Post War Development of the Renewable Energy Sector in Ukraine

Renewable Energy

GOPA International Energy Consultants GmbH

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PREFACE

While renewable energy is positioned to become a cornerstone in Ukraine's recovery efforts, its potential remains largely untapped at present. While investments in new projects are underway, the economic, financial, and regulatory framework must continually adapt to instill the confidence necessary for private investors to tap into Ukraine's full potential and make their projects bankable. This confidence was challenged prior to 2022, as a liquidity crisis tested the central offtaker's ability to fulfill its obligations under the agreed support scheme. Stemming from flaws in the support scheme's design and the broader electricity market structure in Ukraine, this crisis prompted a post-mediation process under the auspices of the Energy Community Secretariat.

Notably, despite the ongoing full-scale war of aggression against Ukraine, the development of market and regulatory frameworks shaping renewable energy production and marketing has persisted. In the summer of 2023, the adoption of a Green Transition Law introduced various measures aimed at aligning with the Energy Community's legal framework for renewable energy. Additionally, secondary legislation on guarantees of origin, procedures for active customers, and licensing conditions for distribution systems and aggregation activities has been approved. Concurrently, comprehensive revisions to electricity legislation are underway to ensure compatibility with European rules, facilitating cross-border system and market integration. A draft National Energy and Climate Plan, focusing on recovery and decarbonization aligned with Energy Community 2030 targets, is nearing finalization.

Against this backdrop, stakeholders gathered in Kyiv on 9 April 2024, under the auspices of the Secretariat, marking the commencement of a pivotal dialogue. Focused on domestic and international recovery planning, market reform, regulatory alignment, and investment facilitation along the renewable value chain, this gathering represents a key moment for collective action. Following the meeting, stakeholders will collaborate to develop a roadmap outlining necessary actions and measures, aimed at fortifying the readiness of the renewable sector to become a central pillar in Ukraine's transition towards a green economy, fuelled by private investments.

This study aims to offer practical recommendations and insights, drawing from exemplary practices within the EU and worldwide, to support the ongoing post-mediation process and facilitate the development of the roadmap. At its core, the study explores insurance mechanisms for risk mitigation and financing new renewable projects. It also examines swift corporate power purchase agreement (PPA) implementation, innovative solutions as well as renewable energy-based heating and transportation electrification options. Additionally, it scrutinizes planning instruments to optimize generation capacities, integrate them with demand-side measures and infrastructure development. Streamlining permitting procedures through a one-stop shop approach emerges in the study as a pivotal strategy for efficiency and investor confidence.

In summary, this study serves as a comprehensive guideline, illuminating the path towards a sustainable future for Ukraine's renewable energy sector, while also supporting the ongoing post-mediation process and roadmap development.

Vienna, 12 April 2024

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ABBREVIATIONS AND ACRONYMS

A-CAES	Advanced Compressed Air Energy Storage
AC/DC	Alternating Current / Direct Current
AFU	Armed Forces of Ukraine
aFRR	Automatic Frequency Restoration Reserve, also known as secondary reserve
AI	Artificial Intelligence
BioPP	Biomass Power Plant
BIPV	Building integrated PV
BOP	Balance of Plant
CB RES	Renewable energy cross-border projects
CE	Circular Economy
CCE	Continental Central East region (ETNSO-E)
CEF	Connecting Europe Facility
CBAM	Carbon Border Adjustment Mechanism of the EC
CCS	Carbon capture and storage
CHP	Combined Heat & Power
COD	Commercial Operation Date
CTF	Clean Technology Fund
DD	Due Diligence
DPT	Detailed Plan of the Territory
DSO	Distribution System Operator (Oblenergo's, Ukrzaliznytsia or similar)
DSM	Demand Side Management
EC/EnC/EnCS	Energy Community/Energy Community Secretariat
EDG	European Green Deal
EGS	Enhanced Geothermal Systems
ENTSO-e	European Network of Transmission System Operators for Electricity
EMBER	a global energy think tank using data-driven insights to shift to clean electricity *ember-climate.org*
EPC	Engineering Procurement and Construction
EPR	Extended producer responsibility
FiT	Feed-in-Tariff
FCV	Fuel cell vehicles
Fit for 55	A package of EC regulations designed for a 55% EU GHG emissions by 2030
GB	Guaranteed Buyer
GO	Guarantees of Origin
HPP	Hydro Power Plant
HV	High Voltage
HVAC	Heating ventilation and air conditioning systems
HAWT	Horizontal Axis Wind Turbine
IBRD	World Bank
ICE	Internal Combustion Engine
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IPS	Integrated Power System
IRE	Institute of Renewable Energy Sources of National Academy of Sciences of Ukraine
IRENA	International Renewable Energy Agency
LD	Liquidated Damages
ML	Machine Learning
MV	Medium Voltage
NEURC	National Energy and Utilities Regulatory Commission
NPP	Nuclear Power Plant
NSCD	National Security and Defense Council of Ukraine

NZE	Net Zero Emissions by 2050 Scenario (NZE is a normative IEA scenario that shows a pathway for the global energy sector to achieve net zero CO2 emissions)
O&M	Operation and Maintenance
OHL	Overhead Line
OVD	Local ESIA document, as required by relevant Law of Ukraine "On OVD."
PV	Photovoltaics
PtH2	Power to Hydrogen
PtH	Power to Heat
PtX	Power to other forms of valuable products
PSPP	Pumped Storage Power Plant
RES	Renewable Energy Source / Renewable Energy Sector
RE	Renewable Energy
R&D	Research and development
SAIDI	System Average Interruption Duration Index
SoS	Scope of Supply
SLD	Single-line diagram
SPP	Solar Power Plant
SPV	Special Purpose Venture
S/S	Substation
TC	Technical Conditions on Interconnection
T&D (system)	Electric transmission and distribution (system)
TDD	Technical Due Diligence
TOC	Take Over Certificate
ToR	Terms of Reference
TPP	Thermal Power Plant
TSA	Turbine Supply Agreement
TSO	Transmission System Operator (NPC Ukrenergo)
TYNDP	Ten Year Network Development Plan
UABIO	Bioenergy Association of Ukraine
VAWT	Vertical Axis Wind Turbines
V2G	Vehicle to Grid
VRE	Variable Renewable Energy
WEC	Wind Energy Convertor (see also WTG)
WF	Wind Farm
WML	Waste Management Law
WPP	Wind Power Project or Wind Power Plant
XtP/X2P	Transformation of other sources of energy to Power

EXECUTIVE SUMMARY *(ES)*

The war has inflicted significant damage upon Ukraine's renewable energy sector, abruptly halting its pre-war momentum and plunging it into a state of profound disruption. This grim reality underscores the urgent imperative to prioritize the sector's revitalization as a cornerstone of Ukraine's post-war economic and environmental reconstruction.

While renewables present a beacon of hope in this bleak landscape, their resurgence hinges upon the establishment of critical preconditions of a regulatory, institutional, and financial nature, thereby unlocking their full potential to drive a sustainable and prosperous future for Ukraine.

ES 0. Key Recommendations

0. **Development of an Updated Ukraine Energy Strategy and NECP**: an updated Ukraine Energy Strategy shall be developed as corresponding National Energy and Climate Plan (NECP). This strategy should incorporate the opinions and contributions of the expert community, representatives from Transmission System Operators (TSOs), Distribution System Operators (DSOs), power plants, associations, and other key stakeholders in the sector. This incorporation should be the result of thorough public discussions and workshops. The document shall duly reflect the existing bottlenecks such as strengthening of congested grid infrastructure (including previously over-populated with RES and now significantly damaged Southern Regions). It is essential that only this collaboratively developed version of the strategy be presented
1. **Feasibility study on Facilitation of RES integration/ Implementation of Goals set in the Strategy.** A similar study was performed back in 2014 for IBRD in course of Second Transmission project. There is a need for a document containing detailed calculations of network modes, reflecting the progress and actual system needs. The expected capacity building and restructuring of the grid has to be re-calculated and analyzed with mandatory coordination by TSO. Priority measures to be identified and structured to enable and plan future procurement.
2. **Harmonization of Subordinate Plans, Programs and development frameworks:** In the process of preparing the overall sector strategy, it is imperative to develop and harmonize subordinate/supporting strategic documents for each of the Power Sector components (Nuclear, Hydro, RES, Environment and emissions, Storage, P2X, Grid infrastructure feasibility. These documents should reflect the overall goals and approaches of EU integration and should align with the general Energy Strategy.
3. **Alignment of legal framework with Energy Community acquis**: Subordinate legislation should be adopted to fully correspond with EU legislation. This process should be led and guided by the Energy Community (EnC).
4. Resolving non-payment issues - to address the present issues, several solutions can be proposed. There needs to be **an independent oversight mechanism** to ensure transparency and fairness in the **calculation and settlement of imbalances**. This can be achieved through proper regulatory reforms and the introduction of external audits.
5. **Strengthening the legal framework to protect market participants from arbitrary and unfair practices is essential.** This includes revising the netting procedures and ensuring that Ukrenergo fulfills its reciprocal financial obligations.
6. **Making the electricity market more resilient by promoting smaller distributed suppliers** can reduce the risk of monopolization and enhance market stability.
7. The Government should intervene to resolve **the issue of mutual indebtedness** and ensure that the financial burdens do not fall disproportionately on certain market participants, potentially through **state-backed financial support or restructuring programs** as the fastest resolution mechanism.
8. **Extension and implementation of legislative framework**: the Law 3320-IX has to be further amended based on feedback from RES sector and concerned stakeholders, secondary legislation to be developed allowing to revitalize the sector
9. **Elimination of debts to producers:** One of the foreseen solutions – introducing clear zero-deficit tariff for Ukrenergo and relevant communication producers assuring further streamline of financing

