



Green Tech Made in Ukraine: Assessing the potential of green value chain manufacturing localisation in Ukraine

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Executive Summary

The rapidly decreasing costs of green technologies - solar photovoltaics, wind turbines, and lithium-ion batteries - combined with the urgent need to decarbonise global energy systems is driving unprecedented global demand for green technologies.

Ukraine may have a strategic opportunity to develop a green technology manufacturing base. There are three reasons that stand out in particular among those in favour of developing these sectors in Ukraine:

- Given the need for large-scale reconstruction of the energy system, manufacturing localisation could help meet domestic energy targets, while retaining more value inside of Ukraine.
- Developing an advanced manufacturing sector could act as a driver of economic growth and significantly contribute to both current and post-war economic recovery.
- Developing competitiveness could further integrate Ukraine into EU value chains as it advances toward EU membership, while its exports could support the EU's climate goals and bolster regional energy security, solidifying Ukraine's role as a long-term strategic partner.

Among the technologies analysed, the study finds that localising segments of the wind turbine value chain in Ukraine is the most promising. Ukraine's wind turbine manufacturing sector could possibly be cost-competitive vis-à-vis the EU, especially in tower and blades production. Nacelle production is costlier due to imports and a less developed supplier ecosystem. However, some components are already produced in Ukraine, and local assembly is economically viable and can be expanded.

In solar PV manufacturing, Ukraine is unlikely to compete with China and South-east Asia purely on cost - and neither are the EU or U.S. Nonetheless, there are opportunities to revive assembly operations and scale up ancillary equipment manufacturing (e.g. inverters), which could deliver important benefits. Several key inputs, including sheet glass and polysilicon are currently being discussed, although their primary role should be in existing industries or as strategic exports to the EU, rather than the currently dormant Ukrainian solar PV manufacturing sector. In the longer-term, Ukraine could be part of a larger integrated EU value chain if energy security considerations lead to larger pan-European solar PV localisation. Here, energy security considerations would trump pure cost competitiveness.

Ukraine currently lacks experience in battery cell manufacturing and prospects for the sector are unclear. However, existing activities focused on assembling imported battery cells could be scaled up to meet domestic demand, particularly for battery storage and other emerging sectors, such as defence. It is currently too early to tell what role Ukraine's critical mineral sector will play in these value chains.

Given the findings, much work remains to be done to catalyse the Ukrainian green technology manufacturing sector. Ukraine must focus on revitalizing its industrial base by leveraging existing infrastructure and developing sectoral linkages that connect different parts of the renewable energy value chain. This would include strengthening logistics for renewable supply chains, creating industrial parks with stable access to renewable energy, and investigating the potential of repurposing existing production sites.

In parallel, Ukraine needs to strengthen its critical minerals strategy by identifying ways to add value domestically and positioning itself as a long-term partner for both EU and global markets.

Financial support mechanisms will be crucial to spur growth, particularly through special financing schemes that include soft loans, government guarantees, and state support. Under current market conditions, the high cost of financing offsets Ukraine's structural advantages, rendering many large-scale manufacturing investments economically unviable. Hence for Ukraine, preferential financing - through grants, guarantees, or low-cost credit - can significantly improve project viability.

Demand-side measures, such as accelerating renewable energy roll-out, enhancing market liberalisation, and in-

troducing corporate power purchase agreements (PPAs), will further strengthen the market environment for green technologies. On the regulatory front, a more cohesive industrial policy and targeted foreign direct investment (FDI) attraction programme would provide the clear framework needed for large-scale manufacturing investments. This should be complemented by a robust labour and skills development programme, with targeted re-skilling initiatives and a national green skills certification framework, ensuring a workforce equipped for the green transition. Finally, Ukraine must invest in research and development, fostering public-private partnerships and building innovation hubs to drive the development of green technologies. These combined efforts will not only boost economic recovery but also position Ukraine as a key player in Europe's renewable energy future.

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1. Introduction

The global energy transition away from fossil fuels is leading to skyrocketing demand for a variety of green technologies.¹ In the decarbonisation of the energy sector, solar photovoltaics (PV) and wind turbines represent two of the most successful renewable energy technologies, with rapidly decreasing costs leading to ever higher deployment rates. Lithium-ion battery adoption has also massively increased in the last decades, initially in consumer electronics, but increasingly much more so in electromobility as well as in electricity storage. As demand for green technologies continues to grow in the coming decades, so will the pressure on manufacturers and suppliers to ensure these technologies are produced at sufficient scale. For already existing producer countries, this elevated demand may lead to an expansion of manufacturing, but for many others, this may provide a “green window of opportunity” to leapfrog into the production of these advanced green technologies.²



For Ukraine, the localisation of green technology value chains may provide a variety of significant economic opportunities. Ukraine's energy sector has been the most heavily targeted by Russia since the beginning of the illegal invasion in February 2022. The Energy Strategy 2050 and the National Energy and Climate Plan 2030 both foresee the importance of the shift to a greener, more decentralised energy system, with large, expected increases in the deployment of solar PV, wind power and energy storage.³ This large domestic demand may provide the first major pre-requisite for the localisation of production, but Ukraine's future accession to the European Union also provides an important potential export market, wherein Ukrainian renewable technology production (and energy trade) could further Europe's own decarbonisation agenda. The manufacturing sector has traditionally played an important role in Ukraine's economy, and some high-tech manufacturing, including in the energy sector already exists. Restarting the manufacturing sector would therefore provide a significant boost to the economy -supporting job creation, wage growth, export revenues, and additional industry demand- all of which are critical drivers of Ukraine's economic recovery.

This study aims to provide, to our knowledge, the first comprehensive assessment of the potential for the localisation of the manufacturing of the three green technology value chains - solar PV, wind power and lithium-ion batteries - in Ukraine. It provides both a qualitative and quantitative analysis of the competitiveness of the three value chains, comparing Ukraine's potential with other global and regional manufacturers. The report also provides an overview of the support needed, as well as the economic impact and contributions that the localisation of manufacturing may have on Ukraine. The report aims to serve as a first step in generating interest from investors into entering the green technology manufacturing space in Ukraine and also presents a roadmap of the necessary policy steps needed to unlock and catalyse investments in the space.

The analysis presented in this report stems from a mix of quantitative and qualitative methods. The research process included primary research and data collection which also involved semi-structured interviews with key Ukrainian and international equipment manufacturers, industry associations, project developers and policymakers, along with other stakeholders. Data on Ukrainian-specific costs was obtained directly from local manufacturers, while international benchmarks were sourced from industry publications and open-access databases. A comprehensive literature review was conducted, and was complemented with additional expert interview and opinions, which were also fundamental to the elaboration of many of the assumptions underpinning both quantitative and qualitative analysis.

The report proceeds in six main sections. Chapter 2 provides an overview of the broader global background, focusing on the rising demand for solar PV, wind turbines, and lithium-ion battery technologies in light of the global energy transition, but also provides a first overview of the evolution of the manufacturing landscape and importance of industrial policies in the process. Chapter 3 then focuses on Ukraine, outlining the fundamental rationale behind the localisation of manufacturing renewable energy technologies including the potential opportunities and benefits. Chapter 4 provides an assessment of the state of Ukraine's high-tech manufacturing sector, breaking down the various key components that are relevant to the potential localisation of green energy technologies. Chapter 5 then, in turn, provides a summary of the renewable technology value chains and presents the quantitative and qualitative analysis for the three selected technologies, including the main findings regarding the potential competitiveness of Ukraine-localised industries, and provides sectoral roadmaps. Chapter 6 provides a discussion of the results in a broader context, focusing also on the necessary policy reforms needed to improve the industries' future competitiveness, before Chapter 7 provides concluding thoughts.



2. Broader global background

The global push for decarbonisation is dramatically increasing the demand for renewable energy technologies including solar PV, wind turbines and lithium-ion batteries. This elevated demand, along with key economic, strategic and geopolitical factors is fundamentally reshaping the global green technology manufacturing landscape, potentially providing an opportunity for new entrants to join these manufacturing value chains. The following sections provide an overview of key demand drivers to demonstrate the size of the opportunity, before presenting the broader manufacturing landscape.

2.1 Global energy transition and the rise of green technology demand

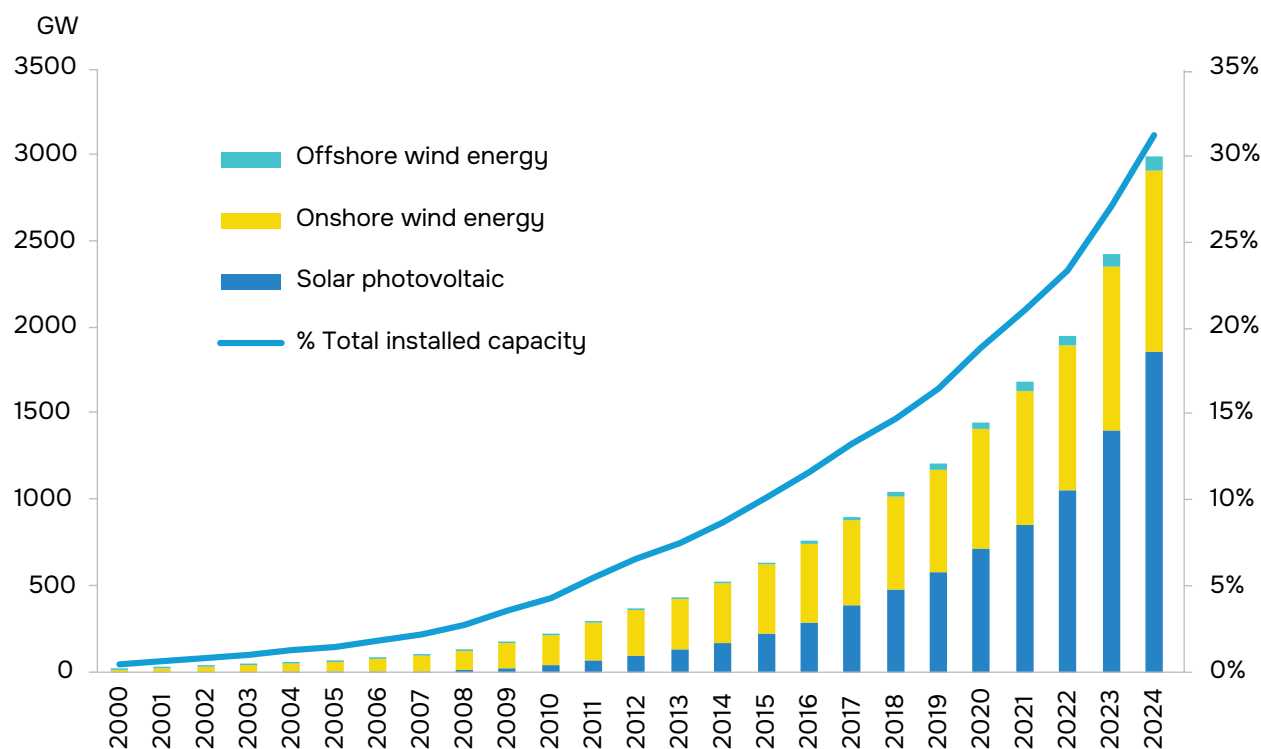
The rapidly progressing pace of global warming and climate change has increased the pressure on countries to rapidly accelerate the global energy transition away from fossil fuels to greener, more sustainable sources of energy. The signing of the 2015 Paris Agreement established a framework for this, agreeing to limit the rise in the global average temperature to well below 2°C above pre-industrial levels, while pursuing efforts to limit it to 1.5°C above pre-industrial levels.⁴

In the power generation and transportation sectors especially, the rate of technological innovation and decreases in costs have significantly improved the availability of green solutions able to replace legacy fossil fuel-based assets. However, to spur the energy transition and meet net-zero targets by mid-century, a significant scale-up of renewable energy capacities - including solar PV, wind power and battery storage - is essential. In 2021, energy was responsible for over 75% of all

global greenhouse gas emissions, with the electricity and heat sector accounting for close to 30% of total global GHG emissions. In addition, the transportation sector contributed a further 14% of global GHG emissions, underscoring the need to rapidly deploy electric vehicles (fuelled by renewable electricity) across all major transportation segments.⁵

Nonetheless, the pace of deployment of renewable energy technologies has dramatically accelerated in the last few decades. While in 2000 the total installed capacity of solar PV and onshore and offshore wind accounted for only 0.5% of total electricity generation capacity, this number increased to 31.2% by the end of 2024. In addition, since 2017 solar PV and wind power jointly consistently account for more than 50% of total newly installed generating capacity, with a high point of 89% of new capacity installed in 2024.⁶

Figure 1. Solar PV, onshore and offshore wind installed capacity



Source: IRENA, n.d.

While the deployment of green technologies has been global, China dominates in terms of total installed capacity. In the solar PV segment, China account for almost 48% of total installed capacity, or 887 GW, with the next four countries, the US, Japan, Germany and India cumulatively accounting for 24% or 445 GW. The story is similar in the onshore and offshore wind segments, where China accounts for 46% or 483 GW and 49% or 39 GW of total global capacity, respectively. For onshore wind, the US, Germany, India and Spain cumulatively account for 30% of total global capacity, or 320 GW, while the offshore wind segment is more concentrated in Europe, where the UK, Germany, Denmark and the Netherlands account for 40% of all deployment.

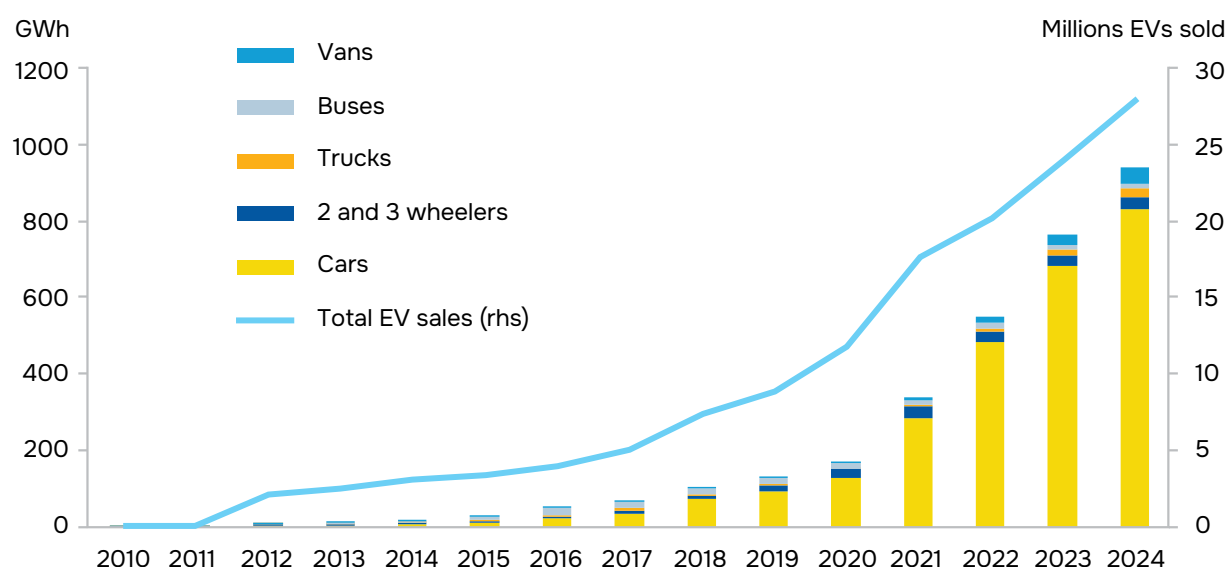
The massive increase in annual capacity deployed - 452 GW of solar PV and 113 GW of wind in 2024 alone - was driven primarily by China, although deployment rates have increased globally. In 2024, China further increased its dominance in renewable energy deployment, accounting for 62% of new solar PV capacity and 72% of newly installed onshore wind capacity.⁷

The growing installed capacity of variable renewable energy (VRE) is accompanied by the increased need for grid flexibility and storage of

electricity for periods with less renewable generation. Battery storage especially plays a central role in both enabling the flexibility through rapid responses to changes in supply and demand and through the ability to store electricity, facilitating a higher overall share of renewables in the electricity mix. According to Bloomberg New Energy Finance (BNEF), the first full GW of global battery storage capacity was installed in 2014, skyrocketing to over 71 GW by 2023, in only a decade.⁸

An even more dramatic increase has been observed in the electromobility segment which relies heavily on lithium-ion batteries. While electric vehicles (EVs) passenger vehicles sales in 2010 amounted to 7,000 cars globally, this number skyrocketed to 17.5 million by 2024.⁹ While the passenger segment continues to drive demand, other forms of electromobility, including vans, buses, trucks and electric two- and three-wheelers have all seen a fundamental increase in demand, leading to massive increases in the amount of lithium-ion battery capacity. While in 2010 the total lithium-ion battery capacity in all electromobility was less than 1 GWh, by 2024 this amount reached 953 GWh, of which 840 GWh was found in passenger cars.

Figure 2. Battery demand in electromobility

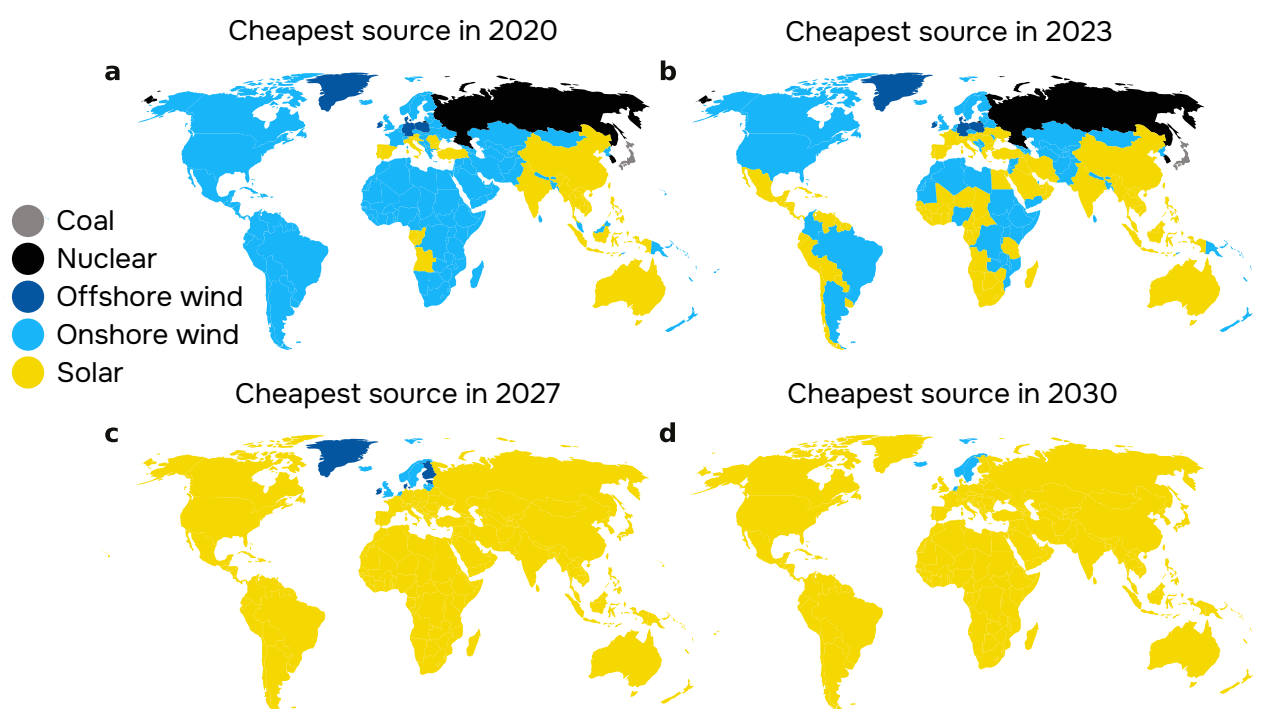


Source: International Energy Agency (2025)

Declining costs have significantly contributed to the rapid rollout of renewable energy sources, battery storage and EVs. Solar PV is already the lowest-cost electricity source in many regions—even with battery storage included—and it is expected to become the most cost-effective option globally by 2027, with a Levelized Cost of Electricity (LCOE) production of around 35 USD/MWh.¹⁰ Wind energy follows a similar trajectory, though at higher costs. In 2024, onshore wind

had an average LCOE of USD 75/MWh, projected to drop by 42% by 2060. Offshore wind, at USD 230/MWh, is expected to decline by 67% over the same period.¹¹ By 2023, when including battery costs, onshore wind was the cheapest option in many countries. Similarly, battery costs have decreased dramatically in the past decade, falling from 780 USD/kW in 2013 to 139 USD/kW in 2023, a decrease of 82%.¹²

Figure 3. Technology with the lowest LCOE including long-term storage costs

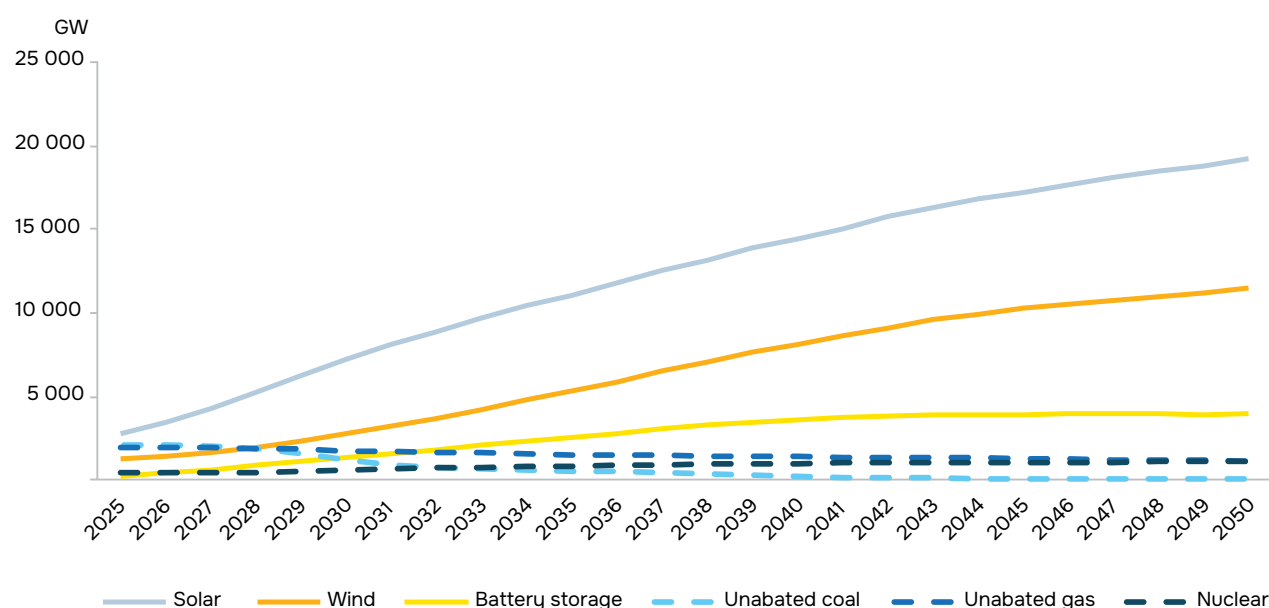


Source: Nijssen (2023). Each map shows the 70 E3ME regions: in 2020 (a), 2023 (b), 2027 (c) and 2030 (d). The biggest shift occurs between 2020 and 2027, which sees a range of technologies give way to solar PV as the cheapest source of electricity.

However, as the pace of deployment further accelerates to decarbonise global energy systems and race towards meeting net-zero targets, significantly more green technology capacity deployment is expected. One such forecast of

a global net-zero scenario from BNEF demonstrates the scale of the amount of deployment needed for solar PV, wind power and battery storage.

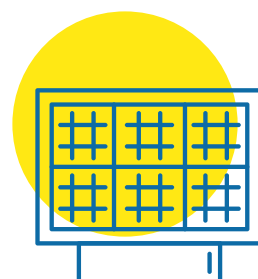
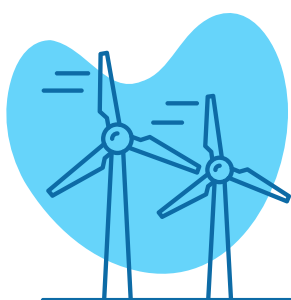
Figure 4. Forecasted Installed Energy Capacity by Source (2025–2050)



Source: BNEF New Energy Outlook (2024). Note: Net Zero Scenario 2050.

Under this pathway, installed solar PV capacity must increase by over 600% between 2025 and 2050 to over 19,000 GW, wind power needs to reach almost 11,500 GW (an 800% increase) and grid-scale battery storage capacity has to increase to almost 4,000 GW, a monumental 1600% increase.¹³ On a global scale, these projections imply that installed solar PV capacity will surpass unabated coal-fired power capacity by 2025, with wind capacity overtaking coal by 2028.¹⁴ In the European Union, the REPowerEU plan set targets of 592 GW of installed solar PV capacity and 500 GW of wind capacity to remain on track for achieving climate neutrality by 2050.¹⁵

In line with the further integration of renewable energy sources into global grids, battery storage demand is also expected to increase dramatically. To align with the global net-zero pathway, battery storage capacity must expand to 1,330 GW by 2030, but an even more significant driver of battery demand will come from the decarbonisation of the transport sector, particularly in the ambitious net-zero scenario. The IEA's Global EV Outlook estimates that by 2030, in the STEPS scenario, close to 75 million electric vehicles will be sold globally, representing a 160% increase vis-à-vis 2024.¹⁶ This also translates to a significant amount of battery capacity needed to power these electric vehicles, which is estimated to reach over 3,200 GWh in the same scenario, a 240% increase vis-à-vis 2024 levels.



2.2 Green technology manufacturing and industrial policy

All available evidence points to very strong market growth potential for renewable technologies in both the short- and long-term. Given the meteoric rise in deployment of all three technologies and anticipated demand, green manufacturing sectors are becoming increasingly more lucrative for countries, with significant positive contributions in terms of employment and up-skilling, economic value-added, export revenues, research and development, technological upskilling and fiscal revenues.¹⁷

The global energy transition is therefore not only reshaping electricity systems, but it is also re-drawing the global map of industrial competitiveness. This shift is creating a new industrial race centred around green technologies and the value chains that underpin them. While fossil fuel-based value chains were capital-intensive and geographically concentrated in resource-rich countries, the emerging green value chains are more modular, technology-intensive, and subject to industrial policy decisions. As a result, the ability to localise segments of these value chains is becoming a central strategic consideration for countries aiming to secure energy resilience, benefit from industrial growth, and gain geopolitical leverage.¹⁸

Some of these processes stem directly from geopolitical competition and security concerns. China is currently the undoubted leader in global manufacturing, and occupies a dominant position across most of the solar PV and lithium-ion battery value chains, with a leading position in wind turbines as well.¹⁹ Importantly, while the country has a strong mineral base of its own, including leading production of many critical mineral inputs needed for green technologies (see section 4.2), it is by far the largest processor and refiner of critical minerals globally, exerting significant influence and raising concern in Brussels and Washington D.C. These concentrated supply chains present systemic risks.²⁰ The COVID-19 pandemic, followed by the global energy crisis and renewed geopolitical fragmentation, has un-

derscored the vulnerabilities of over-reliance on a few supply nodes. Delays, price shocks, and export restrictions in critical inputs have prompted many governments and firms to re-evaluate the structure of their supply chains. As a result, concepts like “friend-shoring”, “onshoring”, and “supply chain resilience” have become embedded in energy and industrial strategies.²¹

In response to these challenges and opportunities, green industrial policy is rapidly becoming a central pillar of economic strategy in many countries. The U.S. Inflation Reduction Act (IRA) is the most notable example, offering tax credits and subsidies tied explicitly to local content and domestic manufacturing. These include production-based incentives for solar wafers, battery cells, modules, and critical minerals. The European Union, through the Net-Zero Industry Act (NZIA), is moving in a similar direction, with measures to streamline permitting for clean tech manufacturing, facilitate access to finance, and prioritize strategic projects for public procurement and permitting fast-tracks. While the IRA has already yielded significant investments, the NZIA has not been backed up by as much financing, with results still to come.²²

In China, green industrial policy has long been a key driver of dominance in clean tech value chains. State-led investment, coordinated research and development, and export-oriented scaling strategies have made China the global manufacturing hub for green technologies. Meanwhile, emerging economies such as India, Indonesia, Vietnam, and Malaysia are adopting targeted incentives to localise segments of production and attract foreign direct investment. Industrial policy is no longer solely about comparative advantage; it is about building capabilities in technologies of the future through coordinated public and private action. The revival of industrial policy creates a unique moment for new entrants to define niches and insert themselves into the emerging green industrial architecture.

For countries without an existing foothold in clean energy manufacturing, the rise of green industrial policy could create a rare opportunity to leapfrog into high-value segments of the global value chain. While for some countries this may mean further expanding their mineral resource production or possibly entering mineral processing, for others it may mean localising a part or the entirety of a green technology value chain. Some may be able to provide important equipment for the value chains without localising the main segments, while others may focus more on recycling and secondary mineral recovery as a pathway forward. Some countries will look to leapfrog into very high technology segments, while others may take a slower route through intermediate products while progressively building up capacity. For all these options, examples abound of countries already crafting and imple-

menting strategies and industrial policies, but it is clear that there is no one-size-fits-all model that can be applied.

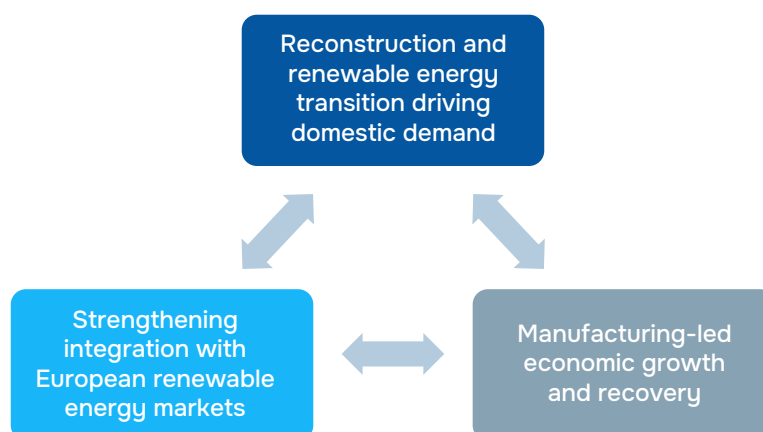
Importantly, while the localisation of green technology value chains may indeed provide for cases of green windows of opportunity and lead to positive outcomes for some, this will not be uniform. The need to pursue industrial policy, which often requires significant fiscal resources, may lock many prospective countries out while further concentrating manufacturing capacities and benefits in the already rich global North countries. While this assessment is out of the scope of this report, this fundamentally developmental debate is highly relevant to Ukraine, both in terms of its historical and current economic situation and visions of economic recovery and reconstruction through manufacturing and green manufacturing-led growth.



