, 50 kW off-grid inverter, etc) – EUR 120 000.00
- Construction cost - EUR 30 000.00

Figure 4-1 Project scheme



4.4 Model project 2.0-2,5 MW renovated wind turbine

Such type of project provides for installing 2.0 - 2,5 MW HAWT (renovated), HH around 100 m, in the territory of the community, production facility. A renovated wind turbine is proposed because of its unit capacity and lower price compared to a new one.

Estimated annual electricity generation – around 6.200 MWh (depending on HH and wind conditions)

Application: community, production facility

Expected timeline: 1 - 2 years (depending on WT availability, project documents drafting, and delivery)

Estimated investment cost (CAPEX): EUR 1.150 mln:

- WT cost – EUR 150 000.00 – 250 000.00 per MW
- Construction cost - EUR 200.000 per MW installed

4.5 Model project 4.0-5.0 MW Wind Turbine

Such type of project provides for installing a 4 MW - 5 MW wind turbine, HH 100m min (depending on on-site wind potential and wind manufacturer).

Estimated electricity generation – 12.260 MWh - 15. 330 MWh correspondingly

Application: innovative industrial park, Mykolaiv Sea port

Expected timeline: 2 years

Estimated investment cost (CAPEX): EUR 1.600 mln – 1.800 mln per MW installed:

WT cost – appr. EUR 1 mln per MW (WT cost is expected to reduce with reducing raw material/commodity costs)

Construction cost EUR 600 000.00 – 800 000.00 per MW (depending on logistics, site condition, etc.)

5 RES legal and regulatory framework

As described in Chapter 5 of the Report D06 Potential of Solar Energy Sources in the Power and District Heating Sectors, the destruction of the power system by russia's missile and drone attacks has unveiled an urgency for Ukraine to have a distributed generation: when the consumer is as close as possible to the energy source.

Understanding the urgency for improving renewable sector legislation and delivering the set target, 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.

This long-awaited law provides for comprehensive changes in the functioning of the electricity market. To stimulate the production of electricity from RES the law implements several European electricity market instruments such as market premium mechanism, Guarantees of origin, RES auctions based on CfD, and cPPA.

Chapter 5 of Report D06 Potential of Solar Energy Sources in the Power and District Heating Sectors gives an overview of the main provisions of the law. Nevertheless, the present chapter focuses on such mechanisms as the Guarantees of Origin, cPPA, and RES auctions as the main tools to promote wind development in the country.

5.1 Guarantees of Origin

It is worth noting that regulations for the issuance of guarantees of electricity origin were first introduced in Ukraine in 2013. The Law of Ukraine "On Alternative Energy Sources" and the CMU Resolution No. 771 dated 24 July 2013 already approved the procedure for issuance, usage, and termination of GOs, but the issuance and circulation of GOs has never taken place in the country. Moreover, on 8 November 2023, the CMU published for public discussion drafts of the Procedure for issuing, circulating, and redeeming GOs and the Procedure for determining the environmental value of electricity produced from renewable energy sources, and canceled its Resolution No.771 from 24 July 2013.

Therefore, Law No. 3220-IX introduces a new notion of the GO as an electronic document automatically generated based on information from the register of GOs. The GO confirms that a certain amount of electricity is produced from RES and its environmental value. It also certifies the rights related to the positive effect of electricity production from RES.

GO confirms the origin of electricity from RES produced by:

- a business entity that generates electricity from RES,
- a consumer who has installed a generating facility for their consumption, or
- an active consumer.

GOs are issued free of charge. The Government shall approve the procedure for issuing, circulating, and canceling GOs based on NEURC proposals. As mentioned earlier, the required draft procedure has been already published for public comments. Its approval is expected still in December 2023.

The NEURC is an authorised body for the issuance, circulation, and cancellation of GOs, which also ensures the functioning of the register, in which GOs are generated automatically based on commercial metering data. The Regulator forms and maintains a Register of Electricity Facilities and Electrical Installations of Consumers (including active consumers) using RES for electricity generation in accordance with the Procedure to be approved by the Regulator. This register is a part of the Register of GOs.

