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Renewable energy in Ukraine: Current institutional environment, investment barriers and prospects

GIZ-Project: Supporting Structural Change in Ukrainian Coal Regions

Work Package 1/C

REPORT

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Executive Summary

This report looks at the role of RES development in Ukraine's energy system in the context of Russia's war of aggression. The data we present shows that Ukraine is a country with significant energy resources that was already on a strong track in terms of RES development even before the war began. However, since the start of the war, Russia has destroyed or captured much of Ukraine's energy infrastructure, especially the large power plants. Much of the remaining energy capacity comes from RES installations because these tend to be distributed locally (e.g. rooftop solar panels) making them harder to target with missile strikes compared with centralised infrastructure.

We highlight several reasons for prioritising RES infrastructure when rebuilding Ukraine's energy system in the coming years. First, distributed RES infrastructure relieves pressure on the electricity grid which is vulnerable to the missile strikes and capture during times of war. Second, Ukraine has significant energy natural potential for the development RES technologies, for example due to its high levels of solar radiation. Third, RES infrastructure meets long-term commitments to the green transition and a sustainable future. Furthermore, using the TIMES model of Ukraine's energy system we show that RES-based reconstruction of the power system will result in the same total costs as the fossil fuel-based reconstruction, while providing much higher resilience and sustainability.

With these considerations in mind, we examine the existing regulatory framework and the availability of financing for RES development. We identify several legislative barriers to RES development and propose ways to overcome them. One of the most important barriers is the problem of obtaining technical conditions for grid connection, which requires a strengthening of the regulatory framework and a de-bureaucratisation of the connection process. We also examine the applicability to Ukraine of a number of policy best practices that have been used to promote RES development internationally, such as the overall market design, RES quotas and effective supervisory bodies. Finally, based on a survey of five communities in Ukraine, the report outlines the main non-legal obstacles to RES development and provides recommendations for overcoming them. In particular, it highlights the role of capacity building for local communities and the urgent need to streamline and expedite grid connection procedures to ensure smoother development and implementation of RES projects.

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CBAM	carbon border adjustment mechanism
CfD	contract for difference
CHP	combined heat and power unit
CMU	Cabinet of Ministers of Ukraine
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
ct	cent
EBRD	European Bank of Reconstruction and Development
ENTSO-E	European Network of Transmission System Operators for Electricity
EPC	engineering, procurement and construction
ESF	energy storage facility
ETS	emissions trading system
EU	European Union
EUR	Euro
FiP	feed-in premium
FiT	feed-in tariff
GHG	greenhouse gas
GoO	Guarantees of Origin
GW	gigawatt
GWh	gigawatt-hour
HH	household
HPP	hydroelectric power plant
IEA	International Energy Agency
IFC	International Finance Corporation
IFI	international financial institution

IPO	initial public offering
IRENA	International Renewable Energy Agency
kW	kilowatt
kWh	kilowatt-hour
MW	megawatt
MWh	megawatt-hour
NECP	National Energy and Climate Plan
NKREKP	National Energy and Utilities Regulatory Commission
NPP	nuclear power plant
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
PPA	power purchase agreement
PSPP	pumped storage power plant
PV	photovoltaics
RES	renewable energy sources
RFNBO	renewable fuels of non-biological origin
SAF	sustainable aviation fuel
SEG	Smart Export Guarantee
SME	small and medium enterprises
SPP	solar power plant
t	tonne
TIMES-Ukraine	The Integrated MARKAL-EFOM System model for Ukraine
TPP	thermal power plant
TSO	transmission system operator
TWh	terawatt-hour
UAH	Ukrainian Hryvnia
UK	United Kingdom

USA	United States of America
USD	US Dollar
UWEA	Ukrainian Wind Energy Association
VAT	value added tax
VET	vocational education and training
WACC	weighted average cost of capital
WPP	wind power plant

1. Introduction

Ukraine's power generation system and grid, as well as other municipal utilities such as heat and water, have been the main targets of Russian missile attacks since the start of its war of aggression. Ukraine's coal-fired power generation capacity has been almost completely destroyed and its electricity transmission infrastructure has also suffered significant damage. The destruction of critical infrastructure has resulted in significant disruptions to electricity and gas supplies, while scheduled cuts in electricity supply to stabilise the grid and rationed water supplies have become a daily reality for millions of Ukrainians across the country.

As the country approaches the winter of 2024/2025, it faces a number of unprecedented challenges, particularly in terms of maintaining national energy security and social stability. In addition to the existing difficulties of power and water cuts, the disruption of district heating systems could potentially exacerbate the situation and trigger another wave of emigration abroad, particularly to the EU.

In this context, both Government of Ukraine and international interest urgently require an in-depth analysis of the current state of energy security and an examination of strategies for developing a more resilient and sustainable energy system. Such strategies should be both expedient and decentralised[1] in the short term but also sustainable in the long term in order to meet the needs of the present (to the best extent possible) as well as the challenges of the future.

This report looks at the functioning of Ukraine's energy system in times of war, with a particular focus on the challenges and risks to be faced. Ukraine has considerable potential for the production of various types of energy, which could facilitate the country's transformation into a continental energy hub. Such a transformation would ensure future export revenues and the country's energy independence in the post-war period.

The report discusses the prospects for replacing destroyed thermal generation capacity with RES, while maintaining the flexibility, resilience and stability of the power system. We suggest that policies to develop RES must include measures to build relevant capabilities as well as awareness among local communities, businesses and households. This should include, inter alia, the development of appropriate values, skills and behavioural models for community leaders.

Section 2 of this report highlights the central role of renewable energy sources (RES) as the key to Ukraine's economic recovery and reconstruction.

[1] Decentralisation of energy supply is crucial for energy security as long as the threat of missile attacks maintains.

Section 3 focuses on the financial side of RES development in Ukraine. It provides an overview of the main RES support mechanisms that are available, such as the feed-in tariffs (FiTs), which provide renewable energy producers with a guaranteed above-market price to support RES development. It also assesses current tariff policies in terms of their ability to cover the full costs of electricity generation.

Section 4 aims to shed light on the current specifics and nuances of the regulatory framework that need to be considered when introducing RES projects at the municipal and community level in Ukraine. It highlights some of the regulatory barriers to RES development and provides recommendations for overcoming them.

Section 5 outlines a number of international practices that have been used to promote RES development, dividing them into economic instruments, regulatory instruments, and procedural measures. The applicability of such practices to Ukraine is also discussed.

Section 6 evaluates several possible scenarios for the emergency reconstruction of the Ukrainian power system in 2025-2031, and estimates the electricity prices needed to cover the required investments. It shows that the RES-based reconstruction of the power system will result in the same total costs as the fossil fuel-based reconstruction, while providing much higher resilience and sustainability. The section also provides insights into the employment requirements of RES-based reconstruction, and possible employment pools that can provide the necessary labour supply.

Section 7 discusses potential non-legal bottlenecks, particularly in the current war situation, and looks at the problems communities face in developing RES. Based on a survey of five communities in Ukraine, it outlines the main obstacles and provides recommendations for overcoming them. In particular, it highlights the role of capacity building for local communities and the urgent need to streamline and expedite grid connection procedures to ensure smoother development and implementation of RES projects.

Section 8 concludes the report and summarises the main findings and recommendations.

2. Ukraine's energy system and RES development

2.1 The pre-war energy system and RES development

Following Ukraine's independence in 1991, the country's energy system, which had been an integral part of the Soviet Union's energy strategy, continued to rely on centralised energy supplies from Russia. Ukraine has the advantage of having an extensive system of gas and oil pipelines, which has made it an important transit area for Russian gas to Europe. This has given Ukraine the ability to influence relations with Russia, but Russia's use of gas infrastructure has also been used as a lever of control over Ukraine. For a time, Ukraine was able to meet its own energy needs, but there was still a significant dependence on imported Russian oil and gas. This relationship was often fraught with tension, exacerbated by Ukraine's orientation towards the West, and the EU in particular, while Russia sought to maintain its geopolitical influence in the post-Soviet space.

In an effort to reduce its dependence on Russian energy suppliers, Ukraine has taken steps to explore alternative ways of providing energy resources, including domestic production of natural gas, contracting with European market players and implementing reverse supply schemes for gas from Europe, as well as the rapid development of various types of renewable energy.

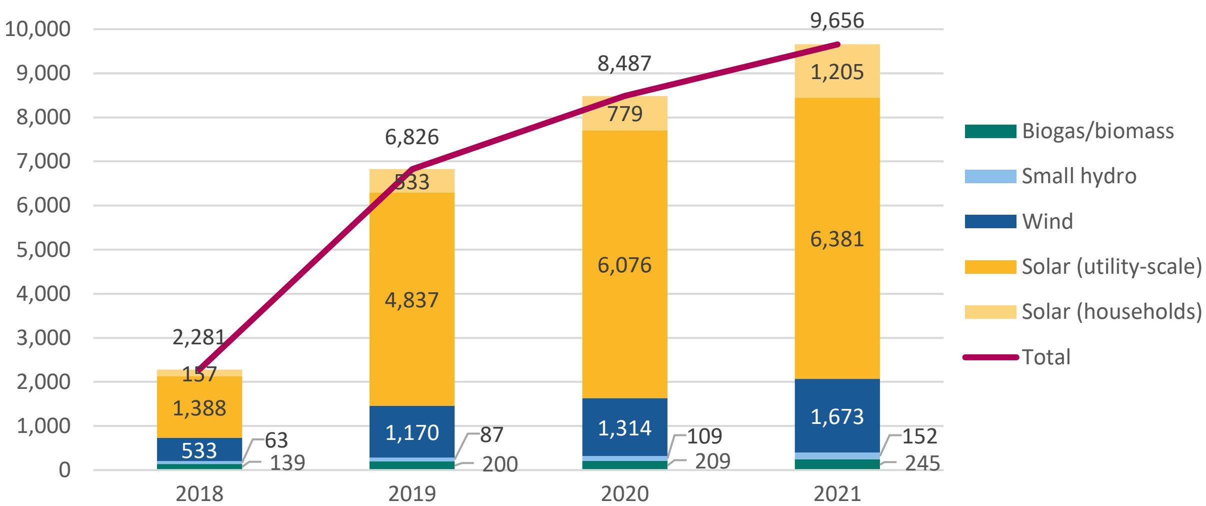
In 2014, Ukraine signed an Association Agreement with the EU and started to align its national legislation with EU law. In 2022, Ukraine was granted candidate status by the EU, and future full alignment with EU regulations, including the European Green Deal, should provide additional impetus to "green" its economy. Significant progress has already been made in aligning with EU legislation. According to Agreement Pulse, an online system that monitors Ukraine's progress in implementing the Association Agreement, Ukraine has implemented 55% of EU legislation on energy security by 2022 and 60% on environmental protection by 2024 (CMU, 2024a).

By 2019, Ukraine was among the top ten countries in the world in terms of RES development. In 2020 it was among the top five European countries in terms of solar energy development (Konechenkov, 2022). In the 2019 Climatescope rating by Bloomberg New Energy Finance (Bloomberg NEF), Ukraine ranked eighth in terms of the country's investment attractiveness in the development of low-carbon energy sources and a green economy. This is an improvement from the previous ranking of 63rd out of 104 countries (Climatescope, 2019). In the 2021 BloombergNEF ranking, Ukraine ranked 48th out of 136 countries in terms of overall investment potential (Konechenkov, 2022).

In general, since 2019 there has been a notable increase in investment in new RES projects in Ukraine, which has been consistently higher than in fossil fuel projects. Over the past decade, leading international and Ukrainian RES investors have attracted more than USD 12 billion in foreign direct investment into the Ukrainian economy, and by the end of 2021, the share of foreign investors in the installed RES capacity reached more than 35%, demonstrating the competitiveness and openness of the Ukrainian RES sector. The list of major international lenders and investors in Ukraine's RES sector includes: EBRD, Black Sea Trade and Development Bank, US International Development Finance Corporation (DFC), BayernLB, Investment Fund for Developing Countries (IFU), Nordic Environment Finance Corporation (NEFCO), and many others (Konechenkov, 2022).

Total installed RES capacity in Ukraine quadrupled between 2018 and 2021, reaching almost 10 GW by the end of 2021. More than three quarters of Ukraine’s overall RES capacity in 2021 came from solar energy at either utility-scale, i.e. solar power plants (SPPs), or at the household level (rooftop PV). The remaining RES capacity was made up of 1.7 GW from wind power plants (WPPs), around 0.2 GW from biofuel and 0.15 GW from small hydro facilities (Konechenkov, 2022). In addition to Ukraine’s RES capacity, it has several important sources of low-carbon electricity generation (CSI, 2024). In January 2022, around 5 GW of electricity was provided by (large) hydro power plants (HPPs), 1 GW by pumped storage power plants (PSPPs) and 14 GW by nuclear power plants (NPPs).

Figure 2-1: Total installed RES capacity in Ukraine in 2018-2021 by type, MW



Note: The data do not include PSPPs and large HPPs.

Source: Own work based on Konechenkov (2022).

2.2 The impact of the on-going war on Ukraine’s energy system and the relevance of RES development

On 24 February 2022, Ukraine urgently launched a test run of the country's power system with the aim of integrating it into the European energy network, the continental synchronous power grid of the European Network of Transmission System Operators for Electricity (ENTSO-E). Following successful tests, Ukraine officially joined the ENTSO-E system on 16 March 2022, marking a pivotal moment for the country's energy sector. From June 2022, Ukraine started exporting electricity to the EU. Ukraine's electricity transmission system is now fully independent from those of Russia and Belarus.

However, the Ukrainian energy system has become a primary target of Russian mass attacks, resulting in the cessation of electricity exports to the EU due to a domestic electricity deficit. Since January 2023, Ukraine has been importing electricity in very limited quantities. However, the current transmission infrastructure remains inadequate to meet Ukraine's electricity needs, with significant unmet demand due to the loss of generation capacity.

In line with the World Bank's assessment methodology, the Kyiv School of Economics publishes estimates of the losses incurred by Ukraine's energy sector. As of May 2024, the total losses (direct and indirect) amount to USD 56.5 billion, of which USD 21.3 billion is due to the loss of power generation capacity (KSE, 2024). The reconstruction needs, which include the extensive rebuilding of the destroyed infrastructure and production facilities in line with the principle of "build back better than it was", are estimated at USD 50.5 billion. Of this amount, USD 29.3 billion is expected to be needed to restore lost power generation capacity throughout the country.

As of June 2024, more than 70% of Ukraine's power generation has been destroyed, damaged or occupied, representing a total loss of around 23 GW of power generation (CSI, 2024). There is only about 11.4 GW of theoretically surviving capacity, a significant portion of which is generated by solar power. This energy shortfall results in a significant power deficit and widespread blackouts. The situation is particularly worrying in view of the upcoming winter and the subsequent increase in electricity demand coupled with a seasonal reduction in solar electricity generation.

In July 2024, Oblenergos, the regional electricity distribution companies, experienced a series of blackouts lasting more than 12 hours a day. As the heating season approaches, the Ukrainian energy system, already facing extreme challenges, will face its most critical test yet. The IEA (2024b) estimates that, taking into account recent attacks on Ukrainian infrastructure and an expected increase in peak demand to 18.5 GW in the winter of 2024-2025 (from around 12 GW in the summer of 2024, which saw record-breaking heat waves), the electricity supply deficit could reach 6 GW. While the rolling blackouts since March 2024 have been met with solidarity by Ukrainians, prolonged winter blackouts will cause enormous hardship, threatening not only livelihoods through reduced electricity and heat supplies, but also the provision of other utilities such as the central water supply. Urban areas, where around 70% of the Ukrainian population lives, are the most vulnerable.

While households were often spared the prolonged blackouts, the industrial sector suffered significant negative consequences. With limited prospects for improved power supply in the short term, industry is trying to adapt by installing small-scale generators. However, this entails additional costs associated with the purchase and maintenance of expensive equipment, while the cost of electricity produced by a generator is three to four times higher than the tariffs set by Ukrenergo. The direct result is a reduction in production activity, a deterioration in business expectations and, for many companies, the threat of closure.

As a result, the current crisis and the risks it poses are well recognised by the central and local governments, which are calling for immediate action to find quick and applicable solutions to restore power generation facilities and ensure a stable supply of electricity to the population and businesses.

2.3 Ukraine's domestic energy resources and RES potential

Ukraine has considerable potential for energy production from a variety of resources, including natural gas, hydro, wind, solar and biomass. In addition, Ukraine has developed one of the world's largest nuclear energy programmes, which provided about 55% of total domestic electricity production in 2022 (IEA, 2024a).[2] This illustrates the potential for energy self-sufficiency and hence energy security. However, despite the availability of a sufficient energy base, Ukraine currently remains a country with an energy-deficient and energy-dependent economy.

Despite the considerable potential of Ukraine's traditional energy sources, it is necessary to take into account the significant risks associated with their development and reconstruction, given their vulnerability to Russian military strikes. While natural gas offers a promising avenue for optimisation and widespread use within the country's traditional energy system, large centralised gas-fired power plants are just as vulnerable to destruction by new missile and drone attacks as the coal-based generation infrastructure.

The establishment of a decentralised system of small-scale electricity suppliers based on RES is therefore often seen as an attractive future path for the national energy system. Due to their distributed nature, RES are much less likely to be completely destroyed by missile attacks. In addition, rebuilding the power system with RES can facilitate the achievement of greater energy autonomy and a reduction in environmental impact. Indeed, in line with the targets set in the National Energy and Climate Plan for the period up to 2030, the share of RES in gross final energy consumption should reach at least 27%.

[2] With a capacity of 6 GW, the Zaporizhzhya NPP is the largest in Europe. Before the large-scale Russian military invasion, it produced a quarter of Ukraine's domestic electricity supply. The NPP is currently occupied by the Russian army and is not producing electricity. Other NPPs in Ukraine have also been temporarily unable to deliver at full capacity due to previous shelling of the associated transmission infrastructure.

The potential of RES technologies varies across Ukraine depending on location. The following section provides an overview of the main available technologies, namely solar, wind, hydro and biomass, accompanied by a brief assessment of their potential for expansion within the country's economy.

2.3.1 Solar energy

Solar radiation in Ukraine is considered to be high throughout the country, ranging from 1100 to 1500 kWh/m². This makes the whole country suitable for the development of solar energy production. Indeed, SPPs and rooftop PV are the most favoured type of RES-based generation in Ukraine. At present, their capacities account for about 75% of all RES installations in Ukraine, excluding large hydro.

The most suitable areas for operation are in the southern regions, including Odessa, Kherson, Zaporizhzhya and Crimea. These regions account for around 60% of Ukraine's existing industrial SPPs. However, these regions are suffering from active warfare, facing constant missile and drone attacks. Among the many destructions, the SPPs in the Nikolaev and Kharkiv regions have been the most affected, with 100% of the generating capacity of the Kharkiv Energy Cluster destroyed.

In the context of the war, with regular power cuts, investors in SPPs began to consider energy storage as a necessary component alongside SPP technologies. This almost doubles the capital investment required for an SPP installation, with 1 kW of storage capacity costing around EUR 300.

Despite these challenges, the potential for solar energy development in Ukraine remains significant. The Institute for Sustainable Futures (2024) estimates the total technical potential of solar PV capacity at over 5,000 GW.[3] This would be enough to produce up to 60 times more electricity than is consumed in Ukraine, which was 130-140 TWh/year before the war and 100 TWh in 2022 (IEA, 2023). In fact, using 1% of Ukraine's land area suitable for solar installations would be sufficient to meet the country's electricity demand (Institute for Sustainable Futures, 2024). However, institutional arrangements and economic considerations mean that the technical potential can never be fully exploited. Barylo et al. (2020) estimate that, with the right policies and investments, Ukraine could reach an installed solar PV capacity of over 80 GW, which would still be close to covering the country's current energy consumption with solar energy alone.

[3] The estimate is based on the area of all available land, excluding protected natural areas and areas with extremely complex topography (slopes greater than 30%, certain types of soil cover, dense forests, wetlands, mosses and lichens), snow and ice cover and water (permanent bodies of water). See also Figure A-1 in the Appendix.

It is important to note that smaller SPP projects as well as residential PV installations can be implemented quickly, e.g. within a 6-12 month timeframe. Larger SPP projects may require longer implementation periods, depending on various factors such as the size of the project, the complexity of the construction, the availability of permits, the availability of financing and other administrative aspects.

2.3.2 Wind energy

Wind energy is one of the most environmentally friendly and at the same time one of the cheapest sources of electricity. According to the Ukrainian Wind Energy Association (UWEA), wind energy accounts for more than one-fifth of the total national renewable energy balance, second only to solar energy.

A total of 34 wind parks or wind power plants (WPPs) with 699 wind turbines were actively generating 'green' electricity in Ukraine before the start of the full-scale war. However, more than three quarters of the pre-war wind power capacity has been completely destroyed or is now located in the temporarily occupied territories. At the same time, more than 228 MW of new wind capacity was built and connected to the grid in the first two years of the war, including 146.3 MW in 2023 (Ukraininan Energy, 2024). On 18 September 2024, the Skolivska wind power plant, the largest wind park in the mountainous Lviv region with a total capacity of 54.6 MW, was commissioned. This brings the total installed wind power capacity in the country to around 2 GW (UWEA, 2024a). In the near future, UWEA member company Elementum Energy, which is owned by British investor VR Global Partners, L.P., is preparing to build three mini wind parks with a total capacity of 58.5 MW (UWEA, 2024b).

The greatest concentration of wind resources in Ukraine is observed in the coastal areas of the Black and Azov Seas, as well as in the steppe regions, where constant winds prevail. The potential for wind power generation in Ukraine is estimated at 30-40 GW, depending on prevailing conditions and technological considerations. Under favourable conditions, Ukraine has the potential to add up to 2-3 GW of new wind capacity annually in the coming years. The National Renewable Energy Action Plan aims to achieve a total of 6.1 GW of onshore and 100 MW of offshore wind capacity by 2030 (UWEA, 2024c).

2.3.3 Hydropower

In recent months, Ukrhydroenergo, the Ukrainian company that operates HPPs across the country, has suffered severe losses of hydropower capacity due to Russian attacks. Almost all the large HPPs have stopped operating and are not supplying energy. In particular, the Dniprovska HPP, Ukraine's largest hydropower plant with an installed capacity of almost 1.6 GW, suffered very destructive attacks, lost most of its equipment and stopped producing electricity. As a result of huge reconstruction efforts, more than 1.5 GW of generating capacity has already been restored, but full restoration to resume power supply in the winter season remains a very difficult task and is still uncertain. Another large power plant - Kakhovska HPP - was completely destroyed and cannot be restored in the near future.

In the context of distributed generation, it would be more appropriate to consider small hydropower systems, or micro hydropower plants (mHPPs). The mHPPs typically range in size from a few kilowatts to 100 kW, making them ideal for supplying electricity to remote settlements, agricultural complexes or industrial facilities. In Ukraine, the total potential of mHPPs is estimated to be between 200 and 500 MW, although only a limited part of this potential - around 180 MW - has been realised to date (Energobusiness, 2023). At the same time, rivers in the Carpathians, such as the Dnister, Prut and their tributaries, which flow through the remote settlements, have sufficient flow and elevation and would be ideal for mHPP development. Also in central Ukraine, rivers with moderate flows, such as the Teteriv and Irpin, can be considered for the introduction of mHPPs. Despite the potential, market awareness of mHPPs in Ukraine remains underdeveloped.

2.3.4 Biomass

Biomass, including forest biomass, is the only renewable energy source that can be used simultaneously to produce electricity, heat and biofuels for transport. In Ukraine, 97% of the energy produced from forest biomass is thermal energy (mainly for heating) and 3% is electricity (WWF, 2023).

The capacity of thermal power plants using solid biomass increased by a further 26 MW in 2023, reaching a total of around 177 MW in 24 plants across the country (IRENA, 2024; Kramar, 2023). In addition to building new bioenergy facilities, there is huge technical potential to convert coal-fired power plants to biomass. However, converting larger power plants would require sourcing large amounts of biomass, potentially over long distances (CERTH, 2021). In addition, as reported above, most of Ukraine's coal-fired power plants have been the target of military attacks and have been destroyed.

At one of the largest TPPs in the Kharkiv region, Zmiivska TPP, all power generation equipment was destroyed and auxiliary equipment was severely damaged. The Trypilska TPP, which was the largest supplier of electricity for the Kyiv, Zhytomyr and Cherkasy regions, also received critical damage during a massive attack. Centrenergo, the company that operates many of the TPPs, initially reported that the plant had been completely destroyed, but later clarified that it could be restored, although restoration would be pointless without improvements to air defences. After the destruction of the Zmiivska and Tripilska TPPs, Centrenergo lost 100% of its generating capacity (Smyshlyaev, 2024).

This confirms the vulnerability of TPPs to Russian attacks and makes further stable use of this type of technology for large-scale electricity production, including using biomass, almost impossible.

However, small-scale cogeneration using biomass and biogas has potential for development in the current circumstances. In particular, modern biogas cogeneration plants produce electricity and heat, using as fuel biogas produced from the disposal of waste from farms, urban sewers and landfills. This technology is gaining priority positions throughout Europe and has great potential for implementation in Ukraine as one of the segments of a decentralised energy system.

2.3.5 Hydrogen

Given its overall massive potential for renewable electricity generation, Ukraine also has a high potential for the production of 'green' hydrogen.[4] Hydrogen will be a key input for the decarbonisation of processes that cannot be electrified (e.g. providing high-temperature heat for cement and glass production, or producing e-fuels for aviation and shipping) and for the substitution of fossil-based feedstocks in the steel and chemical industries.

The EU has a strong interest in hydrogen production in Ukraine despite the ongoing war, both in terms of potential hydrogen exports to the EU and exports of 'green' commodities such as steel. Ukraine's potential for hydrogen exports is supported by its proximity to the EU and a well-established infrastructure of pipelines and seaports that could potentially be repurposed to transport hydrogen (Sukurova, et al., 2023). Although it is unlikely that Ukraine will have sufficient RES to produce hydrogen in the short term, given the current damage to the energy infrastructure and the Russian occupation of key infrastructure and land suitable for RES, hydrogen can become an important building block of the Ukrainian energy system and economy in the long term.

2.3.6 Summary

To conclude this brief review of Ukraine's RES potential, the country's strengths lie in its favourable geography and location, including proximity to major energy suppliers and key energy market players, transit infrastructure and the availability of efficient fuel storage facilities (especially for hydrogen in the future).

[4] Green hydrogen is produced by electrolysis of water using renewable energy sources to provide the electricity needed for the process.