3. Strategic rationale for renewable technology manufacturing localisation in Ukraine

Russia's invasion of Ukraine has caused extensive destruction to the country's economy, energy system and broader infrastructure. Nonetheless, the ongoing reconstruction and long-term strategic development of both the economy and the country's energy sector present an opportunity to build back better with green technologies at the heart of a more sustainable reconstruction. While there is a clear need to accelerate the deployment of renewable energy sources and battery storage, this increased demand, coupled with other strategic opportunities, may also create the conditions for green technology value chain manufacturing localisation in Ukraine. The following three sub-sections provide the strategic rationale underpinning the potential for manufacturing localisation, demonstrating the key potential benefits.

Figure 5. Strategic rationale for localising green value chain manufacturing in Ukraine



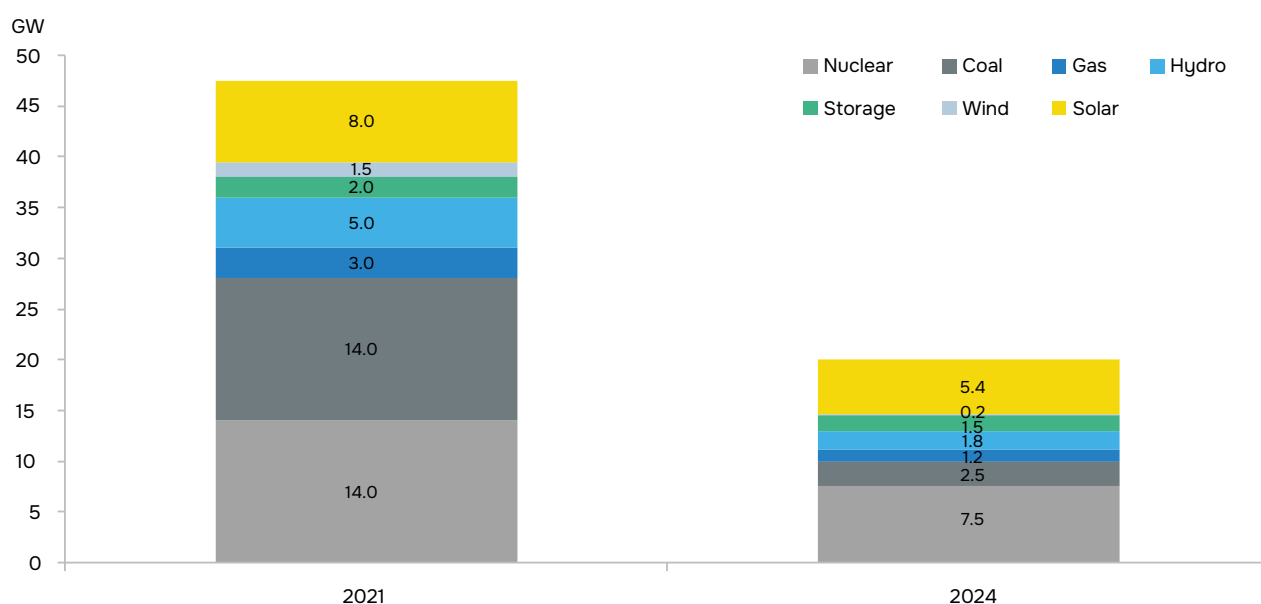
Source: Authors' illustration

3.1 Reconstruction and renewable energy transition driving domestic demand

Domestic demand for renewable energy technologies in Ukraine is driven by both immediate and post-war reconstruction needs, as well as a broader strategic shift away from fossil fuels. As such, the country faces a dual imperative:

rebuilding heavily damaged infrastructure while simultaneously accelerating the transition to a greener energy system needed for long-term economic competitiveness and to fulfil Ukraine's international climate obligations.

Figure 6. Installed generation capacity in Ukraine, 2021 vs 2024



Source: IEA (2024), Empowering Ukraine Through a Decentralised Electricity System, IEA, Paris, [Link](#), Licence: CC BY 4.0

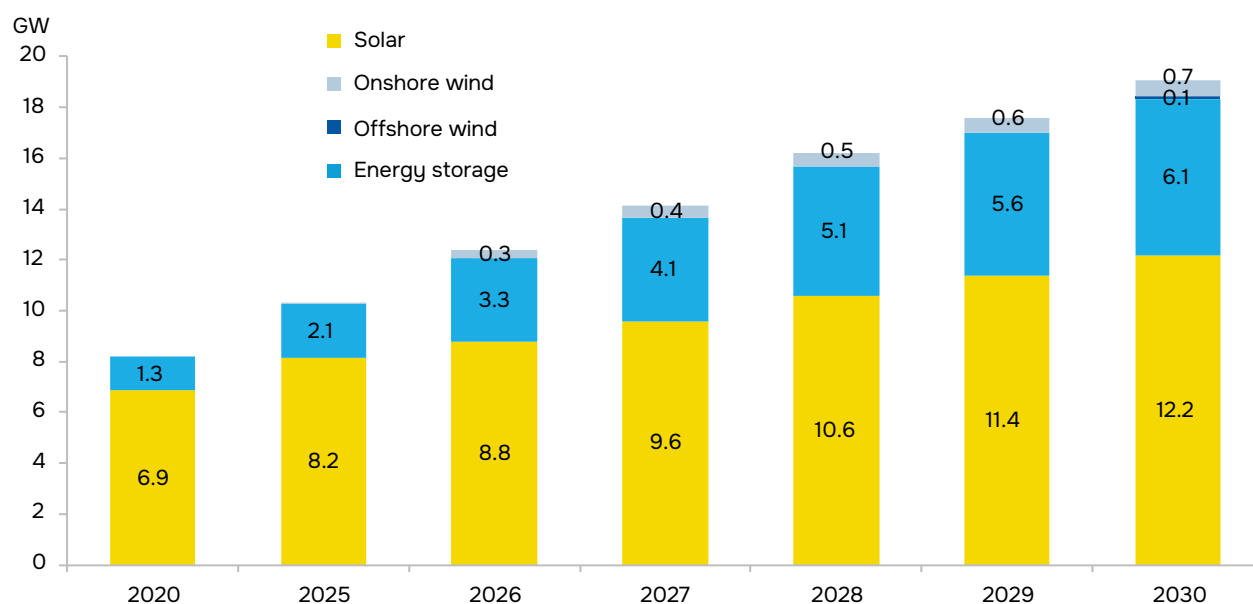
The war has significantly disrupted Ukraine's power system, destroying or occupying approximately 27 GW of generating capacity. About ~82% of all thermal power plant, ~64% of all hydroelectric power plant and ~45% of nuclear power plant capacity has been lost. ~30% of solar and ~90% of wind power has been destroyed, damaged or occupied during the war.

This extensive damage has also led to a fundamental reassessment of Ukraine's energy strategy. Renewable energy sources, particularly solar PV and wind power, are increasingly recognised as essential components of Ukraine's energy future due to their inherent resilience against targeted attacks, stemming from their decentralised nature. When combined with battery energy storage systems (BESS), these renewable sources can significantly enhance grid stability and integration capabilities. Accordingly, long-

term strategic plans set ambitious targets for the expansion of renewable energy technologies, signalling a substantial increase in capacity and driving the need for large-scale deployment over the coming decades. This transition will naturally generate sustained demand for renewable technologies and their associated components and equipment.

As part of its climate commitments, Ukraine aims to reduce greenhouse gas emissions by 65% compared to 1990 levels by 2030, and to achieve a 27% share of renewable energy in total final energy consumption within the same timeframe. Additionally, the country seeks to diversify its energy sources and supply routes, limiting reliance on any single supplier to no more than 30%, as outlined in the National Energy and Climate Plan (NECP) for the period up to 2030.

Figure 7. Ukrainian solar PV, wind power, and energy storage installed capacities (2025-2030)



Source: Ukraine National Renewable Energy Action Plan until 2030 (2024).

According to Ukraine's National Renewable Energy Action Plan for the period up to 2030, solar PV capacity will increase to 12.2 GW, and wind power capacity to 6.2 GW. In 2024, Berlin Economics estimated that a total of 14 GW total solar PV capacity can be added by 2030.²³ In parallel,

the development of grid-scale energy storage is gaining momentum - by 2030, the capacity of lithium-ion batteries is targeted to reach 0.6 GW (up from effectively zero in 2020). The growth of the EV market is also driving demand for batteries.

Localisation of renewable technology production will help reduce dependence on imports and meet domestic needs. Before the war, imports of energy equipment accounted for 1.4% of total imports (EUR 0.9 billion), and by 2023, they had risen to 2.7% (EUR 1.6 billion), reflecting the extent of the destruction and limited domestic production ca-

capacity.²⁴ A strategic localization push would not only boost energy security—by mitigating exposure to global supply chain disruptions and geopolitical risks—but also serve dual purposes: addressing both the urgent reconstruction of Ukraine’s energy system and supporting its longer-term clean energy transition.

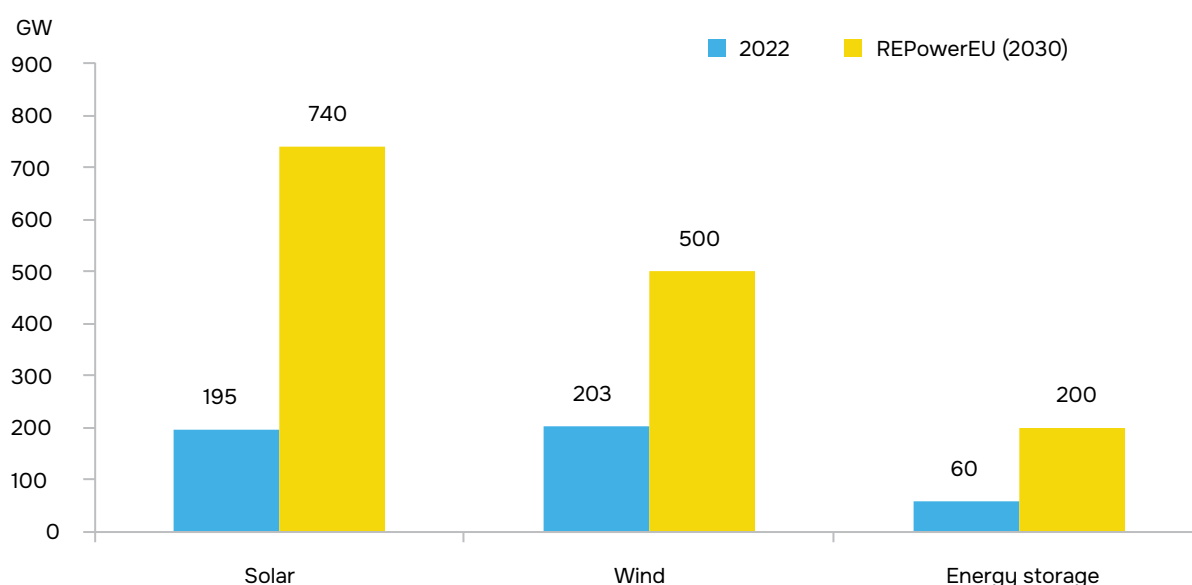
3.2 Strengthening integration with European renewable energy markets

The localisation of green technology value chains would not only satisfy domestic demand but could also further integrate Ukraine into European supply chains, opening access to the wider EU market. Due to its geographical proximity, significant renewable energy potential and integration into the EU, the country has all the pre-requisites to become a long-term energy partner. In addition to the prospect of exporting green electricity and hydrogen -which have been discussed and partially developed- Ukraine has already begun

exporting biomethane to Europe, and could also act as a production centre serving the growing EU market for renewable energy equipment.

The EU has pledged to reduce greenhouse gas emissions by at least 55% by 2030 and 90% by 2040 compared to 1990 levels. To support this goal, the share of renewable energy should reach 42.5% by 2030, and 45% under the REPowerEU plan, which significantly increases the demand for renewable energy technologies.

Figure 8. Installed renewable capacities in EU, 2022 vs 2030



Source: Authors’ illustration based on REPowerEU targets.

By 2030, renewables will account for 66% of electricity generation in the EU, and solar generation capacity will increase to 623-672 GW (more than three times the level of 2022). Wind power will also expand significantly, reaching 450 GW compared to 204 GW in 2022.²⁵ Additionally, the EU targets to increase its energy storage capacity to 200 GW by 2030 and 600 GW by 2050 under the REPowerEU plan, which is almost ten times more than in 2022. At the same time, the EU aims to meet 89% of its domestic demand for lithium-ion batteries, although manufacturers

predict that it will only be able to cover 50-60% of the demand.²⁶

Ukraine could strategically use this market growth by supplying renewable energy technologies, attracting investment, and expanding exports. This is clearly defined in the National Recovery Plan, which prioritises localisation of renewable energy equipment production²⁷ and the development of a gigafactory for integration into European value chains.²⁸

3.3 Manufacturing-led economic growth and recovery

The war severely impacted Ukraine's economy, with GDP falling by 28.8% in 2022. The manufacturing sector was particularly affected by the destruction of facilities, power outages and loss of human capital.²⁹

Historically, the manufacturing sector has been a primary driver of economic growth, with increasing returns to scale, higher labour productivity and virtuous cycles.³⁰ The development of the manufacturing of renewable industries would help to diversify the economy, reduce dependence on the agricultural sector, and stimulate investment and employment.^{31,32}

Production ties with metallurgy and machine building could contribute to technological development, while the greater integration of science and education would ensure the long-term modernisation of human resources. The growth in the manufacturing of renewable energy equipment

could lead to positive productive linkages with other sectors, including high-tech sectors that are key to Ukraine's current efforts, and could spur technological spillovers into other sectors as well. Thus, the localisation of renewables may provide a key pathway for Ukraine's reconstruction, sustainable development and international competitiveness.

In summary, renewable technology manufacturing localisation in Ukraine provides a powerful solution to immediate reconstruction needs, supports long-term economic recovery, and strategically integrates Ukraine into the EU's renewable energy landscape. Looking ahead, it is important to assess the current state of Ukraine's industrial sector, particularly the key features of its manufacturing base that will play a vital role in developing high-tech industries like renewable technology manufacturing.



4.

Ukrainian industrial environment



Assessing the localisation potential of renewable energy production in Ukraine firstly requires an analysis of the existing industrial context and pre-existing linkages. This section provides an overview of the current state of the industry and the key factors for localising solar PV, wind turbine, and li-ion battery value chain manufacturing. Localising the manufacturing of these value chains is not only dependent on the availability of core manufacturing capacity, but also on complementary factors such as transport and logistics for moving large components, an advanced IT sector for integrating digital solutions into manufacturing processes, and a dynamic startup ecosystem for fostering innovation in design and materials. Understanding how these elements interact with industrial base helps identify what Ukraine's existing strengths are and where strategic investment is needed to fill gaps, thereby creating a competitive and resilient base for renewable equipment manufacturing.

4.1 Industrial base

To understand the current state and significance of Ukraine's industrial sector, this section examines the overall sectoral structure and composition, alongside the country's level of economic complexity.

Sectoral overview and disaggregation

Ukraine's industrial production is shaped by three core industries: extractives (mining), manufacturing, and energy, with the manufacturing sector accounting for 56% of all industrial value. Follow-

ing the full-scale invasion, all sectors faced a significant reduction in output, decreasing 22% from EUR 144.8 bn in 2021 to EUR 113.2 bn in 2024.

Table 1: Industrial products sold by type of economic activity

	2021 (EUR bn)	2021 (%)	2024 (EUR bn)	2024 (%)
Industry	144.8	100	113.2	100
Extractive industry	18.5	12.8	12.7	11.2
<i>Thereof: mining of metal ores</i>	<i>9.7</i>	<i>6.7</i>	<i>4.2</i>	<i>3.7</i>
Manufacturing	81	55.9	63.4	56
<i>Thereof: Food, beverages, tobacco products</i>	<i>26.1</i>	<i>18</i>	<i>24</i>	<i>21.2</i>
<i>Thereof: Metallurgy</i>	<i>18.9</i>	<i>13</i>	<i>7.2</i>	<i>6.4</i>
<i>Thereof: mechanical engineering</i>	<i>7.5</i>	<i>5.2</i>	<i>9.2</i>	<i>8.2</i>
<i>Thereof mechanical engineering: Vehicles</i>	<i>2.6</i>	<i>1.8</i>	<i>4.7</i>	<i>4.1</i>
Supply of electricity, gas and steam	43.7	30.2	34.9	30.8
Water supply, sewerage, waste management	1.4	1.3	2.2	2

Source: State Statistics Service of Ukraine, n.d. Figures in nominal values.

The mining sector, particularly focused on metal ore extraction, was well developed in Ukraine. Due to the Russian full-scale invasion, total output had declined from EUR 18.5 bn to EUR 12.7 bn in 2024, but gas, oil, and construction material production remained close to pre-war levels.

The metallurgical sector was the hardest-hit sector during the war, with output plunging by over 60% from EUR 18.9 bn in 2021 to EUR 7.2 bn in 2024. Historically concentrated in Eastern Ukraine, heavy industry (including mining and metallurgy) has suffered severe losses during

the war due to the destruction of key facilities such as Azovstal, Ilyich Iron and Steel Works in Mariupol, as well as the Avdiivka Coke Plant. The full-scale invasion triggered a sharp decline in raw material extraction, driven by reduced domestic demand and major disruptions to logistics, including the loss of Berdiansk port and the blockade of others. Energy supply interruptions and ongoing hostilities further weakened sector performance. Nonetheless, Ukraine's metallurgical sector may be useful for providing the materials needed for the manufacturing of several key renewable energy technology components.³³

Despite the current challenges, mechanical engineering output showed growth between 2021 and 2024. It increased by 23%, from EUR 7.5 bn to EUR 9.2 bn, driven mainly by the automotive segment, which nearly doubled its output from EUR 2.6 bn in 2021 to EUR 4.7 bn in 2024. Furthermore, multinational companies (MNCs) play a vital role in Ukraine's machine-building sector. Before the war, over 18 subsidiaries of international corporations, including Fujikura, Bosch, and Electrolux, operate in the country.³⁴ Although their performance declined in 2022 amid Russia's full-scale invasion, subsequent recovery supported renewed investment and production growth. The growth of the automotive, electron-

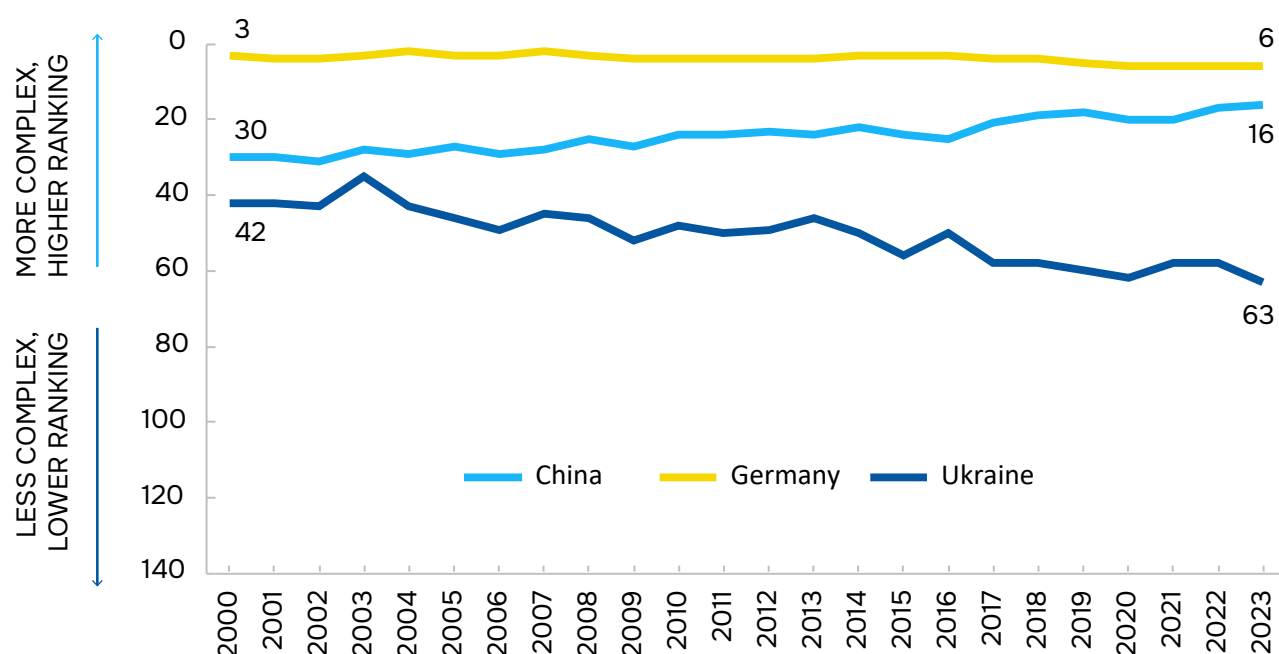
ics and machinery sector segment may prove useful in scaling up the technological complexity of Ukraine's economy, but also for eventually creating a market for some renewable energy technologies or creating linkages and potential for technological spillovers. Energy sector output also faced significant drop in value due to significant damages the sector suffered. Prior to the invasion, the country operated with excess capacity and exported electricity. However, widespread missile attacks and the destruction of critical infrastructure shifted the balance. As a result, electricity shortages now need to be offset through imports.³⁵

Economic complexity

Analysis of economic complexity provides a deeper understanding of Ukraine's industrial capabilities by assessing the know-how embedded in its economy. It measures long-term prosperity through "productive knowledge", reflected in the

diversity of exports and their global commonality. The two key dimensions are diversity (the range of products a country exports) and ubiquity (the number of countries that export those products).³⁶

Figure 9. The evolution of Ukraine's Economic Complexity Index



Source: The Growth Lab at Harvard University (2025)³⁷, Authors' illustration.

Ukraine's position in global economic complexity index declined from 42nd place in 2001, 46th place in 2013 (before the occupation of Donetsk and Crimea), to 63rd in 2023, indicating a simplification of its production potential. Although the country has expanded its export basket, a significant share of these are lower- and medium-complexity products (agriculture and metallurgy).

A strategic shift to knowledge-intensive industries and integration into global production chains may be the key steps needed to halt the declining of economic complexity and support

sustainable growth.³⁸ Concurrently, significant knowledge exists in terms of the production of various high-tech energy applications, including steam turbines for thermal, nuclear and combined heat and power plants, hydropower plant turbines, as well as various types of wind turbines (discussed further in more detail).³⁹ This is key as the existence of these sectors indicates a high level of technological sophistication that could be well suited for various parts of renewable energy value chains.

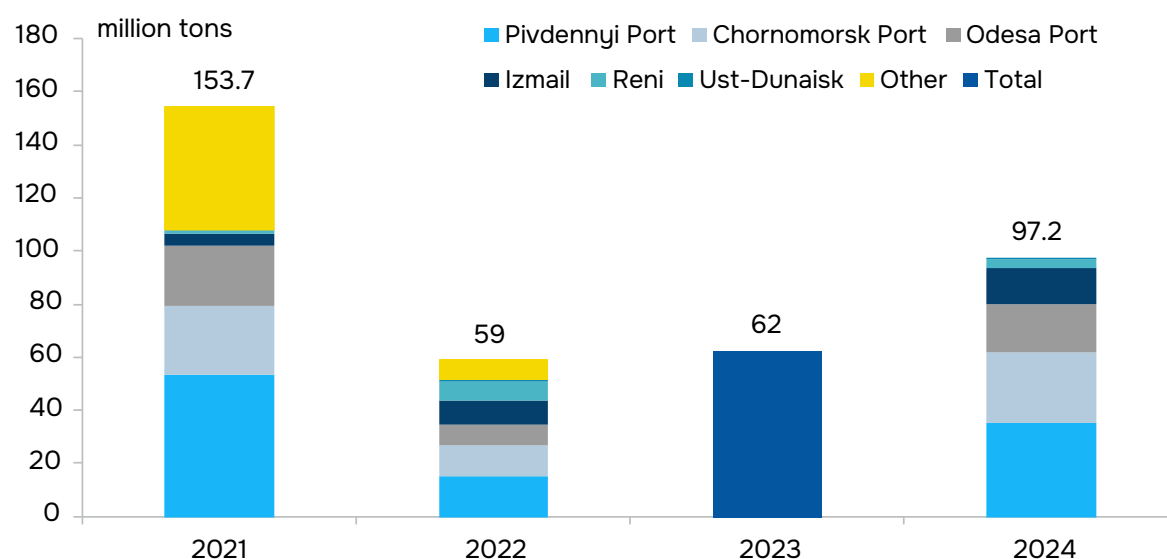
Transportation and logistics

The war has severely damaged this infrastructure, especially in frontline regions. According to the fourth Rapid Damage and Needs Assessment (RDNA4), the total damage to the transport sector reached USD 36.7 billion by the end of 2024, with widespread destruction of roads, bridges, and port facilities. In liberated and government-controlled areas, repair works, and construction of temporary crossings are underway.⁴⁰

Ukraine's ports, critical to its export-driven economy, were particularly affected. Before the war, seaports handled 62% of Ukraine's exports in value in 2021, with a total cargo throughput of

153.7 m tons.^{41,42} With the war, cargo throughput dropped by 61.4% to 59 million tons in 2022 but rebounded to 97.2 million tons by the end of 2024.⁴³ The main driver for the recovery was the opening of Ukraine's sea corridor running along the coastline of NATO member states increasing the security for ships.^{44,45} As of today, of the five largest seaports only the ports of Greater Odesa (Pivdennyi, Odesa, and Chornomorsk) are now operational. Ports on the Azov Sea, such as Mariupol and Berdiansk, were occupied, while others like Mykolaiv and Kherson remain idle due to security risks.⁴⁶

Figure 10. Cargo throughput of major seaports in Ukraine



Source: USPA (2023), GMK Center (2025). Note: Seaports include Danube ports. No disaggregated data available for 2023. "Other" includes temporarily occupied ports (e.g. Maryupol, Berdiansk) or ports idle due to security risks (e.g. Mykolaiv, Kherson).

With the war and seaport blockades, logistics have shifted westward. Cargo has been moved increasingly by road, and significant investment has gone into new infrastructure: 11 new border crossings are under construction and 14 more are being modernised. Abandoned Danube River ports have been revived, with a new Danube logistics cluster underway. This western orientation is expected to continue as Ukraine deepens integration with the EU.⁴⁷

Recovery and reconstruction needs for the transport sector over the next decade are esti-

mated at USD 77.5 bn focusing on national roads (29%), railways (26%), and local roads (18%), with around two-thirds concentrated in Donetsk, Kharkiv, Kherson, and Zaporizhzhia oblasts. Despite extensive damage, Ukraine's core port infrastructure remains functional and has supported a strong rebound in exports following the unblocking of Black Sea ports. This is key as Ukraine has been able to continue exporting its goods to partner markets and would be able to support the exports of potential renewable value chains.⁴⁸

Industrial clusters

Ukraine has no well-established industrial clusters to date, and such mutually beneficial groupings are only beginning to emerge. In March 2022, the Ukrainian Cluster Alliance (UCA) was formed to bring together industrial and high-tech clusters to develop Ukraine's cluster movement in line with EU policies. In response to the war, the UCA has brought together clusters and SMEs, thereby supporting the survival of innovative manufacturers and playing a pivotal part

in Ukraine's recovery and sustainable economic growth.⁴⁹ The country's thriving IT sector has major clusters in Kharkiv, Lviv, Dnipro, and Odesa. Since 2022 most IT companies have relocated to Lviv or Vinnytsia.⁵⁰ Following the relocation of Fuhrlander Windtechnology LLC after the war began, a nascent wind energy cluster has also begun to emerge in Perechyn Industrial Park in the Zakarpattia region.⁵¹

Energy

The ongoing targeting of the energy sector has had a fundamental impact on industrial competitiveness in some sectors. As of 31 December 2024, total energy sector losses were estimated at USD 20.51 billion.⁵² Generating capacity has been severely affected, resulting in capacity shortfalls of 2 GW in summer and up to 6 GW during peak winter periods. Ukraine is no longer a net electricity exporter, and imports reached 4.4 million MWh in 2024.⁵³ Border transmission capacity has increased to approximately 2 GW, with plans to expand it to 6 GW through new infrastructure.

Due to these extensive losses and damage to Ukraine's energy infrastructure, the country is

shifting from a centralised power system to one based on distributed generation, with a strong focus on renewable energy. To improve resilience and autonomy, the government adopted the Strategy for the Development of Distributed Generation until 2035 in mid-2024.⁵⁴

The large-scale destruction of the energy sector, alongside the progressive but sharp increase in energy tariffs has led to significantly higher electricity prices.⁵⁵ While this situation may continue for a period, the design of a least-cost energy system based on renewables may drive costs and tariffs down in the medium-to-long term.

4.2 Critical raw minerals

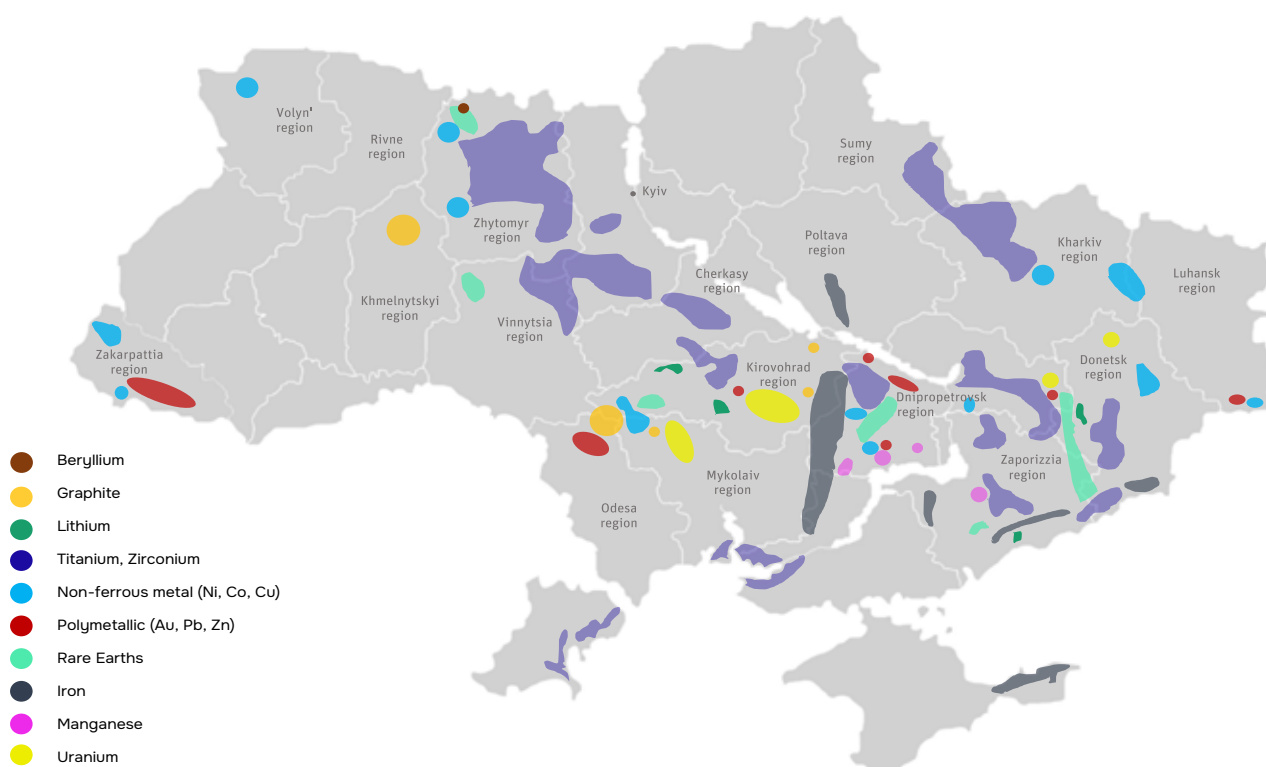
Global efforts toward decarbonisation and electrification are driving demand for critical raw materials, and Ukraine holds a significant number of these, particularly those essential for battery and semiconductor manufacturing. The following section outlines Ukraine's reserves, current production, and future potential in this domain.