10. **Elaborate mechanism for covering military risks**: The issue of covering military risks has not yet been resolved significantly limiting any investment activity
11. **Use of successful institutional experience of other countries**: Instead of creating from the scratch many incentives can be integrated from the experience of such countries as Denmark, Netherlands and Germany, to do so negotiations with these countries are ongoing. For example, in terms of approvals associated with grid connection – these further may be on paid basis to avoid flow of unrealistic developments limiting the grid access for the projects ready to invest.
12. **Utilize the Cost-effective options for RES development**: Please refer to the list of actions foreseen in Clause 3.3
13. **Extension of Technical Conditions**: Investors who were ready to build their objects before the full scale invasion started shall be able to proceed with their plans so a very clear and transparent extension of Technical Conditions shall be arranged – 5 years for projects which are proven to be built
14. **Reliable Payment Systems for RE Electricity Generators.** It's essential to establish reliable and prompt payment mechanisms from offtakes to RE existing and future electricity generators – these mechanisms may be supervised by international referees
15. **Expedient settling of the existing debts and malperformance issues**. Settling debt issues, imbalances and limitations imposed on developers. Lifting bureaucratic limiting by establishment of one-stop-shops and transparent development, construction and operation manuals will provide a very clear signal to investors willing to contribute in Ukraine's "building back better"
16. **Promotion of AI technologies in balancing and forecasting processes.** Ukraine is often proclaiming digitalization as one of the main drivers of Economy restoration.
17. **Active Support for Prosumers**: Encouraging the concept of "prosumers" – consumers who also produce electricity – is crucial. This approach not only reduces the load on the grid but also promotes local energy generation and consumption. Policies and incentives such as feed-in tariffs, net metering, and subsidies for installing renewable energy systems can stimulate prosumer participation.
18. **Grid Reinforcement and Decentralization:** Moving from a centralized system with large generation capacities to a distributed generation model is key. This involves reinforcing the grid infrastructure to support the integration of renewable energy sources from areas most suitable for RE generation to areas with high consumption. Investment in smart grid technologies, which allow for better integration and management of distributed energy resources, is essential. This shift will enable a more resilient and flexible energy system, capable of accommodating diverse renewable energy sources
19. **Demand-Side Management and Harmonizing Supply and Demand:** Effective demand-side management is necessary to align variable RE electricity supply with demand. This requires a combination of significant price incentives (varying by factors of 10 or more depending on RE availability
20. **Development of an Updated Ukraine Energy Strategy** (with due consideration of available technologies as described in cl. 4.3 hereof), Harmonization of Subordinate Plans, Legislation, Programs and development frameworks.
21. **Elaborate a one-stop-shop** for Ukraine in an administrative agency which facilitates and leads the effort.
22. **Establishment of the insurance mechanisms**: the of efficiency of Law of Ukraine "On financial mechanism for promoting export activities" regarding insuring investments in Ukraine against military risks (draft law No. 9015 dated 14 February 2023) will be directly linked to availability of funds for such insurances which shall be involved from IFIs, international donors and other sources. The government can implement comprehensive policy reforms that include subsidies, risk guarantees, and regulatory support, tailored to mitigate the specific risks associated with various sectors.

ES-1.: Current condition of the power sector

International Trends and Commitments

The predominant focus backed by the Paris agreement is on achieving zero emissions by 2050. The Renewable Energy Directive III (RED III) mandates a 42.5% renewable energy share in total EU energy consumption by 2030 in contrast to previous goal of 32% according to RED II, with a non-binding aspirational target of 45%[1]. An upcoming directive will revise this existing one, with the amendments becoming legally binding 18 months post-enactment.

For specific sectors, the targets include 14% for transport and 40% for heating and cooling. Ukraine, aligning with these commitments, is focusing on enhancing renewable energy and technological advancements. Currently according To Decision Of The Ministerial Council Of The Energy Community[2][3] and Energy Community Acquis (REDII) Target for share of energy from renewable sources in Ukraine's gross final consumption of energy by 2030 shall reach 27%[4].

Ukraine's EU candidate status and the EU energy security crisis have both been facilitated by the Russian invasion. The EU is now in the process of accelerating its decoupling from the use of Russian gas and oil as primary energy sources as fast as possible by opening up other prospects for other sources of natural gas to replace Russian gas and also the increased use of green energy.

After the end of the war, attention will be directed to a substantial reconstruction programme taking into account the infrastructure, assets and other services that were damaged or lost as well as providing an opportunity to capitalize on the advancement of the latest technologies underpinned by implementation of best practice policies, measures, standards and regulations aligned with EU energy goals and directions.

Ukraine's Power sector (Pre- and Post-war)

As of December 31, 2021, the total installed capacity of power plants in Ukraine's Integrated Power System (IPS) amounted to 56.247 GW. This capacity comprised 49.7% from thermal power plants, 24.6% from nuclear power plants, 11.2% from hydropower and pumped storage plants, and 14.5% from renewable energy sources, including wind power plants (WPPs), solar power plants (SPPs), and biomass power plants (BioPPs).

A crucial development occurred on March 16, 2022, with the complete synchronization of Ukraine and Moldova's power systems with the European Network of Transmission System Operators for Electricity (ENTSO-E), marking a significant milestone in enhancing the energy sector's development and security

Table 1: Renewable energy sector development in Ukraine

RES technology	RES growth compared to the previous year for 2016-2021, (in MW)					
	Years					
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
WPP	10.9	27.9	60.6	636	86,2	562
SPP	98.9	300.4	466.4	2 565.9	1 807.2	2 222
BioPP	10.2	34.3	1.8	48.3	57	77
Micro-, mini- & small HPP	n/a	5.4	1.9	4.4	6.6	0.9

The ongoing conflict has led to a decrease in electricity demand by 30-35% compared to 2021, influenced by extensive damages to business consumers and persistent blackouts.

As of September 2022, approximately 13% of Ukrainian SPP capacities were under occupation, and 6% of total solar capacity was either destroyed or impaired. Concerning WPPs, the installed capacity in 2023 totaled 1.8 GW, with significant portions located in occupied territories. This situation resulted in damages to, at least reported, 10 wind turbines, impacting about 1% of the total installed wind capacity. Overall, 20% of the installed RES capacity was affected. All Ukrainian hydropower facilities have suffered from

[1] https://www.consilium.europa.eu/en/press/press-releases/2023/10/09/renewable-energy-council-adopts-new-rules

[2] https://www.energy-community.org/legal/acquis.html

[3] https://www.energy-community.org/dam/jcr:421f0dca-1b16-4bb5-af86-067bc35fe073/Decision_02-2022-MC_CEP_2030targets_15122022.pdf

[4] These values are referred to hereinafter as "targets"

damages or attacks, including the complete destruction of the Kakhovka Hydroelectric Power Plant in June 2023.

There overall losses of Ukrainian Power Sector are estimated at a level of USD 8,8 bln (including 638 mln of damages due to devastation of Kakhovka HPP).[5]

Legislative Changes

In 2022, Ukraine's power sector experienced significant legislative and regulatory shifts, including the introduction of energy storage systems, adjustments to feed-in tariffs, virtual PPAs, strategic energy planning for 2050, and a focus on renewable gas development in partnership with the European Commission.

On 21 April 2023, the Cabinet of Ministers of Ukraine (CMU) approved the **Energy Strategy of Ukraine until 2050**[6]. The Strategy has yet to be published, but according to the Ministry of Energy's description, the document reflects the goals of the European Green Deal. It is based on the principles of an integrated approach to the development and implementation of energy policy, thus creating conditions for the sustainable development of Ukraine's economy.