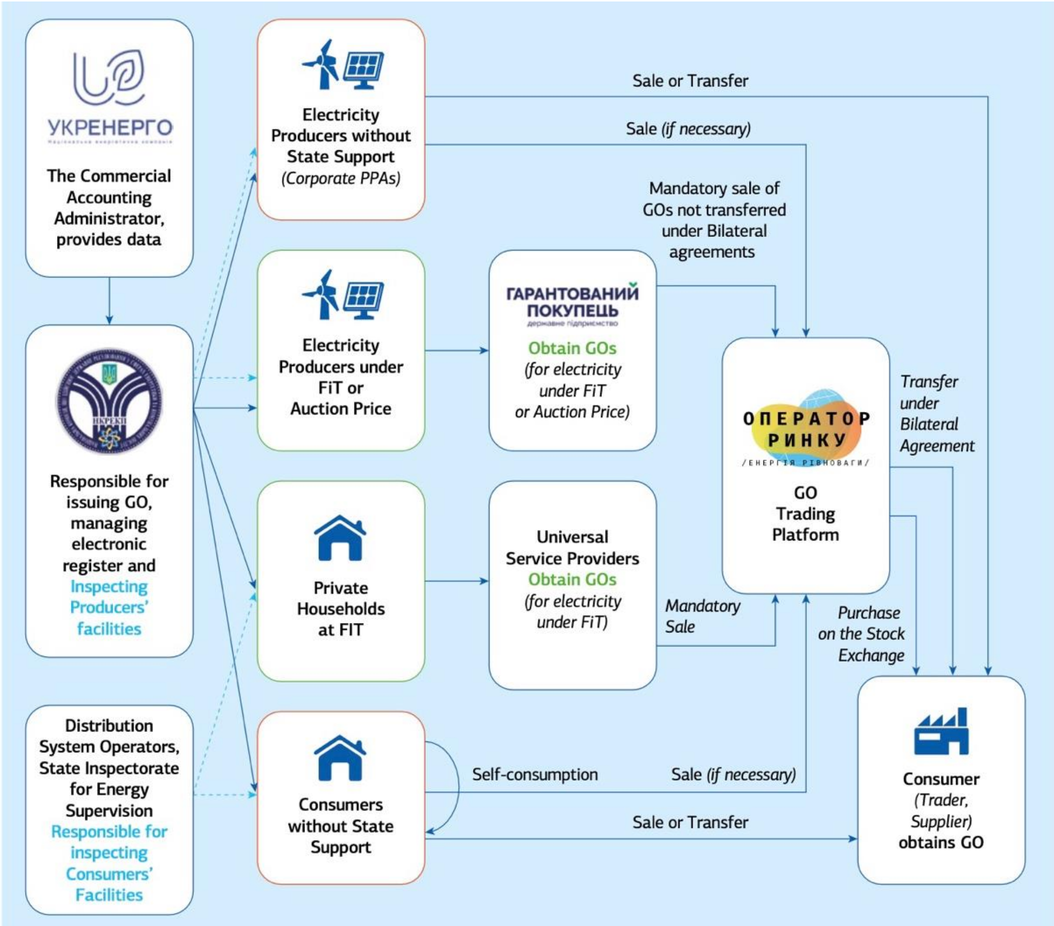
GO is issued for the volume of 1 MWh of electricity supplied to the grid or produced and used for its consumption and shall be valid for 12 months from the date of generation of the respective volume of electricity. At the same time, the holder of GO has the right to cancel it within 18 months from the production date of the relevant volume of electricity, or GO automatically expires after this period.

NEURC verifies the accuracy of data provided to the Register of GOs. If the inspection reveals that electricity is not produced from renewable sources, the Law provides for cancellation of registration of the relevant RES generating facility or installation for obtaining guarantees of origin for 6/12/36 months, depending on the amount of electricity that was not produced from RES as established by the inspection.

The purchase and sale of GOs are carried out on a market basis at free prices. The Law allows for the circulation of GOs at electronic auctions of trading platforms, and relevant amendments were made to the Law of Ukraine “On Commodity Exchanges”, which allows for the organisation of trade on commodity exchanges not only in fuel and energy resources but also in their attributions.

The Law establishes the competence of the Market Operator to approve the rules for the sale of GOs on its platform, ensure the operation of such a trading platform, and set the price of services for organising trading in GOs on its trading platform. Figure 5-1 visualizes the GO mechanism introduced in Ukraine by Law No. 3220-IX.

Figure 5-1 GO mechanism available now in Ukraine, Minenergo, and UWEA



A consumer who owns a GO shall have the right to alienate it and use it to confirm that the relevant amount of electricity consumed for its own needs is generated from RES. The GO certifies its holder's rights to the environmental value and positive effect of electricity production from RES.

The Law defines ensuring integration of the Register of GOs with the registers of the Energy Community, the EU, and the Organisation for Economic Cooperation and Development, as well as facilitating Ukraine's full membership in the Association of Issuing Bodies (AIB) among the main tasks of the NEURC in the electricity market. At the same time, if NEURC does not recognise a GO issued by a Contracting Party to the Energy Community, it shall notify the Energy Community Secretariat.