Reserves and production

Ukraine has reserves of 22 of the 50 strategic minerals classified as critical by the United States, and 25 of the 34 materials designated as critical by the European Union.⁵⁶ Of these, three minerals are fundamental to produce specific types of lithium-ion batteries, namely lithium, graphite, and manganese. Ukraine also possesses reserves of gallium, germanium, and metallic silicon needed for semiconductor manufacturing. However, the production of germanium and gallium was stopped by 2004 and the processing

technologies are no longer present in Ukraine. Furthermore, Ukrainian reserves of so-called strategic construction materials include titanium, zirconium, hafnium and vanadium. While the country has extensive reserves of various critical raw materials, current mining activity is limited to only a few. These untapped resources may therefore present potential for future exploration and development, with various plans for domestic value-addition.⁵⁷

Figure 11. Map of critical raw minerals in Ukraine



Source: Ukraine Geological Survey, 2024

According to the Ukrainian Geological Survey (2024), the country holds 1–2% of the world's lithium reserves and ranks among the top global countries in terms of reserves of titanium, manganese (7% of global total) and iron ore (3% of global total), ranking fourth and eighth worldwide, respectively. Ukraine's titanium deposits are notable for their high-grade ilmenite concentrate, containing 62–65% TiO_2 —significantly above the global average of around 45%. The country also holds deposits with rutile concentrate, which can reach TiO_2 concentrations of up to 95%. In terms of development and production, Ukraine has historically contributed significantly to global titanium output, producing 7% of the global total before falling to 2% in 2022.⁵⁸ Manganese, mined in the oblasts of Zaporizhzhia and Dnipropetrovsk, is used to produce some type of battery chemistries, but its production has decreased from 3% to 1% of global output in 2022. Production of iron

ore shrank from 3% of global production to 2% due to the war.⁵⁹

Furthermore, Ukraine has six known graphite deposits, including one acquired by Australian firm Volt Resources in 2021.⁶⁰ BGV Group, linked to the Turkish ONUR Group, also holds extraction permits in the Odesa and Kirovohrad regions.⁶¹ In addition, three commercially viable deposits of high-quality flake graphite—suitable for battery production—have been identified, with one currently under development. Beyond natural graphite, Ukraine also produces synthetic graphite from carbon black, a byproduct of coke and ferroalloy production, though it is more expensive to manufacture. Some of the mineral deposits have been seized by Russia, including occupying 63% of Ukraine's coal mines, and around half of its manganese, caesium, tantalum and rare earth deposits.⁶²

Future potential

With regard to future potential, Ukraine has three commercially viable lithium deposits that have been explored but remain undeveloped. The highest-quality deposit, Shevchenkivske, is located on the frontline in the Donetsk region. The other two—Polokhivske and Stankuvatske—are situated in the Kirovohrad region. Polokhivske is being developed by Ukrilithium Mining LLC, while the state-owned Stankuvatske deposit is also reportedly of interest.⁶³

Besides lithium, Ukraine's biggest future potential lies in the extraction of graphite and titanium. Onur Group plans to invest more than USD 50 million in the extraction of natural graphite and Spys Ukraine, an affiliate of Onur Group, has received a permit to develop the Burtyn deposit in Khmelnytsky region, which is part of a larger graphite deposit. The Group also intends to develop a new graphite site in the region.⁶⁴

Critical minerals form a key component of the Ukraine Plan, but the country is also co-ordinating with other countries. Ukraine is aligning

with EU industrial and resource strategies and has a Memorandum of Understanding on the topic.⁶⁵ Ukraine also joined the Minerals Security Partnership (MSP) in 2024, a joint initiative of the EU and U.S. to diversify global supply of critical materials. Another agreement focusing on the future development of mineral extraction is the memorandum between Ukraine and the U.S. signed on April 18, 2025, to jointly develop critical minerals, including graphite and rare earths. The agreement includes plans for a joint fund and is part of ongoing peace negotiations, with further details forthcoming.⁶⁶ As such, Ukraine's natural resource base may be an asset in the production of various advanced technologies, but significant constraints remain. The increase in energy and logistics costs due to the war increases costs of production, and significant investments also need to be made into both greenfield and brownfield projects, but also into industrial energy efficiency at both extraction and processing facilities.

4.3 Access to finance

Access to finance is a critical enabler of industrial development, as it allows businesses to invest in initiation, modernisation, expansion of production, and in the case of Ukraine, recover from wartime disruptions. This section outlines the main financial instruments and support schemes currently available to industrial enterprises.

Financing conditions for industrial enterprises in Ukraine remain structurally more difficult than in the EU. The National Bank of Ukraine's key poli-

cy rate stands at 15.5% (June 2025), compared with a corporate borrowing cost of 3.7% in the euro area.⁶⁷ Combined with Ukraine's high equity risk premium due to war related risks and tighter collateral requirements, this pushes the weighted average cost of capital (WACC) for industrial manufacturing into the 19-20% range in Ukraine, whereas comparable projects in Europe often achieve 8-9% WACC –and even lower when grants and state support mechanisms are involved in the capital structure of the projects.

Private investment sources and commercial lending

Private investment in Ukraine primarily comes from companies' own funds and commercial bank lending. However, both sources are under strain. Many companies have depleted reserves to stay afloat during the war, while banks remain cautious, offering relatively short maturities and pricing new hryvnia loans at around 15.5% per

annum.⁶⁸ Foreign-owned banks can be slightly cheaper, but volumes are modest, and domestic bond markets remain shallow. As a result, long-term financing for capital-intensive large-scale projects requiring multi-year payback periods, such as renewable equipment manufacturing projects.

Public funding opportunities

Public support schemes partly offset these constraints, but their reach varies greatly by company size and ownership. In Ukraine, several government instruments are currently available to support business development by lowering costs of selected investment projects.

For Ukrainian SMEs, the Affordable Loans “5-7-9%” programme is the main tool, subsidising interest rates down to 5-9% for Ukrainian companies without foreign capital. By early 2024, loans under this programme accounted for roughly 40% of all hryvnia business lending, though historically the majority of disbursements went to working capital in agriculture and trade. In 2025, UAH 18 bn (USD 430 m) is allocated to this initiative, offering loans of up to UAH 150 million (USD 3.6 m) for terms of up to 10 years. As of 13 January 2025, 46 banks were participating,

with 104,226 loan agreements signed totalling UAH 362 bn (USD 8.7 bn), of which 69,404 loans worth UAH 272.4 bn (USD 6.5 bn) were issued under martial law.⁶⁹ Additionally, SMEs can benefit from the Industrial Parks programme, which co-finance up to 50% of on-site infrastructure (80% in de-occupied territories, capped at UAH 150 million (USD 3.6 m.) per park). A good example is Fuhrlaender Windtechnology LLC, which relocated from Kramatorsk under the government's “business relocation” programme, secured loans through the 5-7-9% initiative, and is now participating in the Industrial Park programme, with the park already operational.

But the scheme is explicitly SME-focused; so larger companies are generally ineligible, which would include large manufacturing projects. For larger Ukrainian companies, financing options

are more limited. They generally borrow at market rates – often 15–16% in hryvnia – and face stricter collateral and tenor conditions. Industrial Parks support is available, but typically only offsets part of site preparation or utility connection costs. The “Investment Nanny” scheme (Law No 1116-IX ‘On State Support of Investment Projects with Significant Investments in Ukraine), which provides state support of up to 30% of capital expenditures for qualifying projects exceeding EUR 12 million (excluding VAT). Support is delivered through tax exemptions, infrastructure compensation, and preferential land use rights.⁷⁰ While the instrument is comprehensive on paper, uptake has been slow due to war-related risks and limited investor confidence.

For foreign investors, domestic public programmes offer little direct support. They are not eligible for 5-7-9 loans, the support amount in Investment Nanny is very small (total budgeted for the program was UAH 3 bln (around USD 77 m), for the entire pool of future investors), and cross-border lending from parent-country banks is constrained by Ukraine’s partial foreign exchange restrictions and the high capital charges applied by European banks under Basel rules. As a result, foreign companies looking to establish manufacturing capacity in Ukraine generally depend on blended finance from international financial institutions (IFIs) and risk-mitigation tools.

International funding opportunities

International financial institutions continue to play a crucial role in supporting Ukraine’s manufacturing sector. In 2024, the European Union launched the Ukraine Facility, a EUR 50 bn support programme running through 2027. It comprises a EUR 38.27 bn in direct budget support, EUR 6.97 bn under the Ukraine Investment Framework (UIF) to mobilise investment, and EUR 4.76 bn for technical assistance. The UIF provides blended finance -combining grants and loans- and guarantee instruments to reduce investor risk, with Phase II launched in April 2025 running until October 2025.^{71,72} Implementation is carried out via IFIs and Ukrainian financial intermediaries, with the explicit goal of de-risking projects so that local and foreign lenders can offer longer tenors and lower rates. The EBRD and World Bank also offer grants, concessional loans, and insurance support to Ukraine and Ukrainian businesses to reduce the overall cost of capital.

War risk insurance plays a critical role in enabling investment during the ongoing war environment as they directly address the high-risk premia embedded in Ukraine’s WACC. The EBRD’s Ukraine Recovery and Reconstruction Guarantee Facility (URGF) works through Ukrainian insurers such as INGO, Colonnade, and UNIQA to cover industrial,

logistics, and energy assets against war-related losses.⁷³ Ukraine’s state Export Credit Agency (ECA) provides similar protection for both domestic and foreign investors holding at least 10% ownership, covering both direct investments and related loans. The German government operates a dedicated Investment Guarantee scheme for German investors, protecting against war, expropriation, transfer restrictions, and breach of contract, with coverage available for both new and certain existing investments. Multilateral and bilateral actors such as MIGA and the U.S. DFC offer comparable political-risk cover for foreign investors, often in combination with IFI financing. In the private market, Ukrainian insurer ARX now offers war-risk policies of up to USD 50 m. per site, while the EBRD also backs a transport-focused reinsurance facility to maintain cargo and supply-chain flows.⁷⁴ By reducing the probability of losses for lenders and investors, these funding instruments help compress both the debt and equity components of WACC. For green manufacturing localisation, where long asset lifetimes and high upfront capital needs amplify the impact of financing costs, effective use of guarantees and insurance can make the difference between a viable and a non-viable project.

4.4 Labour and skills

A well-trained workforce is a key factor in industrial development and the introduction of advanced technologies. Due to the war, the population of Ukraine has decreased from 40 million (2021) to around 28-32 million (2025) due to mass migration and internal displacement.^{75,76} The loss of the working-age population is exacerbating the situation, and the shortage of staff is forcing businesses to adapt. Employment in industry has fallen from 3.3 million (2010) to 1.8 million (2022), and the total number of employees has dropped by 25% from pre-war levels.^{77,78} With the green reconstruction it is expected that 1.5 million additional workers in green occupations will be needed until 2035, whereas estimates for 2023

of the green labour force reach only around 0.3 million.⁷⁹ Together with the business survey by the National Bank of Ukraine showing that 49% of businesses see lack of skilled labour as main hindrance for output growth, it becomes visible that investing in human capital is a fundamental factor for a successful future localisation of green technologies in Ukraine.⁸⁰

The average monthly salary in 2024 was UAH 24,000 (EUR 530), in urban areas UAH 35,000 (EUR 800), and in IT and engineering up to EUR 2,000.⁸¹ Some workers use self-employment schemes, which are currently not well captured in official employment and salary statistics.

Vocational education, universities, and training more broadly

Ukraine has a well-developed educational system that includes universities, colleges and vocational schools. As of 2025, the Ministry of Education and Science operates 121 higher education institutions, with plans to reduce these to 100 as some are consolidated.⁸² As of the beginning of 2024, there were 664 vocational education institutions, and the three-tier education structure remains in place.⁸³ However, the educational system offers room for improvement by adapting curricula more to the actual needs of the labour market.⁸⁴ The business sector supports dual education on a small scale in regions such as Western Ukraine by providing training equipment. This offers the basis for establishing a broader dual education system where theoretical and practical learning is coordinated and curricula are motivated through labour market needs.⁸⁵

In 2024, 155,400 specialists were expected to graduate, including 8,400 in key engineering specialities.⁸⁶ Some universities, such as KPI, Lviv Polytechnic, and Dnipro Polytechnic, actively cooperate with businesses to integrate technical education relevant to the local private sector.

Despite the wide range of programmes, Ukraine does not have a university specialising in renewable energy education integrated into general engineering programmes. In 2021, the speciality “Non-traditional and renewable energy sources” was introduced. Concurrently, the large-scale deployment of especially small-scale RES in the country is driving significant interest in the expansion of education to prevent a lack of qualified labour from slowing down installation rates.



4.5 Research, development and innovation

In addition to human capital, the innovation environment plays a vital role in shaping the success of industrial development by fostering new technologies and driving competitiveness. This section provides an overview of Ukraine's current research and development landscape, the links between universities and industry, and the broader start-up ecosystem.

Research & Development

In 2024, Ukraine was ranked 60th in the Global Innovation Index (GII), down 11 places compared to 2021, primarily due to the war.⁸⁷ Concurrently, international analysts highlight several positive aspects of Ukraine's innovation landscape. Ukraine continues to produce more innovative output than would be expected based on its level of investment relative to GDP. It is one of the few economies where innovation development has consistently outpaced economic development over a long period –namely, from 2014 to 2024. Ukraine also retains its global lead in the utility model sub-index by origin (as in 2023), ranks second in the world for employment of women with higher education, and holds fourth place in global software spending.⁸⁸

Ukraine stands out in IT (Grammarly, Petcube), aviation (Zenit), and agriculture (drones, new grain varieties). It has considerable experience in manufacturing turbines for thermal power plants, nuclear power plants and hydroelectric power plants, which are now used in the wind energy sector.

The defence sector is also developing start-ups through government grants, which have already yielded tangible results. Ukraine is a participant in the EU's Digital Europe programme with a 95% discount on contributions until 2027, receiving funding for artificial intelligence, cybersecurity and supercomputing.⁸⁹

Start-up ecosystem

A strong start-up sector can support green value chain manufacturing by fostering innovation and developing new materials, processes, and digital tools. Start-ups can provide solutions that lower production costs, shorten development times, and adapt manufacturing to changing market and technology needs that would help improve the competitiveness of a country's renewable equipment manufacturing sector.

Ukraine's startup ecosystem has demonstrated resilience and adaptability despite the war. The country has 3,000 startups and 8 unicorns (Grammarly, GitLab), and the sector's valuation has tripled since 2020.^{90,91,92} IT exports generated USD 14 billion in revenue in 2022-2023.

Growth is supported by a network of accelerators (Defence Builder), technology parks (UNIT.City), and government initiatives (Ukrainian Start-up Fund, Diia.City).^{93,94} 1,600 companies have already joined the Diia.City initiative, which creates a favourable environment for IT business.

Challenges caused by the war are however affecting the innovation landscape, including through the forced displacement of labour, conscription, supply chain disruption, and limited access to capital. While the war has led to the emigration of around 120,000 IT professionals, this new diaspora can play a constructive role in expanding Ukraine's global innovation network, fostering new opportunities for international co-operation and investment.⁹⁵

4.6 Policy and regulatory frameworks

A clear and predictable policy and regulatory framework is essential for the development of Ukraine's manufacturing sector, as it shapes investment decisions, supports industrial modernisation, and lays the foundation for long-term, competitive growth in both domestic and international markets.

General regulatory landscape

The business and regulatory environment in Ukraine's manufacturing sector is characterized by a mix of ongoing challenges and notable improvements. While the overall landscape is not the easiest, there is a clear trend toward simplification and support. Institutions like the Business Ombudsman Council have been established to provide recourse and assistance in cases of regulatory or administrative difficulties. Although the country still faces hurdles, especially in terms of infrastructure and enforcement consistency, there are signs that reforms are helping to ease the way for entrepreneurs and investors.

From a procedural standpoint, starting a manufacturing business in Ukraine is relatively straightforward, particularly when compared to many EU countries. The process of opening a sole proprietorship, for instance, is notably quick and simple. Environmental regulations and approval procedures are less burdensome, and the documentation requirements are minimal. However, this regulatory flexibility could change after Ukraine's anticipated accession to the European Union, which will likely bring more stringent compliance standards in line with EU norms.

There are no significant regulatory barriers to entering the manufacturing sector. That said, a key issue for exporters is the lack of accredited

product certification laboratories within Ukraine. Many manufacturers must send their goods to EU countries for testing and certification, which adds time and cost. Land acquisition and usage is another area where improvements have been made: the procedure to change the designated use of land (e.g., from agricultural to industrial) has been significantly streamlined, now taking just two months instead of several years.

Ukraine's regulatory environment is evolving in line with its EU candidate status, with active harmonisation of laws and standards across key sectors. This includes ongoing deregulation and the digitalisation of public services, most notably through the Diia platform, to reduce bureaucratic barriers and support business activity.

One ongoing complication is related to currency controls introduced during the war. While foreign investors can receive dividends in Ukraine and reinvest them locally, they currently face restrictions on transferring these funds abroad. This measure, though temporary, affects capital repatriation and may influence investment strategies during the conflict. Nonetheless, the general direction of reforms and support mechanisms suggests that Ukraine is actively working to become a more business-friendly destination for manufacturing and beyond.

Industrial policy mechanisms and supportive policies

Ukraine is actively developing industrial policy tools to support domestic producers, with a focus on export promotion and industrial parks as drivers of economic growth. Key support measures include infrastructure cost compensation for industrial parks (see section 4.3). Residents of these parks benefit from tax incentives, including exemptions from income tax, land tax, VAT on imported equipment, and property tax which

substantially reduce their financial burden and enable reinvestment in modernisation. However, effective incentives for large-scale investment projects are still lacking.

To address this gap, Ukraine introduced the Law of Ukraine No. 1116 "On State Support of Investment Projects with Significant Investments in Ukraine," (see section 4.3). Projects can also

involve investor-funded infrastructure development. State support is formalized through a Special Investment Agreement (SIA) signed with the Cabinet of Ministers, local authorities, and other stakeholders. Target sectors include biogas, processing (excluding alcohol and tobacco), logistics, healthcare, R&D, tourism, and others, with oversight by UkraineInvest and the Ministry of Economy.

To help businesses adapt during the war public and private relocation programmes were implemented. Since its onset, over 18,000 companies have relocated—more than 800 through a state program and around 7,000 independently—mainly to Western and Central Ukraine. Wholesale trade firms made up over 30% of the relocations. This large-scale relocation of enterprises helped preserve industrial capacity, stabilize production, and reallocate resources. Future recovery will depend on restoring logistics, stabilizing the energy system, and ensuring broader macroeconomic stability.

A key development is the “Made in Ukraine” initiative, which builds on these existing programs and adds new measures, such as non-repayable grants for processing companies and the Invest-

ment Nanny scheme, offering tax benefits and infrastructure support for major projects. The initiative also promotes domestic manufacturing through subsidies for Ukrainian-made agricultural equipment, school buses, and construction materials, as well as a cashback program for locally produced consumer goods. As of June 2025, the Cabinet of Ministers has allocated UAH 2.4 billion for payments under the National Cashback program, as well as UAH 200 million for payments under the program for compensation for the cost of Ukrainian industrial equipment.⁹⁶

Recent reforms have accelerated industrial land zoning, while export growth is being driven by expanded funding for the Export Credit Agency and strengthened trade diplomacy.⁹⁷

To tackle the bottleneck of a lack in qualified personal, Ukraine also focuses on human capital development. With EU backing, the government is modernizing vocational education through initiatives like EU4Skills, focusing on STEM and technical trades. These efforts now target reskilling veterans and displaced workers. The Made in Ukraine platform includes industrial training as a core mandate, while the Diia City regime promotes high-skill development in tech.

Trade policies

Currently, Ukraine has multiple free trade agreements in place, most notably with the EU, Canada, the UK, EFTA, and Israel facilitating trade and reducing related costs.⁹⁸ In addition to that, Ukraine participates in the WTO’s Government Procurement Agreement (GPA), which mutually opens up governmental procurement activities to all GPA participating countries.⁹⁹

However, the trade activity between Ukraine and the EU plays the most relevant role for the Ukrainian economy. In 2024, 50% of Ukraine’s trade in goods materialised with the EU as trading partner. The Deep and Comprehensive Free Trade Area (DCFTA) as part as the EU-Ukraine Association Agreement (AA) and entering into force in September 2017, was a relevant enabler for this.¹⁰⁰ The benefits DCFTA encompasses are an efficient and fast facilitation of customs traffic at international borders as well as the elimination of more than 98% of tariffs.¹⁰¹

Furthermore, as a response to Russia’s illegal annexation of Sevastopol and Crimea in 2014, the EU banned imports from those regions and prohibited investments and selected directly related services there. This was expanded to the temporarily occupied areas of Donetsk, Luhansk, Kherson, and Zaporizhzhia after the full-scale invasion. As additional temporary support in June 2022, the EU granted with the Autonomous Trade Measures Regulation full trade liberalisation including the suspension of import duties, quotas and trade defence measures. This support was in force until June 2025.¹⁰²

Ukrainian Export support includes the Export Promotion Office, the Export Credit Agency ECA as part of the Made in Ukraine programme, which promotes machine building, energy, and transport.^{103,104} There are plans to lift the ban on arms exports, which will open up new markets for the defence industry.¹⁰⁵

5. Technology analysis

This section provides the core analytical part of the report. It examines the three key technologies, starting with an overview of their current status globally and within Ukraine, with a focus on each segment of the value chain. This is followed by a quantitative and qualitative evaluation assessing the localisation of solar PV, wind turbine, and li-ion battery manufacturing in Ukraine, comparing it with other producer countries and assessing the state of play and lessons learnt. Next, the potential economic benefits of localizing the manufacturing value chain for each technology are explored, with a final section providing several additional considerations.



5.1 Solar PV

5.1.1 Value chain overview

Solar PV systems convert sunlight into electricity using semiconducting materials, primarily silicon, though other critical minerals are also involved in the value chain. Crystalline silicon (c-Si) solar cells dominate, making up about 95% of the global market, with the rest comprising thin-film tech-

nologies like CIGS and CdTe.¹⁰⁶ The c-Si sector has a relatively short value chain, typically divided into five main stages. Additional components like mounting structures, inverters, junction boxes, and wiring are also needed to complete the system.¹⁰⁷

	Polysilicon	Ingots	Wafer	Cell	Panel/Module
Description	Quartz is purified into high-grade polysilicon	Polysilicon is melted and formed into silicon ingots	Ingots are sliced into thin, clean wafers	Wafers are processed into electricity-generating cells	Cells are assembled into framed, laminated modules
Major producers (% global market share)	China (79%) Europe (8%) APAC (6%)	China (>80%)	China (97%) APAC (2.5%) Europe (0.5%)	China (85%) APAC (12%) Europe (0.6%)	China (75%) APAC (15%) Europe (3%)
Ukraine production	No production	Production under construction and/or can be restored			Limited existing production

Source: IEA (2022), Authors' elaboration.

The solar PV sector is extremely geographically concentrated, with China controlling over 80% of the entire manufacturing value chain ranging from polysilicon to final module production.¹⁰⁸ The vast majority of the sector is dominated by crystalline silicon technologies, with some thin film production and perovskite technologies in development. China has been the dominant producer in the solar PV manufacturing space since the late 2000's, driven by economies of scale, access to finance, technological improvements and strategic industrial policy support.¹⁰⁹ While at the country level the production is highly concentrated, the competition between companies within China is fierce, with companies LONGi, JA Solar, Trina Solar, JinkoSolar continually driving down costs and investing heavily in R&D and product improvements. In addition, global production capacity is ample, with significant oversupply and

aggressive pricing significantly lowering prices and pressuring non-Chinese producers.¹¹⁰

The upstream stages of solar PV manufacturing—polysilicon, wafer, and cell production—are highly centralized, with China firmly in the lead, including effectively all of the global wafer production. Despite the geographic dispersion of some assembly capacity, the global solar PV industry remains heavily reliant on China for key input materials. Malaysia and Vietnam ranked as the second and third largest producers of solar cells in 2021, each accounting for around 7% of global output. Thailand and South Korea also contributed, though with more modest shares.¹¹¹

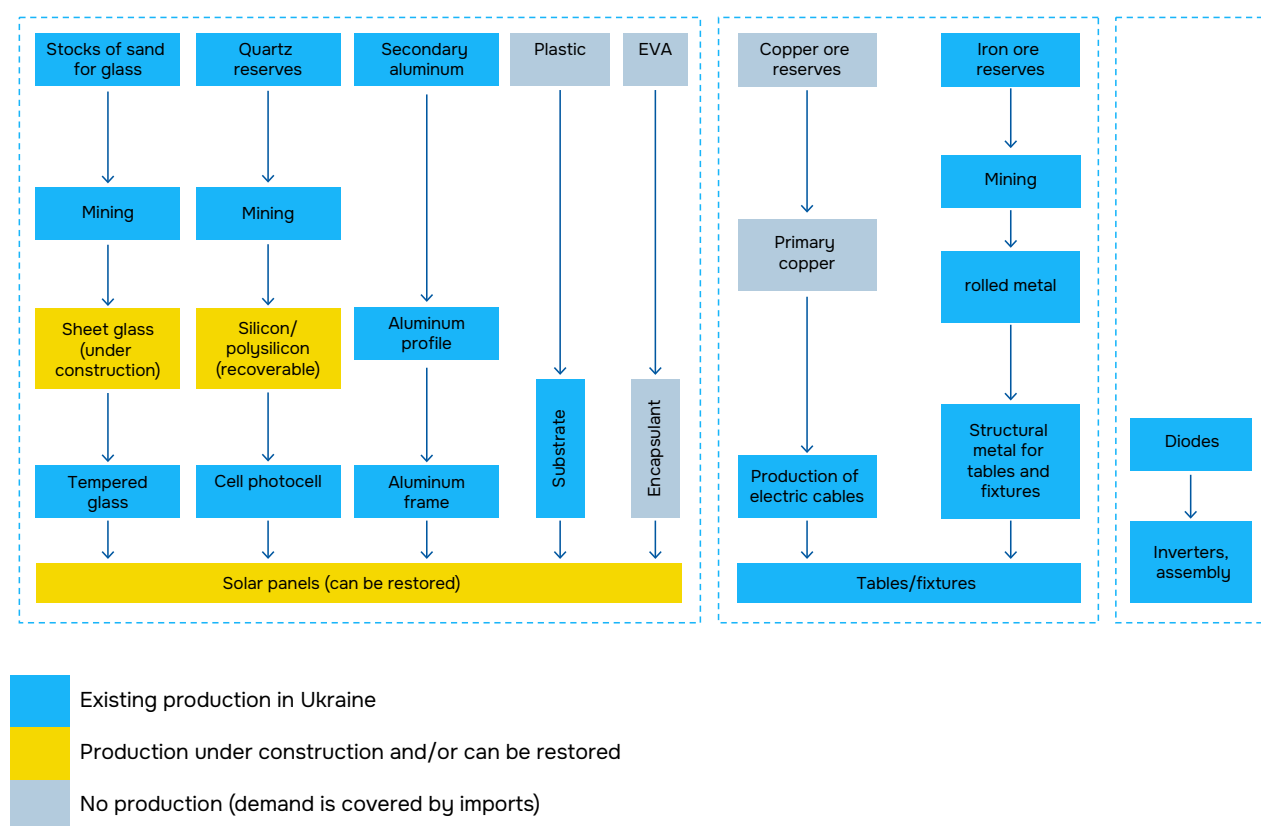
By 2021, solar module assembly capacities were distributed across 38 countries, but when considering only assembly facilities with capacities exceeding 1 GW, the sector is more concentrated,

with just 19 countries hosting such large-scale operations.¹¹² Other notable contributors included Vietnam (5%), Malaysia (4%), South Korea (4%), and Thailand (2%), but many of the facilities in these countries were operated by Chinese companies, often seeking to circumvent antidumping tariffs imposed by importing countries.¹¹³

China's export performance further reflected its industrial strength: solar PV exports exceeded USD 30 billion in 2021, accounting for near-

ly 7% of its trade surplus over the preceding five years. Chinese investments in Malaysia and Vietnam also supported the growth of PV exports in those countries, contributing approximately 10% and 5%, respectively, to their trade surpluses since 2017.¹¹⁴ Overall, global trade of materials and components of solar PV value chain—including polysilicon, wafers, cells, and modules—surpassed USD 40 billion in 2021.¹¹⁵

Figure 12. Ukraine solar PV manufacturing value chain



Source: Authors' assessment.

Ukraine has developed partial capabilities across the wider solar PV value chain, combining domestic resource availability with past industrial activity. These capabilities span from raw materials across the value chain all the way to module assembly and the manufacturing of supporting components.

Silicon and Polysilicon: Ukraine has significant reserves and production of high-quality quartz and quartzite (including with silicon content > 99% at the Hlukhiv quarry). Historically, the

country emerged as a significant global player in silicon production, specifically in polysilicon for photovoltaic applications. Between 2004 and 2009, Ukraine accounted for up to half of global solar-grade polysilicon (So-si) production, centred around the Zaporizhzhia Semiconductor Plant, with annual output reaching 2,200 tonnes.¹¹⁶ Additional production took place at different facilities as well. The company “Kvazar” in Kyiv maintained a fully integrated production cycle from silicon cultivation to wafer manufacturing, with these capacities primarily serving

European markets. However, the rapid expansion of Chinese production capacity post-2010 severely impacted Ukraine's competitiveness in this space, significantly curtailing local silicon production activities. Today, limited silicon manufacturing continues primarily for microelectronics applications.

Ingot, Wafer, and Cell Production: Ukraine has had limited industrial activity in the intermediate stages of the solar PV value chain. KNESS-Group, which was active in solar PV manufacturing during 2019–2020, imported ready-made ingots and carried out wafer cutting domestically. However, no large-scale domestic production of solar cells has taken place in recent years. Earlier activities by Kvazar included cell processing as part of its integrated production cycle, but this line was discontinued following the company's restructuring.