Among other aspects, the Energy Strategy takes into account:

- Consequences of the full-scale war of the Russian Federation against Ukraine, strengthening the role of energy security and the stability of the energy system;
- Results of connecting the Ukrainian electricity network to the European Network of Transmission System Operators for Electricity (ENTSO-E) and deepening the integration of Ukraine’s power system into the pan-European market;
- Availability of the latest technologies (in particular, the production and use of hydrogen for energy purposes, small modular nuclear reactors, energy storage facilities, etc.), technical improvements in the energy sector, world trends and innovative solutions, requirements for environmental safety in line with EU regulations and responsibilities assumed by Ukraine;
- International obligations of Ukraine regarding energy efficiency and the use of renewable energy sources, reduction of greenhouse gas emissions, etc.;
- Decentralization of electricity generation throughout the whole country to improve the stability and reliability of the power supply[7].

The modified strategy was presented again at the Ukraine Recovery Conference 2023 in London however it appeared quite controversial.

The major advances are associated with adopting **Law 3220-IX Green Transformation of the Energy System of Ukraine.** This law revises "green" auction regulations, introduces contracts for difference (virtual PPAs), and sets up new mechanisms like market premiums and self-consumption incentives. It extends pre-PPA validity and technical conditions for wind projects, along with adjustments to the Guaranteed Buyer's (GB) balancing group operations.

While the law shows positive progress, it requires further refinement, particularly in areas like Connection Technical Conditions and Power Purchase Agreements. The law also doesn't address the imbalance calculation formula issue raised in court. Future auctions need a comprehensive legal framework to attract investor confidence. Additionally, provisions regarding Guarantees of Origin need clarification to align with the RED II Directive.

Overall, the Law No. 3220-IX marks a critical step in addressing the renewable energy market crisis and fostering sector development, but it necessitates additional legislative efforts for complete efficacy.

According to the Annual Implementation Report 2023 by the Energy Community (EnC), Ukraine has shown notable progress in implementing the Electricity Integration Package, ranking high among Contracting Parties despite the challenges posed by the ongoing war. Ukraine's efforts in aligning with EU energy laws and market reforms, despite the ongoing war, demonstrate a strong commitment to market integration and energy sector reform. The transposition of the Electricity Integration Package and related legislations like the REMIT Law, alongside ongoing efforts in market unbundling and regulatory

[5] https://kse.ua/about-the-school/news/the-total-amount-of-direct-damage-to-ukraine-s-infrastructure-caused-due-to-the-war-as-of-june-2023-exceeded-150-billion/

[6] https://zakon.rada.gov.ua/laws/show/373-2023-%D1%80#Text

[7] https://mev.gov.ua/novyna/ukrayina-enerhetychnyy-khab-yevropy-uryad-skhvalyv-enerhetychnu-stratehiyu-do-2050-roku

compliance, position Ukraine closer to integration with the European energy market. However, further steps are required to fully realize this integration, including the formal approval of critical legislations and continued collaboration with EU entities.[8]

Recommendations:

- Development of an Updated Ukraine Energy Strategy and NECP: an updated Ukraine Energy Strategy shall be developed as corresponding National Energy and Climate Plan (NECP). This strategy should incorporate the opinions and contributions of the expert community, representatives from Transmission System Operators (TSOs), Distribution System Operators (DSOs), power plants, associations, and other key stakeholders in the sector. This incorporation should be the result of thorough public discussions and workshops. The document shall duly reflect the existing bottlenecks such as strengthening of congested grid infrastructure (including previously over-populated with RES and now significantly damaged Southern Regions). It is essential that only this collaboratively developed version of the strategy be presented
- Feasibility study on Facilitation of RES integration/ Implementation of Goals set in the Strategy. Similar study was performed back in 2014 for IBRD in course of Second Transmission project. There is a need for a preparation of such document containing detailed calculations of network modes, reflecting the progress and actual system needs. The expected capacity building and restructuring of the grid has to be re-calculated and analyzed with mandatory coordination by TSO. Priority measures to be identified and structured to enable and plan future procurement.
- Harmonization of Subordinate Plans, Programs and development frameworks: In the process of preparing the overall sector strategy, it is imperative to develop and harmonize subordinate/supporting strategic documents for each of the Power Sector components (Nuclear, Hydro, RES, Environment and emissions, Storage, P2X, Grid infrastructure feasibility. These documents should reflect the overall goals and approaches of EU integration and should align with the general Energy Strategy.
- Alignment of legal framework with Energy Community acquis: Subordinate legislation should be adopted to fully correspond with EU legislation. This process should be led and guided by the Energy Community (EnC).
- Resolving non-payment issues

  To address the present issues, several solutions can be proposed.

  ✓ Firstly, there needs to be an independent oversight mechanism to ensure transparency and fairness in the calculation and settlement of imbalances. This can be achieved through proper regulatory reforms and the introduction of external audits.

  ✓ Secondly, strengthening the legal framework to protect market participants from arbitrary and unfair practices is essential. This includes revising the netting procedures and ensuring that Ukrenergo fulfills its reciprocal financial obligations.

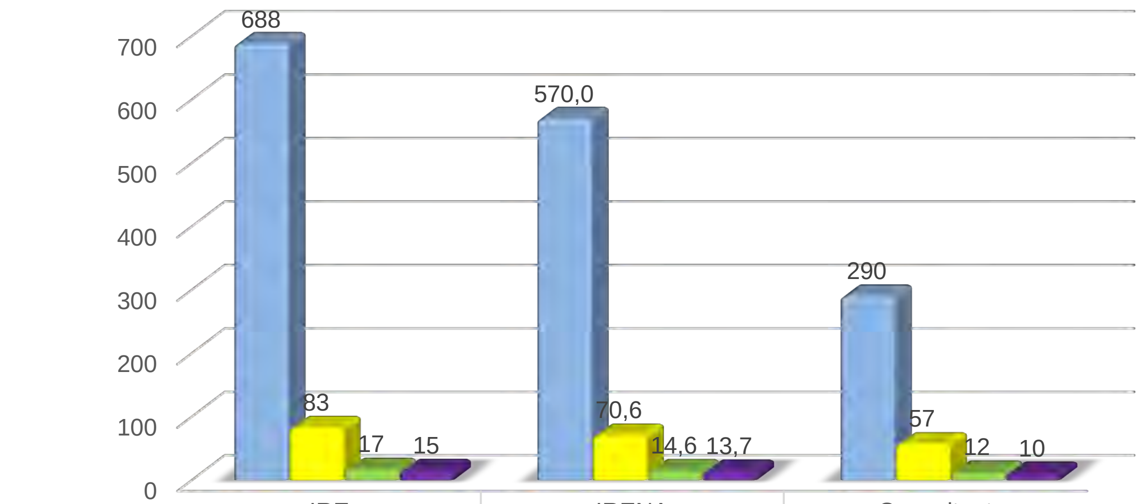
  ✓ Thirdly, diversifying the electricity market by promoting smaller distributed suppliers can reduce the risk of monopolization and enhance market stability.

  ✓ Lastly, the government should intervene to resolve the issue of mutual indebtedness and ensure that the financial burdens do not fall disproportionately on certain market participants, potentially through state-backed financial support or restructuring programs as the fastest resolution mechanism.

[8] https://www.energy-community.org/implementation/report.html

ES-2. Calculation of RES potentials

With regard this **2nd Task (**cf. **Chapter 2)**, Figure 3 below shows estimates for the maximum technical potential for different RE based upon available sources (IRENA[9], IRE - the Institute of Renewable Energy Sources of National Academy of Sciences of Ukraine[10]) as well as the Consultant's own expertise. The Consultant has estimated later the maximum technical RES potential after accounting for topographic limitations, land-use constraints, and system performance.



	IRE	IRENA	Consultant
Wind	688	570,0	290
Solar	83	70,6	57
BioTPP	17	14,6	12
OTHER RES	15	13,7	10

Figure 1: Estimates for the maximum RES installed capacity technical potential for Ukraine in GW
(including offshore Wind; *Source: IRE (Institute for Renewable Energy); IRENA and Consultant's own estimates)*