In general, we expect that the Guarantee of Origin of electricity from RES will:

- make consumers interested in purchasing "green" electricity thus stimulating the implementation of new RES projects under market conditions;
- reduce exporters' CBAM fees for future exports of goods to the EU (to leave funds inside Ukraine).

5.2 Corporate PPAs

Amendments to the Law of Ukraine "On Alternative Energy Sources" introduced by the Law of Ukraine No. 3220-IX, provide an opportunity for the RES electricity producers (who have left the balancing group of the GB) to enter into a service agreement to ensure the stability of the price of electricity generated from RES (cPPAs) with consumers, electricity suppliers or traders. To be eligible for corporate PPAs, RES producers should not sell electricity at the FIT or under the market premium mechanism. The parties to the service agreement to ensure the stability of RES electricity prices shall determine themselves a validity term of the agreement, but not less than one year. The agreement may be concluded at any time before the commencement of construction and/or commissioning of the relative facility.

5.3 Amendments to the RES auction system

It should be noted that the "green" auctions were introduced in Ukraine in 2019, but no green auction has been ever held due to the CMU's failure to set quotas. The UWEA considers the amendments to RES auction regulation as the most controversial. On the one hand, Law No. 3220-IX simplifies the procedure for participating in the auction, on the other hand, it reduces the term of support provided from an initial 20 years to 12 years. In addition, the authority may set a share of the auction price to be fixed for the winner of the auction in the Ukrainian currency i.e. hryvnias.

One of the main changes related to the RES auction procedure introduced by Law No. 3022-IX is establishing security of purchasing services under the market premium mechanisms, instead of securing the purchase of electricity. Therefore, an auction winner shall conclude the agreement on the provision of service under the market premium mechanism. Initially, the winner was supposed to conclude PPA based on the auction results.

At the same time, Law No. 3220-IX expands the list of additional conditions for setting quotas. Thus, within the framework of the annual or additional annual support quota, the CMU may additionally determine i) the technical parameters (characteristics) of energy storage facilities to be installed at the electricity facility; ii) the daily time intervals during which an entity may become eligible for support based on the auction results; iii) the load profiles of the electricity facility in respect of which the right to support at auction may be acquired.

Law No. 3220-IX shortens the list of documents to be submitted for participation in the auction and postpones the date for submitting documents confirming the ownership/ permit for land use and the grid connection agreement. From now on, the investor should provide these documents not for participating in the auction, i.e., before it is held, but rather within 6 months from the date of the contract conclusion based on the auction results.

For solar generation, the period for construction and commissioning of an electricity facility has been reduced from 2 years to 18 months from the date of the conclusion of the auction-based service agreement under the market premium mechanism.

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

The development of renewables is impossible without investments. What policies can build investor confidence in Ukraine's energy sector, especially when political risk and economic devastation will likely remain challenges for the foreseeable future What changes are required in legal and regulatory frameworks to untap wind potential?

Firstly, a comprehensive state energy policy with renewables deployment prioritization should be adopted. But, it means not only drafting and adopting the necessary strategic document which contains the single national program on the whole power sector development including renewables, but ensuring the implementation of this strategic document by all central executive power bodies, state-owned energy companies, local administrations, and other market participants. Like in the European Union, wind projects should be considered as projects of overriding public interest.

Establishing a state insurance fund to secure financing for projects will reduce risks in attracting foreign capital.

We should optimize the use of power and road infrastructures. For example, enabling the connection of wind facilities to the distribution devices of thermal power plants that have been damaged and whose restoration is impractical, or joint use of already issued and implemented technical conditions.

Currently, Ukraine imports more than 90% of its wind turbines. Establishing a local manufactury of wind turbine components is one of the urgencies for Ukraine’s economy. With Ukraine’s manufacturing and intellectual potential and experienced workforce, Ukraine has all the possibilities to become a part of the European wind power supply chain.

The electricity market of Ukraine is to be fully liberalized and avoid cross-subsidy.

And last but not least, we need to simplify our permit procedures. We should remove as soon as possible the legislative barriers that create a lengthy and sometimes corrupt permitting procedure for wind and solar projects including land allocation, environmental impact assessment, connection to the power grid, and construction permits.

Ukraine has also a significant offshore wind resource. According to the World Bank assessment, Ukraine’s technical offshore wind potential for both fixed and floating offshore wind in the waters of the Black and the Azov seas amounts to 250 GW.

To fully harness offshore wind as an energy source, first of all, we should adopt an offshore wind strategy to define a clear, national role of offshore wind technology and set realistic, short-, medium--, and long-term goals and actions. However, the development of offshore wind farms in Ukraine will also require drafting and passing offshore legislation to remove several gaps we have now in our energy legislation plus the demining of our territorial waters.