On the negative side, there is direct dependence on imported equipment, inefficient use of technical capacity, wear and tear of equipment in operation, high energy intensity of the economy and oligopolisation of markets, reduction of domestic capacity due to destruction and loss of energy infrastructure, and lack of financial stability and loans or other financial instruments.

Today, wind, solar, bio, small hydro and hydrogen energy are seen as the key to Ukraine's energy security and independence. Achieving the targets set by the National Action Plan on Energy and Climate for the period up to 2030 would require decisive action to stimulate the introduction of appropriate measures using modern RES technologies.

2.4 Energy usage and distributed RES production in the residential sector and public sector

2.4.1 Residential sector overview

Before the war, the residential sector was the second largest consumer of electricity after industry, consuming 38.7 TWh in 2021, or 30.8% of the country's total electricity consumption. Household electricity consumption varies according to season, weather and economic conditions. In winter, for example, the need for heating increases, leading to an increase in electricity consumption. This in turn affects the load on the grid and the need for a stable energy supply. The extreme heat wave of July 2024 has already shown how power outages during adverse weather conditions can affect people's daily lives and increase health risks, especially for vulnerable groups such as the elderly, children and people with chronic diseases. This effect is expected to be even more pronounced during the cold months.

In the summer, the government and local authorities were forced to take urgent measures to respond to the situation, such as providing energy saving advice, setting up cooling stations for the population and launching information campaigns on the importance of following safety rules in the heat. While similar measures should be an integral part of the response to energy security risks in winter, there is an urgent need to repair and rebuild energy infrastructure, while introducing more resilient solutions such as decentralised energy supply.

Among the RES technologies available to households, solar energy, in particular PV, stands out as a solution with short implementation times and relatively low investment requirements. Household rooftop PV systems typically have a capacity between 0.5 kW and 30 kW and can be installed on top of both apartment buildings and private houses. To compensate for fluctuations in solar activity, rooftop PV should be complemented with batteries to store electricity, making them more efficient during systematic shutdowns and periods of least solar activity.

At the beginning of 2021, the State Statistics Service of Ukraine (2021) reported around 9.16 million residential buildings in Ukraine, of which 3.3 million were located in urban areas and 5.8 million in rural areas (dominated by private houses).[5] Thus, despite the destruction since the start of the war, there is significant potential for rooftop PV. Stetsenko & Zavyaletz (2016) estimate the technical potential of electricity generation from rooftop PV in Ukraine at 26-37 TWh per year, or 2.16-3.08 TWh per month, highlighting the availability of solar energy across Ukraine. They conclude that the cost of electricity generated by an average rooftop PV installation of 10 kW capacity is just under UAH 1 per kWh, well below the feed-in tariff at that time (just under UAH 5 per kWh). Accounting for feed-in tariffs, they estimate that households recuperate the initial investment after somewhere between 5 and 8 years, depending on consumption intensity. Given the technical lifetime of installations is 25 to 30 years, this makes rooftop PV a worthwhile investment. Although many conditions have changed during the war (e.g. the need to combine rooftop PV with battery storage which significantly increases equipment costs) the additional benefits of a (semi-)autonomous RES installation, especially during power cuts, are likely to outweigh the additional equipment costs. In addition, the Ukrainian government is actively supporting the installation of rooftop PV with a variety of financial instruments, which significantly reduce the upfront costs for households (see Section 3 for more details).

2.4.2 Public sector overview

There are more than 77,000 public buildings in Ukraine, making the public sector one of the largest electricity consumers in the country (Filucic, 2023). In 2021, the electricity consumption of public buildings reached 15 TWh, which is 12% of the total electricity consumption in Ukraine (All-Ukrainian Energy Assembly, 2022). This underlines the significant contribution of this sector to the country's energy demand and opens up new horizons for the implementation of initiatives that can significantly reduce energy consumption.

Firstly, a significant reduction in electricity consumption in public buildings can be achieved by modernising lighting, heating, ventilation and air-conditioning systems. However, with frequent power cuts, alternative solutions must be found to ensure the smooth operation of public buildings and infrastructure. Municipalities often resort to the use of petrol or diesel generators to maintain the

[5] Data exclude the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and a part of temporarily occupied territories in the Donetsk and Luhansk regions.

functioning of executive authorities and to provide services to the population. This solution seems appropriate because of the speed and ease of connection, but it is very costly.

Taking into account the cost of fuel and the maintenance cost, in particular the availability of qualified maintenance personnel, the cost of 1 kWh produced by a petrol or diesel generator can reach UAH 13-19. This is 1.5-2 times higher than the tariffs for electricity supplied from the grid. Therefore, optimal and cost-effective solutions are needed to meet the energy needs of public institutions, including through the introduction of RES.

Municipal buildings - such as schools, hospitals and administrative offices - have great potential for installing solar panels on their roofs, which usually remain unused. Taking into account the annual solar irradiation in Ukraine, as discussed in Section 2.3, the number of public buildings and their roof areas, the technical potential for installing rooftop PV can be in the three-digit GWh range. Similar to rooftop PV for households, the costs of renewable energy systems are likely to be offset by the benefits of a stable energy supply in the event of blackouts. Furthermore, projecting the costs of electricity supply using rooftop PV estimated by Stetsenko & Zavyaletz (2016) to installations of similar size in public buildings shows that they are a significantly cheaper option than petrol or diesel generators, even with upward adjustments for inflation and additional equipment.

Technically, municipalities are not restricted to installing RES on the roofs of public buildings. They could also use municipal land outside settlements for small wind and solar parks, which would significantly increase the RES potential available to them. However, this would require a connection between a consumption site and an off-site RES installation, which poses a number of administrative and financial challenges due to the current design of the electricity market (see Section 4.3.6 for details). As a result, this potential remains largely untapped.

2.4.3 Trade-offs of full reliance on grid electricity and distributed RES

The discussion on RES as a source of stable electricity supply often tends to compare two extreme cases: total reliance on grid electricity, which in the current situation would mean facing regular blackouts, and a fully autonomous RES system, which is a distributed RES system completely disconnected from the grid. From this perspective, fully autonomous RES systems have the advantages of independent supply, but they also face some challenges due to supply intermittency.

The main **advantage** of autonomous RES is clearly their **complete independence** from the electricity grid. This means that the energy supply is independent of voltage fluctuations on the grid and there is no need to comply with consumption standards. Moreover, there is no need to sign contracts with

Oblenergos, obtain documents for connection, etc., which significantly reduces the administrative burden.

The **disadvantage** of autonomous RES lies in the **fluctuations in supply** during the day, season or weather conditions, which require either adjustments in power consumption or the installation of back-up power sources. The latter include a battery to bridge a few hours and an additional backup (e.g. diesel generator) for longer periods without (sufficient) generation. This adds significant equipment costs and, depending on the market price of electricity, may make the payback period of an autonomous RES system too long.

For this reason, fully autonomous RES are usually used in remote, off-grid areas to replace more expensive fossil-based autonomous systems (e.g. diesel generators). In grid-connected areas, the use of fully autonomous RES is less likely. Instead, grid-connected distributed RES, supported by energy storage to enable partially autonomous operation, will play a role in combination with other solutions. In urban centres, in particular, the ratio of RES potential (i.e. available space) to consumption intensity is low. In the coming winter, the load on the grid may be reduced by a combination of off-grid solutions, such as RES installations (supported by energy storage to increase the autonomy and physical resilience of the system) and back-up diesel generators, which are already widely used (IEA, 2024b), and mini-grid solutions with dispatchable generation[6] such as small-scale gas-fired combined heat and power generation units (CHPs) that provide heat and power to multiple dwellings.

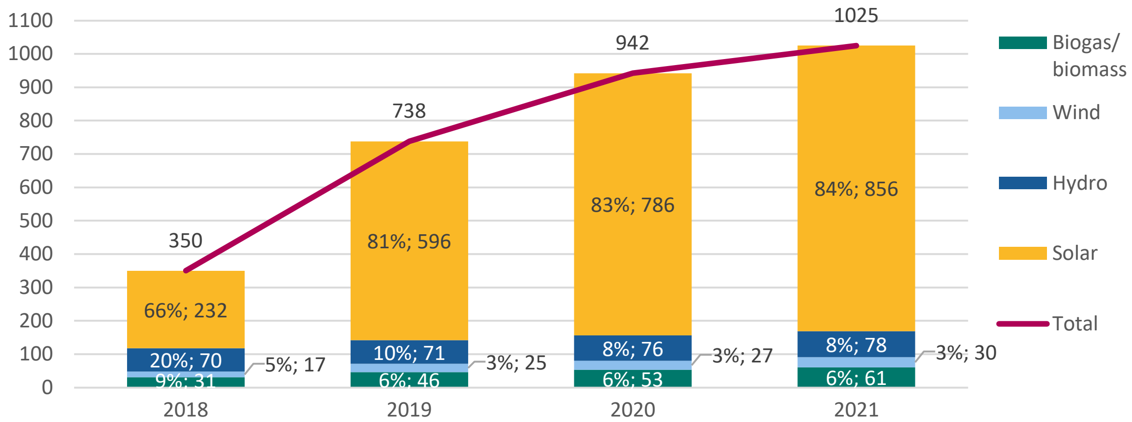
Grid connection is often a significant administrative challenge for distributed generation, both for RES and for small-scale dispatchable generation. The need to obtain technical documentation and permits and to coordinate the connection with local grid operators often leads to long delays. The Ukrainian government has recently taken a number of decisions to simplify the conditions for the installation and grid connection of generation units, with a focus on small gas-fired CHPs. These include a temporary reduction in the list of documents required for the permitting process and a reduction in the time required for the preparation and approval of technical conditions and grid connection (Ministry of Energy of Ukraine, 2024d). In addition, the energy watchdog Derzhenergonaglyad has launched a hotline for problems in obtaining permits to connect power plants (Ministry of Energy of Ukraine, 2024c). On the financial side, the Ukrainian government has stepped up its financial support measures to encourage the development of RES, particularly in households and small and medium enterprises (see Section 3 for more details).

[6] Dispatchable generation refers to power plants that can be easily switched on and off to match their output to demand. Most thermal power plants (burning coal, gas or biomass) and many hydroelectric plants are dispatchable, although the time they can ramp up can range from seconds to hours, depending on the type of plant.

2.5 The RES equipment and installation market in Ukraine

Just before the war, the RES market in Ukraine was developing at an unprecedented pace. Between 2018 and 2021, installed RES capacity quadrupled, driven mainly by wind and solar power (see also Figure 2-1 in Section 2.1). This growth is reflected in the near tripling of the number of companies specialising in the installation and operation of RES facilities over the same period, with a strong focus on companies installing and operating solar-based systems. Their number almost quadrupled from 232 in 2018 to 856 in 2021, accounting for 84% of all RES companies in 2021 (Figure 2-2).

Figure 2-2: **Pre-war dynamics of the RES market: number of companies**



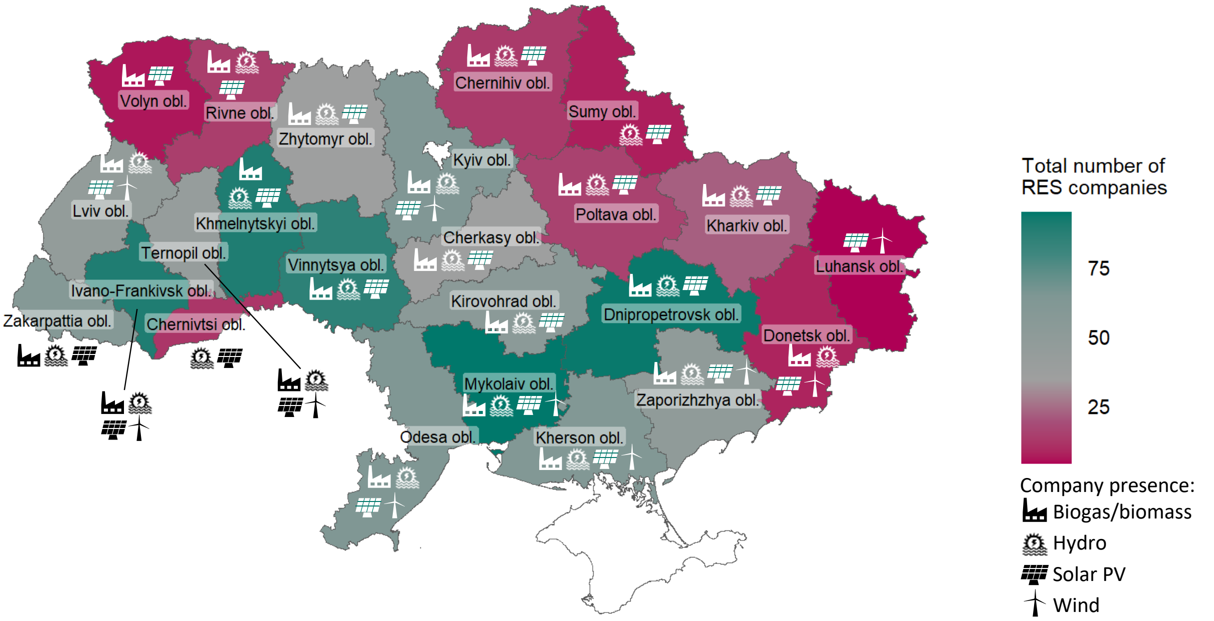
Source: Own work based on DiXi Group (2021).

The development of the RES market is very uneven across Ukraine's regions. Figure 2-3 compares the regions by the total number of companies installing and operating RES systems and highlights the types of RES companies present in each region. Most RES companies tend to be located in central and southern Ukraine, while the north-east and north-west are rather underrepresented. Not surprisingly, the regions with a lower number of RES companies show less diversity in RES types. For example, in Volyn Oblast there are only companies working with solar power and biomass/biogas plants, in Chernivtsi and Sumy Oblasts only hydropower and solar companies, and in Luhansk Oblast only wind and solar companies.

The prevalence of solar power is also evident here, as there is not a single region without at least one company working with it. Dnipropetrovsk Oblast has the most developed solar power market, both in terms of business participation (with a total of 88 solar companies, or 10% of all solar companies in the country) and in terms of solar power capacity (1.1 GW, or 18% of the country's total installed solar PV capacity and generation).[7]

[7] See also Figure A-2 in the Appendix for generation and Figure A-3 in the Appendix for capacity.
Note that the regional data is very incomplete for rooftop solar PV, which make about 10% of total RES capacity countrywide, so it should be treated with caution.

Figure 2-3: **RES installation companies in Ukraine by region**



Source: Own work based on DiXi Group (2021).

Interestingly, bioenergy and hydropower are also well represented across Ukraine, with only Chernivtsi, Sumy and Luhansk Oblasts lacking bioenergy companies and Volyn and Luhansk Oblasts lacking hydropower companies. Wind turbine installers, on the other hand, are present in only 10 of the 24 regions with data.[8]

A comparison between the types of RES electricity produced in each region and the presence of RES companies also shows that every region that produces a certain type of RES electricity also has companies that work with RES systems of this type (see Table A-1 in Appendix). This means that every region has at least some capacity and qualified personnel to work with and expand the RES it already uses. In addition, some regions have companies active in a type of RES from which they do not appear to produce energy. For example, in Volyn Oblast there are twelve companies working with biogas, but no bioenergy production is recorded in the DiXi Group (2021) data.[9] It is therefore expected that, despite the lack of bioenergy capacity in the region, it already has some experience and know-how in this type of RES, which could facilitate its expansion in the future.

[8] There is no data for the Autonomous Republic of Crimea since its annexation by Russia in 2014, which has effectively cut it off from the Ukrainian power system. The city of Kyiv is not included to avoid crowding and because companies may be registered in the capital city without having significant operations there. Due to its relatively small area with high building and population density, Kyiv has a relatively low RES potential. DiXi Group (2021) lists about 2 MW of rooftop PV capacity and 11 solar companies operating this capacity as of December 2021, but there is no record of generation.

[9] It is possible that the biogas companies located in Volyn Oblast serve very small regional capacities, for which the production is not included in the available data, and/or the demand in neighbouring regions.

While the capacities for installing RES systems are already quite well established in Ukraine, this is not the case for RES equipment manufacturing. With solar PV being the largest segment in the Ukrainian RES market with a massive potential for further growth, the following overview focuses on this RES type.

Overall, one can distinguish three types of equipment suppliers based on their production cycle and the degree of reliance on foreign components:

- Companies with a **full production cycle** have the entire solar module manufacturing process in Ukraine. This includes all stages from raw material processing to final module assembly, reflecting a robust local manufacturing capability.
- **Part-cycle** companies source components from international suppliers and assemble the solar modules domestically. They are responsible for marketing the assembled products and providing warranty support, but do not handle the full production cycle.
- **Importers** rely entirely on importing pre-fabricated solar modules. Their role is limited to repackaging and installing the modules on-site within Ukraine, without engaging in any local production processes.

According to Mostova (2020), four solar module manufacturing companies were active in Ukraine before the war, of which only one has a full production cycle and the rest assemble solar modules from mostly imported components (see Table A-2 in Appendix for an overview). The removal of import duties for solar module imports in 2018 reduced the cost of imported modules by 20% compared to domestically produced modules. This has further reduced the competitiveness of Ukrainian producers, who were already challenged by the highly modern and automated production lines in China (Mostova, 2020).

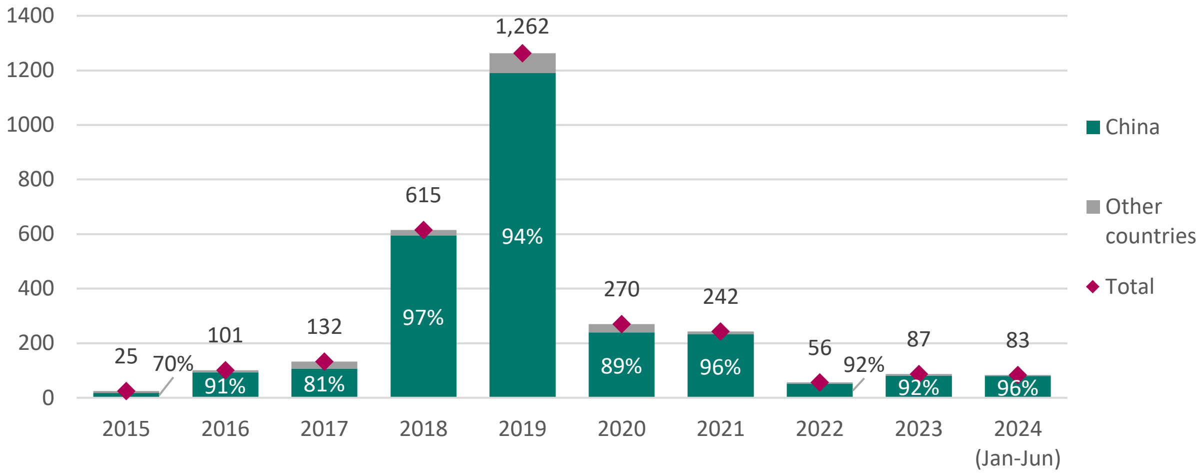
Currently, most of the solar modules installed in Ukraine are imported. The rapid development of solar power since 2015 is reflected in the surge in imports, with the value of imports increasing by a factor of 50 from USD 25.1 million in 2015 to USD 1.26 billion in 2019 (Figure 2-4).[10] China is the single largest source of solar module imports in Ukraine, making up over 90% of total imports by value in most years since 2016.

In 2020, the outbreak of the COVID-19 pandemic severely disrupted global trade, causing solar module imports to Ukraine to fall by almost 80% compared to 2019. Before recovery could begin, imports fell

[10] It should be noted that in 2015-2019 and 2021, the import data for PV modules and elements are grouped together with the data for light emitting diodes (LEDs) in one category, which may slightly overestimate the imports of PV modules. In 2020 and 2022-2024, when more disaggregated data are available, LEDs accounted for between 3 and 14% of imports in this category.

again by 77% as the war began in 2022, with some signs of a gradual recovery in the first half of 2024. Extensive shutdowns in China caused the country to temporarily lose its export position in 2020, with China's share of imports falling to 89%, but quickly regaining its share in 2021.

Figure 2-4: Solar panel imports in USD million and share of China



Source: Own work based on DiXi Group (2024).

China's central role in the global PV sector, and particularly in the Ukrainian supply chain, underlines the critical importance of maintaining stable supply lines for solar technology. The disruptions that occurred in 2020 illustrate how global events such as pandemics and conflict can affect the availability and cost of critical components for PV technologies, highlighting the need for resilient supply chain strategies and strengthening domestic manufacturing.

As noted above, domestic solar manufacturers in Ukraine face very stiff competition from Chinese imports, and the measures to facilitate imports make this competition even tougher. While supporting immediate recovery and energy resilience efforts, in the long term this strategy will discourage domestic production of solar equipment and should therefore be reassessed soon in the light of Ukraine's strategic priorities.

As an international example, the European Union has established a regulatory framework that balances market protection with quality standards. While the EU economy is very open to trade, it takes steps to ensure fair competition, maintain high quality and safety standards at the domestic market, and ensure that imported technologies are in line with its ambitious climate goals. For example, in addition to typical import tariffs, EU protection includes anti-dumping and safeguard measures, as well as technical and sustainability standards. As Ukraine is undergoing legislative alignment for EU integration, the same measures will have to be adopted in future. Table 2-1 provides a brief comparison of the respective policies of the EU and Ukraine.

Table 2-1: The differences and similarities in PV import regulations between Ukraine and EU

Aspect	EU	Ukraine
Context and goal	Ensuring fair competition and protecting European producers while maintaining quality and safety standards.	Responding to the damage and disruption caused by the ongoing war, facilitating the rapid restoration of power facilities and supporting recovery efforts, while increasing energy resilience by accelerating the development of distributed generation systems.
Policies		
Duty-free imports	No general duty-free status; imports are subject to duties and taxes unless under specific exceptions.	Duty-free import allowed for generators, solar panels, and other energy equipment, including exemptions from VAT and import duties as of July 16, 2024.
Anti-dumping duties	Imposed on solar panels from China since 2013. Rates vary by company and product to protect European manufacturers from imports priced below production costs.	No specific mention of anti-dumping duties on solar panels.
Safeguard measures	Introduced in 2018 to limit import volumes of solar panels and components. Exceptions and reduced rates available within quotas to protect European producers.	No specific safeguard measures mentioned, although as a 'soft' measure there is a surcharge on the feed-in tariffs that RES producers receive if a certain proportion of the equipment they install is domestic.
Technical standards and certifications	Imported solar panels must comply with technical standards and certifications such as CE marking, ensuring safety, quality, and environmental standards.	Not specifically mentioned.
Energy efficiency and recycling regulations	Enforced regulations to ensure solar panels meet standards for energy efficiency and waste recycling.	Not specifically mentioned, focus is on immediate import to support energy resilience.

Source: European Commission (2013), SAEE (2024).

2.6 Labour market issues

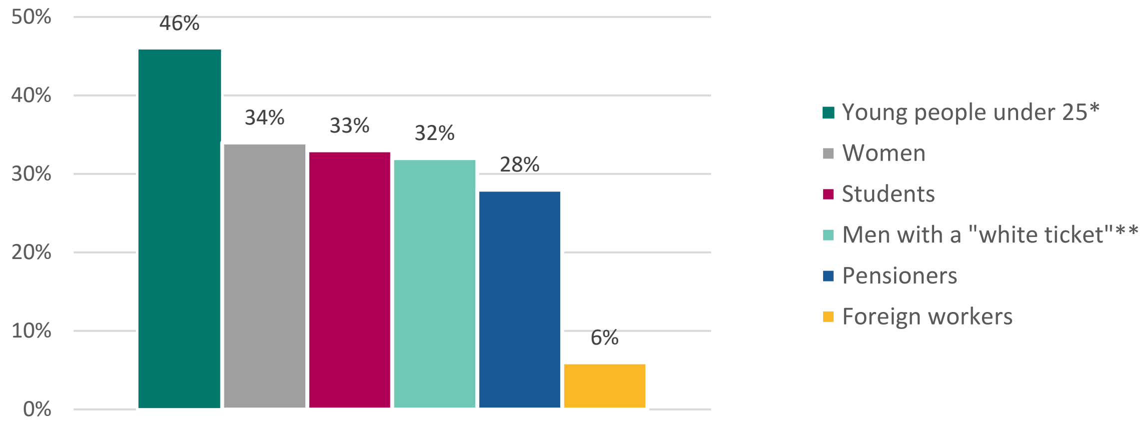
Before the Russian invasion, the Ukrainian labour market faced several challenges. The unemployment rate has been on the rise since late 2019 (State Statistics Service of Ukraine, 2023), and the overall labour force participation rate was 63%, below the OECD average of 73%, despite some growing sectors - notably retail trade, with a higher proportion of women, and agriculture, where employment remained high, representing 17% of national employment (Gorodnichenko, Sologoub, & Weder di

Mauro, 2022). Ukraine also faced demographic pressures from an ageing population and a very low fertility rate, which put pressure on the labour force and the pension system. Immigration has been insufficient to offset population decline, with an annual loss of around 200,000 people since 2005 (Gorodnichenko, Sologoub, & Weder di Mauro, 2022). Following the restrictions of the COVID-19 pandemic, both labour demand and supply were severely affected.

The decline in labour supply was exacerbated by the Russian invasion, which led to millions of people leaving the country, including skilled workers and those in better health (Gorodnichenko, Sologoub, & Weder di Mauro, 2022). In war-torn Ukraine, many women were unable to work, largely due to their caring responsibilities at home, resulting in a higher proportion of men looking for work. More specifically, millions of workers, or 10% of the labour force, were forced to change jobs (Gorodnichenko, Sologoub, & Weder di Mauro, 2022). At the same time, large numbers of men were mobilised, leading to labour shortages and increased female participation, especially in traditionally male occupations such as coal mining (Sauer, 2024). These developments turned a labour market characterised by rising unemployment into an extremely tight one, with around 55% of employers speaking of a labour crisis (Bodnyak, 2024).

In response to this crisis, many companies are looking for employees from previously under-represented groups, thus turning to more inclusive employment. In the survey conducted by the job portal OLX (Bodnyak, 2024) almost half of the companies responded that they were ready to hire young people of non-conscription age, about a third were planning to hire women and men not subject to mobilisation due to health conditions and to attract students through educational institutions, and more than a quarter were considering hiring pensioners (Figure 2-5).

Figure 2-5: Share of companies considering to hire different employee groups



* 25 is the conscription age in Ukraine
** I.e., not subject to mobilisation due to a health condition.

Source: Own work based on Bodnyak (2024).

These inclusive solutions should ease the current labour market situation, but may also help to provide a sufficient workforce for reconstruction, alongside the demobilisation and repatriation of refugees once the situation in the country has stabilised (see also Section 6.4 for a discussion of labour market implications of reconstruction scenarios).