Reference Scenario

- *Based on national strategies, plans and targets*

Technical Scenario

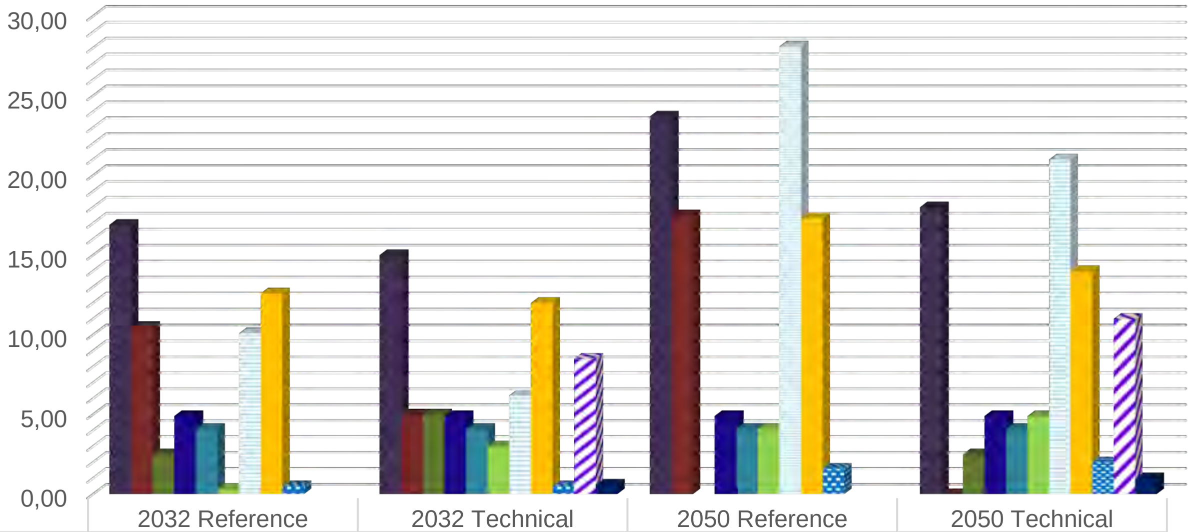
- *Resource reconsidered;*
- *Bottlenecks considered (legislative, land, environmental & social, investment, insurance, logistics, technology, grid to¬pology, as well as local congestions and other grid issues);*
- *Baseline assumptions modified to correspond to the real state of business (GDP growth is considered lower than in strategy (according to Global Trends) and Population change (it is expected that the population will not drama¬tically drop after the victory of Ukraine due to migration and return of citizens), the tempo of energy sector growth is between 3.5% for a first eight years and 2.6 % till 2050, while Energy Strategy provides for almost 5% growth);*
- *Wider and more practical outlook on available technologies;*
- *The resulting power system can be characterized as a carbon-negative, decentralized, self-reliant smart system, with RES forecasting, P2X compliant with both Ukrainian, EU and global goals;*
- *Consideration of adequate increase of ENTSO-e interconnections*
- *It is considered that the human resource will be sufficient to run all of the activities (as in the reference scenario).*

Breaktrhough Scenario

- *Optimistic implementation of technical scenario considerations*
- *Technology breakthrogh (Storage, P2X)*
- *Further advances on decentralisation and Smart Grids*

[9] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/Apr/IRENA_REmap_Ukraine_paper_2015.pdf
[10] https://www.ive.org.ua/wp-content/uploads/atlas.pdf

Figure 2 below displays the results for both scenarios. A spreadsheet and grid model were used for the calculations (which had been developed for other business projects and updated based on publicly available data or provided in the draft Energy Strategy available to the Consultant). As shown in Figure 5, estimated electricity generation is based on RE capacities shown in Figure 2.



	2032 Reference	2032 Technical	2050 Reference	2050 Technical
Nuclear	16,90	15,00	23,70	18,00
TPP	10,50	5,00	17,50	0,00
CHPP	2,50	5,00		2,50
HPP	4,90	4,90	4,90	4,90
PSPP	4,10	4,10	4,10	4,10
BioTPP	0,30	3,00	4,10	4,90
Wind	10,10	6,20	28,10	21,00
Solar	12,60	12,00	17,30	14,00
Storage	0,50	0,50	1,60	2,00
P2X - X2P		8,50		11,00
OTHER RES		0,60		1,00

Figure 2: Projections for installed RE capacities in 2 scenarios for 2032 and 2050 (in GW)

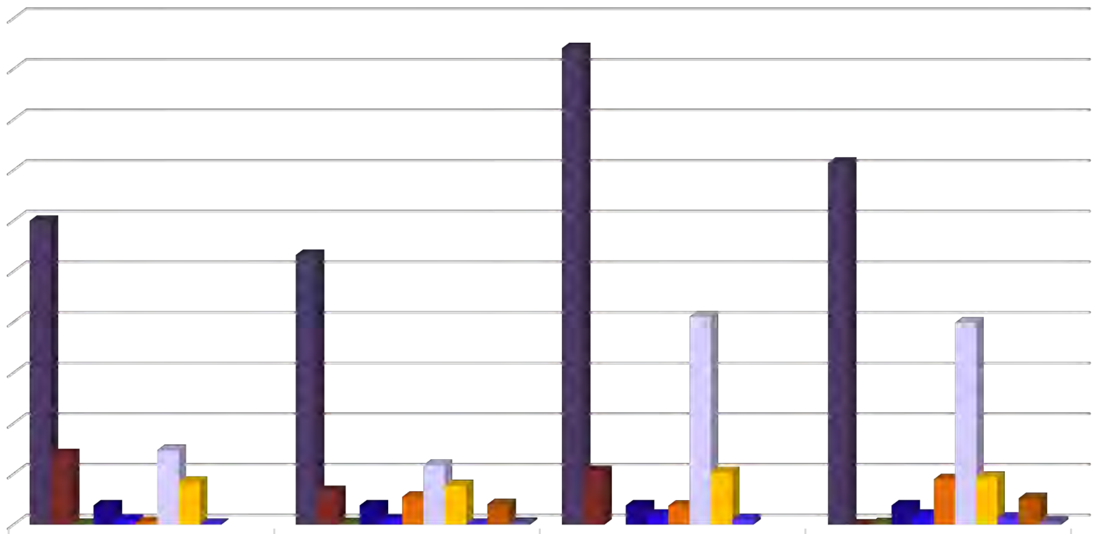
Under the technical scenario, and different from the reference scenario, the coal and most of gas generation (except some CHPP capacities) will be phased out to the maximum extent possible by 2050[11] (with coal as early as 2035, while HPPs' capacities will be significantly expanded [12]and current technologies will be widely implemented (including modern wind turbines). Increased energy storage capacities with PtX technologies will become an important component of the transition. The result will be a carbon-negative, decentralized, self-resilient energy system aligned/in compliance with EU and international goals, targets, regulations and standards.

Achieving and sometimes exceeding the current RES targets[13] signed by Ukraine is confirmed as feasible. This included, among other things, obligations under the European Green Deal. If adequate legislative, technical, and financial measures are taken and the necessary human, technical, and financial resources are available, then it is possible to accomplish the above.

[11] UA intends to phase out coal possibly by 2035 however replacing coal rather by gas. Fossil fuels will hardly be completely phased out before 2050.

[12] The capacities and energy are taken in accordance with a Strategy and program of hydropower development https://uhe.gov.ua/sites/default/files/2018-11/programa_rozvytku_gidroenergetyky_do_2026_roku.pdf . These values (installed capacities) were accepted. The expected increase is 2,6 GW

[13] A list of agreements is provided in Section 2 of the report.



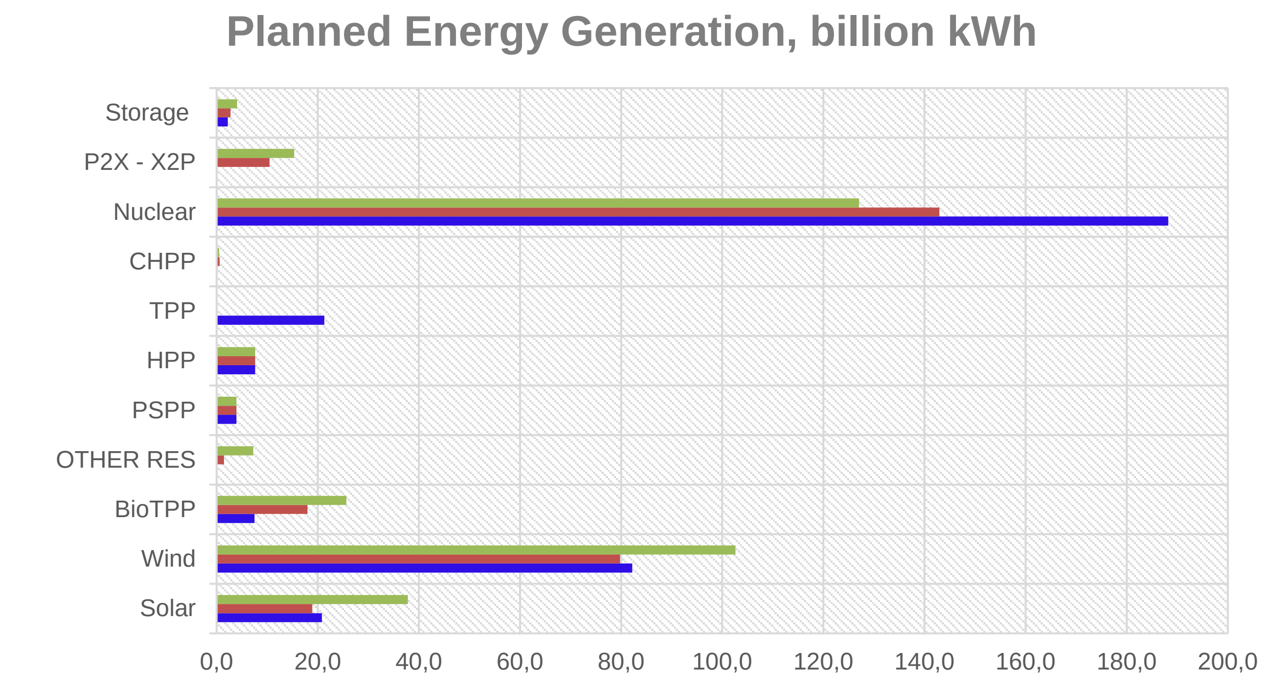
	2032 Reference	2032 Technical	2050 Reference	2050 Technical
Nuclear	120,0	106,5	188,2	142,9
TPP	27,8	13,2	21,3	0,0
CHPP	0,3	0,6		0,6
HPP	7,6	7,6	7,6	7,6
PSPP	2,0	2,0	3,9	3,9
BioTPP	1,1	11,0	7,5	18,0
Wind	29,5	23,6	82,2	79,8
Solar	16,9	15,6	20,8	18,9
Storage	0,3	0,3	2,2	2,8
P2X - X2P		8,1		10,5
OTHER RES		0,7		1,5