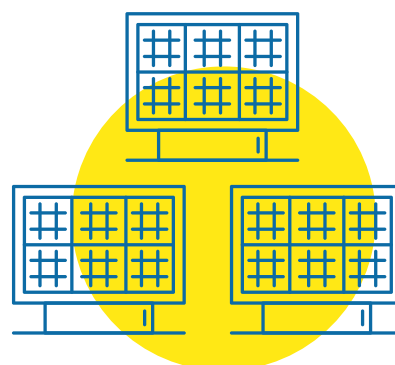
Modules: Ukraine's experience in assembling solar PV modules has been concentrated in two periods. Until 2012, Kvazar produced panels using domestically manufactured polysilicon. From 2019 to 2020, KNESS-Group operated a solar panel production facility in Vinnytsia with an annual capacity of 200 MW. The company assembled modules using imported silicon and encapsulation materials, domestically produced tempered glass and aluminium profiles, and plastic substrates manufactured in-house from imported plastic. The plant ceased operations due to its inability to compete on price with inexpensive Chinese imports. Today, PV module assembly persists in a limited capacity, which specializes in custom, non-standard modules.

Materials and Intermediate Inputs: Several key components used in PV module production are

manufactured domestically. Aluminium frames are produced from recycled aluminium within Ukraine. Tempered glass is also produced locally, although the raw sheet glass used in its manufacture is still imported. Two sheet glass production projects are also underway, aiming to localize supply for tempered glass and solar panels, using Ukraine's high-quality sand. Encapsulants continue to be imported, mostly from China. Plastic substrates used in the assembly of modules are manufactured domestically from imported plastic, while the cell linings rely on imported silicon-based materials.

Balance-of-System Components: Ukraine also has domestic capacities in the production of balance-of-system (BOS) components. Rolled steel products, derived from Ukrainian iron ore, are used in the fabrication of mounting structures and fixtures for solar installations. Copper wiring and electrical cables are produced within the country, albeit with imported copper, and aluminium profiles and supports for the frames and mounting structures are also produced locally. Tempered glass, which is needed as cover for the solar panels is also produced locally, with at least 17 identified producers.

Inverter manufacturing is present but remains limited in scale. As of 2024, Ukraine hosts 11 inverter manufacturers. These firms produced 2,571 low-capacity inverters (up to 7.5 kVA) before the war, which generated EUR 370,000 in revenues. Most production is based on imported components, and a significant share of manufacturers are located in regions affected by ongoing war, such as Zaporizhzhia and Kharkiv. KNESS-Group also produced inverters until mid-2024 but has since stopped producing inverters.



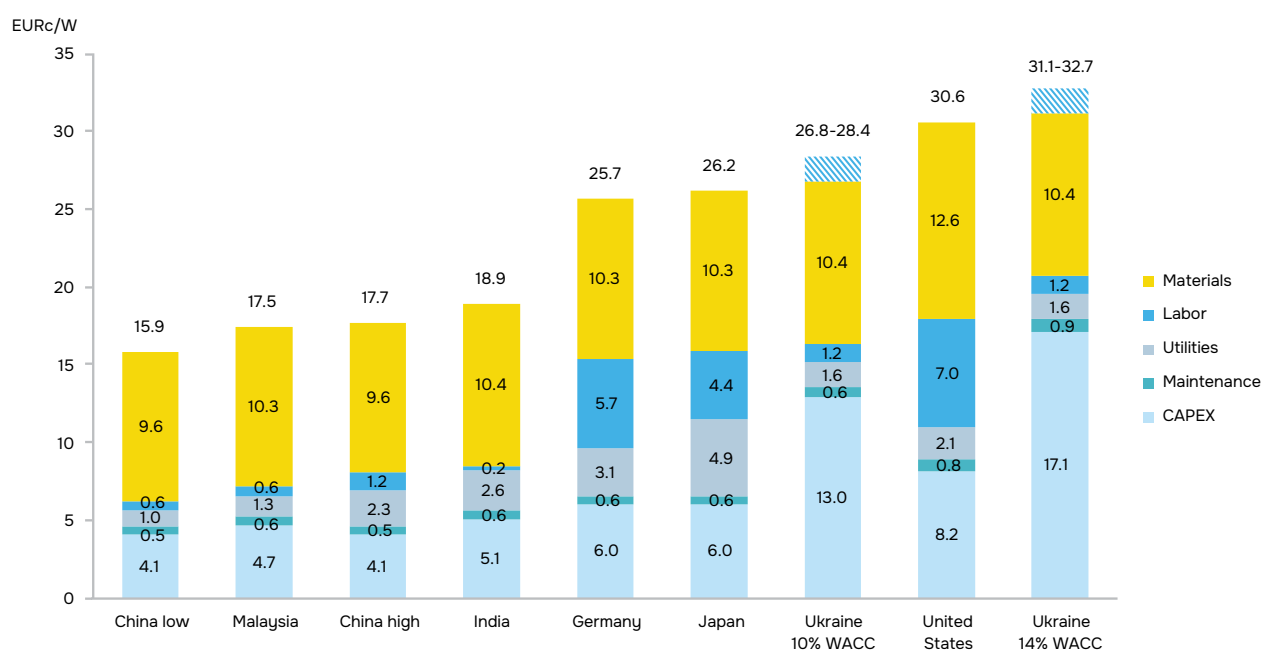
5.1.2 Results and analysis

In order to model the competitiveness of the potential manufacturing localisation of the solar PV value chain, both primary and secondary data on Ukraine and international players was collected and used to derive the quantitative results. To present more scenarios, the following analysis presents two greenfield integrated solar PV plant options of 500 MW annual production capacity and 1 GW annual production capacity, both assessed with WACC assumptions of 10% and 14%. Currently, Ukraine's cost of capital remains exceptionally high at around 20% WACC, rendering project financing prohibitively expensive. However, by incorporating grant funding, state sup-

port, and concessional financing into the capital structure of large-scale projects, the WACC can be reduced to more feasible levels of 10–14%. These adjusted WACC assumptions were applied in the cost modelling (see Box 1). An additional range is also given for the input materials component to reflect supply chain disruptions and general uncertainty. To compare the competitiveness of the facility with other countries, all values are standardised to 2024 Eurocents per Watt (EURc/W) of solar PV capacity produced. The results for both scenarios are presented below.

Results

Figure 13. Costs of production – 500 MW annual production capacity

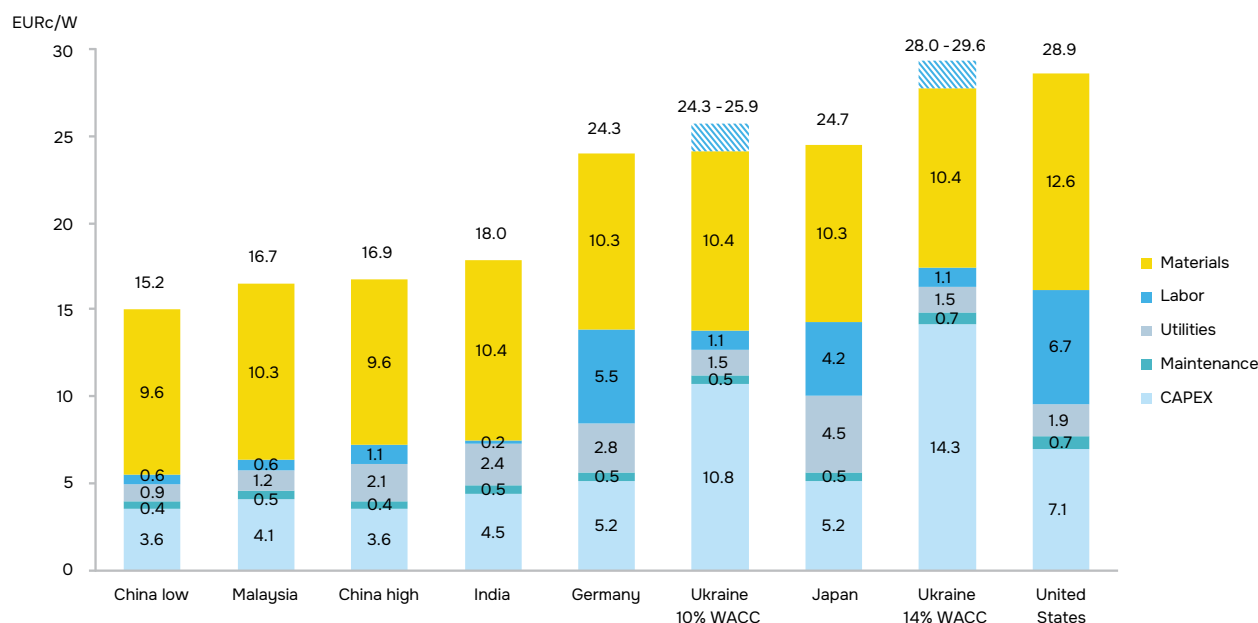


Source: NREL (2024)¹¹⁷, expert consultations, authors' calculations.

In the first modelled scenario, a greenfield integrated facility with a 500 MW annual production facility is established. The cost of production ranges between 26.8 EURc/W in the most optimistic scenario – low WACC of 10% and material input costs of 10.4 EURc/W – to 32.7 EURc/W in the higher cost scenario where WACC is 14% and material input costs amount to 12 EURc/W. These ranges reflect the inherent uncertainty of the

Ukrainian situation, with a significant impact on the standing of Ukraine's solar PV competitiveness. Here the WACC is the largest determinant within the total production cost, wherein lower financing rates mean production may be more competitive than in the US, while a higher WACC would make Ukraine the least competitive in a sample of 11 countries (only 6 comparison countries presented in the figure).

Figure 14. Costs of production – 1 GW annual production capacity



Source: NREL (2024), expert consultations, authors' calculations.

In the second scenario, a larger greenfield integrated 1 GW solar PV manufacturing facility is built. Due to better economies of scale, Ukraine's production becomes more competitive compared to the 500 MW production capacity scenario, reaching as low as 24.3 EURc/W in a lower WACC and lower material costs scenario - on par with modelled production costs in Germany, and surpassing Japan and the United States. In a higher cost scenario, Ukraine's modelled pro-

duction costs are roughly on par with the United States, but now further below Germany and Japan. When compared to other countries in modelled sample, Ukraine lags significantly behind global cost leaders including China (both low and high cost), as well as India and Malaysia, but performs somewhat on par with highly industrialised developed countries.

Analysis

Industrial capability and supply chains are fundamental cost drivers in solar PV manufacturing. While Ukraine has previously, at various points, held significant parts of the solar PV value chain and related industries locally, global leaders have highly established solar PV sectors dating back for multiple decades. The United States, Germany, South Korea, and Japan have produced and innovated in the solar PV sector since the 1970s, gaining significant expertise and establishing important supply chain networks of producers and providers, albeit in different forms. For example, Germany's strategy specifically focused on SME, regional, and industrial development, while South Korea and Japan focused more on traditional large-scale integrated conglomerates. With Chi-

na's entry into the sector in the early 2000s and prioritisation from the 10th 5-year plan onwards, massive support has created a tightly knit, albeit ferociously competitive, domestic sector which now captures the lion's share of global demand. Nonetheless, Ukraine is also able to benefit from some of these developments. The globalisation of trade and production has meant that across all the countries sampled, material costs show the lowest variation, ranging between 9.6 EURc/W in China to 12.6 EURc/W in the US, with a range of 10.4-12.0 EURc/W in Ukraine.

Utility costs on the other hand show significant variations, forming one of Ukraine's modelled factors of production competitiveness, although with some caveats. Ukraine's utility cost of 1.5-

1.6 EURc/W is below other developed nations, reflecting a lower cost especially of electricity, a key production factor in the electricity-intensive solar PV manufacturing process.¹¹⁸

This is especially evident when comparing the utilities segment against Germany (2.8 EURc/W) or Japan (4.5 EURc/W) where energy costs are higher. Concurrently, given Russia's persistent attacks on Ukraine's energy grid, the future of the system is still uncertain, both in terms of longer-term energy mix and pricing. As the grid is reconstructed, it is imperative to continue integrating low-carbon solutions and ensuring a high integration of lower cost renewables, to ensure long-term economic competitiveness, prepare for the EU CBAM and EU ETS, and to meet Ukraine's climate targets.¹¹⁹

However, across much of Europe, complex regulations and long permitting timelines significantly increase **capital expenditure (CAPEX)** for new solar PV manufacturing plants. Setting up a facility can take up to two years, with further delays during testing and ramp-up, slowing the path to profitability. Manufacturers may require as much as EUR 100 million in working capital to cover setup and early operations, making access to finance and capital one of the most critical cost drivers.¹²⁰

Within the modelled results, CAPEX ranges from 3.6 EURc/W in China to EUR 7.1 EURc/W in the United States for a 1 GW plant, but Ukraine under even the most optimistic 10% WACC scenario has a CAPEX of 10.8 EURc/W and an extremely high EURc/W 17.1 for a 1 GW plant under 14% WACC. While clearly the size of the constructed plant is a determinant on the price, and a doubling of size can reduce the CAPEX per unit by 15-20%, CAPEX in general is a significant barrier.

The WACC has in general been increasing globally in the last years, reflecting rising interest rates, tighter credit conditions, and higher risk premia due to economic and geopolitical uncertainty. This marks a shift away from the low-cost capital environment of the previous decade.¹²¹ However, significant regional differences exist due to the sources of finance. China has heavily supported its companies in the solar PV industry, both in terms of manufacturing and export, as well as deployment, providing state-backed, concessional financing. Lending and support for the sector has been a major priority in the last few 5-year plans, and coupled with other support has led to extremely fast build up rates (matter of months) and a very low total CAPEX in general (lowest in the sample).¹²² Simply put, China's financial system benefits from state-backed development banks and green finance mechanisms, which make capital readily available for renewable energy projects. In Europe on the other hand, the situation has been different, with numerous interviewees reporting that access to financing for green technology manufacturing is very difficult to obtain, with very high barriers from development banks or various EU funds. In Germany, the government's funding for the green transition is largely limited, and more broadly, their financial models are not well adapted to financing many climate-related manufacturing projects.¹²³ Tellingly, the solar PV industry was largely omitted from The Draghi report on EU competitiveness, further signalling that it is not the primary priority for large-scale support and financing (although other renewable energy sectors were included). This is despite the fact that the solar PV sector is still present in the EU's NZIA and other strategic documents.



Box 1: Lowering the Cost of Capital in Ukraine: The Role of State Support

Despite some of its competitive advantages (lower labour and utility costs), in terms of the final cost of production, Ukraine lags behind China, Southeast Asia, and also Europe. One of the key reasons is the high cost of financing in Ukraine, which significantly raises the financing burden for capital-intensive projects. Under current market conditions, this high-cost offsets Ukraine's structural advantages, rendering many large-scale manufacturing investments economically unviable.

For example, in China and the EU, large scale projects are implemented under special financial schemes that include soft loans, government guarantees, or subsidies that reduce financing costs. These instruments lower the weighted average cost of capital (WACC), thereby reducing the annualised CAPEX component of production costs. For example, approximately 34% of the total investment in Italy's 3Sun HJT solar PV manufacturing plant was financed through grants from the EU Innovation Fund and Italy's Recovery and Resilience Facility. This blended financing structure brought the project's WACC down to around 3.4%, compared to a market average of 7–8%. Similar financing arrangements have enabled multiple EU battery projects to achieve WACCs of 3.5–4.3%.

The table below illustrates this relationship: greater involvement of grants and concessional finance leads to lower WACC and enhancing the economic viability of large-scale green manufacturing projects.

Table 2. Impact of Grants and State Support on WACC and CAPEX

Country	Debt/Equity/ Grant Ratio	Cost of Debt	Cost of Equity	WACC	Annualized CAPEX (EURc/W)
Germany (at market WACC)	25:75:0	4.5%	10%	8%	7.7
Germany (with grant/state support)	50:25:25	4.5%	10%	4%	5.2 (-33%)
Ukraine (at market WACC)	25:75:0	18%	21%	19%	19.3
Ukraine (with grant/state support)	30:45:25	18%	21%	14%	14.3 (-26%)
	30:25:45	18%	21%	10%	10.8 (-44%)
	30:10:60	18%	21%	7%	8.1 (-58%)

Source: NREL (2024). KPMG Cost of Capital Study (2024). Own elaboration and analysis. Note: Tax shield applied (Corporate Income Tax (CIT): Ukraine - 18%, Germany - 30%).

For Ukraine, at current market WACC levels of 19–20%, the estimated CAPEX burden for a 1 GW solar PV plant in Ukraine would be prohibitively high. Introducing state grants or concessional financing that lower WACC to 14% or 10% can reduce annualized CAPEX by 26–44%. Although reaching full parity with EU WACC levels may be challenging due to Ukraine's high country risk premia, closing the gap significantly would already yield major gains in competitiveness. For example, at even higher financial support levels, WACC could drop to 7%, making CAPEX nearly three times lower than in the no-support scenario. Hence for Ukraine, preferential financing - through grants, guarantees, or cheap credit - can significantly improve project viability. This could make the country a more viable nearshoring destination for solar PV production for European markets but would also require a strengthening of the country's financial ecosystem by introducing new financing instruments and public-private partnerships that could unlock significant growth, especially in the renewable energy sector.

The largest distinctive cost driver of competitiveness for Ukraine's solar PV manufacturing sector is the low **labour cost** vis-à-vis other countries. For a 1 GW plant, in Germany labour costs these compose 5.5 EURc/W of the production cost and in the United States these reach 6.7 EURc/W. In Ukraine however, the labour component only accounts for 1.1 EURc/W, on par with high-cost Chinese production. While the sector is increasingly more and more automated and is not a significant job creator in terms of direct jobs, the labour factor is nonetheless key. For Ukraine, the very high human capital, expertise in engineering and IT, and linkages with other sectors contribute to the potential to fill the needed roles, but several downsides exist.¹²⁴ The large-scale emigration, war casualties and ongoing mobilisation has significantly decreased the labour pool, hence the provision of more specialised university programmes and trainings will be necessary.

A lack of labour is already acutely observed in the deployment and installation segment of the solar PV value chain, with significant work needed to train up new engineers. While also a problem in Germany, targeted programmes have been implemented, including through TVET institutions, specialised training centres and more broadly across education institutions. In addition, private companies are taking the initiative, launching internal solar installer training due to a shortage of certified professionals.¹²⁵ Integration, especially of veterans and women into the downstream solar PV sector could be a win-win situation, but a focus on university level engineering programmes is still key to train the staff for the production factories.

This links with the **research and development and industry-academia** component. Historically fundamental for the development and improvements of the sector, especially in Germany and East Asia, European universities and research institutes such as Fraunhofer are now facing dramatic cuts of around 30% in solar research funding, with a long-term declining trend in solar PV R&D. Importantly, these budgets are also fundamental for pilot production and equipment testing.¹²⁶ Concurrently, interviewed experts assert that Europe has lost its technological lead vis-à-vis China as in the latter support is available for R&D and companies re-invest large portions

of profit to further product development.¹²⁷ In Ukraine, only limited university and R&D capacity in the solar PV sector exists.

The **general business environment** has been a major factor in shaping the global competitiveness of the solar PV industry. China, in particular, has benefited from streamlined permitting, free land allocations, and rapid utility connections—enabling factories to be built and scaled within months, compared to the much longer timelines in Europe.¹²⁸ This contrast is especially stark in Germany, where slow permitting and the need for streamlined grid access continue to hinder progress.¹²⁹ In response, manufacturers are increasingly exploring alternative markets. India is emerging as a potential competitor to reduce dependence on China, while Eastern European countries are gaining attention due to lower energy costs, affordable labour, and more attractive regulatory conditions.¹³⁰ Romania, for example, plans three solar PV manufacturing projects with a combined capacity of 1.7 GW, supported by EUR 47 million in state aid.¹³¹ Poland has launched a EUR 1.2 billion industrial support scheme that includes incentives for solar PV production.¹³²

The general **industrial policy and policy certainty** dimension is the last key pillar. As discussed, government support for supply-side measures across key producing geographies including Germany, South Korea, Japan and others has been a fundamental driver, and early investments into R&D have contributed to increasing efficiencies and dramatically decreasing costs in the solar PV sector. A variety of other tools, including strategic tax breaks, grants, subsidies, export credits and concessional loans have all been fundamental to the sector's development and have been employed even more significantly by China after 2000.

Both the U.S. Inflation Reduction Act (IRA) and the EU's Net-Zero Industry Act (NZIA) have made the solar PV sector a central focus, emphasizing the localisation of key segments of the value chain. The IRA offered tax credits under Section 45X for domestically produced components. According to an assessment by the Rhodium Group in 2024, the installed capacity for solar PV module assembly has seen remarkable growth, doubling from 19 GW at the end of 2023 to 38 GW

by Q3 2024 as a result of the IRA. This expansion is being driven by a surge in investment, which is also fueling the growth of earlier-stage solar manufacturing. Currently, 8.3 GW of wafer manufacturing capacity is under construction, with a further 13 GW announced. The solar cell manufacturing sector is also experiencing significant growth, with a current capacity of 300 MW, which is expected to increase with 11.8 GW of capacity under construction and a further 18 GW announced. The solar manufacturing sector has seen the largest increase in investment since the IRA, with investment increasing tenfold from USD 890 million in the two years prior to the IRA to USD 10 billion by August 2024. This boom has also led to the creation of 22,000 jobs in IRA-related solar manufacturing. Additionally, the IRA provides investment tax credits for manufacturing facilities and supports R&D funding for solar technologies. Meanwhile, the NZIA sets a target for the EU to produce at least 40% of its clean energy deployment needs domestically, including solar PV panels, by 2030, alongside measures to support the localisation of broader parts of the value chain.

Historically, both the U.S. and EU imposed anti-dumping and countervailing duties on Chinese solar PV imports—starting in 2012 in the U.S. and 2013 in the EU—with tariff rates ranging from around 18% up to 250%. While these trade measures aimed to protect domestic industries, they may have slowed solar PV deployment in these regions. At the same time, these tariffs contributed to the growth of solar PV manufacturing in ASEAN countries, as Chinese producers sought to circumvent the trade restrictions by localising production in Malaysia and Viet Nam, among others.¹³³

While the supply-side was driven by long-term strategic visions and regulatory certainty, the demand-side was also fundamental. Although solar PV manufacturing localisation is not as dependent on specific locations due to the relative ease of transportability of components, some segments of the value chain (especially final assembly) are still traditionally located closer to end-markets. A stable future market demand could therefore provide an important guarantee for producers. Inclusion of renewable targets in key planning documents (such as the Energy Strategy or the NECP) is an important step, but key demand-side measures, such as feed-in tariffs, contracts for difference, government procurement and strategic off-takes are even more important in creating an end-product market.

The IRA also includes strong demand-side incentives, notably extending the Investment Tax Credit (ITC), which allows individuals and businesses to claim 30% of the cost of installing a solar PV system on their federal income taxes through 2032. Additionally, the Production Tax Credit (PTC) offers up to 2.5 cents per kilowatt-hour for the first 10 years of a project's operation, provided prevailing wage and apprenticeship requirements are met. The Act further supports solar deployment in low-income and disadvantaged communities through targeted grants, rebates, and technical assistance. On the EU side, the Net-Zero Industry Act (NZIA) seeks to simplify regulatory frameworks by streamlining permitting processes, introduces public procurement rules to boost demand for clean technologies, and allocates support for strategic projects aimed at strengthening local manufacturing and deployment capacities.

5.1.3 Economic benefits

In order to model the economic benefits of the potential localisation of the wider solar PV value chain in Ukraine, some key assumptions were taken. Firstly, the assumed annual demand in Ukraine is a somewhat conservative 850 MW split between both utility-scale and rooftop solar PV. This mirrors the added capacity in 2024

primarily in rooftop solar, with significant upside potential reflected in key strategic documents.¹³⁴ In addition the same annual volume 850 MW is assumed for export to the European Union. As such, two factories of 1 GW, with an 85% utilisation rate are constructed to satisfy the demand.

Employment

The localisation of 2 GW of manufacturing capacity for annual wind installations of 850 MW and an additional 850 MW for exports would have a significant effect on employment in Ukraine.

Table 3. Potential employment creation across Ukrainian solar PV value chain

Category	Type	Low	Average	High
Manufacturing job-years	Direct		13,400	
	Indirect		6,400	
Construction and installation job-years/year	Direct	11,050	16,490	21,845
	Indirect and induced	1,649	7,004	12,444
Operation and maintenance jobs/year	Direct	85	524	893

Source: Hanna et. al. (2024)¹³⁵, authors' calculations

The direct employment at the plants would create about 13,400 job-years across the lifecycle of the project. This includes direct production operations, engineering and maintenance, quality control and testing, logistics and material handling, health and safety, administrative and support staff, an in-house research and development team and a managerial structure. As such, a very broad range of functions and skills is required, including some highly specialised ones that will have to be further developed in the Ukrainian education system or through company-specific training.

Roughly about 6,400 indirect job-years will also be created across the wider ecosystem which has to form around the sector. This includes raw material supply, logistics and transportation, construction and equipment supply, as well as

professional services. Many of these companies, jobs and functions already exist with minimal adaptation requirements to serve the solar PV supply chain.

Nonetheless, the assumption that these panels will meet domestic demand also creates significant employment opportunities in the solar PV construction and installation sector, as well as long-term operations and maintenance jobs. While estimates for direct and indirect and induced jobs range significantly, partly also on the type of installation (utility-scale or rooftop), the average estimate is around 23,500 additional job-years per year and 520 O&M jobs. This further re-enforces the significant need to continue training and integrating more and more labour into the renewables deployment sector to prevent shortages and delays.

Value-added and exports

The localisation of 2 GW of solar PV production capacity and an annual production of 1.7 GW of solar PV modules would have significant contributions to Ukraine's gross value-added.

Depending on the WACC scenario and costs presented in the previous section (26.78 EURc/W-32.75 EURc/W), and potential revenue margins that the plants may impose (assumed 5%-10%), the total contributions to Ukraine's GVA could range between EUR 233 m-EUR 381 m per

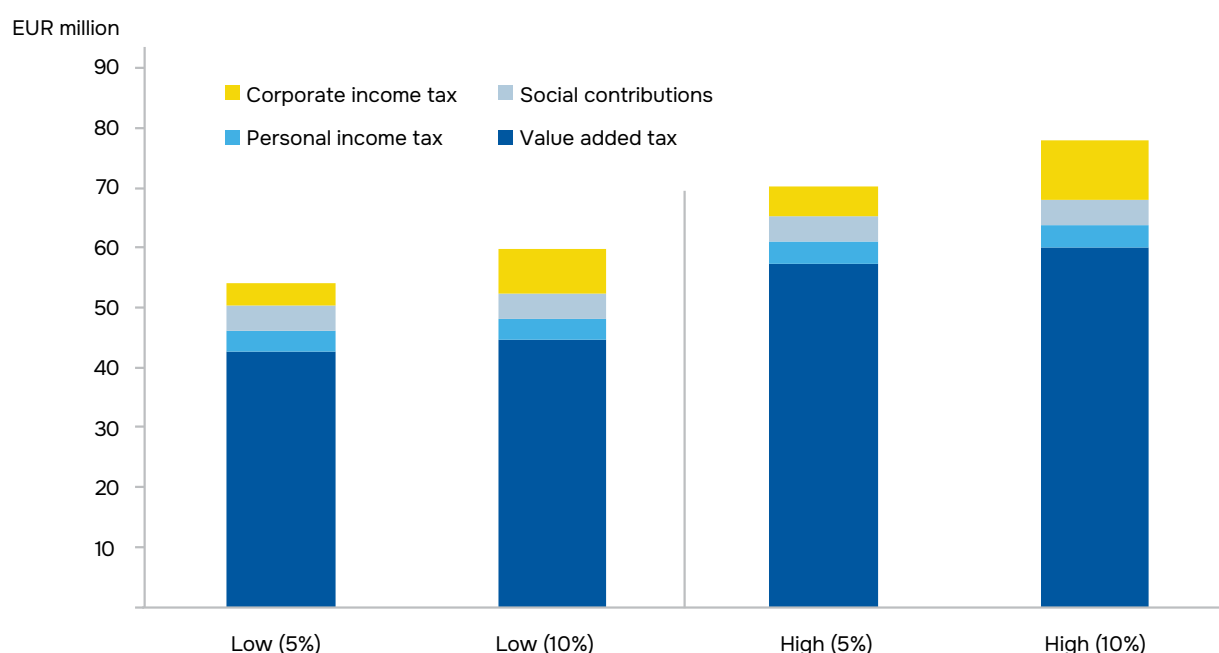
year, equivalent to an impact of 0.13%-0.22% of Ukraine's GDP in 2024.

In addition, the 850 MW of exported panels annually would significantly contribute to Ukraine's trade balance and would act as a key source of foreign exchange. Based on modelled costs and revenue margins, the exported solar panels could bring in between EUR 217 m-EUR 306 m annually in export revenues, which is the equivalent of between 0.56%-0.79% of Ukraine's total exports in 2024.

Fiscal revenues

The creation of a domestic integrated solar PV sector would also have significant implications for Ukraine's budget and fiscal position, bringing in much needed revenue.

Figure 15. Fiscal effect



Source: Authors' calculations. Note: Low and high production cost scenarios, with 5% and 10% gross revenue margins

The contribution to Ukraine's budget would vary depending on the cost structures and revenue margins, with a range between EUR 54.7 and EUR 79.1 m per year. Most of this comes from the gross VAT incurred on the sales of the domestic solar panels, which ranges between EUR 43.5

and EUR 61.2 m. Concurrently, depending on the various scenarios, fiscal support for production may be needed in the form of tax breaks or strategic subsidies or which may decrease the government contribution.

Additional material demand

Localising the solar PV value chain could yield significant demand for materials in other Ukrainian industries as well.

Table 4. Potential additional material demand across the Ukrainian solar PV value chain

Item	Material intensity (tonnes/MW)	Total annual potential material demand (tonnes)
Tempered glass (cover)	46.4	78,880
Steel (racks and mounting)	67.9	115,430
Aluminium (frames and mounting)	7.5	12,750
Copper cables (wiring)	4.6	7,820

Source: NREL (2023), author's calculations

Steel is a significant input for solar PV racks and mounting, with a high mineral intensity per MW of solar PV produced. This could yield over 115,000 tonnes of additional demand for Ukraine's steel industry, providing a much needed off-taker and boost as the industry recovers to its pre-war state. Additionally, a high amount of tempered glass used for the solar panel cover is needed (roughly 79,000 tonnes annually), which could

be supplied by the 17 existing Ukrainian companies. In addition, aluminium frames and mounting as well as copper cable demand would increase.

Importantly, some of these components and demand is needed even if the panels are only assembled in Ukraine, or along other stages of the value chain, meaning that demand will exist even in the absence of a full-scale localisation.



5.1.4 Assessment and additional considerations

The global solar PV value chain is extremely concentrated, with China able to produce virtually every component more cost-competitively than anyone else. Nonetheless, there are strategic opportunities that other countries, including Ukraine can leverage. While this assessment provided an integrated greenfield cost comparison, various segments of the value chain may be more competitive.