In addition to the general availability of labour, Ukraine's education system faces a number of challenges in providing relevant skills for the needs of the labour market. Some are war-related, while others are more structural, including inequalities in access to quality education (Gorodnichenko, Sologoub, & Weder di Mauro, 2022). For example, according to the PISA 2018 national report, Ukrainian students with higher socioeconomic status living in large cities are almost three years ahead of their counterparts (OECD, 2019). Overall, there has been insufficient investment in the development of national assessment tools to monitor the quality of education. The recent government efforts to address the decline in learning outcomes at the primary and tertiary levels have been disrupted by the COVID-19 pandemic and the Russian invasion of Ukraine.

Vocational education and training (VET) is particularly lagging behind in its development and relevance to labour market needs, although many measures have been developed to improve the situation since the sector was recognised by the Ukrainian government as being of strategic importance for providing a professional, skilled workforce in 2017 (Leu-Severynenko, 2022). Table 2-2 provides a brief overview of the main challenges facing the VET sector and the recent measures taken to address them, both before the war and in response to the additional challenges posed by the war.

In addition to the overarching challenges, the distribution of VET institutions across Ukraine's regions is very uneven (Figure 2-6). These disparities have been exacerbated by the war, which has damaged and destroyed the VET infrastructure in 15 out of 25 regions.[11] In several regions, more than half of the VET institutions were damaged or destroyed. Although the development of blended learning approaches is somewhat reducing the reliance on on-site facilities, significant reconstruction efforts will be needed to restore the regions' educational capacity.

[11] The Autonomous Republic of Crimea and the city of Sevastopol are not included in the data.

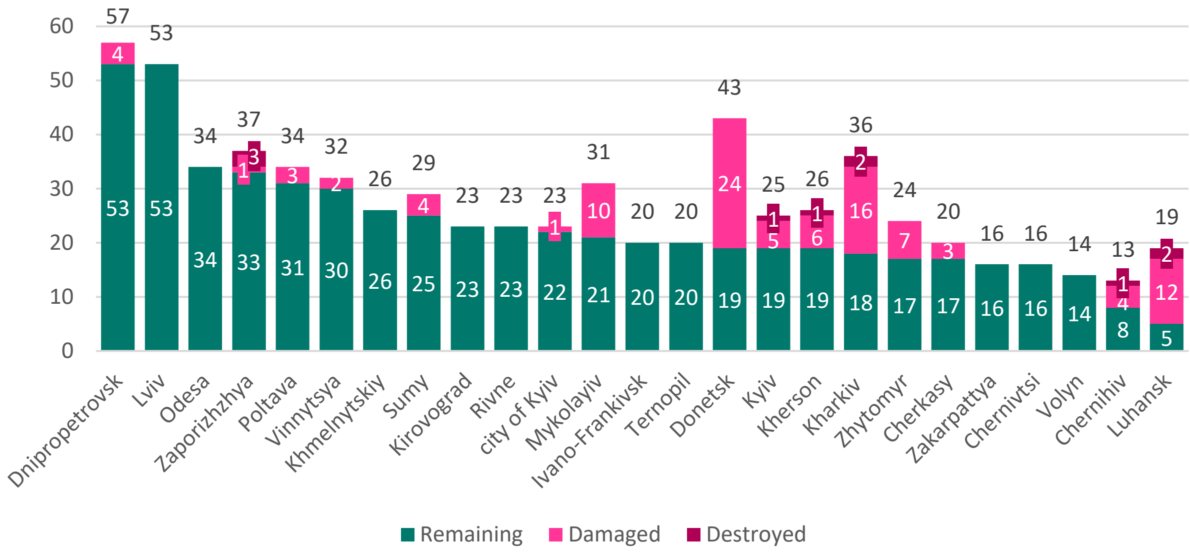
Table 2-2: Overview of challenges in VET and actions taken to resolve them

Issue	Description	Pre-war action	War impacts and planning
Poor VET image	VET has a low status in Ukraine, while higher education remains more popular	□ Creation of parallel structures ("Professional Pre-Higher Education"), □ Measures to improve VET image: ■ Business-education partnerships, ■ Communication campaigns and career counselling, ■ Capacity building for VET representatives.	□ Business partnerships were partially lost but measures are being taken to keep them up. □ Promotion programmes are being resumed (e.g., EU4Skills programme).
Insufficient legislative progress	While the education system in Ukraine has been undergoing deep reforms and alignment with the European Qualifications Framework since the 2010s, progress in VET has been slow. The adoption of a new VET law requires harmonisation with other education legislation, which is complicated by the fact that the other laws were created in different periods.	□ Adoption of Concept for the Implementation of the State Policy in the VET Sector "Modern VET 2027" in 2019 and of the Strategy for the Development of VET until 2023 in 2020 □ Drafting of the new law on VET has been ongoing since 2015	The VET reform was interrupted by the war, and the need for adopting a new law on VET remains.
Lack of financing	Until 2017, the VET system received "minimal support" from local and state budgets. Lack of development budgets resulted in outdated technical infrastructure and lack of modern knowledge and skills.	In 2016, decentralisation of VET was started, and the funding from the local and state budgets was to be combined with financial support from the private sector, external donors, NGOs, households (e.g., through tuition fees), VET's own funds, and other sources. Although it better aligned VET with the regions' needs for skilled labour, most of the funding continued to come from local and state budgets.	□ The funding system is back to the "minimum support" system with a lack of development budgets. □ A mechanism is planned to finance the training of professionals and the retraining of adults to support reconstruction. □ An option is being considered to grant financial autonomy to vocational schools and remove them from the scope of ministerial administration.

Poor management/ coordination	The 2017 EU Delegation Review criticised the ineffective management and lack of coordination in the VET sector. In addition to the low participation of partners, parallel structures - VET and 'professional pre-higher education' - have a negative impact.	A VET Directorate was established in the Ministry of Education and Science in 2017-2018, which improved management and coordination, including through regular coordination meetings with VET schools, partners and donors. However, public-private partnership mechanisms and social dialogue remained underdeveloped.	The Recovery Plan (National Recovery Council, 2022) envisages □ restoration of comprehensive independent assessment for student admissions and certification, □ development of public-private partnerships, □ creation of centres of expertise and the guarantee of their training, □ digital management of vocational training institutions, □ development of learning platforms, □ creation of electronic learning passports. The possible corporatisation of colleges is also being discussed.
Quality gaps	The quality of training in the VET sector remains low due to □ outdated technical infrastructure and lack of digitalisation, □ lack of training tools and materials, □ lack of a quality assurance system, □ lack of relevance to labour market needs, □ low proportion of applied training, □ increasing shortage of teaching staff, especially in applied training, □ outdated approaches to vocational guidance.	To better match labour market needs, a dual education system was introduced in 2016, combining education with work-based training based on partnerships between vocational schools and companies.	□ To compensate for the loss of infrastructure and to improve security, a digital platform "Professional Education Online" was developed in 2022 and officially launched in December 2022 (ILO, 2023), allowing the theoretical part of the curriculum to be covered through distance learning. □ Many links between vocational schools and companies have been lost due to the closure or relocation of companies. There are plans to create a network of qualification centres and to continue the dual education system, which should support partnerships with companies. □ There are plans to adapt and create new training programmes using modular methodology and focusing on competence outcomes. □ There are plans to improve career guidance and to increase the attractiveness of VET. □ A number of activities are planned to provide psychological support and to adapt and support VET staff and students in educational processes in war and post-war periods.

Source: Own compilation based on Leu-Severynenko (2022).

Figure 2-6: Number of VET institutions as of August 2022



Source: Own work based on MoES (2022).

In addition, both the war and the pandemic have resulted in large gaps in educational attainment, so there is a need to invest in strong future human capital by providing remedial education to students who have lost crucial years of education. With regard to the post-war reconstruction of the energy sector, it is crucial for the Ministry of Energy, the Ministry of Education and Science and the Ministry of Digital Transformation to create and modernise relevant educational programmes in higher and vocational education (Ministry of Energy of Ukraine, 2024a). Furthermore, the system needs to address the psychological trauma of war, support the reintegration of vulnerable students and adapt a more inclusive system to encourage students from lower socio-economic backgrounds to learn and enter the labour market with the needed qualifications (Gorodnichenko, Sologoub, & Weder di Mauro, 2022).

The existing national strategic document "Innovation Development Strategy", launched by the Ministry of Digital Transformation and the Ministry of Education and Science, already addresses the skills gap and can therefore be used to prepare professionals for future jobs. In this context, another goal is to restore and modernise the equipment and infrastructure of scientific and educational institutions that train energy industry professionals, while also establishing international partnerships to support these efforts (Ministry of Energy of Ukraine, 2024a).

Another important action area is to make use of existing human capital by training or retraining unemployed workers, with incentives reinforced by easier access to training, better employment conditions and other mechanisms aimed at improving the quality of work (Gorodnichenko, Sologoub, & Weder di Mauro, 2022). The implementation of training programmes for professionals working in the energy sector requires the involvement of public funds as well as funds from international actors and energy sector companies. Exchange programmes and academic mobility could also be effective tools to gain access to advanced knowledge in this field (Ministry of Energy of Ukraine, 2024a).

Finally, to ensure that human capital development supports both reconstruction in the short to medium term and sustainable economic development in the medium to long term, education in Ukraine needs to be reformed as a holistic system, with secondary, vocational and higher education aligned under a unified strategy (Gorodnichenko, Sologoub, & Weder di Mauro, 2022).

3. Availability of financing and existing support mechanisms for green energy

3.1 ‘Green’ tariffs and auctions

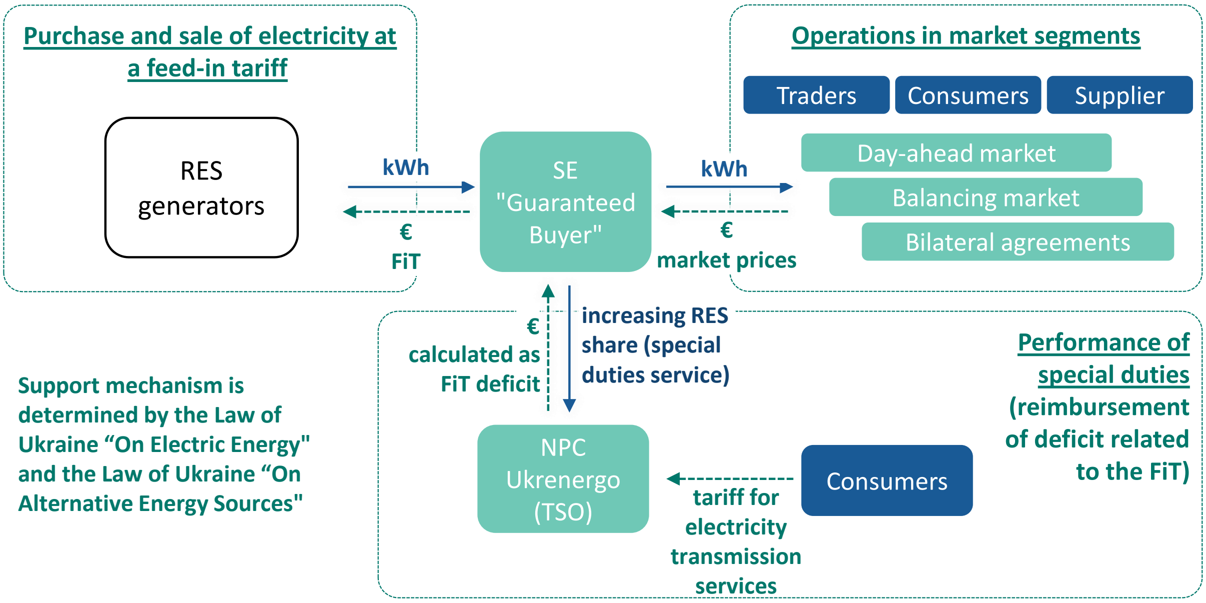
One of the main mechanisms for RES promotion in Ukraine is the feed-in tariff (FiT), also called ‘green’ tariff. It encourages households and businesses to use RES and helps to reduce dependence on traditional fuel sources by providing a special tariff for the purchase of electricity generated by RES power plants: wind turbines (WPP), solar panels (SPP and rooftop PV), biological fuel, and small hydroelectric power plants (HPP). It is currently valid until 1 January 2030 and applies to power plants commissioned by then (Verkhovna Rada of Ukraine, 2003). The FiT in Ukraine has three main features (EEnergy, 2019; Verkhovna Rada of Ukraine, 2003):

- **Guarantees**: The state guarantees the connection of the RES producer to the grid and the purchase of all the ‘green’ electricity produced without restrictions.
- **FiT level**: NKREKP sets the FiT rates for each type of alternative energy and RES producer in accordance with Procedure for Establishing, Revising and Terminating the Feed-in Tariff for Electricity for Business Entities and Private Households. The FiT is strictly linked to the Euro (which is not affected by inflation in Ukraine) and is one of the highest in Europe.[12]
- **Duration**: The FiT has a long duration as it is legally fixed until 2030.

The operation of FiT is illustrated in Figure 3-1. The state enterprise Guaranteed Buyer is responsible for settling accounts with RES producers for electricity produced under the FiT. To this end, the Guaranteed Buyer is entrusted with special duties to purchase electricity from RES producers at the FiT and sell it on the day-ahead, intraday and balancing markets. In order to fulfil its special duties, the Guaranteed Buyer provides the Transmission System Operator (TSO), NPC Ukrenergo, with a service to ensure an increase in the share of electricity generation from alternative sources (Sayenko Kharenko, 2019). NPC Ukrenergo in turn makes payments to the Guaranteed Buyer for these services, funded by the transmission tariff.

[12] See Table B-1 in the Appendix for the overview of FiT rates since its introduction.

Figure 3-1: FiT mechanism



Source: Own work.

The calculation of the cost of the Guaranteed Buyer's service to ensure an increase in the RES share is approved by the NKREKP and includes

- the difference between the cost of electricity purchased at the FiT and its value when sold on the day-ahead and intraday markets;
- the costs associated with the balancing of the power imbalances of the producers belonging to the Guaranteed Buyer's balancing group (to the extent not covered by the producers, see Box 3-1 on more information about imbalance settlement);
- expenses set by the Guaranteed Buyer for its activities (Sayenko Kharenko, 2019).

In practice, the level of the FiT is calculated as the retail price of electricity for consumers in 2009 (approximately 5.38 eurocents per kWh), multiplied by the FiT coefficient established by law, depending on the energy source and the date of commissioning of the power plant. After the NKREKP sets the FiT, it remains unchanged until 1 January 2030 but is subject to quarterly review in accordance with the official exchange rate of the hryvnia against the euro, which is set by the National Bank of Ukraine (NBU). In addition, the NKREKP may set a surcharge of up to 20% on the FiT if the manufacturer confirms the presence of certain equipment of Ukrainian origin in the energy facility in accordance with the procedure established by the applicable legislation of Ukraine.

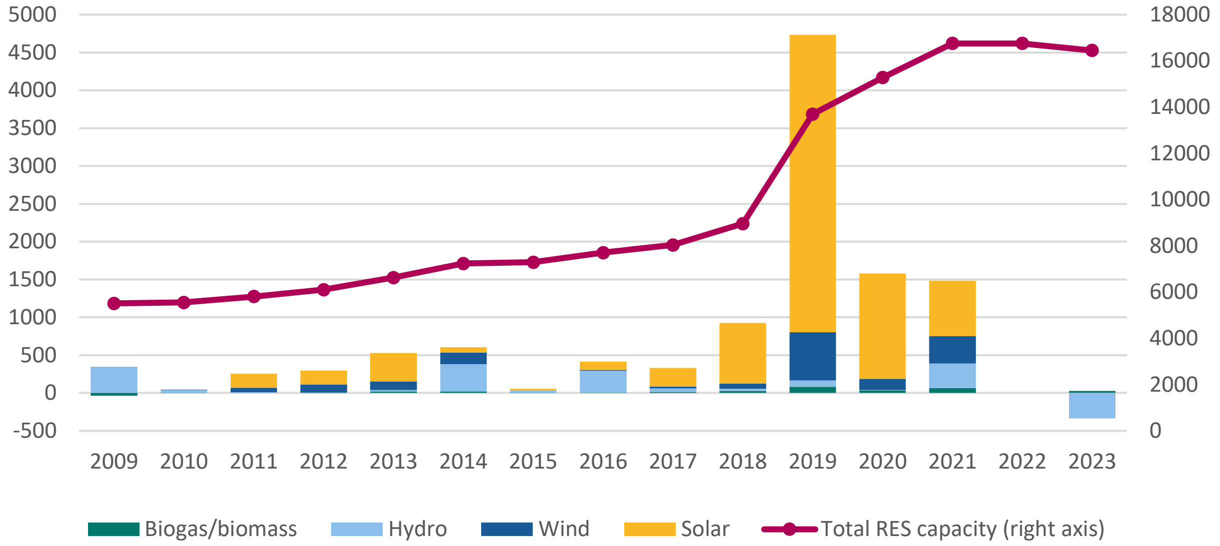
Box 3-1: Imbalance settlement

Electricity markets are divided into sets of settlement periods (e.g. 30-minute time slots over a day) for which contracts for the purchase and sale of electricity are concluded. However, particularly in the case of variable RES generation, the actual electricity supply in the settlement period may differ from the contracted amount. In addition, due to the physical characteristics of the electricity grid, the supply and consumption of electricity must always be balanced. This is often achieved by matching supply to demand, but consumers, particularly large ones such as industrial plants, also provide demand-side flexibility to the market. Therefore, within a balancing group, market participants make offers to increase the amount of energy in the system by increasing generation or decreasing demand, and bids to remove energy from the system by decreasing generation or increasing demand. There may be more than one balancing group in the market.

If, in any settlement period, the amount of electricity generated differs from the amount contracted, or if the grid operator makes use of the offers to increase energy or bids to decrease energy, a discrepancy between the contracted and actual electricity supplied or consumed is called an imbalance. If the energy producer has supplied more electricity or the consumer has bought less electricity than contracted when there was a deficit in the system, they will be paid for the 'surplus' balance at the imbalance settlement price, and vice versa. Since any imbalance can be mitigated by actions on both sides - for example, a surplus in the system can be reduced by producers reducing generation and consumers increasing consumption - some imbalance charges will almost always be paid to some market participants and some recovered from others. Depending on how much adjustment comes from the supply or demand side, the total balance of charges may also result in a surplus or deficit of cash flows in the balancing group. This surplus or deficit is normally credited or charged to active market participants.

Since the introduction of the FiT, it has been planned to reduce it gradually in order not to overburden the budget and to take into account the expected gradual reduction in the cost of generation equipment. In addition, as the FiT is linked to the euro, the real tariff is affected by the exchange rate. At the end of 2014, for example, the hryvnia plummeted and the real tariff was almost halved because the state did not revise the FiT to balance it with the exchange rate (Gmyryn, 2021). The consequences of the real tariff reduction are clearly visible in the amount of new renewable capacity installed during that period. From the introduction of the FiT in 2009 to 2013, there was a steady, though limited, growth in net RES capacity additions, primarily driven by solar and wind energy (Figure 3-2). In 2014, solar additions fell significantly, though this was compensated for by the completion of some larger projects in pumped storage hydropower, and in 2015 almost no new RES capacities were installed. In addition, part of the existing renewable capacity was de facto lost to the Ukrainian electricity system in 2014, as it remained in Crimea and the uncontrolled territory in eastern Ukraine (Hrytsyshyna, 2020).

Figure 3-2: Net RES capacity additions and total installed capacity in 2009-2023, MW



Note: The data include PSPPs and large HPPs.

Source: IRENA (2024).

With adjustments made in 2015 to balance the tariff setting, Ukraine's renewable energy sector experienced unprecedented growth, with new RES installations peaking at around 4.7 GW in 2019. However, market imbalances, debt accumulation by NPC Ukrenergo and a high FiT level, combined with a rapidly growing number of eligible RES producers, led to significant debt accumulation by the Guaranteed Buyer. A payment crisis unfolded in 2020, undermining investor confidence, with the situation exacerbated by the COVID-19 shutdowns and trade disruptions. This is reflected in a sharp decline in new RES installations to just over 1.5 GW in 2020.

In August 2020, as a result of agreements reached between the Government of Ukraine and Ukrainian associations of alternative energy producers to overcome the crisis situation in the sector, several important changes were introduced (DLF, 2020). First, the FiT rates were reduced, while at the same time FiTs for households and energy cooperatives were introduced, which were largely uncovered until 2020 (see Table B-1 for an overview of FiT rates over time). Second, an imbalance responsibility was gradually introduced for renewable energy producers, obliging them to reimburse the Guaranteed Buyer for the costs associated with balancing. Thirdly, the amendments to the law allowed the state to provide financial support to the SE Guaranteed Buyer amounting to at least 20% of the forecast production of electricity from alternative sources for the corresponding year, in order to ensure the continuation of payments to eligible RES producers.

In addition to the FiT, the auction model for larger RES projects (above 5 MW, with a focus on wind) has been further explored. In 'green' auctions, RES project developers bid against each other for contracts to generate electricity from their new plants, and the buyer - the government, acting through the Guaranteed Buyer - selects the projects with the lowest price until the pre-defined quota of new RES capacity is filled. RES producers that win an auction and receive support also enter into a fixed-rate Purchase Power Agreement (PPA) with the Guaranteed Buyer. However, unlike the FiT, the number of supported projects is limited by a quota and auction participants bid for support so that the most efficient projects are selected and the resulting PPA prices reflect actual project costs, rather than offering a (high) flat rate compensation to all RES developers. This allows larger RES projects to be supported efficiently while limiting budgetary costs.

The 2020 reform therefore took a step towards the introduction of 'green' auctions by defining the procedure for conducting 'green' auctions. It also introduced a limit on the maximum starting prices (see Table B-2 in the Appendix) and conditions that can be included in the quotas, such as regional focus, maximum capacity of an eligible RES project, and proposed land plots or roofs/facades for RES installations with specific technical parameters and conditions for grid connection. However, as discussed in Section 4.3, the auctions were not put into practice at that time, and although an update of the auction procedures in 2024 was an important step towards the implementation of this support mechanism, there are still a number of issues to be resolved before it can be launched (GOPA International Energy Consultants, 2024; Makogon, 2023).

3.2 Feed-in Premium and Contracts for Difference

In addition to the FiT, other market-based instruments were introduced in 2023 with the Law "On Green Transformation of the Energy System of Ukraine". The law contains a number of innovations in the regulation of the renewable energy market, putting in place new incentive systems, and transforms the industry as a whole. Overall, it contains many positive aspects that the market has long been waiting for, although some regulatory decisions are controversial. However, the full extent of the regulation will only be understood when the regulator adopts secondary legislation that will put the law in practice.

The two main instruments introduced in RES pricing are the market premium mechanism (feed-in premium) and the self-generation mechanism (net billing), which is discussed in the next section.

The **Feed-in Premium (FiP)** is a system to support the production of electricity from RES, for producers using the FiT or those supported based on the auction results. Under this mechanism, the RES producer can sell electricity to traders, suppliers or consumers at market prices and is compensated by the Guaranteed Buyer for the difference between the FiT/auction price level and the estimated market price if the latter is lower than the FiT/auction price. While ensuring a stable electricity price for RES producers, this mechanism allows them to act freely in the market and optimise their balancing costs by freely choosing a balancing group (Kness, 2023).

In return, the RES producer pays the Guaranteed Buyer the cost of the service under the FiP mechanism, if the estimated market price is higher than the FiT/auction price. The Guaranteed Buyer calculates the cost of the service under the FiP mechanism in accordance with the procedure approved by the NKREKP, either on the basis of the price indices on the day-ahead market or on the basis of the price indices under bilateral contracts, corrected for their relation to the prices on the day-ahead market (Sayenko Kharenko, 2023; Kness, 2023).

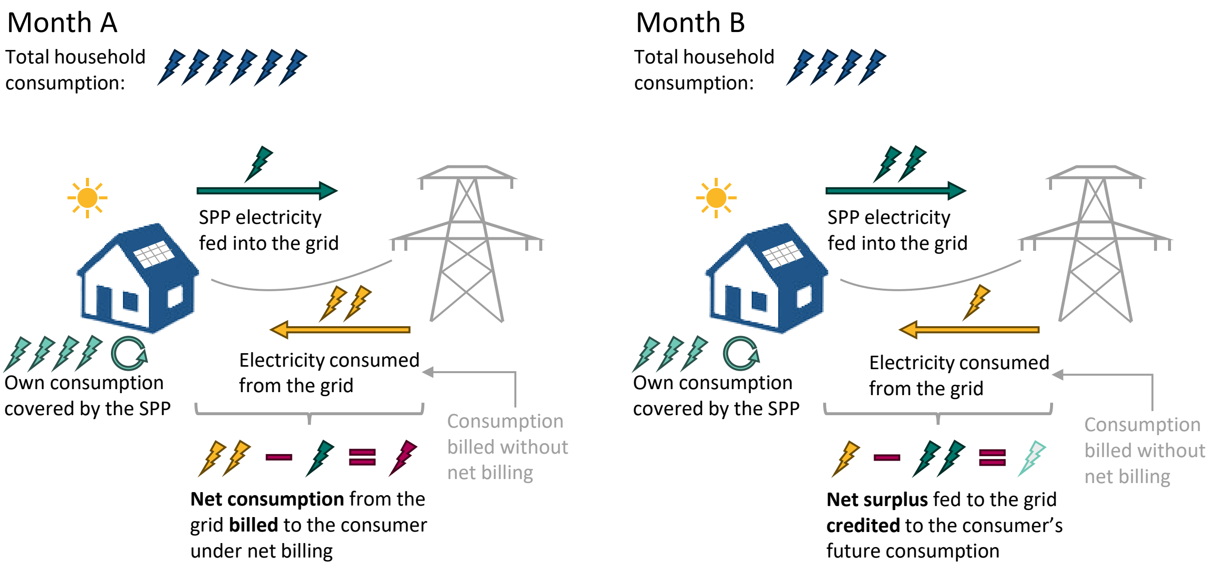
The FiP mechanism therefore works in a similar way to the **Contracts for Difference** (CfDs) used to ensure long-term price stability for energy producers. A CfD is concluded between a RES producer and another market participant and establishes an indicative price, at which the RES producer sells electricity to the counterparty. This indicative price is compared to the price at the wholesale electricity market. If the wholesale market price for electricity falls below the agreed price, the counterparty compensates the RES producer for the difference. This guarantees that renewable energy producers receive a minimum, stable income, which encourages them to make long-term investments in low-carbon energy projects. If the wholesale market price exceeds the agreed price, the RES producer pays back the difference to the counterparty. This prevents the producers from making excessive profits if market prices are higher than expected.