Figure 3: Electricity generation for 2032 and 2050 based on the installed capacities of the 2 scenarios of Fig. 2 (in billion kWh)[14]

To significantly advance the integration of renewable energy (RE) in Ukraine, a comprehensive approach that extends beyond the current moderate measures is essential. This approach should involve refining the power system operation concept to enable smoother RE integration, as outlined in the existing technical scenario. The scenario currently provides moderate predictions for decentralization and technological progress, without expecting major breakthroughs in areas like Cold Nuclear Fusion or significant advancements in storage technologies. Nevertheless, there's a substantial opportunity to enhance both the integration of RE sources and the resilience of the power grid within these parameters. This enhancement is vital for RE to play a central role in the reconstruction and revitalization of Ukraine's power system and its broader economy.

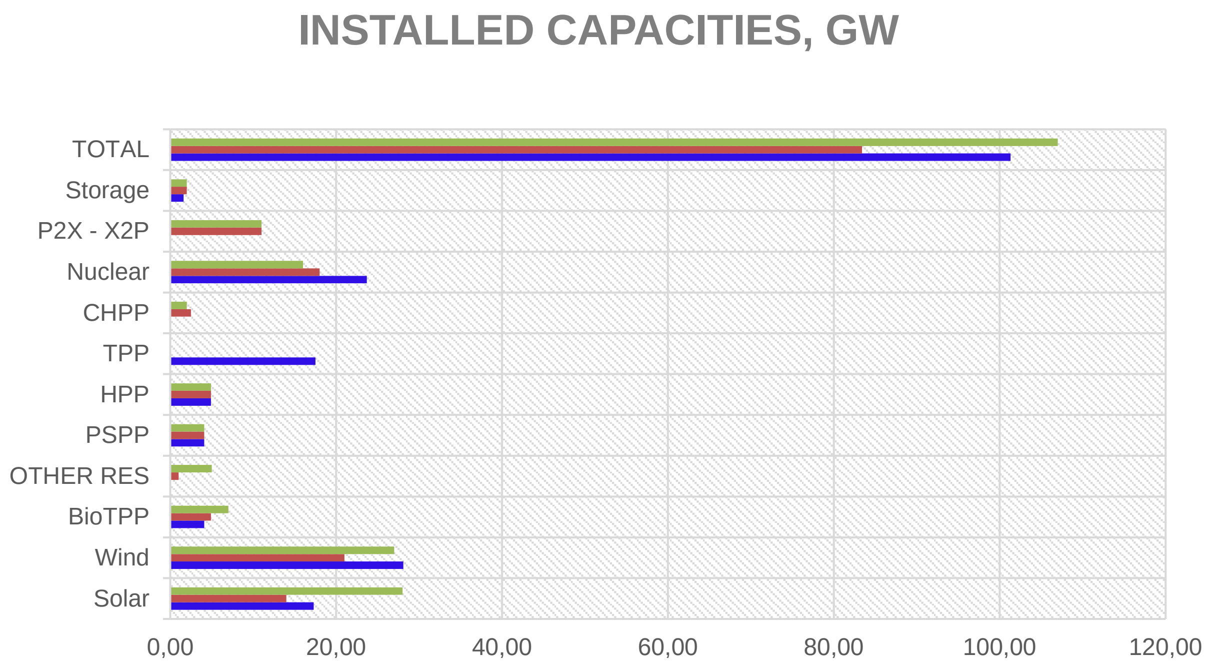
The breakthrough scenario for integrating renewable energy in Ukraine is shaped by acknowledging the conservative flexibility and balancing limits of the pre-war power system, as detailed in Ukrenergo's Generation Adequacy Report and similar studies of pre-war time. This scenario anticipates transcending these constraints through technological advancements and a strategic rethinking of the Ukrainian power system.

[14] The hydropower values were included from available version of energy Strategy. We also consider more intense pumping regimes and | and integration of P2X-X2P technologies at PSPPs (such as ones currently tendered by IBRD)- BESS. This results in more electricity without increase of generation capacities, the provisions in Strategy are verified as acceptable in this regard. This note will be introduced in calculation results to avoid confuse



	Solar	Wind	BioTPP	OTHER RES	PSPP	HPP	TPP	CHPP	Nuclear	P2X - X2P	Storage
2050 Breaktrhough	37,8	102,6	25,7	7,3	3,9	7,6		0,5	127,1	15,4	4,0
2050 Technical	18,9	79,8	18,0	1,5	3,9	7,6	0,0	0,6	142,9	10,5	2,8
2050 Reference	20,8	82,2	7,5		3,9	7,6	21,3		188,2		2,2

2050 Breaktrhough 2050 Technical 2050 Reference



	Solar	Wind	BioTPP	OTHER RES	PSPP	HPP	TPP	CHPP	Nuclear	P2X - X2P	Storage	TOTAL
2050 Breakthrough	28,00	27,00	7,00	5,00	4,10	4,90	0,00	2,00	16,00	11,00	2,00	107
2050 Technical	14,00	21,00	4,90	1,00	4,10	4,90	0,00	2,50	18,00	11,00	2,00	83,4
2050 Reference	17,30	28,10	4,10		4,10	4,90	17,50		23,70		1,60	101,3

Figure 4 Comparison by source, all scenarios

ES-3. Assessment of barriers and opportunities

When addressing the challenges in the Renewable Energy Sector, it is important to note that while the onset of war is a significant hurdle, it is not the sole concern since 2022. Pre-existing technical, legal, and economic issues have (also) led to a slowdown in RES investments.

Figure 5: Potential obstacles and Opportunities

The full-scale Russian invasion of Ukraine has brought unprecedented challenges to its energy sector, exacerbating existing technical, legal, and economic difficulties. Before the conflict, the sector was already dealing with issues related to the intermittent nature of renewable energy (RE), such as challenges in balancing renewable energy sources (RES), curtailments, forecasting inadequacies, coordination issues with Transmission System Operators (TSO) and Distribution System Operators (DSO), retroactive changes in tariffs, uncertainties in renewable energy auctions and Power Purchase Agreements (PPAs), insurance complications, logistical hurdles in Western Ukraine, and a slowdown in legislative simplification.

The war has further strained the energy sector, leading to reduced system stability and balancing capacity, a heightened need for accurate forecasting and more frequent curtailments, significant damage to Thermal Power Plants (TPPs) and key network infrastructures, ongoing conflict escalation risks, and disruptions in payments under the Feed-in Tariff (FiT) scheme.

To enhance the deployment of renewable energy in a cost-effective manner, a multi-faceted strategy is essential. This includes:

- Refining Feed-in Tariffs: Addressing existing issues with FiTs and considering further FiT schemes for smaller projects.
- Power Purchase Agreements: Implementing and stabilizing PPAs to encourage investment in renewables.
- Competitive Auctions: Conducting auctions to ensure the cost-effective selection of renewable energy projects.
- Financial Incentives: Offering subsidies or tax benefits to support renewable energy adoption.
- Net Metering and Small-Scale FiTs: Adopting net metering policies and FiTs for small installations to encourage residential and community participation.
- Grid Modernization: Upgrading the energy grid to integrate renewable sources effectively.
- Energy Storage Integration: Incorporating storage solutions to mitigate the intermittent nature of RE.
- Research and Development Promotion: Investing in R&D for technological advancements in renewable energy.