Ukraine has previously held a role in all parts of the solar PV value chain. While polysilicon production was dismantled and relocated to China after 2014 due to a lack competitiveness and equipment obsolescence, there may be scenarios where these processes could be restarted. Ukraine still holds large reserves of quartz and silica sands, and although no active large-scale production currently exists, an integrated strategy could seek to revive the sector by providing a domestic off-take opportunity. Additional opportunities could also be sought to provide silicon to producers in Europe, although the sector is also very limited in the EU as well. Nonetheless, polysilicon production is extremely energy intensive, and Ukraine's current energy situation means that additional energy generating equipment would have to be constructed and corporate power purchase agreements (PPAs) would have to be concluded.

Across the other stages of the value chain, existing manufacturing assets could be revived and repurposed to at least fulfil domestic demand. For example, KNESS had 200 MW of capacity in the more downstream segments of the value chain. Using existing installations and upgrading them would mean less CAPEX needed as opposed for a fully greenfield project and could improve cost competitiveness of Ukrainian production vis-à-vis other countries. However, greenfield investments would still be essential to achieving the scale needed for economies of scale and export

potential. The high financing costs (WACC) remains a barrier to investment, and therefore also competitiveness and sectoral expansion. Reducing financing costs through grants, preferential lending, equity insurance schemes, and investment refund programs is critical. Additionally, the existence of the asset and a track record could potentially help secure better financing conditions.

In any case, scaling up module assembly may prove most competitive given the existence of industry and a developed supporting infrastructure, but also due to low labour costs and elevated domestic demand. At the same time, even the assembly stage may prove uncompetitive vis-à-vis China, although a more geopolitical and strategic focus on the European solar PV sector may create a situation where more localisation is pursued. In any case, any hope of meeting domestic demand and also satisfying some EU market demand would require significant greenfield investment.

Two key input materials driving the cost of solar PV manufacturing in Ukraine are glass and polysilicon. Since the onset of the war, glass has primarily been imported from the EU at an average price of USD 5.0/m², compared to USD 3.5/m² for Chinese sheet glass. Transport costs to Ukraine add around 15% to the price. Glass currently accounts for 40-50% of the cost of a finished solar module. Crucially though, sheet glass is a strategic good for Ukraine and will be important for the construction sector during the reconstruction of the country. If a glass production plant were to be constructed as part of a national strategic project, as has previously been indicated by a variety of players, it could also support the solar PV sector. Nonetheless, the cost of sheet glass may still be higher than imported glass, but strategic autonomy in the glass sector may justify the creation of the sector.



Polysilicon, a key raw material for monocrystalline silicon used in semiconductors (including in high-tech applications such as drones), is another strategic material. Ukraine possesses high-quality raw materials for polysilicon production, and “Titanium Institute,” an engineering company, has the technology to restore the production chain. Considering these other uses and export potential, a national strategic project might make sense. Taking into account the need for a stable and cheap energy supply, the optimal location for such a plant could be near Khmelnytsky NPP, the newest one of Ukraine’s nuclear power plants, where two new power units are planned to be built. As with the glass sector, this does not necessarily by itself mean that Ukraine should pursue the construction of a polysilicon plant for the sole purpose of solar PV sector, but other uses and further coordination with European partners, including concrete off-take agreements could justify these decisions. Nonetheless, Ukraine is foreseen to have an electricity deficit in the coming few years and new investments into the energy system might in the short-term drive-up costs. It should also be noted there are currently also other, significantly more competitive existing industries that should get priority access to this electricity at lower rates.

Some further strategic opportunities may exist in auxiliary supporting equipment manufacturing. Ukraine’s local steel sector could produce components such as frames and mounting structures, and other companies can be providers of tempered glass, but also aluminium structures and copper wiring needed for the final deployed products. An assessment could also be made regarding the competitiveness of providing these products to the wider EU market, especially in countries where no corresponding production exists. Nonetheless, the introduction of the EU Carbon Border Adjustment Mechanism would have a significant impact on iron, steel and aluminium products, so the decarbonisation of the grid, and these industries in particular, would

need to be prioritised to ensure continued competitiveness.

While some inverter assembly already exists in Ukraine, the EU market has ample production capacity and an expansion of the sector in Ukraine may not be needed. However, inverters are vulnerable to both hardware and software concerns, especially from a security and cybersecurity position, and the European industry may seek to produce all inverters used in technologies deployed in the EU. The EU has lost some expertise, with declining R&D in the sector, and there is a lack of companies able to manufacture some of the specialised tools and equipment, such as ingot wafer puller and diamond wire saws that are critical for the production process.¹³⁶ However, this study has not assessed Ukraine’s overall competitiveness in the manufacturing of these segments.

It is clear that the EU is not on track to meet deployment targets through domestic production alone, especially in the ingot and wafer production stages and slightly less so in the solar cell manufacturing.¹³⁷ While the EU Net Zero Industry Act and the European Solar PV Industry Alliance (ESIA) are making the resuscitation of the EU solar PV value chain a key priority, many of the experts interviewed in the research process expressed scepticism regarding the tools used and prospects overall.¹³⁸ Given Ukraine’s production knowledge and expertise along the value chain, as well as a willingness of local companies to engage in the production process, an expansion of manufacturing and further localisation could be possible, but would clearly require significant public and international support.

Much of the support needed would be financial. In July 2024, import duties on energy equipment imports, including of solar PV, were temporarily suspended to help quickly scale up installed capacity considering the damage to the energy system.¹³⁹ While this was clearly the correct decision from an energy security perspective, there



was an effect on the competitiveness of domestic production. The longer-term view must consider how to balance the cost of deployment and the energy transition with support for domestic actors, considering the limited resources that will be available for the wider reconstruction process. Overt levels of direct financial support, including potential CAPEX grants, tax breaks or subsidies, or protectionist measures, including introducing import duties on final products or tariffs, could significantly slow down or discourage solar PV deployment, which is not the intended objective. A balance therefore must be found, but additional tools can be used.

Public procurement and possibly some local content requirements especially could be a potent tool, especially for rooftop solar PV deployment in public sector building energy efficiency projects. While no such requirements currently exist in Ukraine nor in the EU's Energy Efficiency Directive, conversations regarding Green Public Procurement, strategic autonomy and larger emphasis on local content and industrial policy more broadly may not rule these options out in the future. Notably, Ukraine has already introduced a small step in this direction through its Decarbonization Fund, operational since mid-2024, which provides a 2% interest rate reduction on loans when equipment from a domestic manufacturer is used. While the Fund's resources are limited, it illustrates how procurement and financing tools can support local industry.¹⁴⁰ While a pathway for solar PV (both utility-scale and rooftop) already exists in key planning documents, considering a larger role for government procurement may create a more guaranteed off-take market for potential producers. Concurrently, Ukraine needs to ensure that any public procurement and local content policies are in-line with its international obligations, as well as the evolution of policies in the EU.

As Ukraine progresses towards EU accession, a larger focus on integration into the EU solar PV value chain is needed, which could include export promotion support, incentives for increased export volumes and other performance requirements. This integration should first and foremost be assessed with regards to Ukraine's neighbours, including Poland and Romania that are

looking to further build out their own domestic solar PV value chains, and where complementarities may exist for intermediate products to the benefit of all countries.

The role of technological capabilities, R&D and industry-academia collaboration merits further consideration. For countries with little presence in the solar PV manufacturing value chain, or those entering it for the first time, the adaptation of production technologies, manufacturing processes and final products, and incremental innovation rather than large-scale investment into new products may be more fruitful as they catch-up to the technology frontier. As production costs decrease and processes mature, setting up new production lines and scaling up through learning-by-doing in the solar PV value chain is more possible than previously. Linkages between the solar PV sector and other sectors Ukraine may develop may also prove beneficial. Large overlaps exist with the semiconductor industry and various defence sector applications that Ukraine may pursue in the future, potentially providing an avenue for collaboration and knowledge transfer between the sectors.

On the other hand, throughout the course of interviews for this study, it was mentioned that one potential avenue Ukraine could compete with China is by entering completely new technologies, such as perovskite solar, and building experience there, effectively technologically leapfrogging China.¹⁴¹ For this, collaboration with other European research institutions and start-ups in the space could be rewarding, especially considering how parts of these new value chains could be spread across a Ukraine-including European Union.

While Ukraine is unlikely to compete directly with Chinese or other South-East Asian solar PV producers on a cost basis, a more strategic, EU-driven, and security-based understanding of solar PV supply chains may create the opportunity to localise larger parts of the value chain, leveraging the country's geographic proximity and regulatory alignment to the EU. Doing so would help both the domestic reconstruction of the energy system in Ukraine, and to meet domestic and EU green transition targets.

5.1.5 Conclusion and sectoral development roadmap

Ukraine is unlikely to compete with Chinese or Southeast Asian solar PV module manufacturers purely on cost, but neither can the European or US manufacturers. Ukraine's key advantages, including lower labour and energy costs and geographic proximity to the EU, may make it a strategic player for strengthening EU value chain security. Scaling up module assembly and ancillary equipment manufacturing (e.g. inverters, tempered glass, aluminium and steel frames) can meet growing domestic demand, with additional potential for exports and further integration into the EU. Additional assessments are needed for the polysilicon and sheet glass sectors which may be developed independently and could potentially feed into the emergence of a domestic solar PV sector or for strategic exports to the EU. Importantly, demand-side measures, such as

energy market reforms, power purchase agreements, and public procurement, are also vital to create a stable domestic market.

Without a strategic revival of the EU solar manufacturing sector, Ukraine is however highly unlikely to localise the full value chain. In the short term, Ukraine should align with EU strategies and stimulate ancillary equipment production, and work on reviving and scaling-up the module assembly operations. In the medium term, revisiting local content policies can catalyse domestic demand. In the long term and in conjunction with EU strategies, Ukraine could position itself as a key contributor to the EU solar PV value chain through the manufacturing of targeted strategic components.

Table 5. Solar PV sectoral roadmap

Short-term (1-2 years)	Mid-term (2-5 years)	Long-term (5+ years)
• Alignment with broader EU strategy on sector revival and developments in energy security policy • Assessment of ancillary equipment production scale-up and export potential • Reconsider import exemptions on final assembled modules • Stimulating the production of inverters in Ukraine through localisation mechanisms in public procurement and cashback • Explore opportunities to establish glass and polysilicon sectors, taking into account other sectors and export markets	• Scale-up ancillary equipment markets and assess need for domestic assembly • Evaluate local content policies in public procurement • Re-assess value chain economics (including silicon refining) based on EU policy developments, other sector linkages and domestic requirements • Integrate with European R&D ecosystem and exploration of leapfrogging with new technologies (e.g. perovskites)	• Pursue avenues that can position Ukraine as a strategic contributor to the EU solar PV value chain by focusing on strategic components (e.g. inverters, mounting systems), testing and certification services, and innovation in next generation PV materials and potentially recycling technologies

5.2 Wind turbines

5.2.1 Value chain overview

Wind turbines convert wind energy into electricity. The wind spins the rotor blades, which turn a generator to produce electrical energy. A gearbox adjusts the rotation speed for the generator, while a converter ensures the output matches the grid's frequency. Finally, a transformer increases the voltage for efficient grid distribution. The wind

turbine supply chain consists of multiple stages. It begins with sourcing raw and processed materials, followed by producing sub-components and individual turbine parts. These components are then assembled into complete wind turbines, marking the final stage of the process.

	Towers	Blades	Gearboxes	Generators	Power Converter	Nacelle Assembly
Description	Steel and concrete structures atop which the turbine is installed	Composite materials are molded into aerodynamic blade shapes	Components are machined and assembled into gear systems	Copper wiring and magnets assembled into generator units	Electronic components are integrated into conversion systems	Gearbox, Generator, Converter assembled into the nacelle housing
Major producers (% global market share)	China (~50%) Europe (~20-25%)	China (65%) (Chinese: 61%, Non-Chinese: 4%) Europe (13%) India (8%)	China (80%) Europe (10%) India (9%)	China (73%) (Chinese: 62%, Non-Chinese: 11%) Europe (16%) India (5%)	China (81%) (Chinese: 77%, Non-Chinese: 4%) Europe (10%) India (5%)	China (60%) Europe (19%) USA (9%)
Ukraine production	Existing production	Production under construction and/or can be restored	Existing production			

Source: Global Wind Energy Council (2023), Boston Consulting Group (2023), Authors' elaboration.

The wind turbine value chain is highly complex, often comprising more than 8,000 individual components, some of which are massive in scale, with blade lengths often exceeding 100 meters.¹⁴² This increased complexity and length of the value chain, combined with logistical challenges and a high degree of engineering precision, makes the wind industry structurally distinct from solar PV

manufacturing. While geographically still highly concentrated, the sector is more geographically dispersed, with a larger amount of leading non-Chinese companies. Nonetheless, over the last decade China has built up a scale-driven and backwards integrated industry through steady market expansion. China leads the global market for material refining (steel, aluminium, rare earth

materials), and manufacturing of key wind components like gearboxes (80%), converters (82%) generators (73%) and castings (82%).¹⁴³

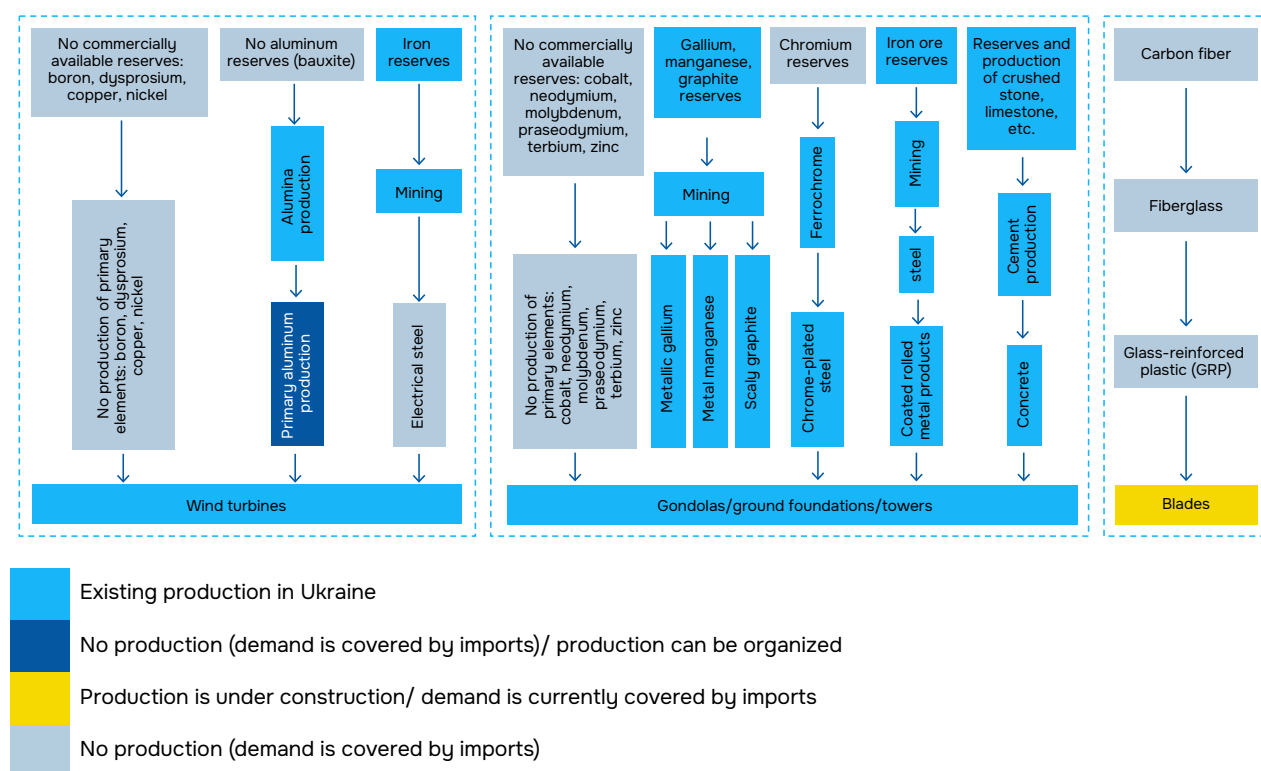
After the mineral and processing stage, only five countries worldwide have the capability to produce all major components found in a wind turbine: China, India, Spain, Germany and the United States (NREL, 2022). The value chain however includes many manufacturers of more niche, specific components, although some vertical integration in the segment also exists.

In 2024, Chinese manufacturers occupied the top four positions in terms of global manufacturing, while Danish Vestas dropped to fifth. Almost all newly installed capacity by these Chinese firms was deployed within China, reinforcing the

country's central role in the global wind energy market.¹⁴⁴ Looking ahead, China is projected to remain the dominant manufacturing hub for key wind energy components, with a market share of 50–70% in the medium term.¹⁴⁵

Despite the strong growth trajectory and a shift towards offshore wind deployment, global manufacturing capacity for wind turbines is expected to reach only about 60% of the levels required by 2030 under the IEA's Net Zero Emissions (NZE) Scenario. Bridging this gap will require substantial and coordinated action from both public and private stakeholders to accelerate wind power deployment and scale up global manufacturing capabilities.¹⁴⁶

Figure 16. Ukraine wind turbine manufacturing value chain



Source: Authors' assessment.

In Ukraine, there are existing capabilities in wind turbine manufacturing, which provides a basis for further localisation of component production. These capacities stem from existing industrial activity in the sector and the potential for Ukrainian industry leaders to expand into the production of specific components.

A key example of domestic production is the wind turbine generator plant established in 2012 in Kramatorsk by Fuhrlaender Windtechnology LLC, under licence from the German company Fuhrländer. The facility had the capacity to produce up to 100 units per year, manufacturing turbines with a rated capacity of 3.5–5.2 MW.

Before the war, the plant operated in Kramatorsk with a localisation rate of up to 80%. However, due to the war, operations were relocated to an industrial park in Transcarpathia, resulting in a reduced localisation level of 50–55%. This decline was primarily due to disrupted supply chains, including the loss of domestic inputs such as rolled metal from Mariupol Metal Works and stainless-steel blanks previously supplied by Energomashspetsstal (EMSS) and Dniprospeetsstal. Current production capacity stands at 25 turbines per year, with an increase to 40 units planned for 2026. Additionally, JSC “Ukrainian Energy Machines” (formerly Turboatom) is a major Ukrainian manufacturer of industrial turbines, including steam turbines for thermal and nuclear power plants, hydraulic turbines for hydroelectric plants, and reversible machines for pumped storage. Although their primary expertise lies in industrial turbines for power generation, there is significant potential to expand into wind turbine manufacturing by leveraging and adapting their existing operations. There is also domestic transformers manufacturing in Ukraine. Ukrelektroapparat, based in Khmelnytskyi, is one of the leading enterprises in transformer construction within Ukraine and the CIS region. The company has a full technological cycle for the production of electrical products, from metalworking and the manufacture of metal structures to the assembly of ready-to-sell transformers and complete transformer substations. Zaporozhtransformator (ZTR), located in Zaporizhzhia, is among the largest manufacturers of transformer equipment in the CIS and Europe, with a production capacity of 60,000 MVA per year. This domestic equipment can play a vital role in supporting the expansion of wind power in Ukraine.

Wind turbines (generators) are produced with imported materials where small-nodal assembly is undertaken, and some key components are also produced in-house. Directly, the production of the generator includes metalworking, coil winding, etc. The company assembles the generator itself in small parts using various components, and buys a number of other components including magnets, copper wire and various electronics, electrical steel and steel for metal structures.

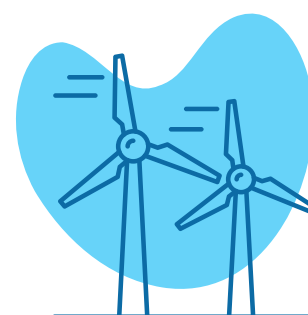
Nacelles (generator housing) are produced in-house from the imported components and assembled on-site. At least 2 Ukrainian companies also produce the steel and cast-iron bedplates that are needed in nacelles.

Blades will be produced domestically from 2025 onwards using imported materials, with sufficient capacity to meet the demand from the domestically produced turbines.

Towers are also produced domestically from Ukrainian low-cost, high-quality steel and from concrete. For steel, 2 major producers are currently operational, while over 50 concrete providers have been identified. Given the very large size, weight and difficulty in terms of transportability, this component is often manufactured close to deployment sites.

The foundation of final wind turbine is also produced locally from Ukrainian steel.

Minerals are fundamental to wind turbine manufacturing, with some key elements, including iron, manganese, gallium and graphite produced in Ukraine, although many key elements, including rare earth elements and nickel are not.



5.2.2 Results and analysis

To assess the competitiveness of potential wind turbine manufacturing localisation in Ukraine, both primary and secondary data were collected and analysed, including international benchmarks. The quantitative results are based on this data and presented across two scenarios.

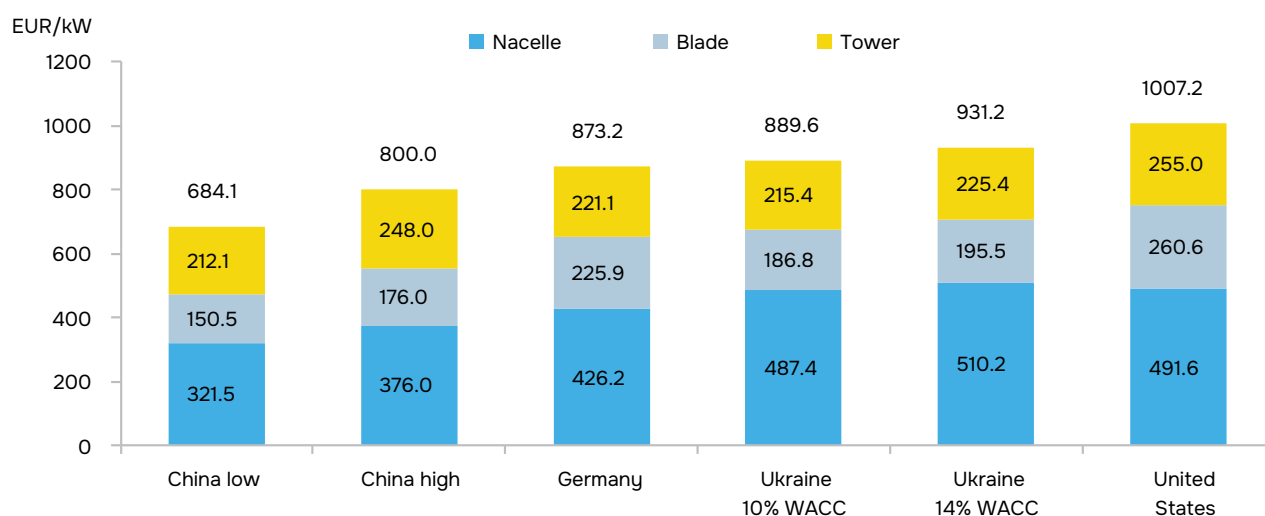
The analysis considers the development of a greenfield integrated wind turbine manufacturing plant in Ukraine, producing turbines with rated powers of 3–4 MW and 4–5 MW—aligned with past production specifications and future production plans. The plant is assumed to have an annual production capacity of 40 turbines, which includes the production and assembly of the nacelles, but also blades and towers. Based

on available national and international data, the results disaggregate the total costs of production by nacelle, blade and tower, but not enough information is available to also estimate other cost factor disaggregation (e.g. energy, labour etc.) quantitatively, although a qualitative assessment is presented. Each scenario is evaluated under two weighted average cost of capital (WACC) assumptions: 10% and 14%. For international comparison, all results are standardised to 2024 Euros per kilowatt (EUR/kW) of wind turbine rated power.

The results of both scenarios are summarised below.

Results

Figure 17. Costs of production – Wind turbines (3–4 MW power)

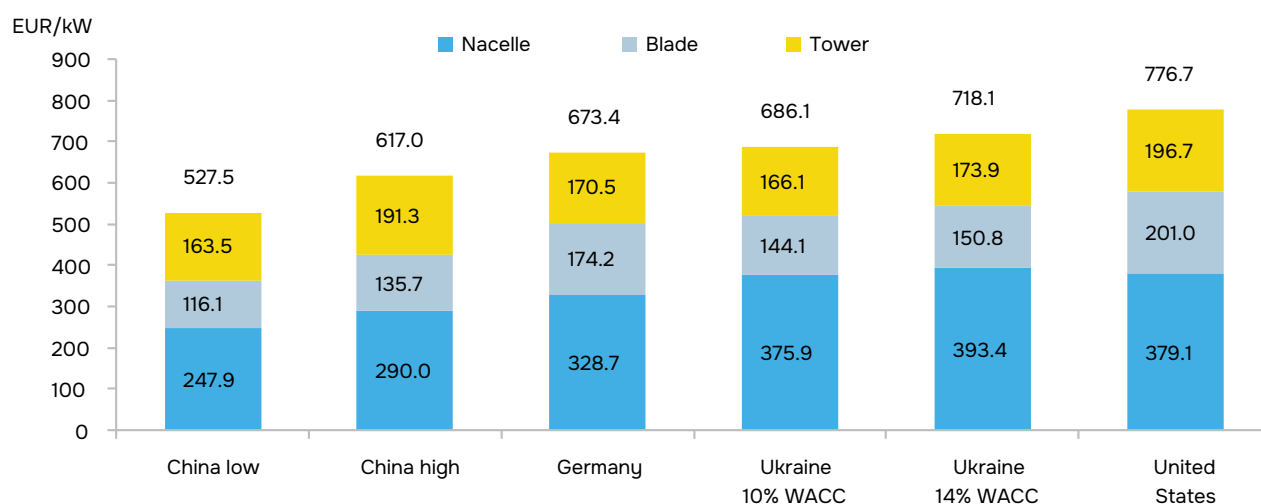


Source: NREL (2024), Deutsche WindGuard (2024), expert consultations. Authors' calculations.

In the first modelled scenario, wherein wind turbines of 3–4 MW of rated capacity are produced, the cost of production in Ukraine ranges from 889.6 EUR/kW in the lower-cost scenario (WACC of 10%) to 931.2 EUR/kW in the higher-cost scenario (WACC of 14%). These cost levels reflect the sensitivity of cost estimates to the financing environment in Ukraine, with Ukraine's cost competitiveness improving substantially with lower financing costs.

At the lower-bound of Ukraine's modelled integrated production costs, it is roughly on par with Germany, but in both WACC scenarios it is more competitive than corresponding production in the United States. When compared to China, Ukraine's production costs across the value chain range between 11%–27% higher, although for some components they are more comparable.

Figure 18. Costs of production – Wind turbines (4-5 MW power)



Source: NREL (2024), Deutsche WindGuard (2024), expert consultations. Authors' calculations.

In the second modelled scenario, larger turbines of a rated capacity of 4-5 MW are produced. As turbine sizes increase, the overall cost per kW decreases due to scale effects, but the relative positioning remains similar: Ukraine with a 10% WACC is about 1.9% more expensive than Ger-

many, and 6.6% more expensive at 14% WACC. Ukraine's production still outcompetes the United States but is beaten out again by China in all scenarios, although the lower bound difference decreases to only 10% when comparing China's upper range with Ukraine's lower range.

Analysis

Strong industrial capabilities and highly developed supply chains are fundamental for the key segments of the wind power value chain. Positively, Ukraine's historical and existing production in the wind power segment, along with a strong resource base and key linkages to other similar sectors (turbines and machinery, among others) do demonstrate some overall competitiveness vis-à-vis other global producers, although this varies by segment.

Comparatively, Ukraine is less competitive in the final production of nacelles, the most technologically complex part of the value chain, which consists of thousands of individual parts and requires significant logistics. Typically, production and various parts of the assembly process may take place closer to the manufacturers of the individual components, with highly integrated supply chains and ecosystems driving down costs. This is especially the case in China and the EU, where decades of production and sectoral development have led to the emergence of a wide

range of local suppliers and tightly knit networks, which are a primary driving factor behind competitiveness.¹⁴⁷ Within the modelled results for the 4-5 MW turbines, Germany's cost of nacelle production is 14%-20% lower than Ukraine and China's is between 30%-37% lower owing to these well-established value chains. The full localisation of all or most of the components needed for a full nacelle would not be practical or feasible given the already well-established networks and would require significant imports of equipment to Ukraine.

Nonetheless, this does not render Ukraine fully uncompetitive in the segment. Some local components are already being produced (including steel frames and cast-iron plates, copper wire and electrical cable, along with gallium and manganese deposits), productive linkages with other sectors exist and low labour costs lend themselves well to assembly-stage production. The historical and continued existence of wind turbine production in Ukraine indicates that the

distance to the end-market (i.e. deployment in Ukraine), along with the other key components may decrease the costs to maintain competitiveness vis-à-vis global competitors. This is particularly the case when assessing the other two major components, blades and towers, where Ukraine is more competitive. In both segments, logistics and distance to end-market, as well as the more labour-intensive and material-intensive nature of production are important factors determining localisation of manufacturing.¹⁴⁸

For blades production, Ukraine's modelled production cost is significantly below Germany (17% less in the 4-5 MW turbines) and the US, and only 6% higher than China. Logistics are still important, but less so than for nacelles, with most materials imported from a range of global providers. Concurrently, the production process is comparatively highly labour-intensive, requiring a large workforce with some segments requiring highly skilled workers.¹⁴⁹ Given the increasing length of blades produced, and the fact that they cannot be split, the logistics of deployment becomes more complicated, sometimes lending itself better to production near the final end-market.¹⁵⁰

Tower production is also highly competitive in Ukraine, with tower manufacturing costs accounting for between 166.1-173.9 EUR/kW of the final cost of production, comparable to China (163.5-191.5 EUR/kW) and Germany (170.5 EUR/kW). Localisation of towers is sometimes easier and more economically feasible than for other components, owing to several factors. One major aspect is the availability of cost-competitive local steel and concrete production. While Ukraine's iron and steel sector has been significantly affected by Russia's attacks, several producers of long products needed for wind towers, including ArcelorMittal Kryvyi Rih and Kamet-Steel still operate, with high quality products. Similarly, more than 50 producers of concrete exist across Ukraine, and a variety of other key metals are also produced or refined in the country. This also means good potential for the construction of wind tower bases. Local production of steel and concrete decreases costs, enabling larger local competitiveness of tower and base production, and further logistical cost reductions if the towers are deployed close to production sites. Nonetheless, the final tower assembly does hap-

pen at the deployment site, with the parts of the tower shipped modularly.

Another fundamental factor related to the manufacturing sector industrial capabilities is logistics and transportation. While some wind components are harder or costlier to transport (blades, and to some extent towers), key transport infrastructure is needed for continued imports, but also potentially for exports of domestically produced parts to other countries. Transportation by vessel is often cheapest, with Ukraine's ports potentially providing a key pathway to ship components to European and/or global markets.¹⁵¹ Importantly, road transport, while not optimal may also be an option as some of Ukraine's direct neighbours, including Poland and Romania are scaling up both the manufacturing and deployment of wind power, with some possible linkages, especially in the nacelle sub-component, tower and auxiliary equipment a possibility.