CfDs are also available in Ukraine, but until recently they could only be contracted with electricity consumers. In addition to introducing the FiP, the new law also clarified the regulation of the use of CfDs by RES producers, allowing them to enter into CfDs not only with consumers, but also with electricity suppliers and traders. It also allows CfD conclusion for both, RES producers receiving support through FiT or auctions and those that do not receive such support. To ensure that the electricity traded under the CfD indeed comes from RES, the law also provides for inclusion of conditions for the transfer of guarantees of origin of electricity (GOPA International Energy Consultants, 2024).

3.3 Net billing

Net billing, introduced in Ukraine as the “self-generation mechanism”, is a mechanism aimed at households, condominiums, energy cooperatives, and small and medium-sized enterprises. It allows ‘prosumers’, i.e. owners of small-scale RES installations, such as rooftop solar panels, who also consume the electricity they produce, to 'sell' the excess electricity they produce and feed into the grid at the same price as their own consumption of electricity. This is done by crediting the amount of electricity they feed into the grid against their current or future consumption of electricity from the grid (see Figure 3-3 for a schematic illustration). This system encourages consumers to produce their own electricity and promotes the efficient use of energy resources (Namyasenko, 2023).

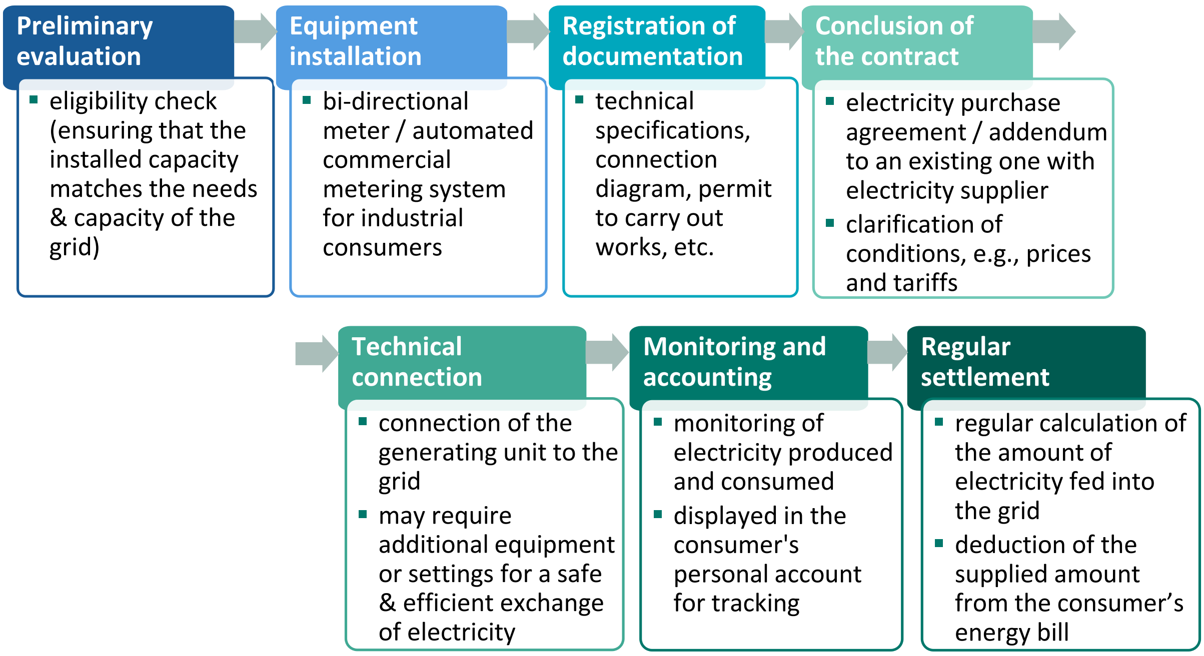
Figure 3-3: Schematic illustration of the net billing mechanism



Source: Own work.

The connection process for the net billing mechanism follows a specific procedure that includes several key steps from preliminary evaluation to monitoring and settlement, as shown in Figure 3-4.

Figure 3-4: Connection process under the net billing mechanism



Source: Own presentation based on ONLYSolar (2024).

In order to ensure the safety and efficiency of the electricity system and to protect the interests of all market participants, there are restrictions on participation in the net billing mechanism with regard to prosumer types, allowed generating unit capacity and feed-in amounts, necessary equipment, and the use of other incentive mechanisms (ONLYSolar, 2024):

- **Eligible prosumers**: Net billing is restricted to certain categories of consumers, such as households, condominiums, energy cooperatives, and small and medium-sized enterprises. Large industrial consumers may have different terms and conditions.
- **Capacity of generating units**: For households and other small generators, there is a limit on the maximum generating capacity that can be connected to the net billing system. This limit helps to avoid overloading the grid. The following maximum capacity limits apply:
  - For solar and wind systems in households: 30 kW;
  - For solar and wind installations by small non-residential consumers: 50 kW;
  - For installations of other non-residential prosumers generating electricity from solar, wind, biomass, biogas, hydropower, or geothermal energy: the permitted (contractual) capacity of their electricity-consuming installations.
- **Restrictions on feeding electricity back into the grid**: There is a limit to the maximum amount of electricity that can be fed back into the grid at any one time. For systems up to 50 kW, the amount of electricity fed back is limited to the capacity of the connected unit. For systems above 50 kW, no more than 50% of the unit’s capacity can be fed back at any one time. However, this limit can be increased if certain technical requirements of the distribution/transmission system operator, which are yet to be defined, are met.
- **Prohibition on simultaneous use of multiple pricing mechanisms**: In order to avoid double incentives, consumers cannot enjoy the benefits of the feed-in tariff (which provides for the purchase of generated electricity at a higher tariff) and the net billing system at the same time.
- **Equipment requirements**: In order to participate in the net billing system, the owner of the generating unit must have installed a bi-directional meter or an automated commercial metering system for industrial consumers, so that both the electricity consumption and the amount of electricity fed back into the grid can be measured. This equipment must be certified and comply with the technical requirements.

3.4 Other incentive schemes and financing mechanisms

Ukraine has used a variety of incentive schemes and financing mechanisms to promote RES development. Some instruments have been used more actively in Ukraine than others. So far, the support landscape was dominated by the use of state subsidies for the purchase and installation of equipment, purchase of electricity, and less often – the conclusion of energy service contracts. More recently, also investment loans backed by state guarantees and provision of loans using dedicated state or local Funds have come into play.

State subsidies for the purchase and installation of equipment typically involve a direct subsidy or rebate on total costs (prices, loan costs) of modernisation or conversion to renewable energy sources. They are provided by state or local authorities with a particular focus on to promoting and improving energy efficiency. One of the most recent examples if the GreenDIM programme aimed at households and condominiums, which covers up to 70% of costs for the purchase and installation of solar panels and heat pumps (see also Table C-1 in the Appendix).

Under **power purchase agreements (PPAs)**, the energy producer pays for and installs the power generation equipment on the user's site, and the property owner buys the electricity generated. The electricity is purchased at a fixed rate for the next 10 to 20 years, and tax benefits for the energy producers allow to achieve a rate below the average market price. In Ukraine, the Guaranteed Buyer concludes PPAs with the RES producers operating under the FiT or receiving auction support, but the RES producers can also conclude PPAs directly with consumers, and this can also be done in combination with CfDs.

Energy service contracts focus on increasing energy efficiency and the use of renewable energy in the public sector. Considering that currently close to 80,000 public buildings in Ukraine (schools, kindergartens, hospitals, universities, etc.) need to be insulated to European standards, requiring an investment of about EUR 13 billion, attracting private investment is crucial. In this programme, energy service is defined as a set of technical and organisational energy efficiency and other measures aimed at reducing the customer's energy consumption and/or costs. Energy efficiency measures in public sector buildings are carried out by private investors - energy service companies (ESCOs) - and paid for solely by the savings (reduced utility and energy consumption) achieved as a result of these measures. This is advantageous for the public sector, as it does not have to bear the immediate investment costs of the energy efficiency measures, but pays them back over a period of 10 years through savings alone, making the measure cost-neutral.

International donors are also actively using energy service contracts. For example, the UNDP project "Removing Barriers to Promoting Investment in Energy Efficiency of Public Buildings in Small and

Medium-Sized Cities of Ukraine by Applying the ESCO Mechanism" focuses on the installation of SPPs in critical infrastructure facilities, such as hospitals and water utilities. Since 2017, the project has concluded 644 contracts worth more than UAH 2 billion, of which 80% have been implemented and 30% already completed, with the equipment handed over to the customers (municipalities, authorities).

A powerful financial instrument for attracting private investment is **investment loans backed by government guarantees**. Under this scheme, private investors finance their projects with loans from banks or credit unions, while the government guarantees the repayment of the funds. This reduces the lender’s risk and leads to better loan terms, such as lower interest rates or flexible underwriting standards. The prerequisites for such loans are the level of development, liquidity and stable financial legislation, which together make it possible to attract financial resources even for high-risk projects. Investment lending tends to favour modernisation projects and the refinancing of renewable energy. However, significant bureaucratic difficulties, with long application processing times, generally high interest rates on bank loans, limited concentration of funds and restrictions on minimising credit risks, may still prevent this type of funding from taking off.

Support for renewable energy development through **dedicated state funds** is currently being established in Ukraine. For example, the State Fund for Decarbonisation and Energy Efficiency Transformation, established in June 2024 (CMU, 2024b), will be a part of a special fund of the state budget of Ukraine. It will be financed by the revenues from the environmental tax on CO_2 emissions from stationary sources and by government loans to support energy efficiency and emission reduction. The resources of the Decarbonisation Fund will be used to finance state programmes in the field of energy efficiency and renewable energy and compensation payments under loan and leasing agreements concluded for the implementation of energy efficiency measures, introduction of energy services, and development of renewable energy sources. The support will be provided in the form of loans with maturities of up to ten years and loan amounts ranging from UAH 120 thousand to UAH 25 million. As the loans mature, the borrowed funds will be returned to the fund to finance new projects.

These schemes of financing renewable energy are project-specific, and the lack of experience in their practical application often means that investors face additional risks. Recently, in addition to banks and international financial institutions providing loans for renewable energy investments, engineering, procurement and construction (EPC) contractors, government institutions and revolving funds have played a special role. Against this backdrop, new financial instruments, including leasing, green bonds and equity markets, are on the rise.

The practice of using **green bonds** in Ukraine is developing, and in recent years many measures have been introduced for the qualitative and quantitative development of this financial market segment. For example, at the end of 2021, NPC Ukrenergo issued the largest amount of sustainable development green Eurobonds – USD 825 million - for a term of up to 5 years with an unconditional and irrevocable state guarantee and a yield of 6.875% exclusively for renewable energy producers.

As an alternative to loan-based financing, **Initial Public Offerings** (IPOs) are external financing mechanisms based on the initial placement of a company’s shares on the stock exchange, capable of attracting significant financial resources and sector-oriented state or individual investors. The advantages of using this mechanism for external investors are verification of the issuer’s reliability by the strict standards of the financial markets and the high expected return on investment through participation in the distribution of the company's profits. However, it requires a strong stock market.

Due to the peculiarities of the functioning of the Ukrainian energy sector, no IPOs have taken place so far. Given the growing interest of both international and domestic investors in the RES market, IPOs may have good prospects in the post-war economic recovery. However, this would require significant institutional changes aimed at comprehensive adaptation to participation in stock exchange trading, including legislative and institutional adaptations and possible tax benefits for investors and companies (e.g., exemption of investors from paying income tax on the sale of shares) to encourage a wider participation in the stock markets.

Effects of the war on RES support

The policies to promote RES have continued despite the war of aggression against Ukraine. As energy infrastructure continues to be the target of attacks, the rapid development of distributed renewable generation is critical to ensuring a secure and stable electricity supply in Ukraine and energy independence of consumers. In this context, a whole package of important decisions and financial programmes has been developed and is currently being implemented at the state level, which will help to stimulate the development of distributed generation in order to ensure the energy independence of Ukrainians, local generation needs and, in general, the energy security of Ukraine (Ministry of Energy of Ukraine, 2024b).

Supporting households and businesses to invest in their own energy generation is key, in particular through access to affordable credit. The Financial Stability Council approved the Credit Development Strategy in June 2024, which reflects a holistic vision of the key principles for improving credit services in Ukraine and the actions needed to implement them, which will contribute to a sustainable economic recovery (National Bank of Ukraine, 2024). The implementation of the Strategy is a matter of the country's financial security and a tool for building a dynamic and competitive economy capable of sustainable development and European integration.

At present, thanks to the consistent policy of the National Bank of Ukraine, the Cabinet of Ministers of Ukraine and significant international assistance, the conditions for lending to the economy and the population are improving with a view to ensuring macroeconomic stability. In particular, the level of lending rates is falling. At the same time, the demand for credit is segmented, and there are serious military risks for a number of industries and regions, making it difficult to access the necessary financial resources.

The Strategy aims to contribute to the provision of financial resources for the restoration of energy infrastructure and to stimulate demand aimed at increasing the country's defence capability, in particular by enterprises of the military-industrial complex, manufacturing, agriculture and business in the de-occupied and frontline stability areas.

The activities of the strategy will be implemented in two directions:

- activation of lending to priority areas under martial law;
- development of the legislative framework for further stimulation of market lending.

The implementation of the Credit Development Strategy will contribute to expanding access to credit resources and developing entrepreneurship, attracting investment, creating new jobs and encouraging the return of Ukrainians from abroad (Дія.Бізнес, 2024). Several new loan programmes have been introduced to encourage households and businesses to develop their own energy resources (see Table C-1 in the Appendix for an overview). Some of these programmes are funded by international donors and investors, which highlights their active involvement in supporting RES development in Ukraine, especially since the start of the war. To name but a few, funding is provided by the European Bank for Reconstruction and Development (EBRD), the International Finance Corporation (IFC), the EU, the German government, and a variety of international donors in programmes managed by the aforementioned organisation and in direct agreements with Ukrainian ministries and energy companies (see Table C-2 in the Appendix for an overview of selected international support programmes).

3.5 Assessment of current tariff policies

Until the 2019 market reform, consumer tariffs were highly regulated by the state. Household tariffs were set at a low level and cross-subsidised by electricity prices for non-household consumers (IEA, 2021). The 2019 reform allowed households to freely choose their supplier on the retail market. In practice, however, the continued subsidisation of retail tariffs resulted in households being supplied by the universal suppliers (Anatolitis & Grundlach, 2020). On the supplier side, the regulated low tariffs still did not cover actual costs, leading to massive debt accumulation (Prokip, How Energy Misregulation Threatens Ukraine's Electricity Sector, 2023). This was exacerbated by the mismatch between FiT levels, actual RES costs and regulated tariffs, coupled with the state's obligation to purchase all RES electricity produced under the FiTs. The mounting problems led to a crisis in 2020, destabilising the sector and affecting RES generators in particular (Prokip, 2020).

Although steps were taken to reform support for renewable energy, cross-subsidisation of household tariffs remained, mainly through the state energy companies. The pressure was exacerbated by the fact that energy infrastructure has been a constant target of missile and drone attacks since the start of the war. With most thermal power plants and the NPPs being owned by state companies, their damage, destruction or loss of control incurred immense losses to these companies and undermined their capacity to continue tariff subsidisation (Prokip, 2023).

As a result, the Ukrainian government hat to make unpopular but vital decisions to stabilise the sector and drastically increase the household electricity tariffs in 2023 and 2024. At 4.32 UAH/kWh from June 2024, the current tariffs seem to approach the cost-covering level (see Section 6). However, the NKREKP still maintains price caps at the wholesale electricity market. The new model, however, is criticised for further aggravating the situation of the RES producers, as the price is allowed to fall close to zero at noon and to peak at night, this further increasing the payment deficit to RES producers (Prokip, 2023).

Therefore, the tariff-setting in Ukraine is still overregulated, and market reforms coupled with a more efficient design of RES price support (e.g., through auctions replacing FiT) will be needed to provide for a sustainable development of the electricity sector (Dombrovska & Lenain, 2024).

4. Overview of legislative regulation of renewable energy in Ukraine

4.1 Relevant legal scope

To understand the scope of Ukrainian legislation on renewable energy, it is important to note that there is parallel use of two terms: *alternative* and *renewable* energy sources. These terms are sometimes used interchangeably, but there is a difference in their definition. The Law of Ukraine "On Alternative Energy Sources" No. 555-IV of 20 February 2003 defines *alternative energy sources* as:

- *renewable energy sources*, which include solar, wind, geothermal, hydrothermal, aerothermal, wave and tidal energy, hydropower, biomass, gas from organic waste, gas from sewage treatment plants, and biogas, and
- *secondary energy resources*, which include blast furnace and coking gases, methane recovered from coal deposits, and recovery of waste energy from technological processes (Verkhovna Rada of Ukraine, 2003).

Thus, the concept of alternative energy sources is a collective category that combines different types of sources. In turn, the concept of renewable energy sources in Ukrainian legislation is a narrower term that meets the requirements of legislative adaptations towards European integration.

Overall, the legal regulation of alternative energy sources in Ukraine is carried out by the Cabinet of Ministers of Ukraine (CMU) or, on its behalf, the National Energy and Utilities Regulatory Commission (NKREKP or Regulator). The NKREKP operates under the Law of Ukraine "On the National Energy and Utilities Regulatory Commission" (Verkhovna Rada of Ukraine, 2016), which defines its main tasks: regulating the production of electricity and heat, in particular at facilities using alternative or renewable energy sources, and issuing appropriate licenses. State regulation also provides for the establishment of tariffs for electric and thermal energy generated from alternative sources. However, the analysis of the regulatory environment indicates the existence of numerous gaps and shortcomings in the activities of the NKREKP, including the lack of clear guidelines for the use of alternative energy sources.

The central executive body for energy policy is the Ministry of Energy of Ukraine, which is responsible the development and implementation of state policy in the field of renewable energy sources and alternative fuels (Shender, 2023). There is also a variety of other ministries and institutions that are responsible for energy policies in certain areas, such as (IEA, 2021):

- Ministry of Energy and Environmental Protection and its subordinate State Agency on Energy Efficiency and Energy Saving (energy supply policies, promotion of energy efficiency and renewable energies, sustainability/climate change),
- Ministry of Finance (taxation relevant to the energy sector),
- Ministry of Communities and Territories Development (local-level policies and programmes),
- Anti-Monopoly Committee (market power in energy markets),
- State Nuclear Regulatory Inspectorate (regulation of nuclear facilities and related operations).

Key legal documents regulating the development and use of alternative and/or renewable energy sources include:

- Law **On Alternative Energy Sources** (adopted 2003, last amended 2024), which sets the concepts of "alternative energy sources", "non-traditional sources", "renewable sources" and basic principles of state policy and public administration in the field of alternative energy sources. It also includes provisions on stimulation of production and consumption of energy produced from alternative sources, including "green" tariffs and state obligation to buy electricity produced by alternative sources, creation of State Enterprise Guaranteed Buyer (Verkhovna Rada of Ukraine, 2003).
- Law **On Electricity Sector** (adopted 1998, last amended 2018), which details the existing legal principles of the "green" tariff and sets requirements for energy producers from alternative sources (Verkhovna Rada of Ukraine, 2017b).
- Law **On Electricity Market** (adopted 2017 replacing the Law On the Principles of Functioning of the Electricity Market of Ukraine from 2014, last amended 2024), which regulates the design of the electricity market, including the removal of state monopoly for selling and buying electricity and establishment of competitive pricing and distinct market segments: bilateral contracts, the day-ahead market, the intraday market, the balancing market, the market for ancillary services, and the retail market. It also regulates conclusion of power purchase agreements (PPAs) and contracts between the SE Guaranteed Buyer and electricity producers (Verkhovna Rada of Ukraine, 2017a).
- Law **On Alternative Types of Liquid and Gas Fuels** (adopted 2000, last amended 2024), regulating biofuels and other alternative fuels, including renewable fuels of non-biological origin (RFNBO) (Verkhovna Rada of Ukraine, 2009).

- **Energy Strategy of Ukraine to 2050** at the strategic development level, which envisions an increase in total RES share in Ukrainian energy mix to 30% in 2030 and the share carbon-free sources in electricity generation to 90% by 2050 (CMU, 2023; Makogon, 2023).
- (draft) **National Energy and Climate Plan (NECP) of Ukraine 2025-2030**, submitted to the EU under the Energy Community Treaty, which aims at coordinating energy and climate policies in the coming five years. It sets a target of a 27% RES share in final energy consumption by 2030 (Ministry of Energy of Ukraine, 2024a).

4.2 Regulatory framework

4.2.1 Electricity market design

Before 2019, Ukrainian wholesale electricity market functioned under a single-buyer model. The state had a monopoly both for buying and selling electricity and all energy producers except TPPs sold electricity at fixed prices set by the NKREKP, while TPPs competed for the remaining demand. Residential consumers paid fixed tariffs and for non-residential consumers, the NKREKP calculated the electricity price as the weighted average of producer prices plus transportation and other costs, including the cross-subsidy for household tariffs (IEA, 2021).

The 2019 reform involved several adaptations demanded by the Energy Community Treaty. It liberalised the wholesale electricity market and created different market segments: bilateral, day-ahead, intraday, balancing, and ancillary services markets. The reform aimed to allow market participants to trade electricity freely, and in the retail market, households were also allowed to freely choose their supplier. In practice, however, the subsidised retail tariffs offered by the state-owned 'universal suppliers' meant that households stayed with the universal suppliers rather than seeking other suppliers in the retail market (Anatolitis & Grundlach, 2020).

Renewable energy producers continued to sell electricity mainly at FiT or auction prices (for large plants) directly to the Guaranteed Buyer on the bilateral market, where contracts for the supply of electricity over several months or years are individually negotiated and concluded between two parties. In addition, liability for imbalances was gradually introduced (see Box 3-1 in Section 3.1 for more information on imbalance settlement). RES producers participate in the Balancing Group, where balancing is done by the Guaranteed Buyer, and are obliged to reimburse the Guaranteed Buyer for the costs associated with imbalance settlement. Previously, the settlement costs were effectively borne by NPC Ukrenergo. The market reform sets the reimbursement rate for energy producers at 10% of settlement costs in 2021, rising to 100% in 2030 (International Trade Administration, 2021).

Since connecting to ENTSO-E in 2022, Ukraine has also been gradually adopting European rules for international trade in electricity. For example, it uses joint auctions to allocate available interconnection capacity between national grids and is planning to couple spot (i.e., the day-ahead and intraday) electricity markets. In addition, Ukraine is planning to gradually adjust regulations consumer tariffs until market pricing can be achieved (Ministry of Energy of Ukraine, 2024a).

4.2.2 Other RES regulation

Much of the focus of RES development has been on increasing the share of RES in electricity generation, with the main mechanism being price support through FiTs. In addition to price support, a number of financial incentive schemes have been adopted to support RES installations, in particular by households and small and medium-sized enterprises (SMEs) (see Section 3 for more details).

In 2023, guarantees of origin for RES electricity were introduced by law, making it possible to certify electricity as "green", e.g. for export purposes, and to benefit from the advantages associated with RES (Ministry of Energy of Ukraine, 2024a). For example, as the EU's Carbon Border Adjustment Mechanism (CBAM) becomes operational, this would allow RES producers to export electricity to the EU without incurring CBAM payments according to default benchmarks of national electricity emission intensity. Since the originally adopted secondary regulation for the guarantees of origin did not work well in practice, the Cabinet of Ministers of Ukraine adopted a new resolution in early 2024 to clearly set up the procedures for issuing, circulating and redeeming guarantees of origin for electricity generated from RES and for determining the environmental value of electricity generated from RES (Dentons, 2024). In the future, the Ukrainian Register of Guarantees of Origin of Electricity will be integrated into the Energy Community Regional Register and Ukraine will become a full member of the Association of Issuing Bodies.

To ensure availability of equipment, the Tax Code and Customs Code also provide benefits for production and imports of RES equipment.

There were also regulatory developments for other RES types and uses. For example, the Law "On Alternative Types of Liquid and Gas Fuels", first adopted back in 2000 and actively developed further over the last two decades, provides for promotion of development and rational use of 'unconventional sources' for the production of alternative fuels (including biofuels and synthetic fuels). So far, the regulatory framework mostly concerned biofuels and biomethane, for which registration procedures and recently regulation of guarantees of origin were implemented (Ministry of Energy of Ukraine, 2024a).

However, the National Energy and Climate Plan also foresees creating a regulatory framework for future energy markets and the necessary infrastructure, e.g. for the development of a hydrogen market. In 2023, Ukraine and the EU have already signed a Memorandum on strategic partnership in the field of RE-based gases, namely hydrogen and biomethane, which aims at information exchange, development of suitable regulatory and certification frameworks, identification and elimination of barriers and mobilisation of investments for infrastructure and ‘energy cluster’ development (GOPA International Energy Consultants, 2024).

The Ukrainian government also recognises the need to develop energy storage to ensure stability of supply and better integration of RES into the electricity system. On 15 February 2022, the Law "On Amendments to Certain Laws of Ukraine on the Development of Energy Storage Facilities" was adopted, which aims to promote the use of energy storage facilities (ESFs) by energy producers and increase grid stability and energy security. It provides a definition of ESFs with a range of technologies, including pumped hydro, batteries, flywheels and compressed air energy storage, and sets out the conditions for licensing and permitting of ESF operators, grid access, tariff regulation and environmental considerations of ESFs. However, secondary regulation to clarify procedures for the operation and market participation of ESFs is still to be developed (GOPA International Energy Consultants, 2024).

Finally, the focus on efficient cogeneration of heat and electricity in CHP plants has been strengthened, as opposed to electricity-only or heat-only plants. Amendments to the Law of Ukraine "On Combined Production of Thermal and Electric Energy (Cogeneration) and Use of Waste Energy Potential" (Verkhovna Rada of Ukraine, 2023b) aimed at facilitating the restructuring of existing heat generation facilities into high-efficiency CHPs and the economic promotion of their use in enterprises, regardless of ownership and sectoral affiliation. The prerequisite for obtaining benefits under this law is a licence to carry out economic activities for the production of electrical and thermal energy and a certificate of qualification of the CHP. CHPs used exclusively for own consumption in enterprises (without sale of energy) and small CHPs under 5 MW that serve as an autonomous energy source to support critical infrastructure (heat supply systems, water supply, sanitation, social institutions such as educational and health institutions) in case of supply disruptions are exempted from licensing (Verkhovna Rada of Ukraine, 2023a). This is an extension of an earlier change in the licensing conditions, when mobile power plants were exempted from licensing.