- Streamlining Permit Processes: Simplifying permitting and licensing to expedite renewable energy projects.
- Public-Private Partnerships: Encouraging collaborations between public entities and private investors.
- Community-Based Renewable Energy Initiatives: Supporting local renewable energy projects for community engagement and benefit.
- Energy Efficiency Programs: Implementing programs to reduce energy consumption and maximize efficiency.
- Education and Outreach: Focusing on public awareness and training to build support for renewable energy.
- Long-Term Planning: Maintaining a strategic vision for the sustainable development of the energy sector.
- Leveraging Economies of Scale: Utilizing large-scale projects to reduce the cost of renewable energy.
- Carbon Pricing Mechanisms: Introducing pricing strategies to incentivize reduction in carbon emissions.

These measures, collectively, aim to bolster Ukraine's renewable energy sector, fostering resilience and sustainability amidst the challenges posed by the ongoing conflict.

RECOMMENDATIONS

- Extension and implementation of legislative framework: the Law 3320-IX has to be further amended based on feedback from RES sector and concerned stakeholders, secondary legislation to be developed allowing to revitalize the sector
- Elimination of debts to producers: One of the foreseen solutions – introducing clear zero-deficit tariff for Ukrenergo and relevant communication producers assuring further streamline of financing
- Elaborate mechanism for covering military risks: The issue of covering military risks has not yet been resolved significantly limiting any investment activity
- Use of successful institutional experience of other countries: Instead of creating from the scratch many incentives can be integrated from the experience of such countries as Denmark, Netherlands and Germany, to do so negotiations with these countries are ongoing. For example, in terms of approvals associated with grid connection – these further may be on paid basis to avoid flow of unrealistic developments limiting the grid access for the projects ready to invest.
- Utilize the Cost-effective options for RES development: Please refer to the list of actions foreseen in Clause 3.3
- Extension of Technical Conditions: Investors who were ready to build their objects before the full scale invasion started shall be able to proceed with their plans so a very clear and transparent extension of Technical Conditions shall be arranged – 5 years for projects which are proven to be built

ES-4. Further development of renewables

The provision of war-related risk insurance to private investors is paramount for ensuring Ukraine's resilience, particularly in the context of the ongoing conflict. The current challenges in this domain include the difficulty in insuring international staff working in Ukraine. The prohibitively high cost of such insurance is a significant barrier, impeding the swift execution of reconstruction projects that require the presence of international experts.

To address these issues and facilitate the implementation of vital insurance mechanisms, Ukraine must establish a regulatory framework conducive to insurance provision. This framework should encourage insurers to offer relevant policies and include measures to subsidize or reduce insurance costs for renewable energy (RE) project developers, thereby making insurance more accessible and affordable.

In addition to insurance mechanisms, the advancement and integration of RE technologies are essential for Ukraine's energy transition. These technologies are crucial for enhancing grid stability, reducing greenhouse gas emissions, and meeting energy transition objectives. The deployment of such technologies has been a key consideration in the development of Ukraine's technical scenario for energy sector development as provided in Chapter 2 of the report.

The Danish Energy Agency (DEA) could provide a model for a one-stop-shop approach in Ukraine. However, adapting this model to the Ukrainian context is necessary. The regulatory framework for the one-stop-shop solution in Ukraine should be tailored to allow project developers to assume development responsibilities using their resources. This adaptation is particularly important where the capacity of a state-appointed agency may be limited or insufficient for ensuring the rapid and high-quality development of projects. Such an adjustment would enable more efficient project execution and contribute to the expedited recovery and development of Ukraine's energy sector amidst the challenges of war.

RECOMMENDATIONS

- Reliable Payment Systems for RE Electricity Generators. It's essential to establish reliable and prompt payment mechanisms from offtakes to RE existing and future electricity generators – these mechanisms may be supervised by international referees
- Expedient settling of the existing debts and malperformance issues. Settling debt issues, imbalances and limitations imposed on developers. Lifting bureaucratic limiting by establishment of one-stop-shops and transparent development, construction and operation manuals will provide a very clear signal to investors willing to contribute in Ukraine's "building back better"
- AI technologies in balancing and forecasting. Ukraine is often proclaiming digitalization as one of the main drivers of Economy restoration.
- Active Support for Prosumers: Encouraging the concept of "prosumers" – consumers who also produce electricity – is crucial. This approach not only reduces the load on the grid but also promotes local energy generation and consumption. Policies and incentives such as feed-in tariffs, net metering, and subsidies for installing renewable energy systems can stimulate prosumer participation.
- Grid Reinforcement and Decentralization: Moving from a centralized system with large generation capacities to a distributed generation model is key. This involves reinforcing the grid infrastructure to support the integration of renewable energy sources from areas most suitable for RE generation to areas with high consumption. Investment in smart grid technologies, which allow for better integration and management of distributed energy resources, is essential. This shift will enable a more resilient and flexible energy system, capable of accommodating diverse renewable energy sources
- Demand-Side Management and Harmonizing Supply and Demand: Effective demand-side management is necessary to align variable RE electricity supply with demand. This requires a combination of significant price incentives (varying by factors of 10 or more depending on RE availability
- Development of an Updated Ukraine Energy Strategy (with due consideration of available technologies as described in cl. 4.3 hereof), Harmonization of Subordinate Plans, Legislation, Programs and development frameworks.
- Elaborate a one-stop-shop for Ukraine in an administrative agency which facilitates and leads the effort.
- Establishment of the insurance mechanisms: the of efficiency of Law of Ukraine "On financial mechanism for promoting export activities" regarding insuring investments in Ukraine against military risks (draft law No. 9015 dated 14 February 2023) will be directly linked to availability of funds for such insurances which shall be involved from IFIs, international donors and other sources. The government can implement comprehensive policy reforms that include subsidies, risk guarantees, and regulatory support, tailored to mitigate the specific risks associated with various sectors.

------ End of the Executive Summary -----

0. INTRODUCTION

The impact of Russian aggression is significantly impeding renewable energy projects and the sector as a whole, causing a substantial setback compared to its status before the war. As of September 2022, a quarter of the existing renewable energy capacity was out of operation, among which the large majority of power generation from wind. The number of projects destroyed, damaged and under enemy occupation increases rapidly. Moreover, debts owed to investors continue to accumulate. It is evident that restoring and speeding up the development of the renewables sector in Ukraine after the war will have to take the highest priority in the context of rebuilding back the economy of Ukraine in line with the European Green Deal. The renaissance of the renewable energy sector in Ukraine will also contribute to diversification and increased energy resilience of Ukraine, attract foreign investors and provide possibilities for trade in green electricity, biogas and hydrogen with the rest of Europe. For this renaissance to happen rapidly and for full potential of renewables to be utilized, a number of preconditions of regulatory, institutional and financial nature need to be put in place.

OBJECTIVE: Providing an analytical assessment of the potential for use of renewable energy sources and propose actions to rebuild, then further develop the renewable energy sector in Ukraine.

The report follows the structure of the assignment and represents the following 4 tasks:

- **Task A (Chapter 1) "Overview of the current condition of the renewable energy sector"** reflects the condition of power sector as of the end of the year 2023, covering the global trends, state of Transmission and distribution system of Ukraine. As well, offering brief information on ETNSO-e integration and the way the Power Sector was able to withstand terrorist attacks initiated by Russian federation. Legislative background, main goals and recent advancements are covered such as an adoption of Energy Strategy and The Law "On the Restoration and Green Transformation of Ukraine's Energy System being the cornerstones for sector development in the post-war condition. It reflects on the sector's resilience in the face of external threats and its commitment to aligning with European standards and practices
- **Task B (Chapter 2): "Calculation of potentials for renewable energy sources"** provides for review of existing Condition of RES sector, available resource, elaboration of scenarios and calculation of technical potential for post-war development of RES. It underscores the importance of data collection and validation, methodology, stakeholder engagement and a proper consideration of all impacts and factors in accurately determining RES potentials and the further RES integration potential. The resource and development potentials are calculated amidst the challenges posed by the current geopolitical, technical and economic conditions in Ukraine.
- **Task C (Chapter): "Assessment of barriers and opportunities"** address the existing bottlenecks faced by sector and analyses of possible solutions and available investment plans. This chapter of the report identifies and examines the multifaceted challenges facing Ukraine's renewable energy sector, both historical and current. It also highlights various plans and strategies designed to address these challenges, emphasizing the potential for growth and development in the sector despite the difficulties. The emphasis on recovery plans and leveraging investment opportunities suggests a forward-looking approach to revitalizing and expanding Ukraine's RES capabilities
- **Task D (Chapter 4)**: "**Options for further development of renewables"** focuses on the critical role of insurance in enabling the further development of renewable energy in Ukraine. It emphasizes the need for effective risk mitigation strategies to attract private investments into the renewables sector. The involvement of international organizations and the assessment of the country's economic resilience and physical damages underscore the comprehensive approach needed to rebuild and advance Ukraine's renewable energy infrastructure, especially in the challenging context of ongoing conflict and post-war recovery. It also provides for the description of technologies and mechanisms considered in technical scenario as well as recommendations on streamlining of permitting procedures in a form of a One-Stop-Shop.