Financing conditions have a significant impact on the total modelled production costs. A WACC of 14% increases Ukraine's total turbine cost by about 6.6% compared to a WACC of 10%. This shows how high financing costs undermine competitive manufacturing fundamentals, especially in capital-intensive processes like wind turbine manufacturing, potentially making Ukraine uncompetitive vis-à-vis other global competitors. Conversely, securing a lower cost of financing may create conditions where Ukraine's integrated wind power value chain would be more competitive than Germany's. While Chinese banks have been fundamental to providing low-cost loans that have spurred the industry forward, Ukraine has also been able to mobilize investment, albeit on the deployment side. Nonetheless, Ukrainian state banks are active and interested in the wind sector, and political support and IFI backing exists, which is a positive sign for future development. Importantly, the existence of war-related risk insurance available for investors, including in the wind sector was mentioned as a highly positive factor by several experts.¹⁵² The decarbonisation of production processes and energy efficiency in the production process could also be key, especially to access potential Horizon EU and Innovation Fund financing which could further spur the sector.¹⁵³

Low labour costs are a key driver for competitiveness in the more labour-intensive production segments, namely blade and tower production, but with some jobs requiring relatively high levels of training and education. This includes welders, composite technicians, machine operators and assembly workers in the production and manufacturing segments, but also mechanical, electrical, industrial and process engineers, as well as quality control inspectors and additional support staff. According to some estimates, Ukrainian labour costs in the wind sector could be below Chinese costs, although this might be offset by varying rates of automation. Ukraine's long strong technical schools and long history and experience in the manufacturing and machining sectors could provide a key boost to the sector¹⁵⁴, but ensuring a strong workforce and pipeline for talent exist will be key to encouraging localisation and preventing delays.¹⁵⁵ Germany's dual education system of apprenticeships and technical schooling, along with industry collaborations (e.g. with Gamesa) or Denmark's specialised wind training institutes and links to Vestas (manufacturer) and Ørsted (energy company) for jobs and internships may provide good examples for Ukraine. Both skills and labour availability are currently an issue due to large-scale emigration, conscription and other losses. While the focus here is on the manufacturing side, the deployment, installation and maintenance sides are even more labour-intensive, and significant upskilling, training and new jobs are needed to keep up with demand, both globally and in Ukraine's renewable energy sector.

This ties in closely with the research, development and innovation field. While currently, state-led research activity on renewable technologies is low due to re-allocation of R&D budgets to other fields, the mechanisms do exist to potentially steer funding if needed. R&D capacity in the wind sector is also increasingly shifting to China, especially due to the ability to quickly creating testing grounds for new technologies and to provide space for innovation and rapid scale-ups.¹⁵⁶ European innovation in the wind sector is

more conservative, with limited risk-taking and long timelines on product development, which contrasts sharply with Chinese rapid innovation. While Ukraine doesn't have to become a new product innovation hub, continuous and incremental improvements to existing production and optimisation of processes could be highly beneficial. This also includes ensuring all certification and standardization with European requirements is met in order to be able to ensure production can also be exported to the EU.

The broader business and regulatory environment are also fundamental for both the manufacturing and deployment of wind power capacity. While Ukraine's regulatory framework is currently supportive of the wind sector and import duty exemptions on wind turbines have not been granted (therefore also shielding domestic producers), expert interviews have pointed out that improvements are still necessary. A focus on transparency and furthering anti-corruption regulation and practices has been raised as key to attract both manufacturers and developers, and aligning fiscal regulations and improving co-ordination between tax authorities and the Ministry of Economy could be helpful to increasing attractiveness.¹⁵⁷ China's model of rapid permitting and free land allocation for prospective manufacturers, as well as OPEX support may provide an interesting case study for Ukraine.

Concurrently, Ukraine's approximation and harmonisation of EU policies, but also strong certification and quality requirements on wind power products make compliance much easier.¹⁵⁸ On the deployment side, issues with permitting and grid access, as seen in Germany and the United States, respectively have the potential to significantly detract from deployment and also manufacturing localisation, so preventing bottlenecks is also key for Ukraine, especially as the sector scales up.¹⁵⁹

The role of industrial policy and state support for the wind sector has been fundamental in terms of scaling up production. Denmark, the home of the wind turbine, is one of the best examples of



this, with the government supporting industry with large-scale R&D, strategic financial instruments and through demand-side measures such as feed-in tariffs that were later adopted by other countries including Germany. As a result of this strategic approach, nearly all wind turbines produced in Denmark between 2004 and 2008 were exported—a trend that continues to this day. Denmark has long been a key hub for wind turbine manufacturing, home to leading companies like Bonus, LM, and Vestas.¹⁶⁰

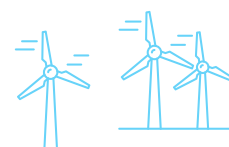
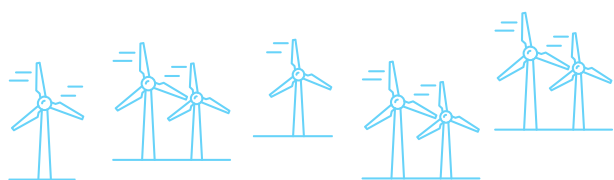
Outside of Europe, the United States also experienced significant demand for wind power expansion, with domestic companies largely meeting this demand. This growth was supported by favorable conditions for wind power and political backing. US renewable energy policies were largely shaped by the Production Tax Credit (PTC) and Investment Tax Credit (ITC), which acted as supply-side measures, though they were often only provided for limited periods of two years. The PTC offered predetermined tax reductions for each output good produced—whether turbine blades or electricity from wind power plants—while the ITC provided tax credits for a portion of investments in green technologies. The Inflation Reduction Act of 2022 established the newest cycle of tax credits.

However, U.S. renewable energy policies have been marked by intermittency, leading to boom-and-bust cycles that have hindered the development of a stable investment environment. While green technology sectors have driven economic development and job creation, policy lapses have caused significant drops in installations, leading to a loss of demand, jobs, and private investment.

China's case study is also key. In 2002, National Development and Reform Commission mandated 70% domestically produced components, enforced in competitive bidding processes. Along with a number of financial mechanisms, low-cost loans and demand-side measures, the number of manufacturing facilities grew from 40 in 2007 to 70 in 2008, with 30 manufacturers offering

commercial products. At the same time, large international wind turbine manufacturers set up production facilities in China to participate in local wind power plant auctions.¹⁶¹ In 2009, China fully revoked the 70% local content requirement following complaints from the World Trade Organization, but by this point the domestic wind manufacturing sector was well-established, with the entire supply chain covered by local companies.^{162, 163} The 2009 amendment to the Renewable Energy Law, which introduced a fixed renewable energy purchase amount for grid operators, further strengthened demand and, in turn, supported local manufacturing. In the following years, additional feed-in tariffs and government programs for large wind power plant developments continued to drive the growth of domestic manufacturing. Now, after stabilizing China has phased out most subsidies.¹⁶⁴

Fundamentally, all experts and respondents noted that the main driver for manufacturing localisation by foreign firms is the existence of domestic wind power demand, with long-term potential, predictable targets and stable policy targets. In Europe, where the demand-side has been strong and incentives have existed, the industry has remained competitive (unlike in the solar PV and lithium-ion battery segments). China's 2006 Renewable Energy Law and subsequent laws mandating renewables adoption have acted as a demand-side pull for turbine manufacturing and other countries including Brazil have been able to achieve localisation. This potential is also strong in Ukraine, where significant deployment of both onshore and eventually offshore wind power may create the needed volume to incentivise foreign company entry or expansion of domestic capacities.¹⁶⁵ While additional drivers and policy reforms are needed both in the EU and in Ukraine (including permitting, grid connections, market design etc.), a strong demand-side vision could spur the larger localisation of foreign companies, firstly as representative office and eventually as potential manufacturing sites.



5.2.3 Economic benefits

In order to model the economic benefits of the potential localisation of the wider wind power value chain in Ukraine, some key assumptions were taken. Firstly, the assumed annual demand in Ukraine would be a somewhat conservative 850 MW of utility-scale deployment. This mirrors the slightly adjusted deployment rates in key

strategic documents. In addition to this, the same annual volume of 850 MW is assumed for export to the European Union. As such, a total annual production capacity of 2 GW, both with an 85% utilisation rate is present in Ukraine to satisfy the demand.

Employment

The localisation of 2 GW of manufacturing capacity and annual domestic deployment of 850 MW of wind power would have significant effect on employment in Ukraine.

Table 6. Potential employment creation across Ukrainian wind turbine value chain

Category	Type	Low	Average	High
Manufacturing job-years	Direct	5,211	6,513	7,816
	Indirect	2,605	3,257	3,908
Construction and installation job-years/year	Direct	2,550	2,635	2,720
	Indirect and induced	340	672	1,003
Operation and maintenance jobs/year	Direct		255	

Source: Hanna et. al. (2024)¹⁶⁶, expert consultations, authors' calculations

The direct employment at the plants creates on average around 6,513 job-years across the life-cycle of the project, although a wide range exists given the varying assumed rates of automation and labour intensity of production across the value chain. Roughly about 3,257 indirect job-years will also be created across the wider ecosystem which has to form around the sector. This includes key suppliers of components, logistics and service providers and other additional inputs.

Significant additional employment is created when the 850 MW of wind power are deployed

in Ukraine, including in the construction and installation sector and thereafter in the continued operation and maintenance sector. Up to 2,720 jobs-years per year would be created directly through construction and installation, while a supporting ecosystem of about 670 FTEs would be needed in terms of indirect and induced labour. In addition, about 255 jobs would be needed for the operations and maintenance of the wind power plants.

Value-added and exports

The localisation of 2 GW of annual wind turbine production capacity would bring significant contributions to Ukraine's gross value-added.

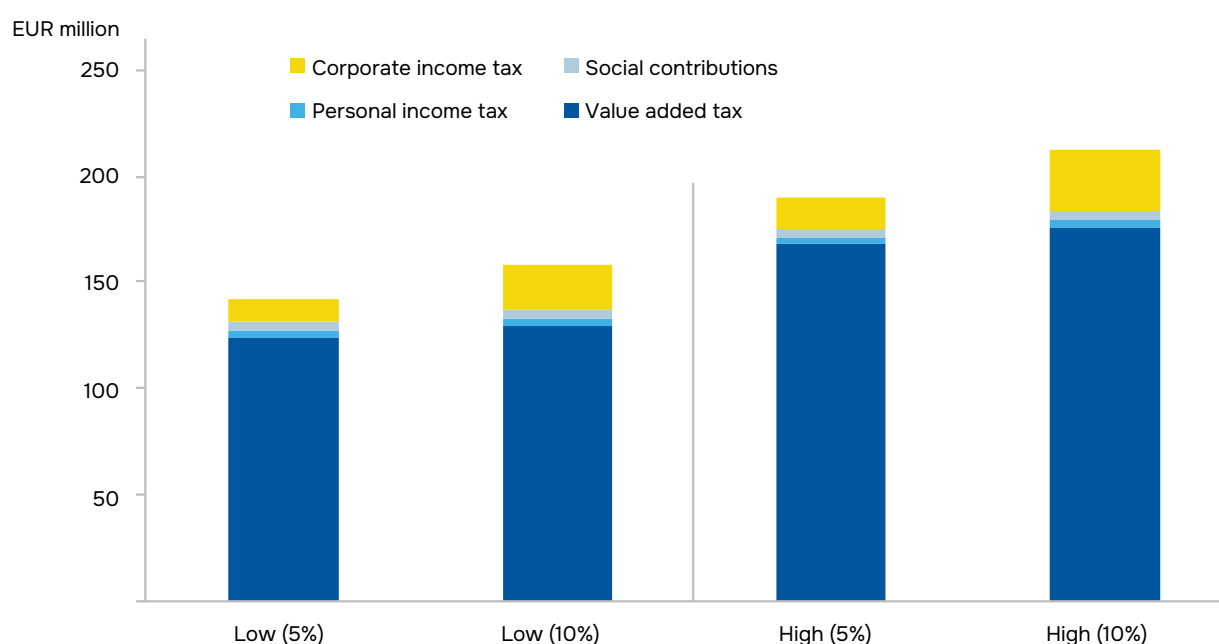
Depending on the WACC scenario and costs presented in the previous section (686.05 EUR/kW-931.17 EUR/kW), and potential revenue margins that the plants may add (assumed 5%-10%), the total contributions to Ukraine's GVA ranges between EUR 247 m and EUR 468 m per year, for an impact of 0.08%-0.16% of Ukraine's GDP.

In addition, the 850 MW of wind turbine exports annually would significantly contribute to Ukraine's trade balance and would act as a key source of foreign exchange. Based on modelled costs and revenue margins, the exported wind turbines could bring in between EUR 612-EUR 870 m annually in export revenues, which is the equivalent of between 1.6%-2.3% of Ukraine's total exports in 2024.

Fiscal revenues

The development of the domestic wind turbine sector would also have significant implications for Ukraine's budget and fiscal position, bringing in much needed revenue.

Figure 19. Fiscal effect



Source: Authors' calculations. Note: Low and high production cost scenarios, with 5% and 10% gross revenue margins

The contribution to Ukraine's budget would vary depending on the cost structures and revenue margins, with a range between EUR 140.4 m and EUR 210.0 m per year. Most of this comes from the VAT incurred on the sales of the domestic wind turbines, which ranges between EUR 122.5

m and EUR 174.1 m. Concurrently, depending on the various scenarios, fiscal support for production may be needed in the form of tax breaks or strategic subsidies or which may decrease the government contribution.

Additional material demand

The localisation of the wind power value chain could have a significant positive impact on domestic material providers across a number of sectors:

Table 7. Potential additional material demand across the Ukrainian wind sector value chain

Item	Material intensity (tonnes/MW)	Total annual potential material demand (tonnes)
Concrete	243.5-413.0	413,950-702,100
Steel	50.6-119.0	86,020-202,300
Cast-iron	4.7-9.0	7,140-15,300

Source: author's calculations

The high material intensity of wind power turbines would translate to significant additional material demand in the concrete, steel and cast-iron sectors. Concrete demand, which is key for the tower foundation and the tower itself, could reach between 414,000-702,000 tonnes per year, which could provide be satisfied by the 50 identified producers or new entrants into the

field. Steel and cast iron is used in both the hub and nacelle, and additional tubular steel is needed in the wind towers themselves. This could lead to annual additional steel demand between 86,000-202,000 tonnes of products annually with an additional 7,100-15,300 tonnes of cast-iron needed, providing a significant market for local steel manufacturers.

5.2.4 Assessment and additional considerations

Ukraine's domestic wind power sector may hold good potential and prove competitive enough to fulfil domestic demand and feed into European value chains as well. While international competition in the wind sector is fierce, Ukraine's wind manufacturing sector has been sustained, with productive forward and backward linkages that have been developed with several other sectors.

Interviews with international manufacturers and experts reveal two primary drivers that shape the decision-making on manufacturing localisation: 1) sustained and stable local demand projections 2) scale of production. On the former point, Ukraine's reconstruction will require significant amounts of wind power, initially onshore and eventually offshore as well. With the rapidly declining LCOE of wind power and good capacity factors, Ukraine's wind future looks bright, which could provide manufacturers with the certainty to make investments into local manufacturing.

Concurrently, on the latter point, roughly 1 GW of domestic annual production was mentioned as a threshold needed to justify investment into local manufacturing. While these deployment levels can be feasible, additional support on the demand-side may be needed for further catalyse deployment of wind power, especially using the domestically produced turbines. Opportunities exist and have already been exploited across the value chain.

Ukraine's domestic resource base may prove key here in terms of driving competitiveness, especially for the provision of cost competitive cement and steel for towers, which show significant potential. This is coupled with a relatively low-cost but highly skilled labour force that is needed for the relatively labour-intensive tower construction process. Blades, which are also more labour-intensive could also be manufactured in Ukraine, although experts' assessment

regarding Ukraine's competitiveness varied. Nonetheless, the modelled results indicate that Ukraine overall is more competitive than at least the German equivalent. Given the logistical challenges imposed by transportation of long blades, local production could be highly justifiable, although significant sectoral investments in the road and logistics sector would need to complement this.

Finally, while full-cycle nacelle manufacturing is not likely due to the high number of components and suppliers required, production of some components already exists, others can be imported, and final assembly can indeed be competitive. Here, strategic import duty exemption on components and equipment that are not produced in Ukraine, or where no possibilities exist could be highly beneficial to decreasing the final cost of the nacelle. Overall, active work is needed on scaling-up the broader supplier ecosystem, but the overall existence of production shows that the sector can be sustained, with potential scaling up as demand increases.

A first step would be the revitalisation of the existing production assets and mapping of the potential for repurposing other assets for production. This would decrease the CAPEX requirements for projects and therefore help diminish the effects of the high current WACC which decreases competitiveness, especially for greenfield projects. Nonetheless, in order to meet both domestic demand and create export markets, new greenfield projects will be needed to increase capacity, meaning that de-risking instruments and concessional financing will be needed in any case to help make projects more competitive. Importantly, more information and further mapping of the existing companies operating across the wider value chain, including sub-component manufacturers, direct suppliers, and companies where existing assets could be repurposed to cater to the wind power value chain. During the elaboration of this report, it has become clear that comprehensive information mapping out the full and expanded wind power value chain is not yet available, limiting the potential for identifying repurposing potential, linkage development and spillovers.

This also opens the possibilities of value chain integration with the European Union, but primarily with Ukraine's direct neighbours, notably Poland and Romania that are developing wind manufacturing sectors of their own. Especially in the supply of steel and additional components, or full towers and blades, Ukraine could leverage its comparative advantage to help fulfil regional demand and contribute to EU's clean energy deployment goals. An assessment could also be made regarding the competitiveness of providing these products to the wider EU market, especially in countries where no corresponding production exists. Importantly, trade financing and export promotion by the Ukrainian government will be key here to catalyse the growth of the sector. Further co-operation and co-ordination are key here as countries scale their wind manufacturing sector, but regulations such as CBAM could also have a major impact on the competitiveness of these exports to the EU. As such, progressive decarbonisation of both the power and metallurgical sector will be needed to ensure long-term economic competitiveness.

Unlike the solar PV and lithium-ion battery segments where Chinese companies dominate, the wind power sector is more heterogenous, with European companies holding significant market shares. Ukraine should primarily attract European companies, both for geopolitical alignment reasons, but also to access additional potential financing sources. As such, deepening contacts with EU players across the value chain is of fundamental importance, with a key role for the government in creating these connections, expanding public-private partnerships, co-operation with international players and further making the case for investments into Ukraine's wind power sector.

This is also the case for the further development of the sector in terms of research, development and innovation. While currently production does exist, continuous improvements in terms of production processes and efficiencies, but also the technologies themselves will be needed to ensure local production can satisfy requirements both in Ukraine and the European export markets. Ensuring technology transfers is key, but further work is needed to establish competent

and well-funded research and innovations centres that work with stakeholders across the value chain and help develop and tailor wind power technologies to local production but also end-market criteria and specifications.

Overall, however, despite some parts of the sector still in a nascent stage, the overall wind technology value chain in Ukraine displays significant promise across numerous segments. Especially the tower and blade segments are highly interesting in the short-term, with additional possibilities also present for further nacelle and sub-component supplier ecosystem development. Further development of the sector is however needed. To strengthen Ukraine's wind turbine supply chain, the country should restore domestic production of specialized steel and heavy plates should be restored, which are critical materials currently imported at higher costs due to war. Before the war, Ukraine produced special steels (used in wind turbine casings and

shafts) at facilities like Electrostal and Dnipros-petsstal, while thick plates (essential for turbine towers and cladding) were manufactured at Azovstal. With these capacities lost, reliance on imports has driven up costs. Re-establishing production is feasible by leveraging existing infrastructure: machine-building plants with electric furnaces could revive special steel output, while Zaporizhstal is well-positioned to resume plate manufacturing. Additionally, idle machine-building capacities should be repurposed to be used in the production of towers, frames, and blades. A set of strategic investment incentives should be provided to manufacturers in support of this transition. There is also a need for government to provide clear and robust deployment targets, but also to further catalyse the development of the sector through both supporting existing players across the ecosystem and spurring new investments.

5.2.5 Conclusion and sectoral development roadmap

Ukraine's wind power manufacturing sector looks more promising. Blade and tower production could be cost-competitive due to labour intensity, strong domestic inputs (steel), and proximity to EU markets. While nacelle production is more complex and the domestic supplier ecosystem is still underdeveloped, partial localisation for selected components and the assembly process is feasible. A mixed model using imported subcomponents and domestic integration is a practical path forward. Ancillary equipment like generators and converters are already produced in Ukraine and can be scaled up further. Altogether, these would provide significant contributions in terms of jobs, economic benefits and would stimulate other industry demand, including for sectors like steel and cement.

Ukraine has the potential to meet domestic wind power goals and supply equipment to the EU, but high financing costs remain a major barrier to investment and sector growth. Targeted support, such as duty exemptions on equipment and key inputs, can help reduce production costs. Equally important are the reliable domestic deployment targets and demand-side policies to attract foreign direct investment and encourage multinational localisation. In the short term, Ukraine should assess and revitalize existing manufacturing and scale up tower and blade production. In the medium term, efforts should focus on expanding nacelle assembly and strengthening component supply chains. Over the long term, investment in R&D, exploration of offshore wind, and diversification into non-EU export markets will be key to sustained growth.

Table 8. Wind turbine sectoral roadmap

Short-term (1-2 years)	Mid-term (2-5 years)	Long-term (5+ years)
• Assess potential of revitalising existing manufacturing • Attract investments in tower and blade manufacturing and assembly operations • Map local nacelle and turbine component and sub-component production and assess export competitiveness • Organise production of special steel at machine-building plants with electric furnaces • Assessment of existing linkages with other industries • Deepen contacts with other regional and EU players across the value chain	• Scale-up tower and blade production and generate new investments into the turbine and nacelle segments • Investment incentives for the organisation of heavy plate production at Zaporizhstal • Strengthen component supply chains ecosystem with strategic support • Provide trade financing support via export credit agency	• Expansion of domestic R&D for existing technologies and entry into new segments (e.g. offshore) • Exploration of export market potential beyond EU

5.3 Lithium-ion batteries

5.3.1 Value chain overview

The lithium-ion battery value chain is relatively short, but highly technologically complex and heavily dependent on a small number of critical minerals mined and processed in a few countries globally. The primary components of li-ion battery chemistries are the cathode, anode and electrolyte, which are used to produce a battery cell which is then integrated into a battery pack. Several battery chemistries exist, with the Nickel Manganese Cobalt Oxide (NMC) and Lithium Iron Phosphate (LFP) chemistries currently dominating the global market. The NMC features a variety of mineral ratios to produce batteries with varying characteristics, but all feature high energy density and good longevity, offering a good

balance between power output, energy capacity and lifespan. The LFP is less energy dense, but it is safer, more durable, and importantly doesn't include the highly geographically concentrated and expensive nickel and cobalt.¹⁶⁷ The anode is primarily made of graphite while the electrolyte is traditionally a lithium salt dissolved in organic solvents. Fields of technological advancements aim especially at better energy density, faster charging, greater safety, and more cost-effectiveness.¹⁶⁸ A major milestone was achieved in 2024 when the average price of an electric vehicle (EV) battery pack fell below the USD 100/kWh threshold.¹⁶⁹

	Material Processing	Component Manufacturing	Cell Manufacturing	Assembly
Description	Refining raw minerals into battery-grade materials (e.g. lithium hydroxide).	Production of cathodes, anodes, electrolytes, and separators.	Assembly of cells using electrodes and electrolytes.	Final assembly of battery cells into packs or stations
Major producers (% global market share)	Lithium: China (57%) Nickel, Manganese: China (70%)	NMCO: China (57%) LFP: China (88%)	China (68%) Europe (9%) USA (9%)	China (75%) USA (7%) Europe (6%)
Ukraine production	Partial capabilities	No production	No production	Past capabilities

Source: Greitemeier et al. (2025), EU JRC (2023), Authors' elaboration

The global battery value chain is extremely geographically concentrated, with China holding shares around 70% in the processed materials, component manufacturing and assembly stages, with very few other major countries currently participating in the supply chain. In 2024, over 75% of all batteries sold worldwide were produced in China at low costs which additionally

dropped further by 30% the same year, outperforming similar European and North American batteries by 20-30%. Several structural factors underpin China's cost advantage: a high concentration of technical expertise and production capacity fosters both economies of scale and continuous innovation. In addition, deeply integrated supply chains have reduced manufacturing costs

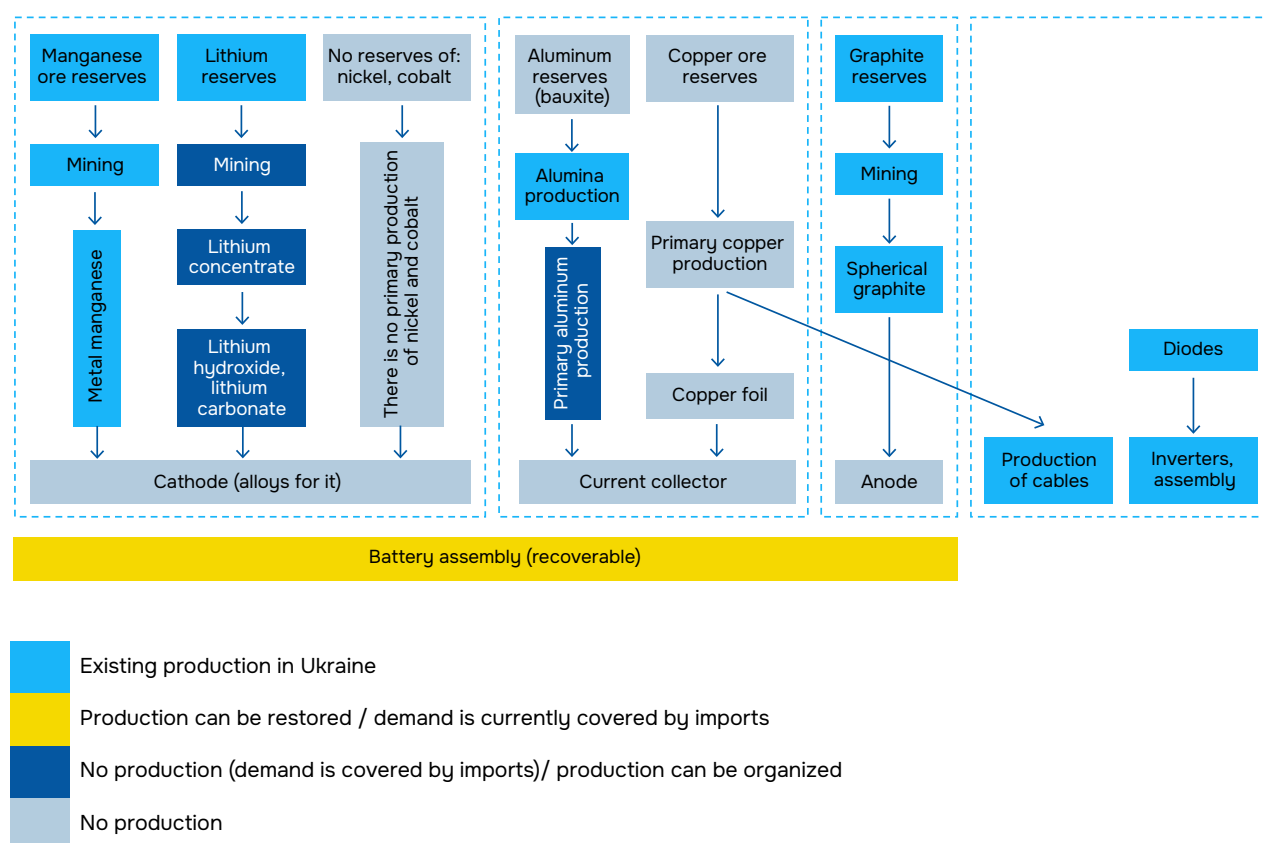
and accelerated product development cycles. The Chinese battery industry has also benefited from its early and sustained focus on LFP chemistries. In addition, intense domestic competition has further shaped the market structure and contributed to lower prices. In addition, the sector is currently facing massive overcapacity, with BNEF estimating 3.1 TWh of production capacity, 2.5 times as much as global demand.¹⁷⁰

Some of the key companies in the segment include CATL, which is the largest supplier of lithium-ion batteries globally, specializing in the production of batteries for electric vehicles as well as energy storage systems. Two major players also from East Asia are South Korean LG Chem and Japan's Panasonic, which are fundamental for batteries for consumer electronics and au-

tomotive applications. Another major player is the American Tesla, with its gigafactories in the US and other locations, partnerships with other major battery manufacturers and wide range of products for electromobility and grid storage.

European battery manufacturers have faced a challenging environment. Production costs remain significantly higher, driven by a shortage of specialized labour, limited economies of scale, and a technological focus on more expensive nickel-based chemistry. These constraints have made it difficult for European firms to compete with Chinese producers or scale operations to reach profitability, most notably evidenced by the bankruptcy of Northvolt, a key hope of the European homegrown battery industry.¹⁷¹

Figure 20. Ukraine battery manufacturing value chain



Source: Authors' assessment.

Ukraine's involvement in the lithium-ion battery value chain is at a relatively early stage, although some potential and experience exists across various stages.

Critical raw mineral mining and process: Ukraine has existing deposits and production of a variety of minerals critical to various lithium-ion battery chemistries. The country already produces sizeable amounts of manganese, and facilities exist for the production of >99% manganese metal at “JSC Zapozihzhzya Plant”, a metal crucial for NMC cathodes. In addition, high-quality processed battery-grade graphite was produced by “Zavalivskyi Graphite”, critical for anode chemistries. There are also additional deposits of high-quality graphite that have been identified in Ukraine.

While no major reserves of nickel and cobalt are currently registered, Ukraine does have several potentially promising lithium deposits. The most promising of these is the Shevchenkiyske deposit near the frontline in the Donetsk oblast, while two others are located in the central part of Ukraine. Currently, no lithium production or processing exists in Ukraine, and prospective costs of both processes are unknown.

Component and cell manufacturing: No manufacturing of either battery components (cathode, anode or electrolytes) or cells has taken place in Ukraine in the past, with all key inputs historically imported.

Assembly: KNESS group assembled batteries from cells imported from China until the end of 2024 when production stopped after the removal of import duties made production uncompetitive.