Shortly after the start of the war, the NKREKP temporarily simplified the procedure for the installation of commercial energy meters when connecting generating units to the grid. More recently, the Ukrainian government has also taken a number of decisions to simplify the conditions for the installation and grid connection of generating units, including a temporary reduction in the list of required documents and in the time required for the preparation and approval of technical conditions and grid connection (Ministry of Energy of Ukraine, 2024d). However, the focus has been on gas-fired generating units.

Facing the wartime challenges to the energy system, Ukraine adopted the Law "On Green Transformation of the Energy System of Ukraine" on 30 June 2023, which makes a number of important provisions for RES development in the country (GOPA International Energy Consultants, 2024; Zhupanyn, 2023). It revised the regulation of "green" auctions and guarantees of origin and introduced several new incentive mechanisms for RES, such as feed-in premium (FiP), contracts for difference (CfDs) and self-generation (net billing) mechanism for prosumers (see Section 3 for more details). It also extended the validity period for pre-PPAs and technical conditions for wind energy projects to accommodate prolonged project implementation due to war conditions, but at the same time prevented the completion and commissioning of wind energy projects located in temporarily occupied territories. Finally, it allowed energy producers to switch between different support forms, e.g. by transitioning from FiT to CfDs while retaining the right to return to FiT (GOPA International Energy Consultants, 2024).

4.3 Barriers to RES development

There are still a number of barriers to RES development emerging from the current state of legislation and partially aggravated by the conditions of the war. Key examples include:

- General lack of coordination
- Retrospective FiT cuts and governmental underperformance of the undertaken obligations
- Absence of the announced "green" auctions
- Problems with issuance of technical conditions
- Uncertainty about finalization of the ongoing construction works
- Market design barriers to public RES investment

The following subsections discuss these barriers in more detail.

4.3.1 Lack of coordination

There is a lack of coordination at different levels of the regulatory framework and its implementation. Even at the highest level, strategic documents sometimes set different targets for the development of RES, which are not coordinated with the technical expert community and are therefore criticised. For example, the National Energy Strategy up to 2050 sets targets of 30% RES by 2030 and 90% carbon-free electricity by 2050, which are considered quite unrealistic (GOPA International Energy Consultants, 2024; Makogon, 2023). At the same time, the National Energy and Climate Plan sets a target of a 25% share of RES in electricity and at least 27% in final energy consumption by 2030 (Ministry of Energy of Ukraine, 2024a).

Coordination problems are also evident at the implementation level. For example, there is also a lack of clear system planning and vision for RES development when technical conditions are issued by local transmission and distribution system operators. Given RES intermittency and grid constraints, this easily leads to an overabundance of planned RES projects in certain areas, interfering with each other and creating cumulative grid impacts, rendering some projects technically infeasible (GOPA International Energy Consultants, 2024).

Therefore, there is urgent need for general harmonisation of the regulatory framework and implementation:

- Harmonisation of strategic documents, subordinate action plans and roadmaps, and sectoral state programmes to work towards the same goals of Ukrainian energy system development, taking into account the EU integration process;
- Creation of an efficient national oversight mechanism, which will ensure that RES projects contribute to a harmonised vision of national RES development.

4.3.2 Retrospective FiT cuts and governmental underperformance of the undertaken obligations

The FiT were originally set at a high level, and any RES producer had the right to sell all electricity generated at that level. While this scheme succeeded in attracting domestic and international RES investors, the regulatory imbalances in the electricity market and non-payments by consumers to the Guaranteed Buyer soon led to massive debt accumulation by the Guaranteed Buyer, so that it was unable to fulfil its payment obligations. As part of the solution, retroactive FiT cuts were made, which directly affected the profitability of the already installed RES and ongoing projects. To limit growth of Guaranteed Buyer's debt, the Ministry of Energy is currently limiting payments to RES producers to 15% (18%) of the average FiT. There is no information on the payment of the remaining part of the FiT, and in the first five months of 2023 the level of payments to RES producers was at around 60% (GOPA International Energy Consultants, 2024).

Both, retroactive changes and non-payment issues critically undermine the credibility of the FiT and investor interest in RES projects in Ukraine. It is therefore crucial to undertake steps to resolve non-payment issues, such as (GOPA International Energy Consultants, 2024):

- Strengthening the legal framework to protect market participants;
- Government intervention to resolve the web of mutual debts and potentially support debt restructuring.

4.3.3 Absence of the announced “green” auctions

“Green” auctions for larger RES installations were originally introduced together with the 2019 FiT reform, but were not put into practice at that time. The Law "On Green Transformation of the Energy System of Ukraine" revived and improved the model, but introduced a number of restrictions, including a shorter support period (12 years, compared to the original 20 years) and project implementation period for auction winners. In addition, the auction price is now only partly fixed in euros, unlike the FiT, which is linked to the euro and adjusted according to the euro-hryvnia exchange rate.

In addition, the necessary secondary regulations and auction documentation have yet to be developed, and no auctions can take place until these steps are completed (GOPA International Energy Consultants, 2024). The adoption in March 2024 of amendments to the Auction Procedures from 2019, which set out the general rules for the auctions (Dentons, 2024), was an important step towards the implementation of the auctions. However, the lack of a long-term plan for the auctions and the amount of quotas to be allocated creates uncertainty about the expected support for RES under this mechanism (Makogon, 2023). Investor uncertainty is exacerbated by the payment problems of the Guaranteed Buyer, which will be responsible for payments under both the FiT and “green” auctions. As with the FiT, this critically undermines the credibility of this support mechanism.

It is therefore necessary to both

- solve the problems of non-payment by the Guaranteed Buyer and
- speed up the process of setting up auction procedures and planning of the “green” auctions.

4.3.4 Problems with issuance of technical conditions

With the Law "On Green Transformation of the Energy System of Ukraine", issuance of technical conditions for grid connection was partially regulated, creating a temporary procedure for connection and suspending certain sections of the code. As a result, decision-making in this field was left to NKREKP, the TSO (Ukrenergo) and the local system operators (Oblenergos), and the project developers are left unprotected from inactivity and delays in the issuance of technical conditions for the connection to the grid and in performing the actual connection (GOPA International Energy Consultants, 2024). This insight is also confirmed by our interviews with selected municipalities (see Section 7.2 for more detail).

Although the Ukrainian government has recently simplified the conditions for grid connection and launched a service to support those having problems with grid connection procedures (Ministry of Energy of Ukraine, 2024d; Ministry of Energy of Ukraine, 2024c), the focus has been on speeding up installation of gas-fired units to support electricity and heat supply this winter.

It is thus necessary to

- Reduce bureaucratic barriers for grid connection for all RES projects;
- Strengthen the regulatory framework for the protection of project developers against arbitrary and unfair practices.

4.3.5 Uncertainty about finalization of the ongoing construction works

The recent extension of the PPAs has protected project developers currently engaged in the construction of renewable energy projects, but there is still no full clarity on how to proceed with projects that were already under construction at the beginning of 2022. For projects located in the temporarily occupied territories and areas close to the frontline, the new regulation effectively provided no extension or clear guidelines. For example, the 288MW South Ukrainian Wind Power Plant in Ochakov, Mykolaiv region, funded by Chinese renewable energy giant Goldwind, has not received an extension and is currently considered cancelled (GOPA International Energy Consultants, 2024; Global Energy Monitor, 2024).

This uncertainty undermines investor confidence and jeopardises RES projects in those regions of Ukraine that are already most affected by the destruction of energy infrastructure. It is therefore essential to provide clear guidelines and regulatory opportunities for the completion of such projects.

4.3.6 Market design barriers to public RES investment

When it comes to power plant construction by local authorities (cities/towns and communities), it is important to take into account their interest in supplying critical infrastructure with electricity from their own sources. The interest of municipalities is to save energy costs and to be able to supply power to their facilities independently in the event of blackouts. This can be done by installing RES directly at the consumption site (e.g., solar panels on a roof of a hospital building) but also by installing larger off-site facilities (e.g., a wind turbine on community's grounds just outside the town).[13]

However, the current market regulation only allows power plant owners, regardless of ownership, to sell any surplus electricity on the wholesale market. This means, for any electricity not consumed directly at the site, the power plant owner has to enter the business of selling electricity. With regard to the development of distributed generation in Ukraine, the business of electricity sale and its full subordination to the United Energy System are implemented under a state programme with respective financing and are controlled by the state. In fact, this programme focuses on private investors, without the participation of municipalities. The management of the installed facilities is transferred to a state enterprise such as "Distributed Generation of Ukraine" (Kurmaz, 2024).

As a result, a city/municipality cannot supply the electricity generated by its own power plant directly to its other facilities in the same municipality. Instead, it would have to:

- Set up its own affiliated electricity supplier, which will be the buyer of electricity on the wholesale market;
- Sell the electricity not consumed on the site to that electricity supplier through a bilateral contract;
- The supplier, acting as a business and able to operate both in the wholesale and the retail markets, can then sell electricity to the consuming municipal facilities through the retail market.

The switch from the wholesale to the retail market entails a payment for electricity transmission services through the transmission and distribution networks. This additional charge consists of the tariff of the national transmission operator NPC Ukrenergo (2.29 UAH/kWh) and the tariff of the local transmission system operator (TSO) responsible for local distribution (0.85-2.9 UAH/kWh, depending on the region). Municipal facilities would thus have to bear an additional cost of about 1.5-3.5 UAH/kWh on top of the price of electricity produced by the municipal power plant. At the pre-war exchange rate, this was about the same as the feed-in tariff for small to large utility-scale solar

[13] According to the Law "On the Electricity Market", distributed generation facilities are power plants with a capacity of up to 20 MW that are connected to the networks of regional energy supply companies (distribution system operators). Thus, also a small wind park would fall under the regulation of distributed generation facilities.

power plants and slightly below the feed-in tariff for rooftop PV. This surcharge applies even if the municipal facilities consume the electricity produced by their own power plant without the actual involvement of the system operator (Kurmaz, 2024).

While under this scheme the final electricity cost might still be below the market prices offered by third-party suppliers, this regulation imposes a financial and administrative burden on the local authorities, partially or completely offsetting the economic benefit of having their own power plants. The only remaining benefit is to have a backup power source for the municipal facilities in case of system failures in the Unified Power System of Ukraine.

Avoiding or minimising the additional transmission and administrative costs for the local authorities would open up a number of important opportunities for them, such as:

- Significant reduction in end tariffs for municipal facilities;
- Accelerated payback of the power plant;
- Accumulated funds for further investment in local energy self-sufficiency.

At the level of overall market design, facilitating electricity sharing for RES owners would significantly increase the interest of both small prosumers (such as households) and local authorities to develop their own distributed generation. Without changing the market design, a first step to support RES investment by local authorities would be to set up a specialised "market agent" with appropriate qualifications to take over the buying and selling operations. This would relieve local authorities of these functions, for which they often lack the skills and capacity, and of the high administrative costs of each city/community setting up its own market intermediary.

5. Best practices for implementing support schemes for small RES installations

Internationally, a wide range of different support measures have been used to encourage the development of renewable energy. These measures can be divided into three groups:

- **Economic instruments** include all measures that affect the cost of installing and operating RES compared to traditional fossil energy sources.
- **Regulatory instruments** are measures that impose controls, restrictions or a preferential treatment on certain activities (e.g. restrictions on fossil installations and preferential treatment for RES installations).
- **Procedural measures** include measures that support RES implementation processes, e.g. by simplifying the way RES-based producers can prove their qualification under different support programmes and administrative procedures.

Table 5-1 provides examples of broadly applied international practices of RES support for each of the three listed groups. These examples are discussed in more detail below.

Table 5-1: Examples of international practices of RES support

Economic instruments	Regulatory instruments	Procedural measures
□ Market design	□ RES/GHG reduction quotas	□ Unified registers
□ Feed-in Tariffs	□ Company Obligations	□ Guarantees of origin
□ RES auctions	□ Offtaker of Last Resort	□ Counter-fraud supervision
□ Carbon pricing		
□ Capital support		
□ General gas/electricity levies		

Source: Own compilation.

5.1 Economic instruments

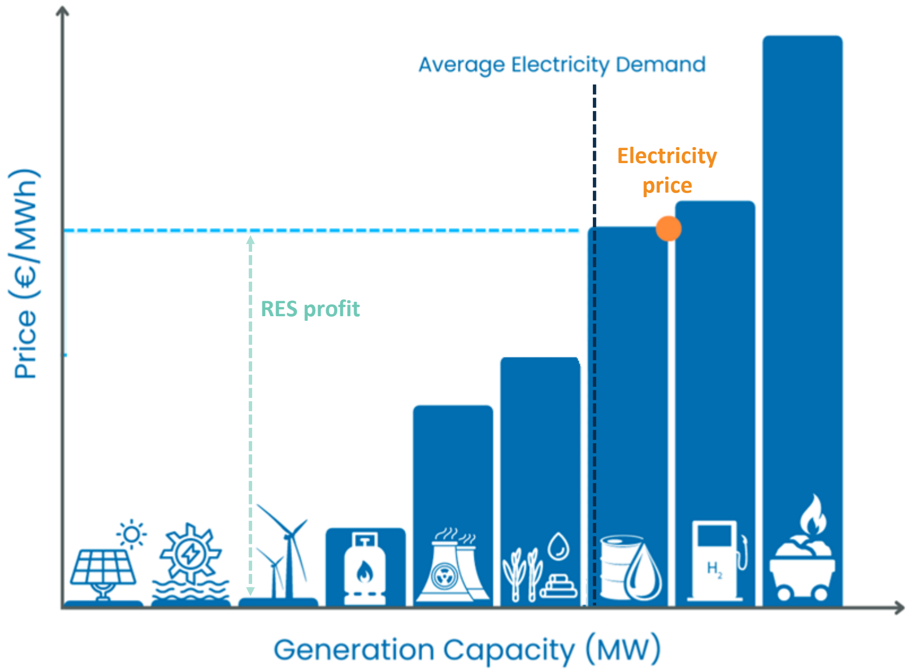
5.1.1 Market design

In countries where free electricity markets function according to the merit order principle, the market design is one of the strongest mechanisms used for RES promotion.

Merit order is a way of ranking electricity generation in ascending order of price, which in turn reflects the order of the short-run marginal cost of production of different generation units (see schematic illustration in Figure 5-1). The merit order effect implies that, to meet electricity demand at any given time, generation from the plants with the lowest marginal costs is dispatched first, while those with the highest costs are dispatched last. The final market price at any given time (whether in the day-ahead, intraday or balancing markets) is determined by the marginal cost (i.e. the cost of the last additional unit of electricity produced) of the last plant to dispatch electricity.

Gas and coal plants with a large fuel cost component have higher marginal costs than renewables such as wind and solar and are therefore ranked later in the merit order.[14] As long as there is fossil fuel generation in the system, these plants will often be the price setters in the electricity market, and this price will be higher than the marginal cost of RES generation.

Figure 5-1: Merit order effect



Source: Amended from Oliveira (2022).

This in turn means that the merit order market design ensures higher profits for RES-based generators than for fossil-based generators. Therefore, the market design alone can make it attractive for investors to implement RES projects.

[14] Their relative position depends on coal and gas prices in the respective country. In the schematic illustration in Figure 5-1 coal is assumed to be more expensive than gas, which would be the case, e.g., in Germany. In Ukraine it is likely to be the other way around.

5.1.2 Feed-in Tariffs

A feed-in tariff (FiT) is a price-based support mechanism that guarantees an energy producer access to the grid and a long-term off-take contract at a fixed price. This mechanism is applied in dozens of countries around the world, including Australia, Canada, China, many EU countries, Japan and the UK (Wang, Gong, & Jiang, 2014). Ukraine already applies the FiT for renewable electricity producers.

Another variation on the FiT is the Smart Export Guarantee (SEG) in the UK (Ofgem, no date (j)). This is a government-backed scheme under which energy suppliers pay small-scale RES-based producers that meet certain criteria to feed electricity into the grid. Unlike the classic FiT, the tariffs are not pre-determined by the government, but set by the energy suppliers, with the condition that the tariffs must always be above zero. RES-based producers interested in participating in the SEG scheme will have to search among the available energy suppliers for the most advantageous tariffs and conditions.

FiTs and FiT-like mechanisms are not limited to electricity generation. For example, the UK's Green Gas Support Scheme provides eligible biomethane producers with payments over 15 years based on the amount of biomethane they inject into the gas grid (Ofgem, no date (f)). The UK has also introduced schemes for domestic and non-domestic renewable heat. Their approach is very similar to the FiT, although they support heating solutions whether or not they are connected to heat or gas networks. Households, businesses, the public sector and NGOs that install renewable heat solutions receive regular payments over 20 years based on the amount of eligible heat generated (Ofgem, no date (g); Ofgem, no date (c)).

While Ukraine already applies FiTs in the electricity sector, the introduction of similar mechanisms in the gas sector, for example, is a promising avenue. Ukraine has significant potential for domestic gas production, though one of the two major gas fields is located in the temporarily occupied territories or close to the front line. At the same time, Ukraine also has a massive potential for bioenergy development (UABIO, 2020); its large area of agricultural land and, therefore, availability of cheap inputs may ensure high competitiveness in biomethane production for the future. In addition, biogas production is much more decentralised, similar to other RES, which increases its security of supply. Greater promotion of biogas as a substitute for natural gas would therefore be an important element of RES policy.

5.1.3 RES auctions

Auctions can be used as a market mechanism to allocate different types of support, which can be the purchase of electricity at a pre-determined price (similar to FiTs or PPAs), but also preferential treatment such as simplified procedures and preferential access to the grid. The advantage of auctions is that they are a cost-effective mechanism that allows information on the costs of generating electricity using different technologies to be revealed through the bidding process.

Auctioning is quite well developed, e.g., in the EU, and next to a standard auction procedure, where the participants compete with their bids on the price, at which they will sell electricity from their installations, the EU Member States can also use more specialised forms, e.g., with bid ceilings, negative bidding and inclusion of non-price criteria (European Commission, 2024).

- **Bid ceilings** are a useful tool when the government provides financial support through the auction. Auctions to provide financial support are particularly relevant for immature or less competitive RES technologies for which there are specific development targets. For example, many countries aim for a balanced mix of solar, onshore wind and offshore wind, but offshore wind parks are more expensive to build and may not be able to compete with solar and onshore wind in free markets. Auctioning such capacity would still allow the most efficient projects to be selected, while bridging the funding gap between project costs and market revenues. Bid ceilings in such auctions provide a guarantee that the government will not spend more than planned or necessary. The ceiling is usually set based on the financial characteristics of a reference project, e.g. by analysing a set of comparable past projects.

- **Negative bidding** occurs when the bidder offers to pay the government for the right to install a RES facility. This occurs in offshore wind auctions because the project developer must obtain a concession to use the seabed from the government, whereas for other RES technologies there is flexibility in siting the project and the associated costs are borne outside the auction. While there have been concerns that negative bidding could increase electricity prices for final consumers, the merit order market design is an effective mechanism to prevent such outcome. As negative bidding results in fixed payments from the generator to the government, it does not affect the short-run marginal cost of electricity production and thus the market price of electricity.

- The **inclusion of non-price criteria** in the auction process can serve a variety of objectives. For example, if the government wants to level the playing field for SMEs or energy cooperatives, which typically have less technical and administrative capacity to participate in the auction than large developers, it can allow them more flexibility in pre-qualification requirements or create separate auction baskets. Setting non-price criteria is also an important mechanism to ensure that participants meet certain minimum standards (through pre-qualification requirements) or that the selected projects also provide non-financial benefits such as improved environmental protection or innovation (through non-price award criteria).

5.1.4 Carbon pricing

Carbon pricing is a market instrument that internalises the cost of greenhouse gas emissions and encourages polluters to reduce their use of fossil fuels. While this is not a direct support measure for RES, it increases the cost of fossil fuel use and thus the competitiveness of RES. Particularly in the electricity market, where mature RES technologies exist, it helps to push fossil-based generators down the merit order.

Carbon pricing most often takes the form of a carbon tax or an emissions trading scheme (ETS). A carbon tax is an administratively simpler instrument and easy to implement if the fuel combustion is the only technology to be taxed. It is usually applied to the amount of fuel consumed by the taxable entity by setting an explicit tax rate using standard fuel-specific emission factors. An ETS, on the other hand, is a market where emitters trade emission allowances. In a cap-and-trade ETS - such as the EU ETS - each emitter has to surrender the number of allowances corresponding to its actual emissions at the end of a reporting period (e.g. annually), while the total number of allowances in circulation is limited by a market cap. The price of allowances is then determined by the balance of supply and demand (European Commission, 2023). The revenues from carbon pricing can be used for different goals, including supporting decarbonisation and protection of vulnerable population affected by it.

Carbon pricing is widely used both at regional (e.g., EU), national (e.g., carbon tax in Switzerland, Canada, China and selected EU countries) and sub-national level (e.g., in Japan and the USA). World Bank (2024) currently counts 50 national and 39 subnational carbon pricing mechanisms.

Ukraine has also formally adopted a carbon tax in 2011 and has been developing an ETS since 2016, but the level of the carbon price, at around USD 1 per t CO_2e, is too low to have any impact (World Bank, 2024). Given that the overall regulatory framework is already in place, strengthening carbon pricing in Ukraine can be considered 'low-hanging fruit' and would further induce development of RES.

5.1.5 Capital support

Capital support includes various types of government support for up-front investment costs, and is particularly common for small producers/prosumers (households, SMEs) and for innovative projects that are in line with government strategic objectives but too risky or not yet profitable without external support (e.g. commercialisation of hydrogen technologies). It can take the form of grants and subsidised loans (e.g. through direct interest rate subsidies or government guarantees).

Most countries with an active climate policy in place use capital support in one or other form to support all types of RES installations. To name just a few examples, the UK provides grants for the installation of heat pumps and biomass boilers in residential and non-residential buildings under the Boiler Upgrade Scheme (Ofgem, no date (a)), many German regions partially cover the costs of 'balcony PV'[15] (Vattenfall, 2024) and Spain subsidises 30 to 50% of thermal insulation and heating replacement measures in demographically challenged municipalities (Repsol Foundation, 2023).

Ukraine already implements capital support measures and promotes them intensively for the coming years. Although numerous projects are on their pilot stages yet, the relevant mechanisms are developing relatively quickly as the government, international investments funds and donor organisations continue to put forward their instruments for the market players.

5.1.6 General gas/electricity levies

Some countries also put in place general levies for gas or electricity, which allow to raise funding for other forms of RES support, such as FiTs or capital support. For example, the UK has introduced a Green Gas Levy, which applies to gas suppliers and is used to fund the Green Gas Support Scheme described above (Ofgem, no date (f)). In Germany, a RES levy ("EEG Umlage") was included in the electricity price for all consumers, which covered the difference between the market electricity price and the (higher) feed-in tariff for RES producers.

Implementing the relevant levies in Ukraine would demand amending the fiscal laws and numerous other regulatory acts. Although may finally prove effective, at the current stage this might turn to be a very time- and recourse-consuming for the policy makers and cannot be considered as an efficient policy option to achieve the current goal of RES promotion.

5.2 Regulatory instruments

5.2.1 RES / GHG reduction quotas

Quotas are obligations for energy producers to reach certain shares of RES or certain emission reductions by a given deadline. They can be used for a variety for energy types and even for industrial actors. E.g., the EU has set binding obligations for sustainable aviation fuels (SAF) and mandates that every flight leaving the larger EU airports carries at least 2% SAF in 2030 and 5% in 2030 (EASA). In the UK, the Renewables Obligation scheme, in place until 2017, put an annual obligation on electricity

[15] Mini plug-in solar panels up to 800W that can be plugged directly into standard sockets to generate electricity for self-consumption.

suppliers to surrender a certain number of Renewables Obligation Certificates per MWh of electricity supplied to their customers (Ofgem, no date (i)).

5.2.2 Company Obligations

The UK is an example of active policies putting obligations on energy companies to contribute to energy efficiency improvement and emission reductions through measures in households. These policies may to some extent be seen as a variation of a quota approach, but they can also be used as a support measure for vulnerable households.

For example, in the Carbon Emissions Reduction Target scheme, in place between 2008 and 2012, gas and electricity suppliers were obliged to reduce carbon emissions in the household sector by a pre-defined total through certain eligible energy efficiency improvements (Watson, Bolton, & Richards, 2013). In the Great British Insulation Scheme, which began in 2023 and will end in 2026, medium and large energy companies are obliged to deliver measures that result in reduced energy usage in low-income and vulnerable households and those living in homes with poor energy efficiency rating (Ofgem, no date (e)). Furthermore, under the Energy Company Obligation, the medium and large energy suppliers are obliged to promote measures resulting in reduced energy use, such as thermal insulation or energy system upgrading, so that low-income, fuel-poor and vulnerable households have better access to heating (Ofgem, no date (d)). In addition, in the Warm Home Discount programme, the UK energy suppliers with over 1000 customers are obliged to provide an annual discount to customer bills for the low-income customers who are vulnerable to cold-related illness or live in fuel poverty (Ofgem, no date (k)).

5.2.3 Offtaker of Last Resort

To support the availability of power purchase agreements for RES generators, the UK has enacted a programme, where the state acts as an “Offtaker of Last Resort”. Under this scheme, RES generators who have an investment contract or a CfD contract can participate in an auction to conclude a short-term “backstop PPA” for a maximum duration of 12 months. This allows the RES generators to bridge the gap when they are not able to get a usual commercial PPA. To keep this as a measure of last resort, the contract price under a backstop PPA is set at a specified discount below the market price.

5.3 Procedural measures

5.3.1 Unified registers

The creation of a single register for RES generators can significantly reduce the administrative burden of proving eligibility for different support schemes or monitoring support, both for generators and regulators. For example, the UK's electricity and gas regulator, Ofgem, has established a web-based Renewables and CHP Register (Ofgem, no date (h)), which is used to manage a variety of support schemes in the electricity and gas sectors. Electricity suppliers use the Register as a one-stop-shop to apply for and manage their accreditation, submit output data, manage their certificates (such as the Renewables Obligation Certificates mentioned above) and submit their annual declaration/reports. This streamlined and digital approach significantly reduces the administrative costs associated with participating in support schemes.

5.3.2 Guarantees of origin

A guarantee of origin is a certification scheme that provides market participants with transparency and reliability regarding the authenticity of renewable electricity or the share of renewable energy in the electricity supplied. It makes disclosure more reliable and ensures that electricity suppliers do not sell renewable energy more than once (Umweltbundesamt, 2023). This scheme is implemented, e.g., in the EU as the Guarantees of Origin (GoO) and in the UK as the Renewable Energy Guarantees of Origin (REGO). While being an important disclosure mechanism for electricity consumers, the use of GoOs as a “RES seal” also makes a business case for RES suppliers as the demand for renewable electricity grows (McKinsey, 2024).