1 Current Condition of the Power Sector

This Chapter 1 addresses the condition of power sector as of the end of the year 2023, covering the global trends, state of Transmission and distribution system of Ukraine, brief information on ETNSO-e integration and the way the Power Sector was able to withstand terrorist attacks initiated by Russian federation.

Separate attention was given to energy demand variation, electricity prices growth including the DAM market price as well legislative background and recent advancements such as an adoption of Energy Strategy and The Law "On the Restoration and Green Transformation of Ukraine's Energy System being the cornerstones for sector development in the post-war condition.

Another particular focus is directed towards the current challenges faced by the power sector and the existing progress in resolving the sector crisis that began before the full-scale invasion.

1.1 Trends for development of RES (Globally)

According to 2023 Climatoscope by Bloomberg NEF in 2022, global funding for renewable energy projects reached USD 560 billion[15]. According to Irena[16], global investments across all energy transition technologies reached a record high of USD 1.3 trillion in 2022, yet fossil fuel capital investments were almost twice those of renewable energy investments. With renewables and energy efficiency best placed to meet climate commitments - as well as energy security and energy affordability objectives – governments need to redouble their efforts to ensure investments are on the right track.

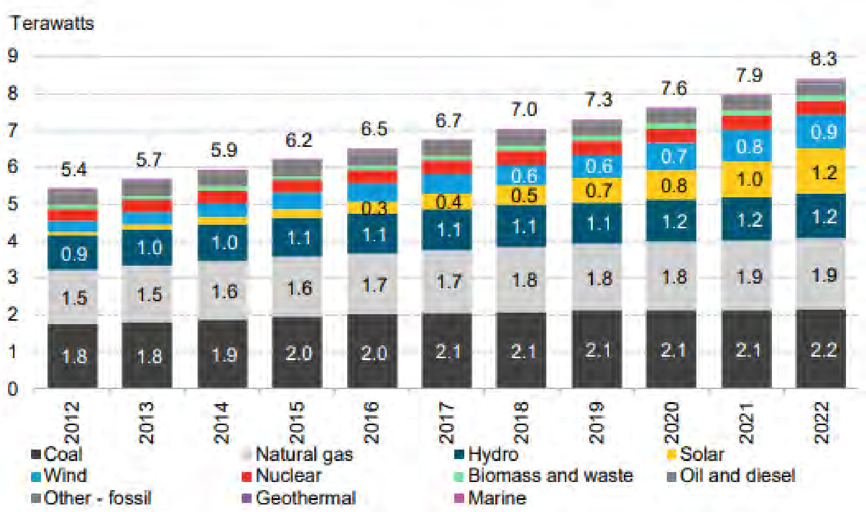


Figure 6 Change in global installed capacity by technology (Bloomberg)

Wind power: *Share*: **8%** (up from 4% in 2016) Contribution: Nearly doubled in six years	**Solar power**: *Share:* Nearly **5%** (up from less than 1.5% in 2016) Contribution: More than tripled in six years
Zero-carbon technologies: Share: **40%** Contributors: Hydro (15.4%), Nuclear (9.5%), Wind, Solar, Geothermal, Biomass	**Fossil fuels:** Share: **59%** (down from 65% at the beginning of the decade)

Wind and solar surpassed 25% of global power capacity for the first time in 2022, reaching nearly 26% as of year-end. Zero-carbon technologies now account for 46% of global capacity, up from 33% in 2012. Solar being the fastest growth of any type of generation, with capacity increasing 20% to 1,228 GW in 2022 (11 times more than 2012 and 176 times more than 2006). Global wind capacity also grew 10% in 2022, reaching 930 GW (tripling in a decade) while the combined additions in 2022 for both wind and solar resulted in **341 gigawatts**, 222 gigawatts of which were added in developing economies.

New power-generating capacity added globally reached a record 424GW in 2022, with solar and wind accounting for 80% of the total. This was up 14% from 371GW in 2021, and up more than 80% compared with the 231GW added in 2012. Solar accounted for 59% of all capacity added, followed by wind, at 21%. Solar photovoltaic (PV) additions in 2022 were nearly 40% higher than in 2021. Wind capacity additions dropped by 10% compared with 2021, held back by challenges around permitting, interconnection, supply

[15] https://global-climatescope.org/

[16] https://www.irena.org/Digital-Report/World-Energy-Transitions-Outlook-2023

chains and profitability. Supply chain bottlenecks have limited late-stage project deployment as well as rising costs for developers.

In 2022, the world produced nearly 3,500 terawatt-hours (TWh) of electricity. Of this total, wind and solar energy sources combined for a significant **12.6%,** demonstrating their rapid growth in recent years.

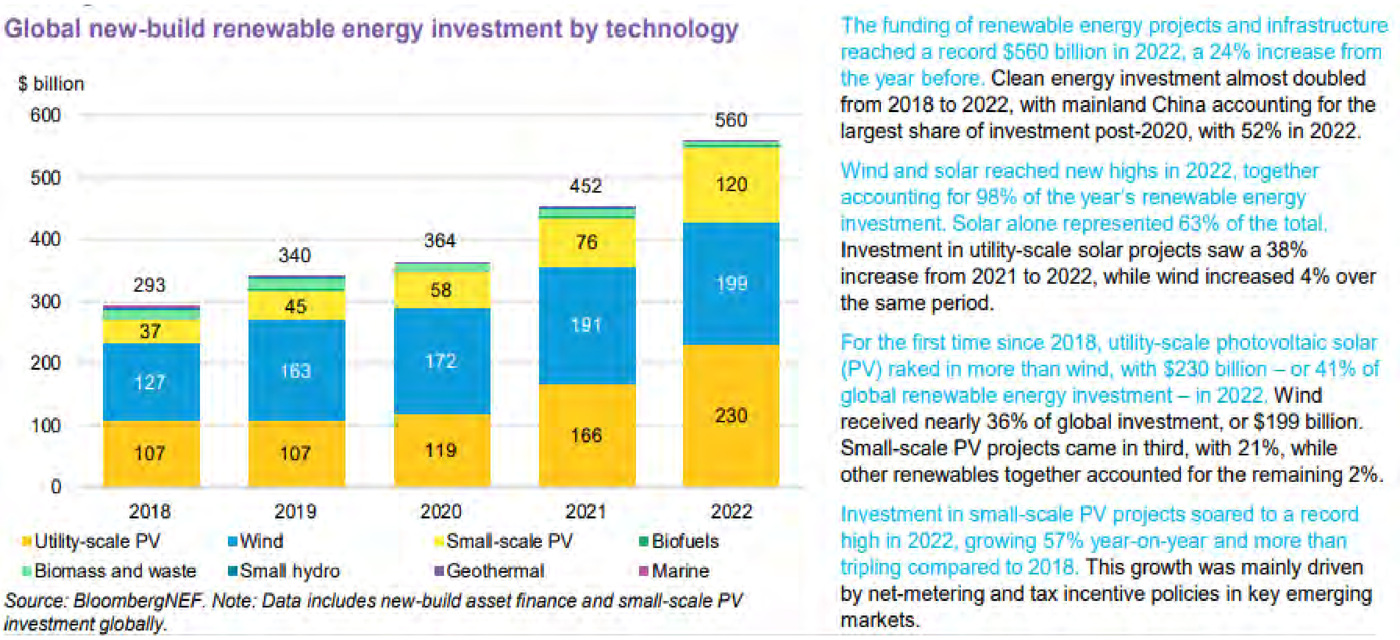


Figure 7: Global generation trends during the last 6 years (data from Bloomberg)

At the same time, these impressive figures, **according to IRENA[17],** are not sufficient to keep the energy transition on the track. Limiting global warming to 1.5°C requires cutting carbon dioxide (CO_2) emissions by around 37 gigatones (Gt) from 2022 levels and achieving net-zero emissions in the energy sector by 2050. Despite some progress, significant gaps remain between the current deployments of energy transition technologies and the levels needed to achieve the goal of the Paris Agreement to limit global temperature rise to within 1.5°C of pre-industrial levels by the end of this century.

While there were record renewable power capacity additions in 2022, the year also saw the highest levels of fossil fuel subsidies ever, as many governments sought to cushion the blow of high energy prices for consumers and businesses. Global investments across all energy transition technologies reached a record high of USD 1.3 trillion in 2022, yet fossil fuel capital investments were almost twice those of renewable energy investments. With renewables and energy efficiency best placed to meet climate commitments - as well as energy security and energy affordability objectives – governments need to redouble their efforts to ensure investments are on the right track.