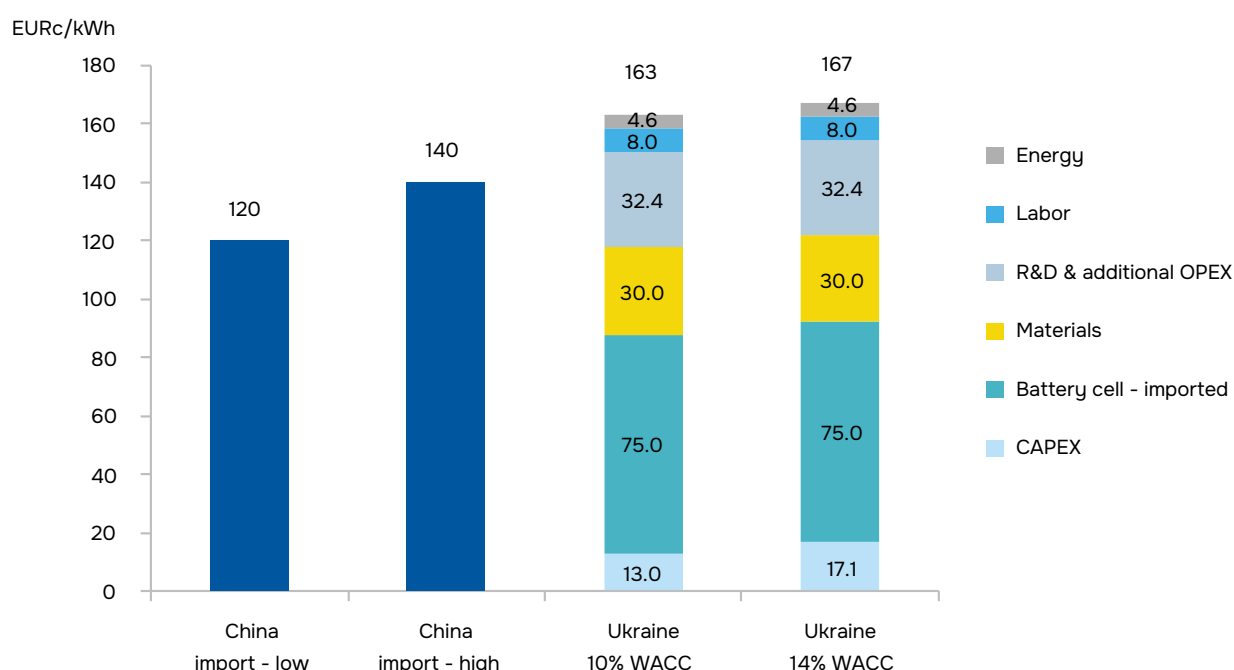
5.3.2 Results and analysis

Due to a general lack of Ukrainian cost data for the processed critical mineral inputs as well as the component and cell manufacturing, the analysis focuses primarily on the final assembly step. Both primary and secondary research was used to create a scenario where an assembly plant with an annual capacity of 3 GWh is built in Ukraine under the WACC assumptions of 10%-14%. The cells are imported from China and are

then assembled locally at the plant into battery stations. As the focus here is primarily on the domestic market, the only major point of comparison are the Chinese imported stations. All values are standardised to 2024 Euros cents per kilowatt-hour (EURc/kWh) of lithium-ion battery capacity produced. The results for both scenarios are presented below.

Results

Figure 21. Costs of production – 3 GWh annual production capacity



Source: Expert consultation. Authors' calculations.

Ukraine's battery assembly costs in a 3 GWh facility range between 163-167 EUR/kWh, which are between 16%-39% more expensive than imported final Chinese battery stations. This difference is highly significant, and without any

additional industrial policy would make domestic production deeply uncompetitive. Domestic assembly has nonetheless existed in the past and additional factors may help make the sector more competitive.

Analysis

Indigenous industrial capabilities in the lithium-ion battery sector in Ukraine but also Europe are generally weak. The leading producer across most of the stages of the value chain, as well as the most important companies are all Chinese or East Asian.¹⁷² The sector is currently also facing significant overcapacity, which has further depressed costs and made it harder for other players to enter the space and compete.¹⁷³ Nonetheless, some significant capacity and upcoming additions in across the value chain are expected in some of Ukraine's neighbours. In 2022, Poland held the second largest battery cell manufacturing capacity globally at 73 GWh, with 6% of the global total and Hungary held 38 GWh, 3% of the global total.¹⁷⁴ In Hungary significant capacity additions are expected from SK Innovation, Sam-

sung and CATL, while Slovakia and Romania are also experiencing investments in major capacity additions.

Ukraine does possess some of the key critical minerals needed for lithium-ion battery production (although not all of them), including some downstream refining and processing capacity. This is especially the case in manganese metal (cathode material) and graphite (anode material). The competitiveness however differs by production stage. The competitiveness of Ukrainian graphite production has been impacted by the war, including through the sharp increases in electricity costs, electricity outages and higher logistics and transportation costs.¹⁷⁵ Manganese production has also declined sharply since the

start of the war, including for processed ferromanganese and silicomanganese. Production of battery-grade manganese metal at the Zaporizhzhya Ferroalloy Plant has currently been suspended as the primary end-market – China – has ample refining capacity. Nonetheless the remaining key minerals, including lithium, nickel, cobalt and phosphates (for various chemistries) are either not present or still under the assessment of development, and the sector is not further assessed here.

Historically there has been no production of precursor materials or the cells themselves within Ukraine and competitiveness is difficult to assess given the lack of estimates of future domestic processed mineral input prices (if the assets are restarted or developed) and the CAPEX required for facilities. A 20 GWh integrated battery being constructed in Slovakia by Chinese Gotion High Tech and Slovakian Inobat is currently estimated at USD 1.29 bn for 20 GWh of capacity. The lack of domestic production of any precursor materials or the cells themselves leaves Ukraine highly dependent on imported battery cells for its final battery station production but also exposes it to significant price fluctuations. The imported battery cells account for 75 EUR/kWh or roughly 45% of the total cost of the final battery stations being produced in Ukraine.

Other materials which are required to produce the final battery stations, including copper cables, imported diodes for inverter assembly and other components used in the production process, which account for roughly 18% of total production costs. Energy costs, unlike in the further upstream sectors play a much less significant role, accounting for only 3% of the total final cost of the battery station. Ukraine's energy cost has generally been low compared to the rest of Europe, and although significant capacity additions and investments will be needed, an overall greening of the electricity sector could be beneficial to creating green power purchase agreements able to supply the battery assembly plants.

The CAPEX component as a share of total production cost is relatively low compared to the other value chains, accounting for only between 8% to 10% of the total levelized cost of production under a 10% and 14% WACC scenario re-

spectively. While decreasing the financing rate is key in general, the difference in WACC here only has a 2.5% effect on the total cost of production. While countries such as China and Indonesia significantly relied on state-owned banks for the development of the broader lithium-ion battery value chain (along with other methods), Ukraine could assess additional opportunities. These may include loan guarantees from institutions such as EIB, but also blended finance, concessional capital or establishing off-take agreements to provide greater clarity on sales.

The labour component is very low, despite the relatively labour-intensive nature of the assembly stage, accounting for only 5% of total costs. This reflects the low-cost nature of the Ukrainian labour force, with many of the specific skills required for battery assembly present in the country. This indicates a potential advantage in areas not only related to assembly but also pack integration and additional pre-assembly services. Concurrently, additional training and upskilling would be needed, especially if other parts of the value chain were localised. For example, Indonesia established the National Battery Research Institute, which has training, education and industry support as a major pillar, and has been fundamental to help quickly support and upskill the population to enable the quick ramp-up of the country's battery industry.¹⁷⁶ In terms of private-led initiatives, Northvolt in Sweden launched its Greenhouse Academy, an in-house educational platform that combines online learning with case studies and expert-led courses to upskill the company's employees.¹⁷⁷

A more general category of research, development and additional operations expenditure, including maintenance and upgrades takes a large share of total production costs. In terms of the R&D specifically, significant effort is needed to adapt the final battery stations to the end-user specifications, including for high-customisation segments such as aerospace and defence applications. In an integrated facility that includes precursor and cell manufacturing, the total R&D spending would be a significant share of the total cost, with many countries creating specific policies to ensure continued technological innovation. Japan has significantly supported R&D in the sector through the 2023 Act on the

Promotion of Natural Security, which included direct support for R&D to enhance its domestic production capabilities, with a specific focus on establishing advanced production facilities meeting high product standards with subsidies conditioned on meeting higher product standards compared to current benchmarks. In 2024, China also introduced regulations requiring lithium-ion battery producers to re-invest 3% of their revenue into R&D.¹⁷⁸

The industrial policy dimension is fundamental to the global and Ukrainian lithium-ion battery sector, with significant support for the supply-side. Ukraine previously had import duties on lithium-ion battery stations which enable domestic competitiveness in the assembly stage, and a corporate income tax exemption exists for companies in the sector. While these duties, along with VAT on energy equipment, were temporarily lifted after July 2024 to rapidly stimulate the import of equipment, they are set to expire in 2026. This means that the imported energy equipment will once again be subject to VAT and customs duties. A reversal of the duty exemptions and consideration of domestic incentives may be needed after stabilization to restore the competitiveness of domestic players.

Some lesson can be learnt from China's industrial policy approach to the battery sector, where the government has implemented loans, tax breaks, and foreign investment incentives to foster innovation and efficiency within its domestic battery manufacturing sector. Additionally, the country has implemented strategic policies such as export licensing for lithium extraction and advanced battery materials in 2025 to ensure control over essential technologies and maintaining its dominant market position. Nonetheless, subsidies have been reduced significantly since 2017 given attainment of global competitiveness in the industry, a good example of the infant industry argument. Japan's approach has also included various financial incentives aimed at advancing its battery sector. The government allocated substantial subsidies in 2021, with USD 900 m directed towards supporting battery storage

production and improving manufacturing infrastructure. Furthermore, the US has offered substantial tax incentives to support domestic battery manufacturing, such as the Investment Tax Credit (ITC) under Section 48C, which provides a net capital expenditure benefit, reducing costs by 30%, or approximately USD 65 million per GWh, compared to gross CAPEX for establishing manufacturing facilities. This brings US manufacturing costs closer to those in China, where the CAPEX for lithium-ion batteries is USD 60 million per GWh. These incentives are reshaping the US battery cost curve by lowering domestic production costs by USD 45 per kWh. As a result, US gigafactory capacity has increased from around 700 GWh in 2022 to over 1.2 TWh in 2023, although the future of these benefits is somewhat uncertain under the second Trump administration.

Importantly, creating long-term local demand-side certainty is a key piece of the puzzle to ensure stability and investment. In the case of Ukraine, demand will come in the form of battery stations needed for utility-scale electricity storage, but also for battery packs used in electromobility. The government is already supporting electric vehicle deployment through tax and import customs duty exemptions, but there are also tax exemptions on potential producers which could further help strengthen demand for the domestic battery sector and lead to repurposing and upgrading within the automotive sector. Both the power and electromobility sectors however require significant deployment support to ensure adoption and may include some local content requirement to ensure Ukrainian batteries are used. A key example is the U.S. Inflation Reduction Act (IRA), which provides significant support for EV and battery manufacturing. It offers a tax credit of up to USD 7,500 for battery electric and plug-in hybrid vehicles, split between meeting local content requirements for battery components and critical minerals. These requirements will rise progressively, reaching 100% domestic sourcing for battery components by 2029 and 80% for critical minerals by 2027.



5.3.3 Economic benefits

When modelling the economic benefits of the localisation of a new battery assembly facility, some key assumptions were taken. The facility has a rated annual capacity of 3 GWh, with a utilisation rate of 85%. The total annual production of the facility is sold and deployed domestically.

Employment

The actual plant itself could employ between 250-375 full-time employees, on-site, including battery assemblers, a variety of engineers, quality control, testing and inspection teams as well as general management and administration. An additional 250-375 jobs could be created indirectly in logistics and transportation, raw material and equipment supply as well as additional professional services.

The much larger job creation is at the deployment stage. Deploying 3 GWh of battery storage annually could generate between 5,625 and 7,125 jobs across the construction stage, in professional services and wholesale trade and distribution.

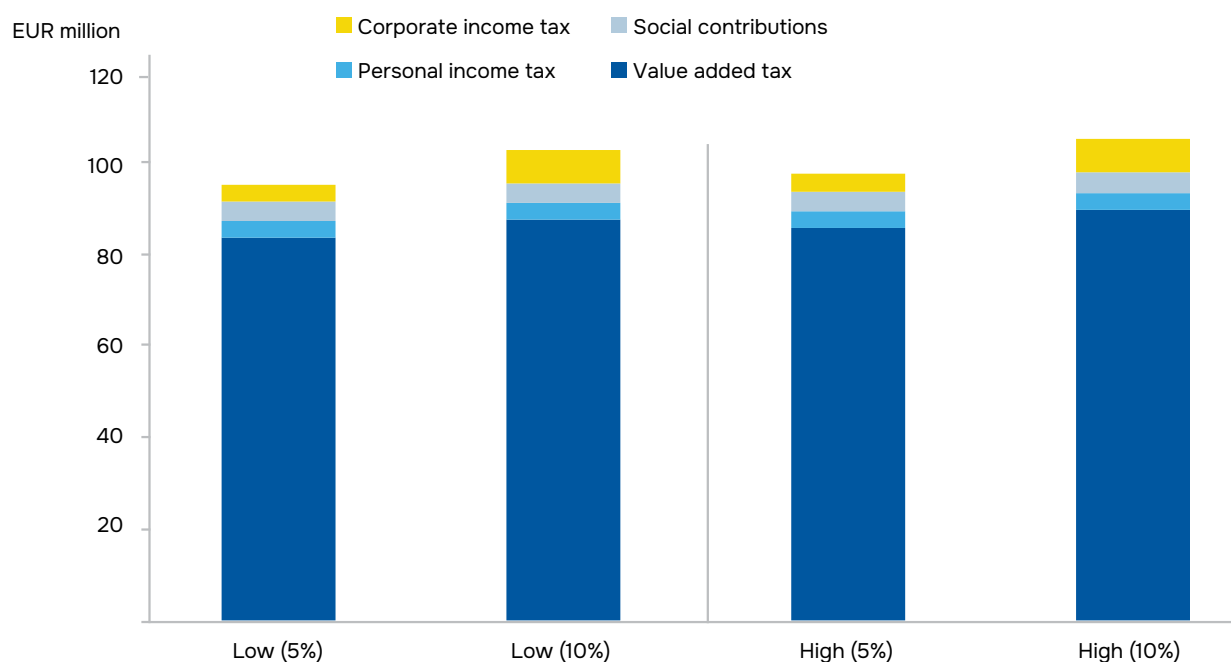
Value-added

While the annual revenue of the battery assembly facility could range between EUR 436 m and EUR 469 m based on WACC and revenue margin considerations, the gross value-added is significantly lower due to the high share of inputs that are imported from abroad, specifically the cells from China. As such, the GVA for 3GWh of annual battery capacity ranges between EUR 74 m and EUR 107, representing roughly 0.04%-0.06% of Ukraine's 2024 GDP.

Fiscal revenues

The further localisation of li-ion battery localisation in Ukraine could have significant positive effects on government budgets. At the moment, all profits of enterprises engaged in the production of lithium-ion batteries are exempt from taxation, with the profits intended to be re-invested back in to further research and development.¹⁷⁹

Figure 22. Fiscal effect



Source: Note: Low and high production costs, with 5% and 10% revenue margins

According to the model based on the 3GWh plant, and with the exemptions on profit taxation, Ukraine's government could receive between EUR 93.5 m and EUR 99.8 m annually, primarily

from the VAT received on the li-ion batteries sold within the country, providing a significant boost to the government budget.

5.3.4 Assessment and additional considerations

It may be too early to truly assess the competitiveness of Ukraine's potential integrated lithium-ion battery sector, especially if the ambition is primarily to utilise domestic critical minerals.

While critical minerals play a crucial role in all three of the assessed value chains, their role is arguably the greatest in the lithium-ion battery value chain. Especially for NMC, but also LFP chemistries, large volumes of extracted and then highly processed minerals are required. China holds the vast majority of global critical mineral processing, but Indonesia's entry into the lithium-ion battery chain provides a possibly interesting case study for Ukraine. With the world's largest reserves of nickel, the Indonesian government has forced Chinese nickel smelters to relocate to Indonesia under a raw ore export ban, eventually also compelling in-country precursor manufacturing, then cell manufacturing and assembly, and also electromobility production. Tools used included

the aforementioned raw ore export bans, tax holidays, import duty exemptions on capital goods, super deductions tax schemes on R&D and TVET, the creation of industrial zones, as well as the creation of a state-owned battery enterprise with significant global partnerships.¹⁸⁰ Similarly, Indonesia is attempting to build an end-to-end domestic battery value chain centered on its vast nickel reserves, which account for roughly 21% of the global total. The Indonesian government has an aspiration to develop 140 GWh of battery cell manufacturing capacity by 2030 and has attracted major players like LG, CATL, and POSCO. The strategy relies on leveraging its upstream mineral advantage to attract downstream investment in refining, cathode production, and cell manufacturing. However, analyses show that even with vertical integration and scale, Indonesia's production costs are expected to be 5-10% higher than the PRC's, highlighting the critical need to accelerate operational learning

curves and reduce capital expenditures to close the gap.¹⁸¹ Nonetheless, this experience may not be replicable in Ukraine due to significant mineral specificities, global mineral market shares, energy costs and a variety of other factors.

Ukraine's critical raw minerals base does indeed hold potential, with strong potential deposits of some of the key battery minerals including lithium, manganese, iron and graphite. Nonetheless, Ukraine does not hold a highly significant market share in any of the critical minerals, production costs for some are still unclear and the lead times for new mines – for example for lithium extracted from spodumene rock – could take up to 5-15 years, depending on variety of factors such as regulatory and permitting processes, infrastructure availability, and financing. The economics of critical mineral mining and processing are also highly complex with high CAPEX and would be complicated by the high WACC, although this may be reduced through the US-Ukraine Agreement and other initiatives. At the same time, off-take requirements may be a part of any investment, which could leave limited mineral production capacity available for domestic refining. Importantly, there are also some key minerals including nickel, cobalt and phosphates that are not produced in Ukraine and would have to be imported (based on the chemistry chosen). The supply of refined critical minerals is already highly concentrated, and the lead company operating the lithium-ion production plant would need to ensure off-take agreements and stable supplies are in place.

The European Union and the United States are actively seeking supply chain diversification and reducing their reliance on China through the Net Zero Industry Act and the Critical Raw Minerals Act in the EU and the Inflation Reduction Act, Defence Production Act, as well as several Executive Orders. Ukraine could position itself as a strategic nearshoring partner, initially especially in the upstream parts of the value chain, providing a stable critical mineral supply chain to refineries and processing plants in the West.

While this is not a long-term strategy and may lock Ukraine into a pattern of low-value-added exports, it could be a first step towards eventually localising the refining or processing steps within the country or skipping it and importing some refined metals for precursor production. In any scenario, the importance of regulatory compliance, adherence to environmental, social and governance standards and alignment with the EU Battery Alliance aspects would be key.

Ukraine could also consider positioning itself as a recycling hub for lithium-ion batteries. Given the relatively short life cycle compared to other renewable energy technologies significant recycling capacity will be needed to decrease the pressure on primary mining production. Most metals can be recovered with little loss of their physical and chemical properties and recycling hubs may become an important provider of minerals for EU producers. At the same time, the economics of battery recycling differs dramatically based on chemistry types, and the sector may face overcapacities as well.¹⁸² Partnerships with other recyclers, including cost-sharing agreements and joint ventures may be an option and would help fulfil circularity targets under EU battery regulations.

Further integration into the EU battery value chain could also be feasible via increased co-operation with Ukraine's direct neighbours, most of whom are building up some of the most important lithium-ion battery sectors in Europe. As Poland, Slovakia, Hungary and Romania build up their own battery manufacturing capacities, strategic opportunities may exist for Ukraine either as a supplier of raw or processed minerals, but also additional auxiliary supporting equipment including cabling, casings and other systems. In addition, the economies of scale attained by Ukraine's neighbours may lead to lower costs of the battery cells that can then be assembled into packs and stations in Ukraine, especially given geographical proximity, the existence of integrated supply chains and regulatory convergence.



Concurrently, the domicile of leading multinational companies in the sector is also key considering the geopolitics of critical mineral supply chains. The major battery manufacturers are primarily Chinese, often with vertically integrated value chains and long-term agreements with electromobility companies. At the same time, there are also South Korean and Japanese companies that may not be as adverse investing into Ukraine and the country's reconstruction.

While the prospects for integrated lithium-ion battery value chain production in Ukraine are still highly unclear, there are strategic considerations behind having at the least the assembly stage localised in the country. Given the development of Ukraine's defence and aerospace sector, there

may be significant potential for batteries in military technologies, the supply of which would therefore be a key supply chain risk. As such, in addition to the existing and growing battery storage market, and possible longer-term potential in the wider electromobility space, defence technologies battery demand could create the levels of scale needed for larger assembly localisation and better economies of scale.

This may be especially important as a potential avenue could be to rather focus on more niche, small-scale cell manufacturing for highly specialised applications, including military-grade applications such as drones, aerospace tech or defence-related battery markets which need more specialised manufacturing and adaptation.

5.3.5 Conclusion and sectoral development roadmap

Ukraine currently lacks experience in battery cell manufacturing, but assembly from imported cells could be scaled up to meet domestic demand. The estimated cost of assembled battery stations ranges from EUR 163-167/kWh, roughly 16-39% higher than imported Chinese equivalents. Imported battery cells currently account for about 45% of the total cost, while R&D and OPEX, which includes maintenance and upgrades needed to adapt final battery stations to end-user specifications also make up a significant share.

Ukraine has deposits of lithium and several other battery minerals, but development is uncertain due to the yet to be confirmed production costs, generally long lead times in the mining sector, and very high capital requirements, exacerbated by investment risk and financing costs. However, opportunities to develop the sector may exist through EU financing, the US-Ukraine Minerals Deal, and off-take or product-sharing agreements. Strategic cooperation in mineral supply and ancillary battery components with nearby

EU manufacturers (e.g. Poland, Slovakia, Hungary, Romania) could also be beneficial, especially in terms of reducing the cost of imported cells. Expanding assembly for domestic EVs and public transport and other niche applications would help scale the sector, but significant demand and strategic impetus may come through the scaling of Ukraine's defence and aerospace sector.

In the short term, Ukraine should map domestic battery demand, scale up assembly using imported cells, and invest in RD&I to adapt products to end-user needs. It should also reassess its critical mineral reserves and the viability of extraction under current risks. In the medium term, regional supply chain cooperation with neighbouring battery-producing countries (e.g. Poland, Slovakia, Hungary, Romania) can help reduce costs. In the long term, Ukraine can continue developing its critical minerals sector through off-take and product-sharing agreements and position itself within the broader European battery value chain.



Table 9. Lithium-ion battery sectoral roadmap

Short-term (1-2 years)	Mid-term (2-5 years)	Long-term (5+ years)
• Map domestic li-ion battery demand including other sectors. • Reconsider import exemptions on final assembled battery stations • Support revitalisation of assembly capacity • Explore RD&I in assembly for end-product applications • Explore linkages with IT sector, especially for EMS software for both Ukrainian and EU markets • Re-assess existing critical mineral reserves according to international standards (e.g., JORC) and economics of extraction	• Pursue regional supply chain co-operation with neighbours to reduce costs • Scale-up assembly capacity in line with domestic sector developments (energy, electromobility, defence) • Re-assess economics of domestic mineral processing in line with extraction and global developments	• Explore potential of entering other parts of the value chain (pre-cursor or cell production) • Continue with domestic critical raw mineral sector development, assessing strategic opportunities

6.

Discussion and policy implications

The localisation of renewable technology manufacturing in Ukraine is an opportunity to meet domestic renewable deployment goals, strengthen the country's industrial base, enhance energy security, and position the country as a player in emerging green value chains. Building on the analysis of the solar PV, wind, and battery technologies, this section synthesises cross-cutting insights from Ukraine and outlines key policy dimensions and strategic recommendations need to be considered.



Industrial capabilities

Ukraine's industrial capability for renewable technology manufacturing localisation will require substantial rebuilding and modernisation. While Ukraine exhibits a medium level of economic complexity according to the Harvard Growth Lab's Economic Complexity Index (ECI), measuring the diversity and sophistication of a country's productive capabilities, the record has been mixed in terms of the manufacturing of high-tech products. Within the renewable energies segment some production of high value-added technologies exists (e.g. final wind nacelles), and some high-tech manufacturing in other energy technologies (e.g. turbines for thermal and hydro power plants) and other components (e.g. transformers) is also localised in Ukraine. Significant modernisation and investment are however needed to revitalize these sectors, and to prevent the further loss of production capabilities and knowledge, both of which could be worsened by the ongoing war. This reduction in economic complexity is in contrast with other countries that have been building up their industrial and high-tech base and where significant policy efforts and investments have been made to scale up production. Countries such as Czech Republic, Poland, Romania or Malaysia may provide interesting case studies in how technological upgrading, product development and export diversification has developed and what lessons can be learnt for Ukraine.

Exploring the repurposing of underutilized facilities and technical expertise could accelerate localisation, while keeping CAPEX low, but would not be enough if Ukraine wishes to dramatically scale up production to meet both domestic demand and create export industries. Strengthening industrial capacity will require leveraging cross-sectoral synergies, particularly with advanced industries like defence and aerospace, which may share some manufacturing processes and standards with renewables technologies or may include them in various parts of the production process. Many countries have successfully repurposed assets or entered new product lines based on horizontal, vertical and transversal linkages. For example, Czech Republic was able to use knowledge from automotive component

manufacturing to enter the aerospace segment, with significant use of EU structural funds that helped support diversification through regional innovation centres.¹⁸³ Ukraine's turbine, machinery and IT sectors here especially may provide opportunities to enter new, more high-tech segments.

A key component of developing a robust green technology manufacturing strategy is conducting a comprehensive mapping of existing companies within the sector, which includes identifying all suppliers and potential producers of related products. This mapping process would provide a detailed understanding of the current supply chain and help uncover any gaps or opportunities for collaboration among businesses within the green technology space. Additionally, it is important to investigate the potential to restart or repurpose existing production sites or manufacturing assets that may no longer be in use or are underutilized. This could involve assessing whether facilities from industries such as automotive or traditional energy could be adapted or retooled to produce renewable energy components across the three value chains. Such initiatives could rapidly scale up domestic production capacity while reducing the need for expensive new infrastructure investments.

The country also ranks low on the Logistics Performance Index, a World Bank measure assessing transport infrastructure, customs efficiency, and delivery reliability which highlights bottlenecks in moving goods efficiently across the country and beyond. Concurrently, key logistical and transportation routes are being restored, but significant investment into roads, railways and export infrastructure will be needed to reduce logistics costs and times and help export competitiveness. Some of these administrative and customs processes are already taking place given the harmonisation with EU standards as part of Ukraine's EU accession process, but many others issues remain. A key step in helping the competitiveness of the renewable energy manufacturing sector would be to conduct a targeted logistics audit to identify infrastructure gaps affecting the transport of equipment. This audit would focus on key road and rail links connecting

industrial zones to deployment areas in Ukraine and to EU borders, pinpointing areas needing upgrades. Addressing these gaps will improve the efficiency and cost-effectiveness of moving renewable energy components to market, boosting the competitiveness of the sector.

Energy reliability, currently undermined by war-time damage to generation and transmission infrastructure, will need to be restored through targeted investment in grid stabilisation and decentralised, resilient energy systems. Addressing these vulnerabilities will be essential to ensure a stable power supply for energy-intensive manufacturing activities, especially as some industries suffer high loss rates or even risk equipment damage if blackouts occur. While Ukraine's power mix is still uncertain, it is possible that energy costs could be low, which may offer a long-term cost and competitiveness advantage. Corporate PPAs and domestic renewable deployment can play a central role in ensuring reliable, cost-effective utilities for manufacturers and may pro-

vide an avenue for long-term economic competitiveness. Ultimately however, the question of energy and utilities more broadly rests on a wide range of other policies that must be implemented, but which are fundamental to the roll-out of the renewable energy sectors (see more in the Demand-side section below).

The government could further support the sector by designating renewable energy industrial parks across Ukraine with significant investments made into resilience, utility provision (both on-site or nearby), logistics and transportation connections and optimal placement between deployment areas and export infrastructure. Ultimately, further co-ordination is however needed and could be done through the establishment of a Renewable Manufacturing Development Agency that would tie together all aspects of the industrial process, including coordinating industrial parks, land allocation, supply chain mapping, and investor services for target technologies.

Critical raw minerals

While Ukraine's critical raw minerals sector could hold potential for the country's economic development, further work is needed. Iron and steel, titanium, manganese and graphite are all already produced and hold significant promise for future development and expansion, while the status of the lithium sector is still unclear given questions around the deposits and project economics. At the same time, the production of metals that Ukraine already historically produced, including gallium, germanium and silicon could be revisited, especially in light of the dominance of China and the importance of these metals for the global and European semiconductor sector.

To ensure the sustainable development of the sector, Ukraine's government should develop a comprehensive national mineral strategy that takes a broader, long-term view of the sector, considering existing agreements and obligations and matching these with its other industrial plans. This strategy should include realistic pathways to add value to Ukraine's minerals, taking into consideration the competitiveness of the sector while evaluating potential domestic and EU de-

mand across industries. A crucial component of this strategy would be the development of a national minerals demand-supply model. Such data and analytics are essential for creating holistic industrial policy and strengthening negotiating positions. These models can assess the projected mineral demand tied to national energy transition plans, identify resource gaps or surpluses for meeting manufacturing localization targets, and highlight needs for regional and international cooperation.

While not directly replicable, the case of China does provide some important lessons in long-term planning and domestic diversification. As just one example, China over the course of three decades moved from rare earth element mining to processing, to basic product design (e.g. permanent magnets) to high value-added products (e.g. electric engines), through consistent and well-supported industrial policy.¹⁸⁴

If the processing of critical minerals is pursued as a strategic policy, it is important to ensure that sufficient amounts of minerals are available for the domestic market. Investment and off-take

contracts with developers must be structured in a way that does not fully constrain the availability of minerals for domestic use, allowing Ukraine to meet its own needs while participating in glob-

al markets. Any processing should also consider how the evolution of Ukraine's energy and financing system may adversely impact new facilities, and mechanisms to counteract this.

Access to finance

Access to finance presents a critical barrier to large-scale manufacturing localisation. Ukraine lacks deep domestic capital markets, and private lending for green industrial projects is limited due to high perceived risks and the unavailability of long-term, affordable credit. Concessional financing from international financial institutions (IFIs) remains limited, and risk mitigation instruments for manufacturing investments are largely absent. The current financial ecosystem does not offer the scale, cost structure, or instruments needed to support capital-intensive localisation efforts. Access to finance has been a fundamental driver of the development of green technology value chains in China and many other countries, and given the current competitive landscape and modelled results, decreasing the WACC is a primary priority to improve sector competitiveness. Unlocking investment will require lower financing costs, enabled by grants, IFI support, targeted de-risking tools, including insurance and scaled-up concessional lending. For foreign companies, additional barriers include ineligibility for key domestic programmes, restrictions on foreign currency operations, and high capital charges imposed by their home-country banks under Basel rules, which further inflate the cost of financing Ukraine-based projects.