5.3.3 Counter-fraud supervision

An important element of investor security and confidence is a stable and predictable environment, including protection from fraud and unfair practices. At the same time, in order to ensure the proper and efficient use of funds and to maintain the credibility of the programmes, the state must prevent fraud in the implementation of the support schemes it provides. A good example of anti-fraud oversight is the establishment of an anti-fraud unit within the UK's electricity and gas regulator, Ofgem. This dedicated unit is tasked with detecting, preventing and deterring fraud in environmental or social programmes administered by Ofgem. It proactively monitors trends and risks and uses data analytics to identify potential high-risk areas. It also investigates the activities of individuals and companies where there is evidence of fraud (Ofgem, no date (b)).

6. Reconstruction scenarios and required electricity prices

6.1 Financial viability of the power system

Rebuilding Ukraine's power system will require significant investment in new generation capacity, rehabilitation and expansion of the transmission and distribution network and, in the case of high levels of renewables, energy storage capacity.

Most of these investments will be made by private investors who will demand a return on their investments. If their investment costs are not covered by electricity prices, there will be no private investment in new capacity and the power system will not be viable. To compensate for the missing private investment, the state would have to step in with public funds and either directly finance new generation capacity or cover the difference between the tariffs and the actual costs of power generation in order to attract domestic and international investors. Both options are economically inefficient, as they burden public budgets and divert government spending from other policy priorities.

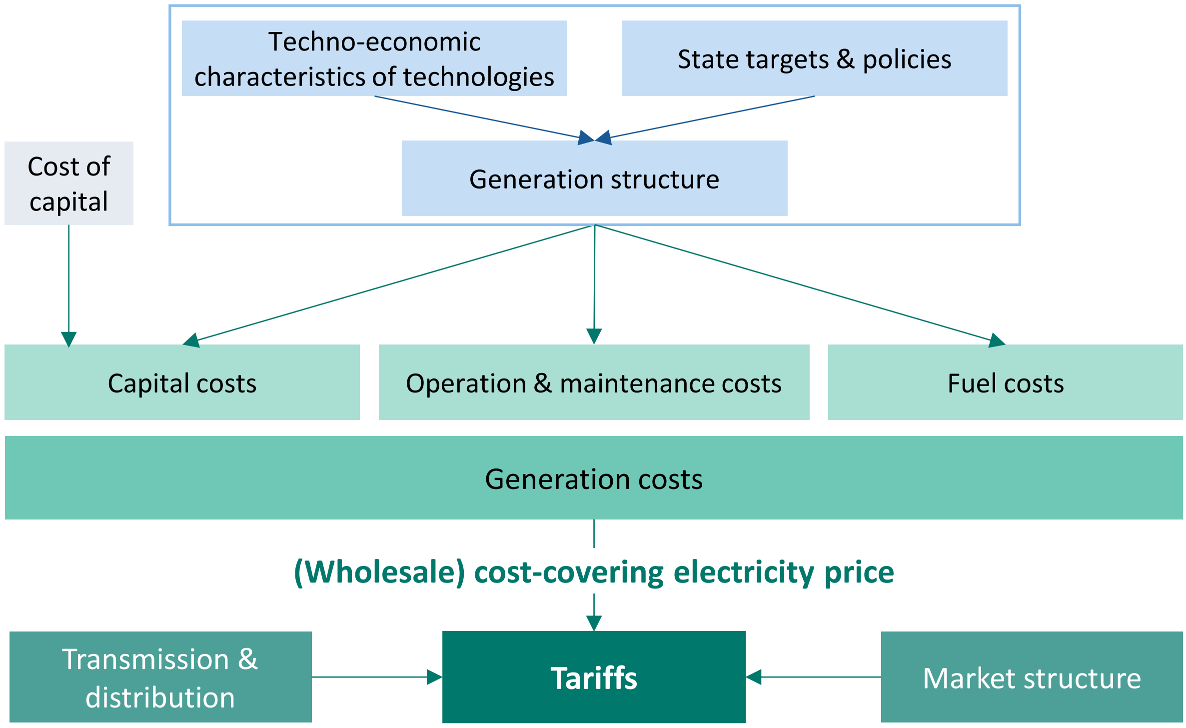
Figure 6-1 outlines the main techno-economic cost determinants in an economically viable power system. The optimal generation structure by energy source of the reconstructed Ukrainian power system will depend on the techno-economic characteristics (e.g., efficiency, equipment costs) of technologies, such as renewable and fossil generation capacity, and the institutional environment set by the government targets and policies. The generation structure in turn determines (i) the amount of capital required - as some sources require more capital than others - which, multiplied by the unit cost of capital, gives the total capital cost, (ii) the variable and fixed operation and maintenance costs, and (iii) the fuel costs. These cost components make up the generation costs, and in order to ensure the viability of investment in rebuilding the power system, the **electricity prices would have to cover all generation costs**.[16] In other words, the (wholesale) cost-covering electricity prices reflect the average price for a unit of electricity that covers all costs along the value chain of power generation and allows the power system as a whole to operate *profitably*. Because cost-covering prices reflect the costs of the system, they will differ from the prices that result from a market process or are observable to electricity consumers (e.g., tariffs or merit order pricing).[17] Moreover, the tariffs observable to final

[16] Typically, carbon pricing also influences the generation structure and is included in generation costs, but the current carbon price on power generation in Ukraine is negligibly low and is therefore not further considered here.

[17] The cost-covering prices also do not depict variation in the levelized costs of electricity from different generation sources, which arises from different fuel inputs, ages of power generation facilities, or capital investment needs, because the focus is on the average final price.

consumers include not only the generation costs, but also the costs of electricity transmission and distribution, any other market surcharges, and taxes and levies.[18] Therefore, as will be discussed below, the applied consumer tariffs in Ukraine are typically higher than the cost-covering electricity price based on the generation costs.

Figure 6-1: Techno-economic structure of the power system



Source: Own work.

The financing model to determine the cost-covering electricity price uses the results of the TIMES-Ukraine modelling – the volume and structure of power generation and capacity, including energy storage, investment, operating and fuel costs by technology – in five scenarios (see below for more detail). As investments are one-off payments made before the power plant is commissioned, they are converted into annuities – annual payments over the lifetime of the plant – using the weighted average cost of capital (WACC) estimated by Grubb et al. (2017) to reflect the investment payback in the electricity prices (see Box 6-1 for more information on WACC).[19] The model distinguishes between the WACC for fossil and renewable power generation capacity.

[18] Note that market surcharges, taxes and levies are also partly government policies, and if they are applied differently to different energy sources (e.g. a carbon tax is applied to fossil fuels based on their carbon content), this may also affect the optimal generation structure.

[19] While the cost of capital in Ukraine has risen sharply due to the risks associated with the war (Kroll, 2022), a stabilisation of the situation, which is assumed for the reconstruction scenarios, will also lead to a stabilisation of the WACC. Furthermore, as the high country risk increases the WACC for all sectors and projects, it will increase the costs in all scenarios and will not affect their evaluation against each other.

As the technological structure of power generation and investment requirements differ between scenarios, capital, operating, and fuel costs will also differ, changing the cost-covering electricity prices over time and between scenarios. The cost-covering price approach therefore shows the relative performance of the fossil and renewable systems and how current investment decisions affect future power generation costs.

Box 6-1: The weighted average cost of capital (WACC)

The WACC is the average rate of return on an investment. Most large physical investments – such as the development of a wind farm or the construction of a thermal power plant – are financed by a combination of different sources of capital, mainly equity (held by the new owners of the asset) and debt (loans, etc.).

These two types of capital differ in the cost of capital (interest rate/yield). The required return on equity (i.e. the required profit) is usually higher than the interest rate on debt because creditors can hedge risks in their loan portfolios and have preferential rights in the event of bankruptcy. In addition, interest rates depend on a variety of technological, economic, regional and investor characteristics, such as the type and technical lifetime of the investment, exchange rate and inflation expectations, general country risk, alternative/risk-free investment options available to an investor, etc.

The WACC therefore determines the average interest rate by weighting the interest rates of each funding source by its share of the total investment. Because interest rates differ between funding sources, the capital structure of an investment is a critical component of the WACC. More advanced versions of WACC may also take into account additional source-specific characteristics, such as taxes.

Since the cost of capital co-determines the total cost of power generation, the WACC has a direct influence on the tariffs required to cover all the costs of the power system, i.e. the cost-covering prices. In addition, investors face different WACCs for renewable and conventional fossil capacity. Grubb et al. (2017) estimate the WACC for investments in renewables in emerging markets at 8.2%, and the WACC for investments in fossil generation capacity at 9.8%. Given the growing proportion of investors seeking environmentally responsible investment opportunities, it is plausible that this gap will persist in the near future.

6.2 Reconstruction pathways of the power system

Five reconstruction scenarios have been modelled in TIMES-Ukraine for the period between 2020 and 2031. TIMES-Ukraine is a technology-rich, bottom-up model of the Ukrainian energy system, covering all stages of energy production and use across the Ukrainian economy, from primary energy supply, through conversion into electricity, heat and fuels, to final energy consumption in different sectors. It uses linear programming and detailed information on available technologies and their costs to simulate and optimise a least-cost energy system over a given time period, subject to a set of user constraints.

In other words, it allows the exploration of possible energy futures based on different scenarios and policy objectives.

The TIMES-Ukraine model uses the 2020 energy balance as the main source of information on the structure of the Ukrainian energy system, but also uses the latest available data to account for the war damage and its impact on the energy system in 2023 and 2024. A general assumption for all scenarios is that by the end of 2024 only 10% of the existing coal-fired power generation capacity will remain operational, which corresponds to the current known level of sustained damage (Evstigneeva, 2024).[20] TIMES-Ukraine then simulates for the years 2025-2031 how the destroyed capacity can be replaced to restore electricity supply, and how much investment this would require.

The five scenarios are defined as follows.

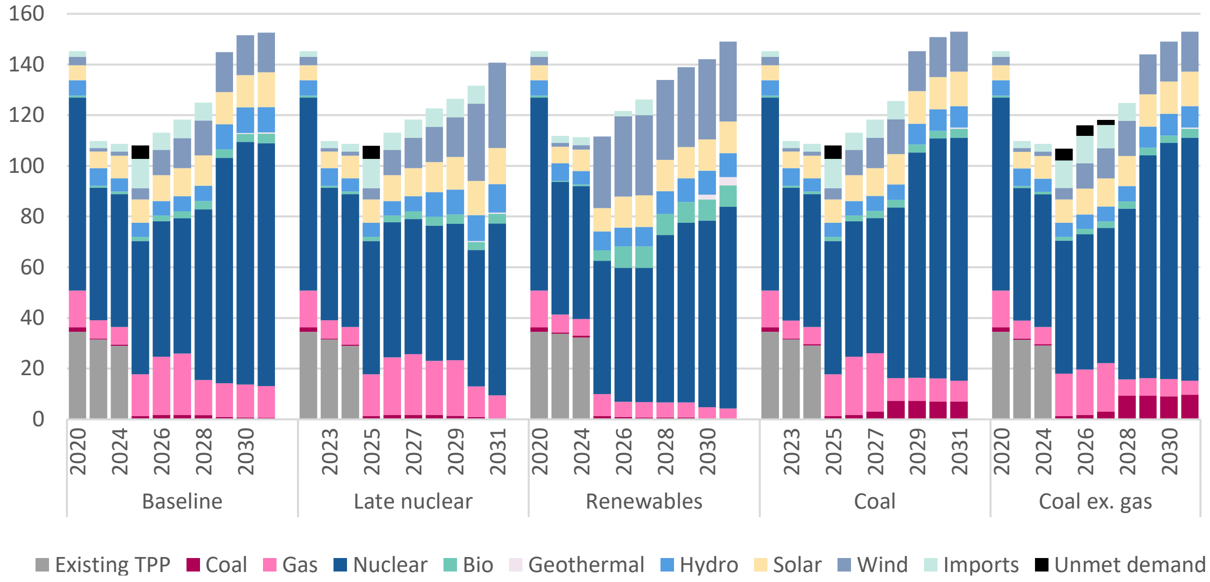
- Baseline: This is the default scenario against which all alternative scenarios are compared. It takes into account current government policies and short-term policy targets or constraints and assumes that the Zaporizhzhya NPP will be gradually reintroduced into the power system from 2028.
- Late nuclear: This scenario replicates the baseline, but assumes that Zaporizhzhya NPP is not reintroduced until 2031.
- Renewables: Compared to the Baseline scenario, this scenario removes all constraints on the expansion of renewable energy generation and therefore focuses on replacing the destroyed coal-fired power plants with green energy. As in the baseline, the Zaporizhzhya NPP will be gradually reintroduced into the power system from 2028.
- Coal: In contrast to the Renewables scenario, this scenario assumes that the destroyed coal-fired power plants are replaced with new fossil (mainly coal-fired) capacity. Taking into account the construction time for large power plants of around three years, commissioning of new coal capacity is allowed from 2028.
- Coal ex. gas: This is a variation of the Coal scenario, in which new gas-fired capacity is restricted. In particular, new gas-fired combined cycle plants are excluded, and the possibility of fast-start gas power plants is significantly reduced. This scenario therefore reduces reliance on natural gas and puts more emphasis on the use of more readily available coal.

Figure 6-2 shows the structure of power generation in 2020 and 2023-2031 by energy source and scenario. The destroyed power plants that go offline in 2024 are shown by the disappearing grey bars for ‘existing TPPs’, but there is still some fossil capacity (mainly gas-fired combined heat and power

[20] It is not yet clear if and when this capacity will be repaired. Although there are some repair plans, the risk that the repaired plants will be hit again makes the repairs pointless (Smyshlyaev, 2024).

units, CHPs) that continues to produce electricity after 2024. In all scenarios except the Renewables scenario, power generation from gas-fired CHPs doubles in 2025, as the utilisation rate of the remaining capacity increases as the main source of emergency power generation alongside rising imports. Nevertheless, there is still a significant amount of unmet demand (i.e., supply shortfalls) of around 5 TWh, or almost 5% of generation, in 2025. In the Coal scenario with restricted gas capacity additions (Coal ex. gas), there are cases of unmet demand as late as 2027. The total economic cost of unmet demand is estimated to be around EUR 3.8 billion in the Baseline, Late nuclear and Coal scenarios and EUR 7.7 billion in the Coal ex. gas scenario.

Figure 6-2: Electricity production, imports, and unmet demand by scenario and energy source, TWh



Source: Own work, based on TIMES-Ukraine.

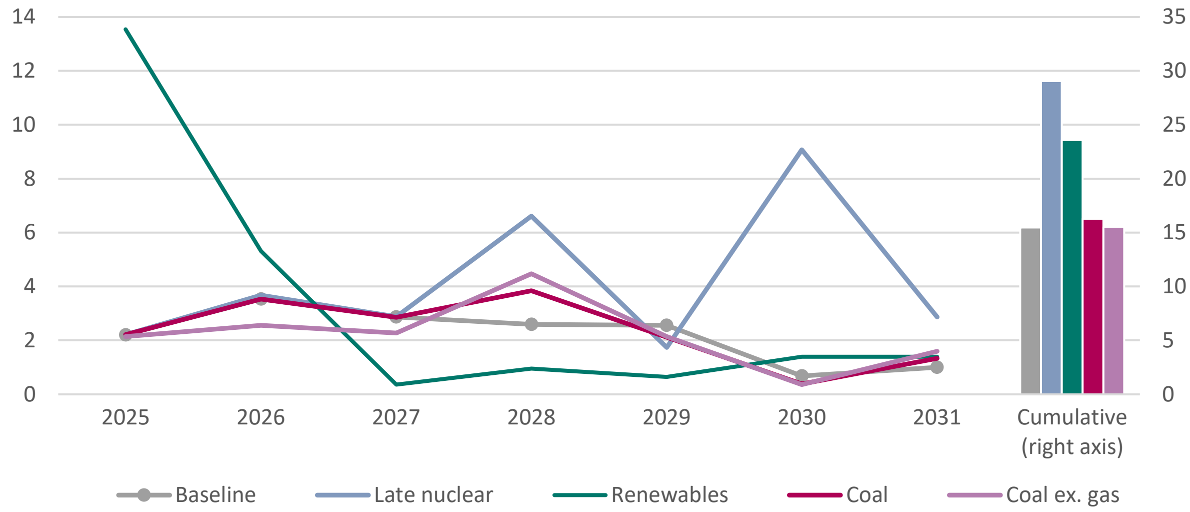
In contrast, in the Renewables scenario, around 9.5 GW of wind power generation capacity is added in 2025. Together with a 40% increase in gas CHP utilisation, this is sufficient to avoid both, supply interruptions and electricity imports. Further increases in power generation are supported by the addition of about 3.4 GW of solar PV capacity (mainly rooftop PV), 1 GW of biomass-fired CHPs and small-scale geothermal energy and storage capacity (battery storage and pumped-storage hydropower) between 2025 and 2031.

The accelerated return to self-sufficiency in the Renewables scenario is also reflected in the timing of the required investments (Figure 6-3). The investment needs of around EUR 13.5 billion in 2025 in the Renewables scenario are much higher than in the other four scenarios (around EUR 2.2 billion). Although the investment needs decrease thereafter and remain mostly below those of the other scenarios, this high requirement in 2025 contributes to the total cumulative investment of EUR 23.6 billion between 2025 and 2031 in the Renewables scenario, which is about 50% higher than in the

Baseline scenario (EUR 15.5 billion). Only the Late nuclear scenario has even higher investment needs, accumulating to EUR 29 billion between 2025 and 2031, almost double the Baseline.

The high investment costs are typical for power systems with a high share of renewables, as renewable power generation capacity (wind and solar PV) typically has lower utilisation / efficiency rates over the year due to weather variability. As a result, more capacity needs to be installed to generate the same amount of electricity compared to fossil fuel power plants. However, wind and solar power plants have slightly lower operating costs and do not require fuel input, making them cheaper to operate.

Figure 6-3: Required investments in 2025-2031 by scenario, EUR billion



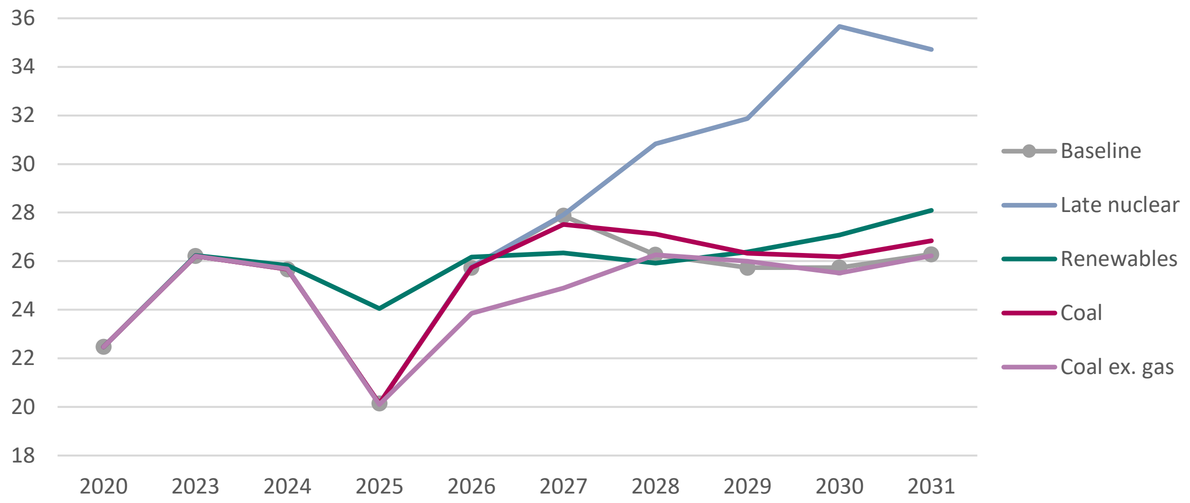
Source: Own work, based on TIMES-Ukraine.

In addition, in the case of the reconstruction of the power system in Ukraine, the higher investment costs should be weighed against the losses in power generation and, consequently, the additional costs of imports and unmet demand in 2025-2027 in the other scenarios. Therefore, the next section takes the perspective of cost-covering electricity prices and places the costs incurred in the context of electricity supply to consumers.

6.3 Cost-covering electricity price and cost components

Figure 6-4 shows the development of the cost-covering electricity price in 2020-2031 by scenario. The cost-covering price rises from around 22 EUR/MWh (2.2 ct/kWh) to 26 EUR/MWh (2.6 ct/kWh) between 2020 and 2024, an increase of 17%. In all scenarios except the Renewables scenario, the cost-covering electricity price drops significantly to around 20 EUR/MWh in 2025, which is even lower than in 2020. This is because little new capacity is added in 2025, i.e. little investment is made, and the remaining capacity is used at a higher rate, producing more electricity for the same fixed operating costs.[21] However, as discussed below, this picture only represents generation costs and does not take into account the more expensive imports and the high cost of unmet demand in these scenarios.

Figure 6-4: Cost-covering electricity price (generation cost) by scenario, EUR/MWh



Source: Own work, based on TIMES-Ukraine.

After 2025, investment in new (mainly fossil) capacity rapidly increases system costs and the cost-covering price returns to the level of 2023-2024. As investments are included in the electricity price as annuities over the lifetime of the plant, each new investment increases the cost-covering electricity price for the next 20 years or more. Thus, after the initial surge of large investments in a few years, prices stabilise and grow only moderately as annual investment needs decline after 2028. In the Baseline, Coal and Coal ex. gas scenarios, the cost-covering price reaches 26-27 EUR/MWh in 2031, around the level of 2023-2024 and 17-19% higher than in 2020. In the Late nuclear scenario, significant investments are made in 2028 and 2030 to compensate the missing ZNPP capacity, so that the cost-covering electricity price continues to increase rapidly, reaching almost 35 EUR/MWh in 2031, 54% higher than in 2020.

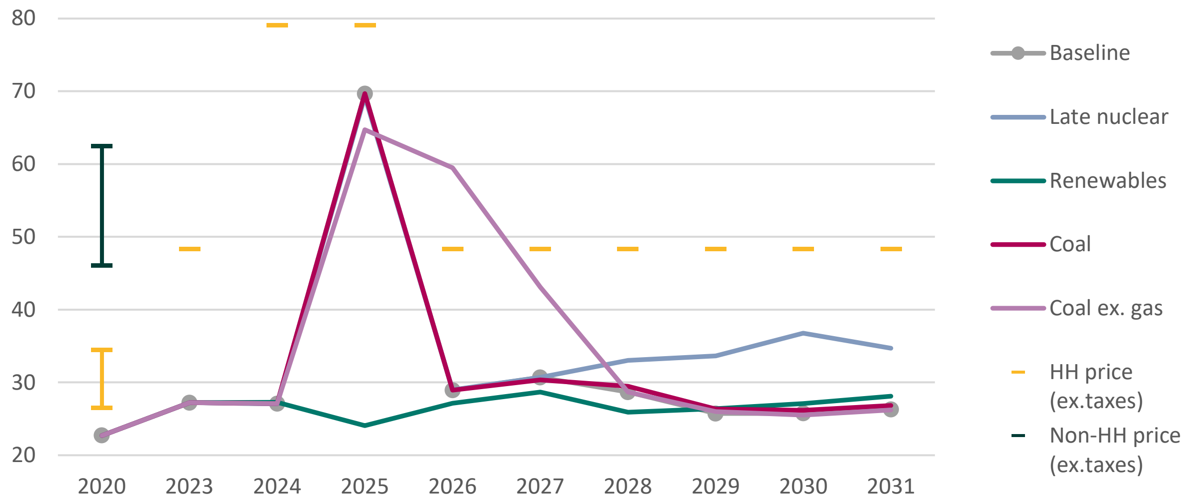
In the Renewables scenario, the cost-covering electricity price also falls in 2025, but by less and remains above the 2020 level. The difference between the generation costs in the Renewables scenario and the other scenarios is due to the massive investment in wind power generation in 2025 in the Renewables scenario (compare Figure 6-3). As the investments in the other scenarios kick in, the prices converge rapidly, and in 2028 the cost-covering electricity price in the Renewables scenario is actually the lowest of all five scenarios. With more investment in 2029-2031, it continues to rise moderately,

[21] Variable operating cost and fuel cost would increase with an increase in generation, but because of the fixed component the total cost change is not proportional to the change in electricity generation, leading to a drop in the average cost and, consequently, the cost-covering price.

reaching 28 EUR/MWh in 2031. This is only 0.2 ct/kWh (7%) higher than in the Baseline scenario and 0.1 ct/kWh (5%) higher than in the Coal scenario.

If only generation costs are taken into account, the cost-covering electricity price in 2025 in the Renewables scenario is up to 19% higher than in the other scenarios. The picture changes dramatically when the cost-covering electricity price is adjusted for the import price and the cost of unmet demand, weighted by their share in electricity supply. In particular, the high economic cost of unsatisfied electricity demand leads to a surge in the cost of electricity to 70 EUR/MWh in 2025, three times the cost-covering electricity price in the Renewables scenario. Although there is no unmet demand after 2025 in the Baseline, Late nuclear and Coal scenarios, higher import shares, with imports being around twice as expensive as domestic power generation, keep the cost-covering electricity price above that in the Renewables scenario until 2029. It is only when imports disappear towards 2029 that prices in all scenarios converge and are driven only by generation costs.

Figure 6-5: Cost-covering electricity price adjusted for cost of imports and unmet demand by scenario and current / projected consumer prices, EUR/MWh



Source: Own work, based on TIMES-Ukraine, Eurostat (2024a; 2024b), New Voice of Ukraine (2024).

Adjusting for the import costs and unmet demand is a step towards the consumer perspective. The cost-covering electricity price can also be compared with current and projected consumer tariffs for electricity. For 2020, Eurostat (2024a; 2024b) provides information on tariffs for household (HH) and non-HH consumers net of taxes and levies. The bands in Figure 6-5 show the price variation for different consumption levels. It is clear that the tariffs passed on to final electricity consumers are up to three times higher than the average generation costs. This is comparable to the share of production costs, e.g., in the German electricity price (enverde, 2021) and is the result of the difference between the market price of electricity and the average cost of generation, plus transmission and distribution costs.[22]

There is limited information on the final tariffs for different types of consumers since the start of the war, so the household tariff is used for further comparison. In May 2024, the Ministry of Energy of Ukraine announced a tariff increase from the previous 2.64 UAH/kWh (5.8 ct/kWh) to 4.32 UAH/kWh (9.5 ct/kWh) from June 2024 to April 2025 (New Voice of Ukraine, 2024). Net of taxes and levies, this corresponds to a net electricity price of 48 EUR/MWh in 2023 and 79 EUR/MWh in 2024 and 2025.[23] As the current tariff increase is expected to be temporary, this analysis assumes that the tariff will return to the 2023 level by 2026.

It is immediately noticeable that the change in the tariff is much larger than the change in the average generation cost in 2023-2024. There are several reasons for this:

- Despite the introduction of a new electricity market design in 2019, significant restrictions on electricity prices remained, including price caps on wholesale markets and artificially low household tariffs. This created significant financial imbalances in the electricity market and limited the recovery of generation costs even before the war. Losses in the power system due to Russian occupation and war damage exacerbated the situation, and the drastic tariff increases in 2023 and 2024 were designed to stabilise the situation and partially offset the inherent problem of too low tariffs (Prokip, How Energy Misregulation Threatens Ukraine's Electricity Sector, 2023).
- Transmission and distribution costs, which make up a significant part of the final tariff, may have increased even more than generation costs due to grid damage and resulting congestion problems. For example, the National Power Company Ukrenergo, Ukraine's transmission system operator, has more than doubled transmission tariffs between 2020 and 2024 (NPC Ukrenergo, 2024; energy365, 2021).
- In 2024, the cost of maintenance and repairs may have risen more than TIMES-Ukraine predicts. The situation is currently very fluid, and the labour markets are extremely tight. There is anecdotal evidence that the costs have risen recently due to shortages of materials and personnel, but there is no reliable data on this, nor is it clear how long the high prices will last. This analysis therefore abstracts from the current bottlenecks in the labour markets, and they are discussed qualitatively in Section 6.4.

[22] Particularly in merit order markets, the market price at any given time is determined by the marginal cost of the last (most expensive) plant to dispatch electricity at that time. It will therefore differ from, and may well exceed, the average cost of generation, particularly in markets with a high share of renewables.

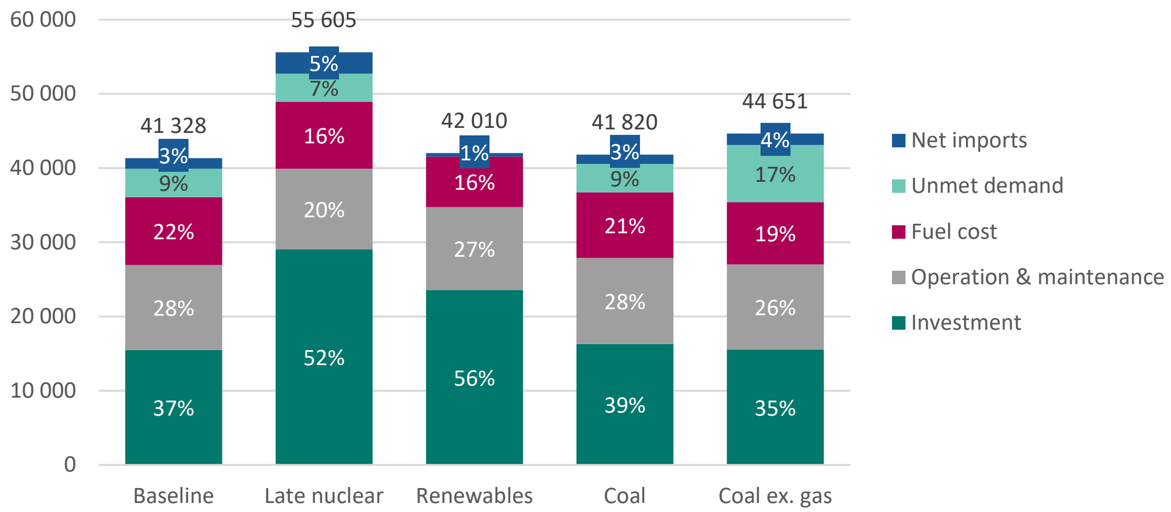
[23] It is assumed that the 2020 share of taxes and levies in the final tariff remains constant.

Overall, as generation costs are only a part of the total electricity price observed by consumers, a 5-7% price increase in the Renewables scenario compared to the Coal and Baseline scenarios will result in a marginal increase in the final price in the medium to long term. In the short term, rebuilding Ukraine's power system with renewables while avoiding imports and supply interruptions is actually cheaper than relying on fossil technologies.

This is also reflected in the cumulative total cost of electricity supply in 2025-2031. Figure 6-6 shows the cumulative cost of electricity supply by cost component and scenario. As discussed above, expanding the power system with renewables typically requires higher investment costs, which is reflected in the highest share of the investment component in the total costs (56%) in the Renewables scenario. In contrast, the share of fuel costs is the lowest, although the relative savings on fuel costs in the Renewables scenario are limited, on the one hand, by the reintroduction of the Zaporizhzhya NPP (with high nuclear fuel costs) in all scenarios and, on the other hand, by the low cost of coal in Ukraine. The latter is further illustrated by the comparison between the Coal and Coal ex. gas scenarios, where the Coal ex. gas scenario has more coal-fired generation for the same total production level and lower fuel costs.

While the large investments in the Renewables scenario increase the cumulative total cost of electricity supply over the time period 2025-2031, taking into account the short-term additional costs of imports and unmet demand, the total costs in the Renewables, Baseline and Coal scenarios are almost equal. Cumulated over seven years, the Renewables scenario is only 1.7% more expensive than the Baseline scenario and only 0.5% more expensive than the Coal scenario. The addition of transmission and distribution costs, other market surcharges, and taxes and levies, which can reasonably be assumed to be the same in all scenarios, would reduce the relative cost difference even further.

Figure 6-6: Cumulative cost of electricity supply in 2025-2031 by cost component, EUR million



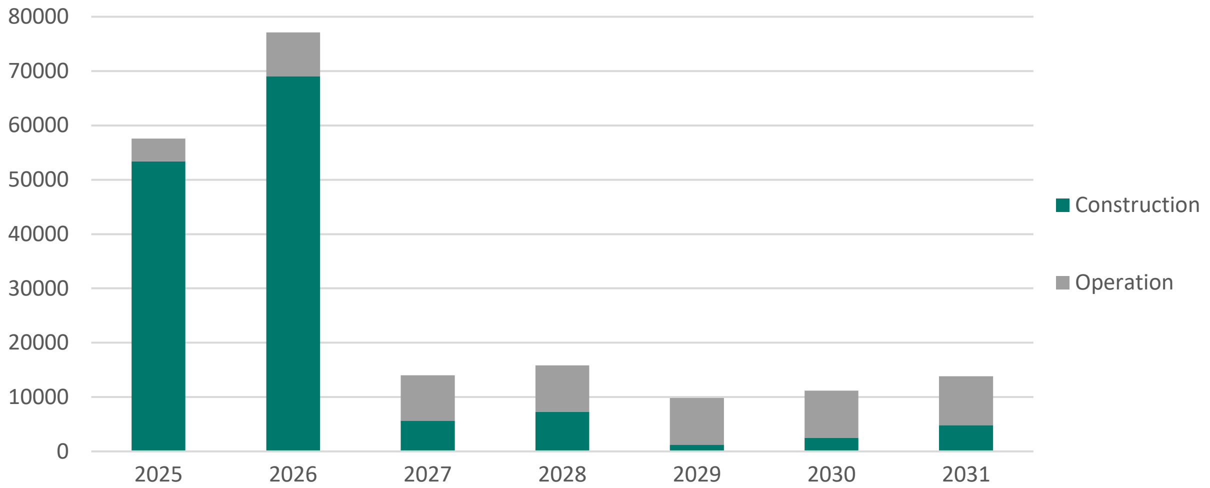
Source: Own work, based on TIMES-Ukraine.

In conclusion, the expected system costs, and therefore the electricity prices needed to cover the costs of rebuilding Ukraine's power system, would hardly change if the Renewables scenario were preferred to the Baseline or the Coal scenario. Taking into account the high environmental and health costs of fossil (coal) power generation and the risks of centralised fossil power supply, renewables are a feasible and reasonable option to replace the destroyed thermal power plants in Ukraine.

6.4 Labour market implications

For the Renewable scenario, employment needs have been calculated using multiplier analysis for the construction and operation phases. Figure 6-7 shows the estimated number of jobs by year and by project phase. Especially in 2025-2026, the massive expansion of wind and solar energy will require a large number of construction and installation jobs - up to 70,000 jobs in 2026. By comparison, renewable energy projects have already created more than 30,000 jobs by 2021. In other words, renewable energy employment may need to almost double by 2025. After this initial spike, much less capacity is added each year from 2027 onwards, so relatively few construction jobs are needed in the medium term. At the same time, the number of jobs needed to operate the plants gradually increases from 8,000 jobs in 2026 to 9,000 jobs in 2031.

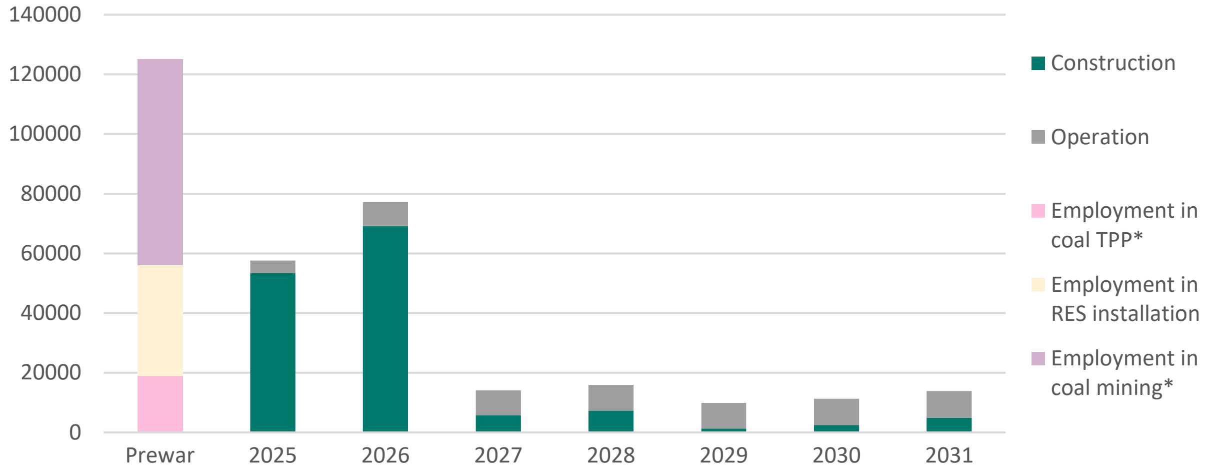
Figure 6-7: Estimated employment needs in the Renewables scenario, persons



Source: Own work.

The potential labour pool for RES construction and operation is provided by the RES sector itself, by the release of labour from destroyed coal-fired TPPs, and potentially (though to a limited extent) by possible initial closures of coal mines. In fact, before the war, the sum of employment in coal-fired TPPs and the fast-growing RES sector itself would have provided an almost sufficient pool of workers for rapid RES expansion (Figure 6-8). As the first coal mines close by 2031, retraining of miners could help fill the remaining gap and provide jobs for the displaced workforce.[24]

Figure 6-8: Employment needs compared to pre-war employment in sectors providing potential employees, persons



* pre-war, estimated
** pre-war, estimate based on average annual RES additions in 2018-2021

Source: Own work.

However, the labour market situation has significantly changed because of the war. By some estimates, Ukraine's working population has shrunk by 40% by early 2024 compared to 2021 due to migration and mobilisation, leading to extremely tight labour markets (Dyachkina, 2024). To address labour shortages, companies are increasingly focusing on inclusive employment, opening up jobs to women, young people, older people and people with disabilities (Bodnyak, 2024).

The recovery scenarios described in this section are based on an assumption of a general stabilisation of the situation. This implies that labour markets would become less tight than they are at present, with demobilisation and refugee return measures. Still, the current strategies of enterprises provide a good insight in the previously unused potentials in the Ukrainian labour market. For RES expansion, most of the jobs needed in the construction phase are low-skilled (Andrusevych, Andrusevych, Kozak, Ptashnyk, & Romanko, 2023), making it easier to exploit the potential for inclusiveness, together with the re-employment of 'brown' jobs lost due to infrastructure destruction, with relatively little training effort. Thus, there are different areas of the labour market, which can be activated to manage the RES-based reconstruction.

[24] At first sight, it would appear that the expansion of RES would not require sufficient employment to re-employ the coal miners laid off when the coal mines are closed. However, it should be noted that the reconstruction scenarios modelled focus on restoring the power system to at least its pre-war generation capacity, rather than fully decarbonising it or the rest of the economy. This means that from the 2030s at the latest, a much larger expansion of renewable energy and projects in other sectors will be needed to decarbonise the Ukrainian economy, which should be able to absorb the workforce from the closing mines.

7. Non-legal obstacles for investment into small RES projects

Ukraine is facing an extremely difficult task of urgently rebuilding the infrastructure and other livelihoods destroyed by Russia's full-scale invasion, while meeting its targets to decarbonise its economy and combat climate change. The Energy Strategy of Ukraine until 2050, adopted in 2023, sets ambitious goals for increasing the RES generation capacity by 2050, as shown in Table 7-1:[25]

Table 7-1: 2050 RES capacity targets of the Energy Strategy of Ukraine until 2050 and expected investment needs

	Wind	Solar	Hydro	Storage	Nuclear	CHP & Bio
Capacity	140 GW	94 GW	9 GW	38 GW	30 GW	18 GW
Investment need	USD 134 bn	USD 62 bn	USD 4.5 bn	USD 25 bn	USD 80 bn	na

Source: Own work based on Savchenko (2024).

Achieving these ambitious goals will require solving a number of financial, technical and social challenges. A brief overview of some major issues is provided below.

Financial costs	High initial investment: Installing renewable energy infrastructure, such as wind and solar power plants, requires significant initial investment. This can be problematic for government budgets and private investors, especially in conditions of economic instability.
	Network modernisation costs: Integrating RES into the existing energy infrastructure requires large investments in the modernisation of electrical networks and control systems. This is particularly relevant for Ukraine, where the energy infrastructure needs serious upgrading.
	Financial risks: Investors may be sceptical about the financial sustainability of RES projects, given the potential risks associated with the political situation, energy price fluctuations and changing market conditions.
Technical issues	Intermittent supply: Renewable energy sources such as solar and wind depend on natural conditions and their electricity supply is variable and usually not fully predictable. This creates challenges for the stability of electricity supply and requires appropriate balancing solutions, which require planning and additional investment.
	Inadequate development of energy storage: Energy storage technologies are an important balancing solution to compensate for the intermittency of renewables. So far, their deployment has lagged behind in Ukraine and needs to catch up to support the increasing share of RES in the electricity system.

[25] Due to martial law, the document is not available to the public. However, news and comments from officials in open sources can provide a basic understanding of key strategic goals and indicators.

	Infrastructure constraints: Many regions of Ukraine do not have sufficient infrastructure to support large-scale RES deployment. Some projects are technically infeasible because the planned electricity production would not be absorbed by local consumers or the grid. Careful planning is therefore required for both project siting and infrastructure development, with appropriate investment in the electricity grid.
Social challenges	Local community resistance: Communities often resist the construction of RES facilities because of environmental concerns, changes to the landscape, or perceived negative impacts on health and quality of life. It is therefore necessary to raise awareness of the benefits of RES and to counter misconceptions about it.
	Employment issues: The switch to RES could lead to job losses in traditional energy sectors such as coal or gas. This requires active measures to retrain and support workers who lose their jobs, thereby reducing resistance to change and ensuring a sufficient labour force for RES development.
	Social justice and access to energy: The transition to renewable energy in Ukraine must be socially equitable to ensure that all sections of the population, including low-income communities, can benefit from new technologies and access to clean energy.

This overview shows that many of the issues are intertwined. For example, providing technical solutions to expand renewable energy and integrate it into the grid will require significant additional investment. This cannot be provided by the state alone, and Ukraine will rely on private domestic and on foreign investors to rebuild the electricity system in a resilient and sustainable manner. As such, environmental criteria are becoming increasingly important for financial institutions and investors. International financial institutions (IFIs) are setting targets in their policies and determining the proportion of funding for environmental and sustainable projects, and the trend is growing. By 2025, some IFIs plan to spend a significant portion of their budgets on sustainable projects, e.g.:

- The European Investment Bank (EIB), with planned lending of almost EUR 32 billion per year (EUR 62 billion by 2022), and the European Bank for Reconstruction and Development (EBRD), with planned lending of almost EUR 6.5 billion (EUR 13 billion by 2022), plan to spend between 50% and 100% of their budgets on sustainable projects;
- Nefco (the Nordic Green Bank), which has earmarked EUR 128 million for Eastern Europe (by 2022), is devoting 100% of its funds to sustainable projects;
- The World Bank plans to spend 35% of its budget on adaptation, allocating almost USD 3 billion for adaptation (by 2022) (Ryabchyn & Kulaga, 2023).

At the same time, in its task of green transition Ukraine is facing important trade-offs between the long-term objectives and the current priorities determined by the ongoing war.

Key challenges include:

- **Low uptake of green approaches in recovery policy frameworks**. While plans are being developed for the recovery of the Ukrainian economy, and the Recovery Plan (National Recovery Council, 2022) as an overarching recovery strategy sets the goal of a 'green reconstruction', the green approaches are still underdeveloped at many policy levels. It is therefore necessary to:
    - Ensure that the principles of sustainable development and environmental safety are clearly integrated into all strategies and plans for post-conflict reconstruction;
    - Develop clear regulatory frameworks and incentives to promote green investments and practices in the reconstruction process;
    - Involve all stakeholders, including government, business and civil society, in shaping the green reconstruction agenda.
- **Priorities for rapid (post-war) reconstruction**. The most urgent need is to ensure a rapid recovery of the Ukrainian economy, security in a number of dimensions, such as military, energy, infrastructure, etc., and social stability. However, it is also necessary to balance the urgency of reconstruction with the long-term goals of sustainable development. It is therefore crucial to:
    - Develop clear roadmaps and coordination mechanisms to combine rapid recovery with environmental innovation and green solutions;
    - Ensure that short-term priorities do not jeopardise long-term environmental and climate goals.
- **Focusing Ukraine's economy on urgent priorities**. With the current focus on socio-economic recovery priorities, the potential of green technologies to contribute to recovery and security of supply is often overlooked. In particular, RES can play a key role in securing a decentralised and independent energy supply. It is therefore important to:
    - Develop special incentives and support to help companies implement green initiatives despite (and even as a way of overcoming) current challenges;
    - Strengthen the dialogue between government and business in order to better understand the needs and barriers that businesses face in their environmental transformation;
    - Ensure the availability of finance, technical assistance and know-how that will contribute to the greening of business.

In general, overcoming these obstacles will require coordinated efforts by government, business and civil society to systematically integrate sustainable development principles into the process of post-war reconstruction in Ukraine.

7.1 Closer look at the potential bottlenecks

7.1.1 Low prioritisation of green recovery in recovery framework policies

There are significant differences in the vision and understanding of what the approach to green recovery should be, both in the broader context and in relation to the reconstruction of Ukraine during and after the war. These differences are observed among different stakeholder groups, in particular Ukraine's international partners, its government, the public sector and the expert community.

These differences in approach can complicate the planning and implementation of the reconstruction process, as well as Ukraine's ability to obtain the necessary international funding for government and business initiatives. Ukrainian stakeholders face a lack of financial resources and tools for recovery, and high interest rates on loans. This is compounded by a lack of understanding of the climate and environmental impact requirements of IFIs and development agencies.

At the same time, these international institutions have the resources to finance a green recovery in Ukraine, usually at favourable interest rates. However, the level of awareness and readiness of Ukrainian government and business structures does not allow them to meet such requirements. This gap can be closed by:

- harmonising approaches between different stakeholder groups,
- harmonising regulatory requirements and environmental performance indicators to increase transparency and reduce the burden of project-by-project assessments, and
- deepening Ukrainian stakeholders' understanding of IFIs' long-term investment vision and strategies, taking into account climate action.

7.1.2 Rapid recovery measures or priorities for post-war reconstruction

While a reconstruction that is fully in line with the Paris Agreement and best European and international standards is likely to be challenging at this stage, it is important to consider these issues now. The infrastructure to be rebuilt will typically be in use for decades, and rebuilding it around traditional fossil fuel assets will re-create a fossil fuel-dependent economy, harm the environment, and lead to stranded assets in the long-term green transition.

The regulatory and institutional framework in Ukraine that could ensure environmentally sound and sustainable reconstruction is underdeveloped. Current legislation, regulations and financial incentives are insufficient to ensure a recovery process that follows the trajectory required to achieve zero greenhouse gas emissions or to prevent an increase in pollution compared to pre-war levels.

This bottleneck can be overcome by addressing the following key issues:

- inadequate government communication that does not provide a clear vision and does not motivate stakeholders to act,
- difficulties in managing and coordinating green recovery, and
- the need to combine short-term tactical needs with strategic priorities for EU integration.

7.1.3 Ukrainian business survives, not develops

Ukrainian business, which is primarily concerned with survival, pays insufficient attention to reducing its environmental and climate impact. The lack of motivation to implement sustainable practices or innovations in technologies and processes is partly due to the lack of clear government guidelines and signals from the international community.

The consequences of such corporate short-sightedness go far beyond the current problems of survival. In the future, we can expect a decline in competitiveness, unpreparedness for a tougher regulatory environment that will result from Ukraine's European integration, and significant losses to the environment and public health. Given the long-term implications, a strategic approach to development is needed that includes both a regulatory framework and incentives to align business activities with environmental and climate goals.

This problem can be solved by addressing the following key challenges:

- lack of resources for effective climate action and
- low awareness of recovery plans and next steps related to EU accession.

7.2 Deep dive: Readiness of communities to invest in RES

In addition to national barriers to the development of distributed generation and investment in renewable energy, there are also local barriers. Municipalities often lack the expertise and specialists needed to make decisions about the integration of electricity generation technologies.

To examine the local situation in more detail, selected communities were surveyed to assess their potential readiness to invest in renewable energy. The sample is not representative, and a wider survey would be needed to generalise the conclusions. However, the communities were selected to sample different types of regions: de-occupied communities, communities on or near the frontline, and communities in the rear (far from the frontline). Of the seven communities originally selected, two could not be contacted, so responses from five communities are analysed:

- Irpin, a medium-sized de-occupied community in the Kyiv Oblast,
- City of Lviv, a large community far from the frontline and the administrative centre of the Lviv Oblast,
- City of Poltava, a large community far from the frontline and the administrative centre of the Poltava Oblast,
- Chortkiv, a medium-sized, far-from-the-frontline community in the Ternopil Oblast, and
- Sumy District Council in the Sumy Oblast, consisting of 16 small communities (14 villages and 2 towns) close to the frontline.

The surveyed representatives were mainly municipal leaders, energy managers and specialists responsible for the preparation of strategic documents on energy and related to the system of decision-making on the installation of RES.

Prior to the survey, respondents received a notice about the survey, and a short telephone call was made to clarify the time and date. The first step was to collect data using a Google form.[26] Telephone interviews were then conducted to obtain additional comments and clarify any issues. In particular, respondents often did not provide detailed information about the solar installations in their communities in the first step, but retrieved this information at the time of the interviews.

In general, there was a high level of interest in the study, with all respondents expressing a desire to receive the results of the study and a willingness to participate in the large-scale surveys when they are organised.

An overview of results by community is provided in Figure 7-1.[27] Common to all the communities surveyed is that the security situation is forcing them to make decisions about additional energy sources. In the current situation of constant missile and drone attacks on the Ukrainian energy system, the installation of an SPP or other RES facilities to supply energy to the community is more a matter of energy security than of green transition. However, all surveyed communities are willing and making efforts to have RES, in particular SPPs, on their territories. Most communities have pointed out the importance of climate issues and are already including RES development in their strategic documents

[26] https://docs.google.com/forms/d/1MHz-agKquRFusMyxJneMtrHtLIleN0gUxhZdCsJkRNc/edit

[27] The interviewee from the Sumy District Council did not consent to detailed representation of individual communities, so the results of the interview were only included in a generalised form.

and preparing technical and economic assessments for it, though some of the existing strategic documents are outdated.

Currently, many Ukrainian municipalities are preparing local energy plans - strategic documents that define the strategic goals of sustainable energy development and measures to achieve them. The development of local energy plans is regulated by the Law "On Energy Efficiency" (Verkhovna Rada of Ukraine, 2017a) and the corresponding methodology is developed by the Ministry of Infrastructure (Ministry for Communities, Territories and Infrastructure Development of Ukraine, 2023). The development of local energy plans can be carried out both by energy managers of the municipality and by other specialists, if there is no such position. The main idea of the document is to record the state and perspective of energy development in the municipality and to identify measures to increase energy efficiency and introduction of RES in the municipality.

Although the legislation requires local energy plans to be developed and approved by November 2024, by the end of August only a handful of communities had approved such plans. However, many understand that such a document is necessary to structure and confirm the community's plans for energy independence. Of the communities surveyed, only one (Poltava) is already developing a local energy plan, while the others are still at the data collection stage. The reason for the delay is that most communities do not have specialists capable of preparing such documents.

The communities also lack information on which funding sources to target. They are used to energy efficiency or RES projects being traditionally funded from the local or national budgets. And while large communities tend to have their own budget resources, the smaller ones, while generally expressing a willingness to finance RES projects from their budgets, often need financial support, such as grants or low-cost loan schemes. However, they have little or no knowledge of other sources of funding or investment in the community and often need help in finding funding. Although all existing RES installations have been fully or partially funded by international donors, the projects only started after the international donors approached the communities. Communities are not aware of the opposite approach - seeking funding.

Figure 7-1: Survey results by community

	Irpin	City of Lviv	City of Poltava	Chortkiv	Sumy District Council
Type	de-occupied	rear	rear	rear	frontline
Respondents	department heads (infrastructure development, investment, housing and communal services)*	department heads (energy, work with condominiums)	specialist (infrastructure department responsible for energy issues)	energy manager, deputy mayor	deputy head of the district council
Capacity (solar PV): installed	7 [medical ambulant facilities] - 16.1 kW 2 [hospitals] - 50 kW	2 [schools] (no detail) 1 [hospitals] - 72 kW 4 [public buildings] - 44 kW	-	1 [schools] - 6 kW | 1 [medical ambulant facilities] - 5 kW 1 [hospitals] - 71.6 kW 1 [water utility] - 355 kW	limited use (no detail)
Capacity (solar PV): planned	2 [hospitals] - 200 kW	[water utility] [heat utility] (no detail)	3x in final stages (no detail)	-	-
Energy management system	-	[✓] + research	-	[✓]	[✓] - partially
Experts: technical, legal, funding	[legal] [funding]	[technical] [legal] [funding]	[technical]	[technical] [legal] [funding]	[legal] [funding]
Previous RES funding	IFIs	own budget + IFIs; local programmes for private RES owners	-	own budget + IFIs	IFIs
Funding readiness	Self- & co-financing	Self- & co-financing	Self- & co-financing	Self- & co-financing	Self- & co-financing
Decision-making	Deputies (meeting of the Municipal Council)	Deputies (meeting of the Municipal Council)	Deputies (meeting of the Municipal Council)	Deputies (meeting of the Municipal Council)	Deputies (meeting of the Municipal Council)

[medical ambulant facilities icon] medical ambulant facilities [hospitals icon] hospitals [public buildings icon] public buildings [schools icon] schools [water utility icon] water utility [heat utility icon] heat utility

* Additional information on the installed solar capacities was provided by the facility directors.