To encourage private sector financing for green manufacturing, the government could extend loan guarantee schemes that reduce the risk for commercial banks. By including green manufacturing into the scope and covering part of the loan default risk, the government would make it more attractive for banks to lend to companies in the renewable energy sector. This would help businesses secure funding for manufacturing plants, equipment purchases, and production scaling, ultimately fostering growth in green technology industries.

The government, in collaboration with state-owned banks, could offer low-interest loans

specifically for companies investing in renewable energy manufacturing. These loans would cover costs such as purchasing equipment, upgrading facilities, and expanding operations. By providing affordable financing options, the government would ease the financial burden on companies and support the growth of renewable energy manufacturing. Given that manufacturing projects are typically large and capital-intensive, support schemes need to be designed to meet the financing requirements of such enterprises, while also ensuring accessibility for smaller businesses and startups that struggle to obtain traditional financing.

In addition to direct financing, project preparation and feasibility study grants could play a critical role, particularly in segments of the value chain where no domestic production capacity currently exists. Such grants would help investors de-risk early-stage planning, attract co-financing, and accelerate time-to-market. Targeted ecosystem support is also essential, including grants for establishing and upgrading testing and certification infrastructure for new products and components. This would help Ukrainian manufacturers meet international quality standards and improve their competitiveness in both domestic and export markets.

To attract investment in the early stages of greenfield renewable energy manufacturing, a co-financed Green Equity Insurance Fund could be launched with contributions from the actors including the EU, European Bank for Reconstruction and Development, European Investment Bank, as well as the Ukrainian government and state-owned banks. This fund would focus on underwriting political and war risks, as well as co-financing equity for renewable energy equipment manufacturing investments.

Labour and skills

Ukraine retains a technically skilled workforce, with workforce skills and research engagement in general at a relatively high level when compared to its GDP, although lagging behind when compared with many other green technology producers. However, the availability of labour is a growing constraint. Military conscription, war casualties, and large-scale emigration have significantly reduced the accessible labour pool, especially for manufacturing jobs requiring on-site presence. Without active measures to retain and retrain the remaining workforce and attract returnees, scaling production across green technology sectors will be difficult. Closing the skills gap across the renewable technology value chain and helping ensure a stable labour supply will therefore be a monumental, but not insurmountable challenge for Ukraine.

Technical and vocational training and partnerships with technical institutes will be key to securing the human capital needed for localisation. Re-skilling programmes for the existing workforce will need to be scaled up by both the public and private sectors, with the former actor also ensuring the targeting of workers from sunset sectors (such as coal or fossil fuels) to help work towards a Just Transition in Ukraine.

To promote a more inclusive and resilient workforce, targeted training programs should be implemented for underrepresented groups such as women, military veterans, and individuals returning to the workforce. These programs should incorporate wage replacement mechanisms and wraparound support services like childcare, transportation assistance, and career counselling to ensure accessibility. By investing in such tailored training initiatives, Ukraine can help alleviate labour shortages while supporting the reintegration of skilled but underutilized individuals. These efforts would contribute to a more inclusive economic recovery and strengthen community resilience and the national talent pipeline across the renewable energy value chain.

In parallel, education and training pathways must evolve to reflect the dynamic needs of the green technology sector. The introduction of dual study programmes which blend academic instruction

with hands-on, industry-based training can play a vital role in this. Co-developed with renewable energy companies, these programmes should focus on high-demand roles such as solar and wind energy technicians, battery storage specialists, and smart grid maintenance professionals.

Embedding practical learning through internships, apprenticeships, or cooperative placements ensures students gain real-world experience with current technologies and practices. This model produces graduates equipped with industry-aligned skills, reducing onboarding costs for employers and accelerating the deployment of green infrastructure. Moreover, these pathways can help attract youth and transitioning workers into the sector, broadening participation and building a more future-ready workforce. Germany provides a good example here, especially in terms of the use of companies and the private sector in training and up-skilling, but programmes also exist in Ukrainian companies that have led to some training of renewable energy jobs.

To underpin and coordinate these efforts, there is a need to establish a national green skills certification system to standardize, validate, and recognize competencies in the renewable energy and broader green economy sectors. Such a system would serve multiple functions: providing clear skill benchmarks for employers, guiding curriculum development for training institutions, and offering job seekers a portable, credible way to demonstrate their qualifications.

This certification framework should be developed in collaboration with industry leaders, vocational education providers, and regulatory bodies. It should cover a wide range of roles, from technical and engineering positions to project management, installation, operations, and maintenance, and be flexible enough to accommodate emerging technologies and regional labour needs. A national certification system would enhance transparency in the labour market, reduce skill mismatches, and improve mobility and career progression opportunities for workers. Moreover, it would help build employer confidence in the capabilities of graduates and retrained workers, ultimately supporting the scale-up of the green

technology workforce needed to meet national climate and energy targets.

This could be done through the creation of a National Green Skills Initiative, linking vocational

schools, universities, and manufacturers to jointly design curricula, apprenticeships, and certification schemes in solar, wind, and battery technologies.

Research, development and innovation

Ukraine's technological foundation for renewable technology manufacturing can be improved. The country scores relatively low on R&D intensity and innovation performance when compared to other leading renewable equipment manufacturers. The gap between research output and industrial application hinders the country's ability to move up the value chain or develop competitive advantages in technology design or materials processing, and currently limited linkages exist between the private sector and academia in many manufacturing sectors.

To enable technology-driven localisation, Ukraine must foster stronger cooperation between research institutions and manufacturers. This includes building applied research capacity in areas such as materials science, engineering, and process automation, and improving the commercialisation of academic innovation. On the latter point, looking especially at the US or UK models could provide helpful examples for Ukraine.

To boost renewable energy research and development, the government could establish a cross-institutional, cross-sectoral public research institute focused on clean energy manufacturing and deployment, ideally designed as a joint public-private program. This institute would foster collaboration between universities, research organizations, and the private sector, driving innovation and accelerating the commercialization of renewable energy technologies. In addition, financial support for demonstration and pilot projects should be provided to prove the feasibility of new technologies and bridge the gap between research and market deployment. To further encourage collaboration, public-private and private-academia partnerships should be promoted, facilitating connections among

domestic and international stakeholders. Shared funding and co-investment schemes would reduce risk for both companies and universities, enhancing the quality and scope of green technology innovations by pooling expertise and resources. Key examples of this include Germany's Fraunhofer institutes spread across the country or the UK's Catapult Centres.

The further expansion of R&D capacity may entail having to scale up the Innovation Fund, possibly also with additional international financing, with the focus expanded to include a broader range of renewable technologies. As most funding is currently allocated to defence, this expansion could in the short-term be justified with a focus especially on technologies that intersect with emerging sectors, including defence, where green energy solutions could have strong applications and synergies.

Importantly, dedicated innovation and accelerator centres, or "green tech clusters," should be prioritised to bring together all key stakeholders including businesses, academia, and government to work on green technology solutions. These hubs would encourage knowledge-sharing and innovation. Additionally, co-funding options should be offered to early-stage green technology startups, particularly those in niche areas that may not have the financial resources for large-scale R&D projects, helping them scale their innovations and bring new solutions to market. While national level centres would be a strong start, thinking also about regional innovation centres, such as those present across Europe provide strong case studies of the potential for sectoral growth and regional economic and industrial development.

Policy and regulatory frameworks

Ukraine shows mixed performance in terms of the broader business environment. Ukraine ranks as average on the Economic Freedom Index, reflecting a moderate level of regulatory efficiency, property rights, and openness to trade and investment. However, its low score on the Index of Export Penetration which compares a country's actual exports to its potential exports based on global demand indicates weak integration into international markets and limited competitiveness of tradable manufactured goods. Further work in marketing Ukraine's products and expanding the reach for its companies will be needed, with ample good practice examples from organisations such as Germany Trade and Invest and the various business associations promoting German business interests abroad.

Nonetheless, the business environment is gradually improving. Recent administrative reforms, particularly in land-use regulation and permitting, have streamlined processes critical for industrial and energy investments. For instance, changes to land designation that once took over a year can now be completed within two months, with permit issuance times now often below EU averages in some regions, signalling tangible progress in investment facilitation. These are fundamental drivers of competitiveness, especially given the regulatory and permitting bottlenecks that many of the interviewed experts mentioned as an obstacle to Europe's green technology scale-up. Ukraine could take this further by introducing "Fast Track" permitting schemes for renewable manufacturing facilities including pre-zoned industrial land, one-stop-shop procedures, and prioritised grid connections for qualifying projects.

Ukraine's industrial policy is evolving but lacks depth and coordination. While there is some strategic vision, subsidies, and demand stimulus, existing initiatives remain fragmented and small-scale. The current policy framework does not yet provide the sustained support, such as production-linked incentives, green public procurement, or localisation mandates, required to crowd in investment and reduce risk in the early stages of industry development. A more coherent and well-funded industrial strategy will be

essential to realise localisation potential. This aligns with findings from other regions seeking to build their renewable manufacturing capacity. For instance, a report on Africa's potential, based on interviews with leading Chinese manufacturers, identified several key 'pull factors' for investment. These include the assurance of a large and growing local market, often supported by national capacity plans and regular tenders to guarantee offtake. Furthermore, investors prioritize enhanced production factors, including a skilled labor force, reliable and low-cost green electricity, and preferential financing packages.¹⁸⁵ Concurrently, Ukraine's limited fiscal capacity makes it increasingly challenging to provide the types of financial incentive that other countries can provide. Nonetheless, recent programmes like "Made in Ukraine," which already offer partial compensation for domestically produced energy equipment, signal positive momentum. With UAH 3.6 bln (USD 86.4 m) allocated for this scheme in 2025, there is an opportunity to build demand for local manufacturing. However, given fiscal constraints, industrial policy must be targeted, strategic, and focused on interventions that maximise value chain development and investor confidence.

However, in order to support Ukraine's industrial growth, a broader industrial policy vision should be created that selects key sectors for further development, supported by significant mechanisms tailored to each industry's needs. This strategy should be complemented by the development of a targeted Foreign Direct Investment (FDI) attraction program, which would align with Ukraine's industrial and export priorities. This program should identify specific key projects that have the potential to drive sustainable growth and technological advancement. In the export dimension, this should include a value chain approach that boosts trade in intermediate goods, enabling Ukraine to capture more value through local refining and processing, and to take advantage of preferential treatment for pre-assembled goods in key markets.

An investor support programme is crucial to facilitate both foreign and domestic investments in green value chain manufacturing. Ukraine al-

ready has a dedicated investment promotion agency, UkraineInvest, which serves as a one-stop shop for investors, providing outreach, advice, and end-to-end support throughout the investment process. Its services include assistance with legal and regulatory matters, facilitation of state aid, and coordination with relevant authorities. To unlock the potential of renewable energy manufacturing, UkraineInvest's mandate and resources could be expanded with a specific focus on attracting investment into solar PV, wind turbine, and battery production, ensuring targeted promotion, sector-specific guidance, and faster resolution of project-related issues. A successful model for this is Malaysia's Investment Development Authority (MIDA), which provides a "one-stop shop" for foreign investors. MIDA's non-financial support has been critical to attracting solar PV manufacturing, offering services like talent matchmaking, connecting multinational corporations to the local supply chain, coordinating incentive offerings across government agencies, and fostering R&D partnerships between universities and companies. This approach was cited by major manufacturers as a key reason for investing in Malaysia.¹⁸⁶

Some important financial mechanisms are however needed. Key here could be the establishment of a capital investment refund programme, which would be highly beneficial given the sizeable role that CAPEX plays in determining project viability. To further attract large-scale manufacturing investments in renewable energy, it is crucial to expand the scope of Ukraine's Law No. 1116, "On State Support of Investment Projects with Significant Investments in Ukraine." Alternatively, a similar reform could be introduced, offering a CAPEX refund for large manufacturing projects that meet specific criteria. This could be in the form of tax exemptions or direct monetary compensation for newly built infrastructure. Additionally, businesses could receive the right to use land plots under special conditions, including a pre-emptive right to purchase the land. Such financial incentives would make Ukraine more appealing to investors by offsetting the upfront costs of establishing manufacturing plants. Tax exemptions could include corporate income tax (CIT) reductions for a set number of years, value-added tax (VAT) exemptions, and import duty exemptions, making it easier for businesses to

establish operations and scale up production. By providing these incentives, Ukraine would create a more competitive investment environment, particularly for large-scale renewable energy manufacturing ventures. Concurrently, Ukraine's current fiscal situation is highly dire after three and a half years of war, and any corporate benefits or exemptions should only be given to the highest priority sectors.

Import VAT and duty exemptions could also be selectively applied to components that are not currently manufactured or assembled in Ukraine, although these have to be carefully selected. For components that are already produced or planned to be produced domestically, regular VAT and duties should be maintained to protect the emerging local industries. Furthermore, introducing a watchlist for renewable energy equipment would help target VAT exemptions to components and equipment with identified domestic production gaps. This approach ensures that exemptions are precisely directed to where they are needed most, supporting the growth of Ukraine's green technology sector.

Local content-based VAT eligibility could be introduced as a financial mechanism to encourage the use of Ukrainian-manufactured equipment, although this has to be balanced against Ukraine's domestic, international and EU accession obligations. VAT exemptions should be conditioned on meeting a minimum local content threshold for project developers or contractors. Projects using Ukrainian-made equipment (where available) should receive preferential tax treatment or faster customs clearance, incentivizing the use of domestic resources and contributing to the local economy. Such measures should be aligned with existing market capacity to ensure feasibility and be complemented by initiatives to build firm-level capabilities, enabling domestic producers to meet quality, volume, and technology requirements as the sector scales.

Additionally, providing working capital support and testing/certification subsidies is vital for Ukrainian manufacturers and the government should step in further to assist. These measures would help companies meet international quality standards, reduce production costs, and overcome financial and technical barriers, en-

abling them to compete with imported products. Progress on the Agreement on Conformity Assessment and Acceptance of Industrial Products (ACAA) with the EU will be particularly important, as this would ensure recognition of Ukrainian conformity assessments for industrial products in the EU and vice versa, hence further lowering non-tariff barriers to trade. Most of the required technical regulations have already been harmonized, and only a limited number of sectors remain to be aligned, meaning Ukraine is close to readiness for signing the Agreement once political circumstances allow.¹⁸⁷

Demand-side measures

Creating stable and predictable domestic renewable energy demand is one of the keys to helping spur manufacturing localisation. To create market certainty, it is important to further develop renewable energy roll-out pathways and set binding long-term commitments, along with renewable energy procurement targets across key sectors. While the Energy Strategy 2050 and the draft National Energy and Climate Plan are steps in the right direction, further policy coherence and vision is needed, especially when it comes to the uncertainty regarding the future of the thermal fossil fuel sector, the expansion of the nuclear sector and therefore also the role that RES and BESS will play in Ukraine's energy system of the future.

In Ukraine, a key ongoing reform process is the liberalization of the energy market, which should continue to create the incentives and signal needed to further develop the sectors. This means reforming the wholesale market design, eliminating the price caps and floors and therefore reducing market distortion. Support mechanisms for renewable energy and storage also need to be redesigned, moving away from the mechanisms including the Green Tariff, which formally remains in place until 2030 but is only attractive to projects connected before 2020. For new projects, the Green Tariff is not economically viable, and most solar and wind investors

Effective policy implementation requires capable institutions. Currently, responsibilities for industrial policy, energy, innovation, and regional development remain fragmented. As such, strengthening institutional coordination and leadership for green industrial development is a fundamental task. This could be achieved through the creation of an Inter-Ministerial Task Force on Green Manufacturing Localisation, reporting to the Cabinet of Ministers, to oversee progress and coordinate decisions and donor support to ensure alignment among all key stakeholders.

now opt either for normal market conditions or emerging support instruments such as auctions for allocating quotas and the market premium mechanism.¹⁸⁸ Exploring and strengthening these new approaches will be essential to incentivize further renewable energy deployment. Additionally, ancillary service markets should be opened up to private battery energy storage system (BESS) operators, imbalance pricing should be aligned with EU benchmarks, and the market reforms removing price caps will also create opportunities for arbitrage in the battery segment.

A multi-year auction calendar should be published to provide manufacturers with the planning security needed for long-term investments. Renewable energy auctions could also consider including local content scoring to prioritize domestic production, although this must be balanced against energy security and potentially increasing energy costs. For corporate power purchase agreements (PPAs), efforts should continue to develop these contracts and work with off-takers to ensure sufficient market demand but further coupling the EU and cross-border PPAs are needed to further enable Ukrainian green electricity exports. In Ukraine, PPAs have recently become more widespread, particularly among SMEs, partly as a response to high financing costs, which underlined its importance as a market-driven support tool.

Policy recommendations

Given all the factors assessed in this report, it is clear that much work remains to be done to catalyse the Ukrainian green technology manufacturing sector. The below summarizes some of the key policy recommendations, before providing

a policy roadmap and phased approach for the development of the domestic localisation of solar PV, wind power and lithium-ion battery manufacturing:

Table 10. Policy recommendations

Policy measure	Recommendation
Industrial base	
Sectoral linkage development, complementarities and spillovers	• Conduct comprehensive mapping of existing sectoral companies, including all suppliers and potential producers of related products • Investigate potential to restart production or to repurpose other production sites or assets for renewable energy manufacturing • Develop a dedicated programme to encourage the restart or repurposing of enterprises from other industrial sectors to manufacture equipment for renewable energy
Intra-country and cross-border renewable supply chain logistics	• Conduct a targeted logistics audit to identify infrastructure gaps for renewable energy equipment transport, including identification of upgrades to key road and rail links connecting industrial zones to EU borders • Increase the maximum amount of state funding for the development of industrial parks from UAH 150 m per project to UAH 300-400 m per project (~ USD 7.3-9.7 m)
Renewable industrial park development across Ukraine	• Ensure continued development of industrial parks, taking into consideration resilience, stable access to energy and other utilities (including on-site or nearby generation), transportation and logistics as well as distance to potential renewable deployment sites
Development of manufacturing infrastructure	• Develop a mechanism to provide investors with free access to land plots or ready-to-use production sites equipped with the necessary infrastructure such as energy supply, road connections, and water
Critical minerals	
Comprehensive strategic sectoral strategy	• Develop national mineral strategies, taking broader, long-term view of the sector in light of development, agreements and obligations • Create realistic pathways to add value to Ukraine's minerals assessing potential domestic and EU demand in industries and competitive positioning vis-à-vis other processing countries

Domestic critical mineral supply	• If processing of critical minerals is pursued as a strategic policy, ensure that sufficient amounts of minerals are available for the domestic market, and that investment and off-take contracts with developers do not fully constrain this • Ensure streamlined access for investors to participate in tenders for licences to develop critical mineral deposits, and introduce a mechanism for production sharing agreements (PSAs) for the extraction of minerals such as lithium, graphite, manganese, and titanium, to help attract investment by international companies into extraction and processing
Finance	
Government-backed loan guarantees	• Extend loan guarantee schemes, which would reduce the risk for commercial banks in financing these ventures. By covering a portion of the loan default risk, the government could attract private financial institutions to support new green tech projects • Raise the maximum financing available for investment projects under the 'Affordable Loans 5-7-9%' programme from the current UAH 150 m per project to UAH 500 m (~USD 12 m) • Raise the maximum funding available under the 'Non-repayable Grants for Processing Enterprises' programme from the current UAH 8 m to UAH 40 m (~USD 0.9 m)
Greenfield equity insurance fund	• Launch a fund co-financed by EU, EBRD, EIB, and Ukrainian government and state-owned banks to underwrite political and war risk and co-finance equity for greenfield renewable energy equipment manufacturing investments to reduce the risk of early-stage investment in manufacturing plants
War insurance	• Extend subsidized war-risk insurance to renewable equipment manufacturing plants to ensure their operational continuity and support geographic diversification of Ukraine's industrial base • Explore EU-backed resilience insurance via ISDA-type reinsurance underwritten by EU institutions
Project and ecosystem grants	• Introduce project preparation and feasibility study grants for segments of the value chains where domestic capacity does not yet exist • Offer ecosystem development grants to establish and upgrade testing and certification infrastructure for new products and components
Labour and skills	
Re-skilling programmes for existing workforce	• Provide publicly funded retraining of workers, including from declining sectors (e.g. coal) into green technology equipment manufacturing and deployment and service roles
Targeted training for women, veterans and returnees	• Expand subsidised green skills training (e.g. PV assembly, inverter installation, C&I and O&M) for underrepresented groups (e.g. women, veterans) with wage replacement and supporting services

Dual study programmes in renewable energy	• Introduce applied-academic tracks co-developed with industry in key renewable energy occupations (e.g. solar/wind technicians, battery integration) to ensure job-ready graduates aligned with manufacturing and deployment needs
National green skill certification system	• Create a certification framework for green energy jobs to standardise training, improve recognition, and support labour mobility to build credibility for Ukrainian-trained workers that is aligned with EU labour standards
Human capital development support	• Provide state grants to support human capital development for green tech production, including worker training and education, as well as investment in residential and social infrastructure to attract and retain employees near manufacturing sites
Research and development	
Renewable energy research task force	• Create cross-institutional and cross-sectoral public research institute on clean energy manufacturing and deployment • Provide financial support for demonstration and pilot projects
Expansion of Innovation Fund	• Scale-up Innovation Fund through additional international financing and expand scope to renewable technologies, especially those with strong linkages with other emerging sectors, e.g. defence
Public-private and private-academia partnerships	• Facilitate connections and linkages between the various actors and stakeholders both domestically and internationally • Create incentives for private companies and universities to collaborate on R&D projects. Shared funding or co-investment schemes can lower risk and improve the quality and breadth of green tech innovations -for example through tax breaks linked to the volume of research projects funded by the private sector or matching grants
National or regional innovation centres	• Establish dedicated innovation hubs or “green tech clusters” that bring together businesses, academia, and government to share knowledge and work on green technology solutions • Provide co-funding options for early-stage green technology startups, particularly in niche areas that may not have the financial resources for large-scale R&D projects
Policy and regulatory frameworks	
Strategic approach to industrial policy	• Create broader industrial policy vision of Ukraine that selects key sectors for further development with significant support mechanisms • Develop a targeted FDI attraction program aligned with Ukraine’s industrial and export priorities by identifying key projects
Create new investor support programme	• Engage with investors through direct outreach and negotiations and provide end-to-end support to investors in every stage of the process, including legal, regulatory, and state aid facilitation
Capital investment refund programmes	• Expand the scope of, and simplify access to, Law of Ukraine No. 1116 “On state support of investment projects with significant investments in Ukraine”

Local content-based VAT eligibility	Condition VAT exemption on meeting a minimum local content threshold for project developers or contractors. Projects using Ukrainian-manufactured equipment (where available) would receive preferential tax treatment or faster customs clearance
Import VAT and duty exemptions	- Apply exemptions only to components not currently manufactured /assembled in Ukraine. Maintain regular VAT/duties on components already/planned to be produced in Ukraine (e.g. wind turbine towers and blades, solar PV mounting structures, inverters, battery stations) - Introduce a watchlist for renewable energy equipment, which would list components and equipment eligible for VAT exemptions based on domestic production gaps, to ensure that VAT exemptions are precisely targeted
Working capital support	Provide working capital support and testing/certification subsidies for Ukrainian manufacturers to meet quality standards and reduce production costs, which would ease financial and technical entry barriers for domestic manufacturers and enable them to meet export-grade standards and compete with imported alternatives
Ukraine's participation in EU industrial development programmes and financial instruments	Provide investors planning to launch projects in Ukraine with access to industrial development programmes and instruments comparable to those available to investors in EU member states, including the Innovation Fund, InvestEU, the European Regional Development Fund (ERDF), the Just Transition Fund (JTF), and others
Demand-side measures	
Deployment targets and policy certainty	Further develop renewable roll-out pathways and set binding long-term commitments and renewable energy procurement targets across key sectors to create market certainty.
Energy market reforms	Continue energy market liberalisation, including revision of wholesale market design to remove price caps and floors, reducing market distortions
Renewable and storage support mechanisms	- Re-design support mechanisms, phasing out the legacy Green Tariff scheme and shifting toward new instruments such as auctions and the market premium mechanism to incentivise RES deployment - Align imbalance pricing with EU benchmarks and gradually remove electricity price caps to incentivize battery arbitrage investments
Renewable and storage auction reform	- Publish multi-year auction calendars to give planning security to manufacturers - Consider including local content scoring in renewable energy auctions
Power purchase agreements (PPAs)	- Continue work on developing corporate PPAs, working with off-takers to generate sufficient market demand - Introduce cross-border PPAs for Ukrainian green electricity exports
Local content in public procurement	- Consider mandating minimum local content thresholds for clean energy equipment in public tenders - Utilise Prozorro or other digital procurement platform linking public buyers with certified domestic producers

Source: Author's elaborations and conclusions

7. Conclusions

Ukraine demonstrates varying levels of competitiveness across the solar PV, wind, and lithium-ion battery value chains, with significant potential to expand its role given ambitious domestic deployment targets and export aspirations.

In the solar PV segment, like most European and Western producers, Ukraine cannot currently compete with the extremely low-cost, subsidized production from China and Southeast Asia. Without state support to strategically revive solar equipment manufacturing, full localization of the solar PV value chain in Ukraine remains unlikely.



However, if energy security considerations lead to significant support for Europe's solar PV sector, Ukraine could be well positioned to integrate into these value chains. To facilitate this, Ukraine should:

- In the short term: Align actions with the broader EU strategy for industrial revival and energy security. Assess auxiliary equipment production capacity and export potential. Review import duty exemptions for finished modules. Stimulate inverter production through localization requirements in public procurement and cashback mechanisms. Consider the possibility of building a glass factory and producing polysilicon, taking into account the needs of related industries and export markets.
- In the medium term: Expand auxiliary equipment markets and determine domestic assembly needs. Reassess public procurement policies for local content. Review the economics of the full production chain, including silicon processing, in light of EU policies, inter-sectoral links, and domestic demand. Integrate into the European R&D ecosystem and explore "leapfrog" opportunities, particularly in next-generation technologies such as perovskites.
- In the long term: Position Ukraine as a strategic participant in the EU solar value chain, focusing on key components (inverters, mounting systems, tempered glass, potentially polysilicon), testing and certification services, and innovation in next-generation and recyclable technologies for sustainable integration with the EU market.

Ukraine's wind turbine manufacturing sector appears more competitive, especially in tower and blade production, where costs compare favourably with other EU countries. With regional export potential and opportunities for further EU integration, scaling up domestic production could unlock major opportunities. While nacelle component manufacturing and some final assembly capacity exist, these remain limited, yet they still indicate a foundation that could be expanded. To expand this potential, Ukraine should:

- In the short term: Assess opportunities to restore existing production sites and attract investment in tower and blade manufacturing

and assembly. Map local production of nacelle and turbine components and subcomponents with an assessment of export competitiveness. Restart special steel production at machine-building plants with electric furnaces, analyse inter-sectoral linkages, and strengthen engagement with regional and EU partners across the value chain.

- In the medium term: Scale up tower and blade production and attract new investments in turbine and nacelle manufacturing. Introduce incentives for thick sheet production at Zaporizhstal, strengthen the supplier ecosystem with targeted support, and expand access to trade financing through an export credit agency.
- In the long term: Develop domestic R&D to enhance existing technologies and move into new areas such as offshore wind. Pursue export markets beyond the EU, consolidating Ukraine's role in the global wind energy value chain.

In the lithium-ion battery value chain, Ukraine currently lacks capacity for battery cell production or component manufacturing. The most immediate potential lies in assembly using imported parts to meet growing domestic demand.

The development of electronic mobility and the growing Ukrainian defence industry can create demand that justify establishing domestic assembly facilities. At the same time, attracting investment into the extraction and processing of critical minerals such as lithium, manganese and graphite could open the door to moving further up the value chain -towards the production of components like cathodes and anodes, and eventually full battery cells. Achieving this will require the involvement of strategic investors and specialised international partners. To enable these, Ukraine should:

- In the short term: Undertake a detailed mapping of domestic demand for lithium-ion batteries (including energy, transport, IT, defence and other sectors). Review import privileges for battery stations and support the restoration of assembly capacity. Launch R&D in end-product assembly and develop links with the IT sector -primarily for EMS software- for

both the Ukrainian and European markets. Re-evaluate existing critical-mineral reserves and the economics of their extraction.

- In the medium term: Develop regional supply chain cooperation with neighbouring countries to reduce costs. Increase assembly capacity in line with demand dynamics in energy, e-mobility and defence sectors. Re-assess the economics of domestic mineral processing, taking into account extraction scale and global industry trends.
- In the long term: Explore opportunities to enter other parts of the value chain, particularly the production of precursors or battery cells. Continue developing the domestic critical-minerals sector, systematically assessing strategic opportunities for integration into European and global supply chains.

In addition, the localisation of renewable energy equipment production and the development of a competitive green industry in Ukraine require the following overarching measures:

- Strengthen industrial capacity through targeted investment in production modernisation, alongside a comprehensive mapping to revitalise and repurpose existing assets where appropriate.
- Develop a national mineral extraction strategy that aligns the development of critical raw materials with industrial objectives and domestic demand trends, using off-take agreements to ensure a secure domestic supply.
- Overcome financing challenges with extended loan guarantees, low-interest financing, a de-risking fund for manufacturing investment, and expanded support programmes including CAPEX refunds and tax incentives for large-scale projects.
- Support investors through a simplified, universal investor-support platform.
- Labour and skills development via a national initiative to retrain workers and support the re-integration of returnees into the workforce.
- Scale up research and innovation through a national research institute, innovation clusters and an innovation fund.

- Provide demand-side certainty by adopting binding renewable-energy targets, publishing a multi-year auction calendar with local-content scoring, expanding corporate PPAs and introducing local-content requirements in public procurement -underpinned by continued energy-market liberalisation

A critical precondition for the deployment of these manufacturing industries in Ukraine is systematic participation in EU industrial development programmes and financial instruments that provide grants, low-cost loans, and risk guarantees for industrial investment. These include grant and operational instruments such as the Innovation Fund; InvestEU, with the involvement of the European Investment Bank (EIB) and the European Investment Fund (EIF), as well as intermediary banks providing long-term, lower-cost loans; and funds aimed at supporting regional economies (e.g. ERDF, JTF).

The process of involving investors who intend to operate in Ukraine in accessing European industrial support instruments should include concluding framework agreements and mechanisms for associated participation and harmonising state-aid rules; establishing a national “window” for interaction with the EIB/EIF and identifying partner banks; building a high-quality pipeline of investment projects that covers feasibility studies as well as ESG assessments, localisation plans and certification; introducing blended financing options that combine grants with loans and guarantees and that also provide tailored schemes for SMEs; deploying a support network for applicants such as NCPs and project offices; and publishing a multi-year schedule of national co-financing and targeted auctions or procurements with clear requirements for technological capacity and the share of local added value.

With significant prospects across various parts of the wind, solar PV and lithium-ion battery chains, now is the time for all key stakeholders to focus their efforts, expertise and capital to mobilise Ukrainian green technology manufacturing for the good of the country, its people, and the ongoing reconstruction.

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