Source: Own work.

All decisions regarding the installation of RES, including the allocation of funds and the inclusion of the equipment on the balance sheet of a utility or budget institution, are taken by the deputies at a municipal council meeting. However, both project preparation before the final decision and project implementation afterwards require a number of specialists in communities. In addition to the lack of financial resources and qualified staff for strategic planning, all communities, with the exception of the City of Lviv, also report a lack of qualified staff for the development and implementation of RES projects as an obstacle. This mainly concerns technical specialists capable of selecting solar PV equipment and other RES installations according to the project needs and supervising the technical side of the project, so communities often look for them among the technical staff of companies that install solar PV. But sometimes there is also a lack of experts with knowledge of legislation on the use of RES or knowledge and experience of the financing landscape for RES projects, such as grant programmes, funds, banking products, or financing from international organisations. For the same reason, many communities do not yet have energy management systems, and energy management issues are often dealt with by economic or infrastructure departments. This does not seem to depend on the size of the city, but rather on the awareness of the importance of such a position in the community. Therefore, capacity building and awareness raising of local communities will be an important step in supporting local RES development.

However, the main problem with the installation of solar panels has been the reported reluctance of the Oblenergos (regional distribution system operators) to connect the installed solar panels and to provide all the necessary technical documentation, with long delays being a common problem. The reluctance to cooperate is often due to limited balancing or other technical capacity. Streamlining connection procedures and building the capacity of local grid operators is therefore crucial to ensure the implementation of RES projects.

Communities close to the frontline also face a high risk of active hostilities. In addition to the overall negative economic and demographic impact of hostilities, this is the reason why there are few RES installations, including solar PV. This creates a high risk that these communities will fall behind in RES development, while they are the ones most in need of securing more resilient energy supplies through the maximum possible decentralisation of generation capacity. It is therefore important that measures are taken to support the installation and rapid grid connection of small-scale RES installations, especially in these vulnerable areas.

8. Conclusion

Ukraine faces the unprecedented challenge of maintaining energy supply during the 2024-2025 winter season and rapidly rebuilding the energy system in the coming years. A 'green' reconstruction, replacing destroyed capacity with renewable energy sources, will not only contribute to Ukraine's long-term sustainable development goals, but will also increase the resilience and security of the energy system.

Ukraine has a huge potential for diversified RES development, with significant endowments of solar and wind energy, water resources suitable for hydropower, and biomass. Prior to the war, the RES sector developed at an unprecedented pace, demonstrating the general availability of technical knowledge and skilled personnel to support rapid RES expansion. However, the severe disruption to the labour markets caused by the war may become a major constraint to resuming the same or even faster pace of RES development in the coming years. In addition to demobilisation and repatriation of refugees as the situation stabilises, more inclusive employment practices and retraining of workers from destroyed coal power plants and some coal mines can help to overcome labour supply bottlenecks.

At the same time, a number of measures still need to be taken to remove regulatory and other barriers to RES development. Better coordination is needed at different levels, from harmonising different strategic objectives and short-term priorities into a single vision, to coordinating the activities of regional transmission and distribution operators to ensure that larger RES projects in particular do not cluster so much as to interfere with each other. Overall, long and poorly organised grid connection processes appear to be a major problem for both private and public RES investors. While some measures have already been taken to speed up the deployment of small gas-fired units, streamlining these processes for (all types of) RES will be a prerequisite for a RES-based reconstruction of the power system.

Green reconstruction will require significant initial investment compared to fossil fuel-based reconstruction scenarios. However, it will help avoid costly electricity imports and blackouts in the early years of reconstruction, and has lower operating and fuel costs. The total system costs up to 2031 therefore do not vary between the different scenarios. Moreover, the consumer tariffs needed to cover the required investments are only moderately higher than the (subsidised) pre-war levels and well within the range of the 2023 tariff increase implemented to better align consumer tariffs with real generation costs. This further confirms that renewables are a viable and sensible option to replace Ukraine's destroyed fossil fuel generation capacity.

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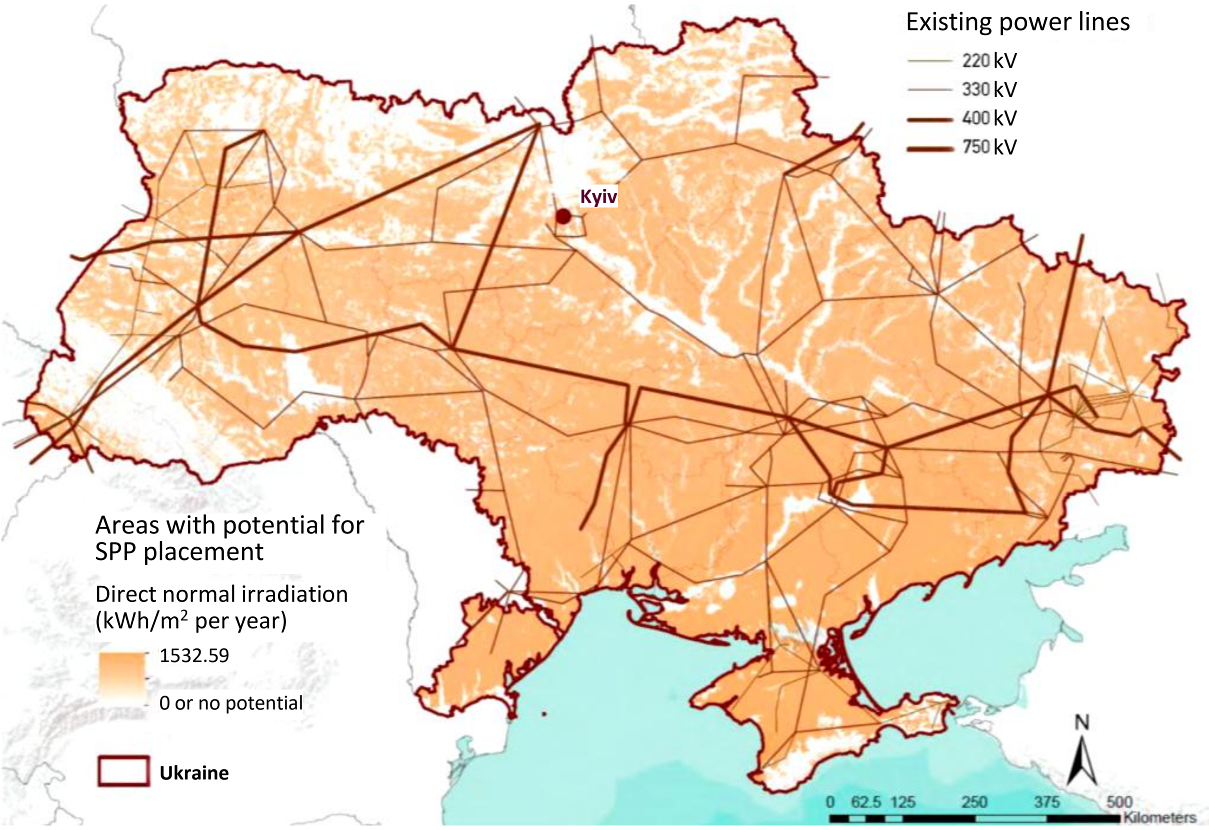
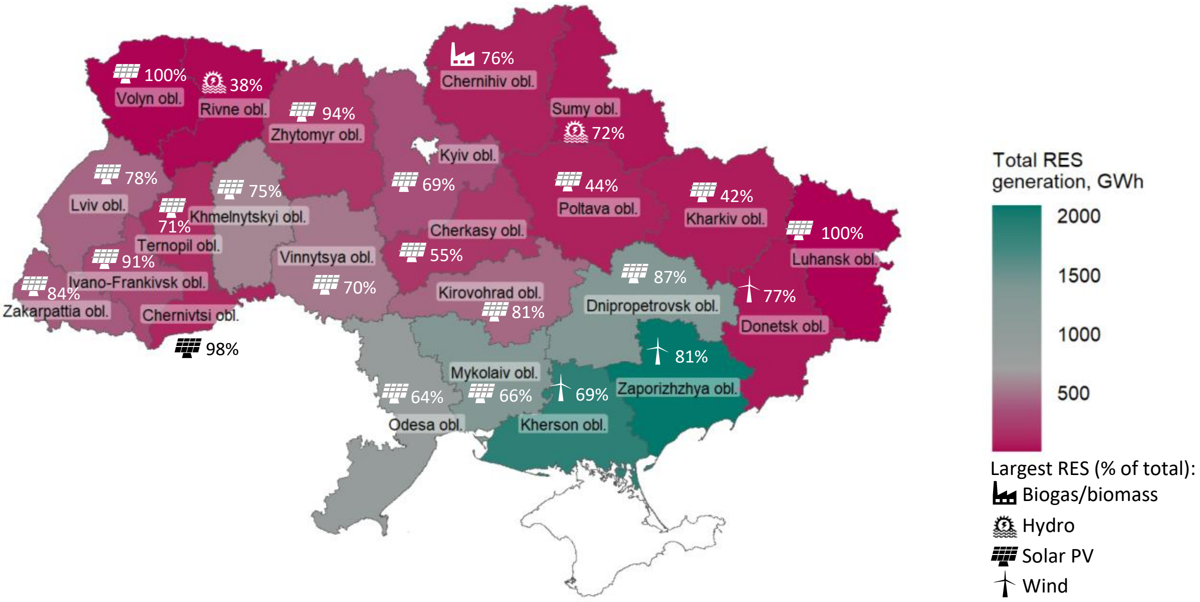
Annex A. RES development and potential in Ukraine

Figure A-1: The potential of solar energy in Ukraine with no restrictions on grid proximity



Source: Institute for Sustainable Futures (2024), own translation.

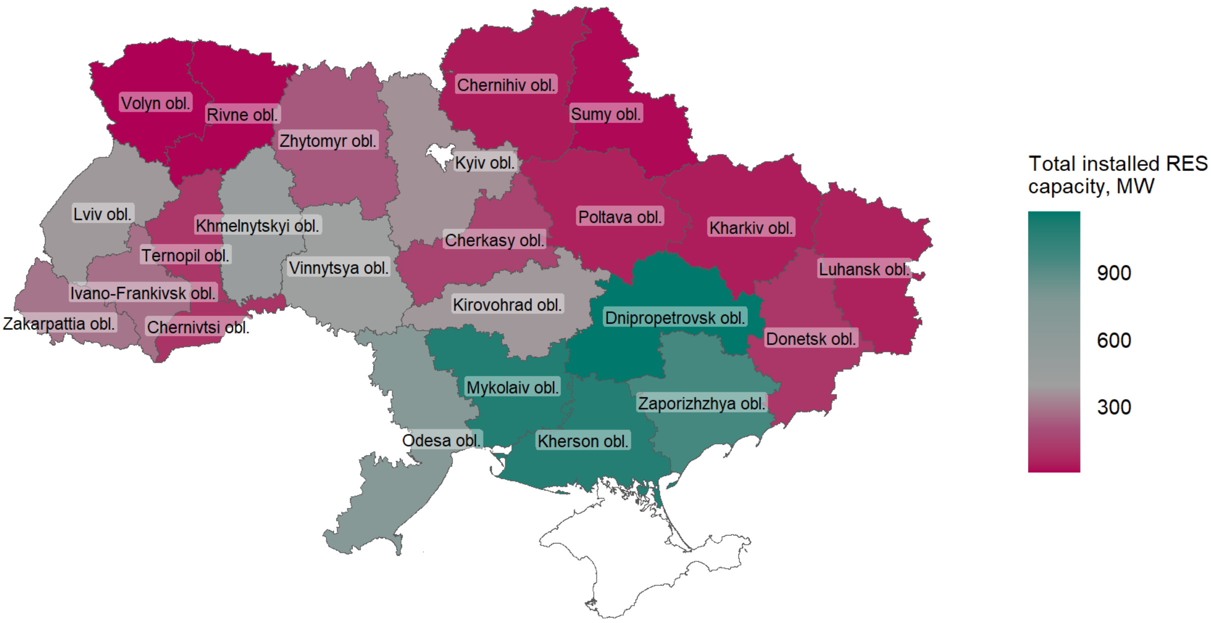
Figure A-2: RES generation, GWh, and the largest renewable source in Ukraine by region



Note: The data is very incomplete for rooftop solar PV, so that the total across regions is about 13% of the total installed capacity in Ukraine as reported by Konechenkov (2022). Taking into account the share of rooftop solar PV in the national capacity, the use of the incomplete regional data leads to an underestimation of the total RES capacity by 11% at the national level. However, the bias may be unevenly distributed across regions, so the data should be treated with caution.

Source: Own work based on DiXi Group (2021).

Figure A-3: RES capacity in Ukraine by region, MW



Note: The data is very incomplete for rooftop solar PV, so that the total across regions is about 13% of the total installed capacity in Ukraine as reported by Konechenkov (2022). Taking into account the share of rooftop solar PV in the national capacity, the use of the incomplete regional data leads to an underestimation of the total RES capacity by 11% at the national level. However, the bias may be unevenly distributed across regions, so the data should be treated with caution.

Source: Own work based on DiXi Group (2021).

Table A-1: Comparison of RES power generation and installer presence by RES type and region

	Bioenergy		Hydropower		Wind power		Solar PV	
	Generation	Installers	Generation	Installers	Generation	Installers	Generation	Installers
Cherkasy obl.	✓	✓	✓	✓	✗	✗	✓	✓
Chernihiv obl.	✓	✓	✗	✓	✗	✗	✓	✓
Chernivtsi obl.	✗	✗	✓	✓	✗	✗	✓	✓
Dnipropetrovsk obl.	✓	✓	✓	✓	✗	✗	✓	✓
Donetsk obl.	✓	✓	✗	✓	✓	✓	✓	✓
Ivano-Frankivsk obl.	✓	✓	✓	✓	✓	✓	✓	✓
Kharkiv obl.	✓	✓	✓	✓	✗	✗	✓	✓
Kherson obl.	✓	✓	✓	✓	✓	✓	✓	✓
Khmelnytskyi obl.	✓	✓	✓	✓	✗	✗	✓	✓
Kirovohrad obl.	✓	✓	✓	✓	✗	✗	✓	✓
Kyiv obl.	✓	✓	✓	✓	✗	✓	✓	✓
Luhansk obl.	✗	✗	✗	✗	✗	✓	✓	✓
Lviv obl.	✓	✓	✓	✓	✓	✓	✓	✓
Mykolaiv obl.	✓	✓	✓	✓	✓	✓	✓	✓
Odesa obl.	✓	✓	✓	✓	✓	✓	✓	✓
Poltava obl.	✓	✓	✓	✓	✗	✗	✓	✓
Rivne obl.	✓	✓	✓	✓	✗	✗	✓	✓
Sumy obl.	✗	✗	✓	✓	✗	✗	✓	✓
Ternopil obl.	✓	✓	✓	✓	✓	✓	✓	✓
Vinnytsya obl.	✓	✓	✓	✓	✗	✗	✓	✓
Volyn obl.	✗	✓	✗	✗	✗	✗	✓	✓
Zakarpattia obl.	✓	✓	✓	✓	✗	✗	✓	✓
Zaporizhzhya obl.	✓	✓	✓	✓	✓	✓	✓	✓
Zhytomyr obl.	✓	✓	✓	✓	✗	✗	✓	✓

Source: Own work.

Table A-2: Companies producing solar panels in Ukraine

Company	Type	Capacity	Employees	Details
Prolog Semicor (Kyiv)	Full-cycle	12 MW/year	≤ 170	Established in 1997 for the production of silicon and silicon wafers, currently active in the export of silicon. Since 2014, an automated line for monocrystalline solar panels.
DP Kvazar-7 (Kyiv)	Part-cycle [previously full-cycle]	30 MW/year (before restructuring)	Kvazar-7: ≤ 20 Kvazar: 180-200	Started in 1994 as Kvazar and was a major producer until 2015. Then stopped production and went through a bankruptcy restructuring procedure, with subsidiary Kvazar-7 (on the market since 2001) continuing to assemble solar panels using imported equipment and specialising in custom orders and quality control.
Kness PV (Vinnytsia)	Part-cycle	200 MW/year	220 (in Ukraine)	Established in 2018 as part of the international Kness Group, it operates a highly automated assembly line using both foreign and Ukrainian components. A doubling of capacity was planned for 2020, but no further information is available.
Info-zvyazok (Odesa)	Part-cycle	unknown	22	Established in 2013 on the premises of the equipment and electronics manufacturer "Promzvyazok". Uses imported photocells and Ukrainian-made profiles and glass.
ENHOL (Energodar) [production stopped]	Part-cycle	10 MW/year	unknown	Established in 1991 in the refrigeration and ventilation equipment market, the solar panel assembly line was launched in 2018 but closed in 2019 after a short period of operation.

Source: Own compilation based on Mostova (2020).

Annex B. FiT rates and auction prices

Table B-1: FiT rates for various RES in Ukraine, EUR/kWh

PP type	Facility commissioning date												
	Until Mar '13	Apr '13 - Dec '14	Jan-Jun '15	Jul-Dec '15	Jan-Dec '16	Jan '17 - Dec '19	Jan-Oct '20	Nov-Dec '20	Jan-Mar '21	Apr-Dec '21	Jan-Dec '22	Jan '23 - Dec '24	Jan '25 - Dec '29
Ground-mounted SPP ≤10 MW	0.4653	0.3393	0.3053										
Ground-mounted SPP >10 MW	0.2585	0.1885	0.1696										
Ground-mounted SPP <1 MW				0.1569	0.1479	0.1389	0.1097	0.1097	0.1061	0.1061	0.1024	0.0987	0.0950
Ground-mounted SPP >1 MW				0.1442	0.1359	0.1277	0.1097						
Ground-mounted SPP 1-75 MW								0.0788	0.0761	0.0435	0.0420	0.0405	0.0390
Ground-mounted SPP >75 MW								0.0450	0.0435	0.0435	0.0420	0.0405	0.0390
Rooftop/facade PV (≤ 100 kW)	0.4265	0.3586	0.3226	0.1804	0.1723	0.1637	0.1228	0.1185	0.1185	0.1147	0.1147	0.1104	0.1066
Rooftop/facade PV (>100 kW)	0.4459	0.3489	0.3139										
Private PV ≤ 30 kW (rooftop/ facade)		0.3586	0.3226	0.2003	0.1901	0.1809	0.1626	0.1626	0.1626	0.1626	0.1626	0.1626	0.1449
Rooftop/facade PV consumers / cooperatives (≤ 150 kW)						0.1637*	0.1228	0.1228	0.1228	0.1228	0.1228	0.1228	0.1066
WPP <600 kW	0.0646	0.0646	0.0582 / 0.0538	0.0582 / 0.0538	0.0582 / 0.0538	0.0582 / 0.0538	0.0504	0.0504	0.0494	0.0494	0.0483	0.0478	0.0441
WPP 600 kW - 2 MW	0.0754	0.0754	0.0679	0.0679	0.0679	0.0679	0.0588	0.0588	0.0578	0.0578	0.0567	0.0557	0.0515
WPP >2 MW	0.1131	0.1131	0.1018	0.0941	0.0941	0.0941	0.0882	0.0882	0.0882	0.0882	0.0882	0.0882	0.0772
Private WPP (≤30 kW, from 2019 ≤50 kW), from 2019 incl. consumers/ cooperatives (≤150 kW)				0.1163	0.1163	0.1163	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.0932
Combined WPP/SPP private (≤50 KW) and consumers/ cooperatives (≤150 kW)						0.1637*	0.1228	0.1228	0.1228	0.1228	0.1228	0.1228	0.1066

PP type	Facility commissioning date											
	Until Mar '13	**Apr '13 - Dec '14**	**Jan-Jun '15**	**Jul-Dec '15**	**Jan-Dec '16**	**Jan '17 - Dec '19**	**Jan-Oct '20**	**Nov-Dec '20**	**Jan-Mar '21**	**Apr-Dec '21**	**Jan-Dec '22**	**Jan '23 - Dec '24**	**Jan '25 - Dec '29**
Biomass / biogas (from 2019 incl. consumers/ cooperatives ≤150 kW)	0.1239	0.1239	0.1115	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239
Small HPP (1-10 MW)	0.1163	0.1163	0.1045	0.1045	0.1045	0.1045	0.0942	0.0942	0.0942	0.0942	0.0942	0.0942	0.0835
Mini HPP (200 kW - 1 MW)	0.1163	0.1551	0.1395	0.1395	0.1395	0.1395	0.1255	0.1255	0.1255	0.1255	0.1255	0.1255	0.1115
Micro HPP (<200 kW, from 2019 incl. consumers/ cooperatives ≤150 MW)	0.1163	0.1939	0.1745	0.1745	0.1745	0.1745	0.1572	0.1572	0.1572	0.1572	0.1572	0.1572	0.1395
Geothermal energy (from 2019 incl. consumers/ cooperatives ≤ 150 kW)			0.1502	0.1502	0.1502	0.1502	0.1352	0.1352	0.1352	0.1352	0.1352	0.1352	0.1201

* in the period between January and December 2019.

Source: Tryboi, Radchenko, Zubenko, & Gaidai (2021).

Table B-2: Maximum starting prices for "green" auctions

RES type	Maximum starting price
WPP and SPP (auctions held until 31 December 2024)	9 eurocents per kW/h
WPP and SPP (auctions held from 1 January 2025)	8 eurocents per kW/h
Other alternative energy sources	12 eurocents per kW/h

Annex C. Financial support measures for RES

Table C-1: National support programmes introduced in 2024

Programme (type)	Maximum amount	Rate/ (max.) duration	Target group	Funding purpose
0% loans (loan)	UAH 480,000	0% / 10 years	Households, business	Purchase and installation of power generation equipment that produces electricity from alternative sources (solar panels with electricity storage systems, wind turbines).
Affordable loans 5-7-9% (loan)	UAH 5 million (households, condominiums) UAH 150 million (business)	7% / 5 years (households), 10 years (business)	Households, condomi-niums, business	Purchase and installation of power generation systems using alternative energy sources, as well as power storage systems and auxiliary equipment. For businesses, also purchase and installation of gas turbine, gas piston or biogas generating equipment.
GreenDIM (grant)	70% of equipment cost but not exceeding: UAH 1 million (SPP) UAH 2 million (heat pump) UAH 3 million (SPP + heat pump)	-	Households, condomi-niums	Purchase and installation of solar power systems and/or heat pumps and related equipment.
Add energy to your business (loan)	EUR 500,000	variable / 5 years	Micro, small and medium enterprises	Installation or modernisation of machinery and equipment, reconstruction, repair and renovation of premises in energy efficiency projects with a minimum CO_2 reduction of 20%. The SMEs must be in operation for more than one year, have a positive credit history and not be under sanctions by Ukraine, the EU, the UN Security Council or Germany.
Preferential bank loans (loan)	EUR 25 million	1st year: 13.5% or UIRD-3+0.5% 2nd+ year: max. UIRD-12+3% / 5-7 years	Business	Implementation of energy infrastructure rehabilitation projects, in particular construction of own power generation facilities costing more than UAH 150 million.

Programme (type)	Maximum amount	Rate/ (max.) duration	Target group	Funding purpose
State Fund for Decarbonisation and Energy Efficiency Transformation (loan)	UAH 120,000 to UAH 25 million	variable / 10 years	State programmes for business, households	Implementation of energy efficiency measures, introduction of energy services, development of renewable energy sources.

Notes:
UIRD-3 is the 3-month Ukrainian Index of Retail Deposit Rates, UIRD-12 is the 12-month Ukrainian Index of Retail Deposit Rates.
Preferential bank loans are not a single state programme but rather a set of programmes/loan offers operated through 19 of Ukraine's largest banks. The “Add energy to your business” programme with specified loan conditions is a special case of this support mechanism.

Source: Own work.

Table C-2: Selected international support programmes in Ukraine

Programme (if specified) / donor	Funding	Ultimate beneficiary (if known)	Funding purpose
European Bank for Reconstruction and Development (EBRD)	EUR 19.7 billion	Business, cities/ communities	Maintaining liquidity and sustainability of key business entities of critical infrastructure; RES and energy efficiency projects (e.g., joint venture with a German investor for an SPP, loan for a biofuels project, loans to local banks to support SMEs, including energy efficiency projects).
International Finance Corporation (IFC)	USD 2 billion	-	Projects to restore: ☐ transport and logistics (airports, ports, railway stations, road logistics); ☐ urban infrastructure (public transport, heat, water supply, etc.); ☐ social infrastructure (schools, kindergartens, hospitals, affordable housing); ☐ energy infrastructure.
Energy Efficiency Support Programme for Ukraine (EE4U) / German government (funding), IFC (management)	EUR 20 million	Households	Upgrading Ukraine's housing stock for energy efficiency (grants to condominiums to co-finance energy efficiency measures in apartment buildings).

Ukraine Energy Support Fund / EU-managed pool for financial support by IFIs and international organisations	EUR 758 million pledged / EUR 693 million transferred	Cities/ communities	Supply of power equipment (generators, transformers, etc.) and the restoration of the energy infrastructure, in particular for critical social infrastructure facilities such as schools, hospitals, transport and water supply.
Ukraine Investment Facility (UIF) / EU	EUR 1.5 billion (blending/ grants/ technical assistance) EUR 7.8 billion (guarantees)	Public and private companies	Reconstruction of Ukraine's electricity transmission system. Specific example: EUR 100 million grant agreement with KfW for reconstruction, repair, rehabilitation and replacement of destroyed and/or damaged parts of the Ukrainian electricity grid, equipment, construction of new substations and power lines using modern and energy-efficient technologies, and measures to physically protect the elements of the electricity infrastructure.
"Add Energy to Your Business" programme funding / German government through KfW	EUR 7 million	Business	Energy efficiency projects with a minimum CO_2 reduction of 20%.

Source: Own work.