<u>Hereunder, the main trends are mentioned setting out the framework for the RES potential estimation:</u>

- Most international commitments aim to achieve zero emissions by 2050, and earlier Finland aims to achieve this goal by 2035, Austria and Iceland by 2040, Sweden by 2045, and the EU by 2050.
- In order to fulfil obligations to reduce CO2 emissions and dependence on fossil fuels, countries worldwide are actively developing RES.
- According to the IEA "Renewable Energy Market Update"[18] in 2023, the increase in global RES capacity is expected to remain stable compared to 2022. However, solar will break another record in 2023, reaching nearly 200 GW, while wind and bioenergy growth will remain steady.
- To ensure the energy security of the EU, several changes in the international supply chains of energy resources are foreseen, such as:
  (i) An increase in the supply of LNG from the USA and Canada;
  (ii) Pipeline gas from Norway, Azerbaijan and Algeria;
  (iii) Cooperation with African countries on the potential increase of export capacities of natural gas

[17] https://www.irena.org/Digital-Report/World-Energy-Transitions-Outlook-2023

[18] Renewable Energy Market Update, URL: https://iea.blob.core.windows.net/assets/d6a7300d-7919-4136-b73a-3541c33f8bd7/RenewableEnergyMarketUpdate2022.pdf

from Nigeria, Senegal and Angola;

(iv) The beginning of a collaboration with major producers of the Persian Gulf, including Qatar, as well as with Australia;

(v) Political agreements with gas suppliers such as Egypt and Israel to increase the supply of LNG and other changes.

- According to NZE[19] under the IEA scenario, the use of fossil fuels will decrease sharply by 2050[20].
- Low-emission fuels (biogas, bio-methane, hydrogen and hydrogen-based fuels) will show rapid growth in the consumption mix, accounting for nearly 10% of global final energy consumption in 2050, up from 1% in 2020.
- In 2050, more than 450 Mt of low-carbon hydrogen will be produced, of which about 70% will be made by electrolysis.
- Although there is an annual increase in the energy efficiency of the world's economies, in the IEA's NZE scenario, electricity demand will triple between 2021 and 2050 in developing countries.
- **Natural gas:** Diversification of import sources for reduction of dependencies from Russia; active financing for development of biogas and bio-methane for replacement of natural gas; development of ways for supply of LNG gas.
- **Oil**: Diversification of import sources for reduction of dependencies from Russia.
- **Coal:** Regardless of the accepted obligation to achieve Net Zero, coal is still considered by different countries as leverage to reach independence from Russia (Ukraine plans to phase out coal in energy in the medium-term perspective taking into account everyone's energy safety - significant part of thermal generation of Ukraine depends on coal. Implementation of this obligation depends on the terms for reaching the resolution of military actions on the territory of Ukraine and further helping international partners in recovery power systems, including financial aid.
- **RES:** Active development of RES for reduction of dependencies from fossil fuel.
  - Per "Technology and innovation pathways for zero-carbon-ready buildings by 2030", about 100 million households worldwide will have rooftop PV according to the NZE plan. By 2030 solar and wind energy will provide about 40% of electricity consumption in buildings[21].
  - "REPowerEU Plan" in the EU foresees the share of RES in accordance with the "Renewable Energy Directive" to 42.5% by 2030.
- By assessments of International renewable energy agency' energy sources (IRENA), by 2050, 90% of world electricity can and should come from renewable sources[22].
  - Ukraine aspires to continue the active development of RES. The indicative RES consumption goal in 2030 is 27% in the following sectors: electric power industry – 25%; heating and cooling – 35%; transport – 14%. These targets were approved on 15 December 2022 by Decision of the Ministerial Council of the Energy Community (Decision 2022/02/MC- EnC).
- **Hydrogen:** Active building up production capacities of hydrogen.
  - IEA notes that in 2020 world demand for hydrogen constituted about 90 million tons, mainly produced from fossil fuels, leading to CO_2 of about 900 Mt[23].
  - A significant part of hydrogen will be used in heavy industry (steel production, for instance), and in the transport sector, about 26% will be transformed into other fuels based on hydrogen (for example, ammonia, synthetic fuel), 13% will be used in gas power plants, according to NZE[24].
  - In the NZE scenario by IEA, in 2050, 10% of the world's final demand for energy will be provided by hydrogen[25].
  - By 2030 global installed electrolyser capacities may reach 54 GW, taking into account projects under active development. If early developments are also considered, the capacity may grow to 91 GW in 2030. The majority of projects are to be constructed in Europe and Australia[26].
  - The EU, in the "REPowerEU Plan" foresees 10 million tons of renewable hydrogen production and 10 million tons of imports until 2030.

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[19] Net Zero by 2050. A Roadmap for the Global Energy Sector. URL: https://www.iea.org/reports/net-zero-by-2050
[20] World Energy Outlook 2022, URL: https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf
[21] IEA, URL: https://www.iea.org/reports/approximately-100-million-households-rely-on-rooftop-solar-pv-by-2030
[22] World energy transitions outlook 2022: https://www.irena.org/publications/2022/mar/world-energy-transitions-outlook-2022
[23] IEA Global Hydrogen Review 2021, URL: https://www.iea.org/reports/global-hydrogen-review-2021
[24] World Energy Outlook 2022, URL: https://www.iea.org/reports/world-energy-outlook-2022
[25] World Energy Outlook 2022, URL: https://www.iea.org/reports/world-energy-outlook-2022
[26] IEA Global Hydrogen Review 2021, URL: https://www.iea.org/reports/global-hydrogen-review-2021

- Ukraine has the potential for the production and export of hydrogen. Hydrogen Europe's 2X40 GW Initiative provides for cooperation with Ukraine and the construction of electrolyzers with a capacity of 8 GW by 2030 for export goals[27].
- The Central European Hydrogen Corridor (CEHC) initiative was launched in 2021 by four gas infrastructure companies (OGE, NET4GAS, eustream, and Gas TSO of Ukraine) driven by the vision to develop a hydrogen "highway" through Central Europe. The initiative explores the feasibility of creating a hydrogen pipeline corridor in Central Europe for transporting hydrogen from major hydrogen supply areas in Ukraine via Slovakia and the Czech Republic to hydrogen demand areas in Germany. The hydrogen corridor will also enable the transport of hydrogen between hydrogen production facilities and hydrogen consumers in the Czech Republic and Slovakia[28].

- **Nuclear:** Extending the service life of existing reactors; construction of new nuclear reactors.
  - The pandemic and the war in Ukraine have revealed the vulnerable dependence of world economies on fossil fuels. Nuclear energy is becoming relevant again because it can contribute to achieving zero emissions and become the basis of a more sustainable energy ecosystem.
  - According to the World Nuclear Association, in 2021, nuclear reactors produced 2,653 TWh of energy.
  - In 2022, the European Commission adopted **Complementary Climate Delegated Act,** covering the EU taxonomy of nuclear and gas energy and defining them as transitional sources on the way to increasing the capacities of renewable energy sources[29].
  - According to the “Net Zero by 2050” report the IEA's[30] 2050 Roadmap, nuclear power generation will grow by 40% by 2030 and double by 2050, with the total share of energy generation to be less than 10% in 2050.
  - Now that the new taxonomy bill has been passed through the European Parliament and includes both natural gas and nuclear energies, it is even easier for Ukraine to help the EU transition in the short and medium term. For Ukraine's export of nuclear power to reach its short-term potential, cross-border capacities need to be increased.

- **Electrification**:
  - In its strategic plans, Ukraine focuses on the EU Directives on energy efficiency, energy performance of buildings, and establishing frameworks for energy labelling. At the same time, national plans and strategies for electrification and energy efficiency are foreseen.
  - The EU has banned the sale of new cars with internal combustion engines from 2035.
  - In Ukraine, the share of electric cars is expected to grow to about 50% of the total number of vehicles in the country by 2050.

- **Heat:** Development using thermal pumps; heat supply from renewable sources.
  One of Ukraine’s liabilities in line with the Agreement on association with the EU is the development of highly efficient cogeneration and the creation of energy-efficient schemes for centralized heat supply, where one of the elements is the combined production of thermal and electric energy. RES share in heat generation by 2025 is expected at a level of 30%, in 2035 to 40%.

- **A circular economy for manufactured goods** is a strategic opportunity for Ukraine to decarbonize and ensure sustainable access to scarce resources, and extend the economic value of materials and products.

- **Synchronization with ENTSO-E.** Even in spite of the war starting on the day of islanded mode operation, the Ukrainian power system has proved its stability and, since 16 March 2022, has been synchronized with ENTSO-E providing valuable technical potential for trade and security.

[27] Green Hydrogen for a European Green Deal A 2x40 GW Initiative, URL: https://www.waterstofnet.eu/_asset/_public/WIC/Hydrogen-Europe_2x40-GW-Green-H2-Initative-Paper-1.pdf
[28] https://www.cehc.eu/cehc-project/
[29] European Commission, URL: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_4349
[30] Net Zero by 2050. A Roadmap for the Global Energy Sector. URL: https://www.iea.org/reports/net-zero-by-2050

1.2 Pre-war condition of the power system in Ukraine

Total installed capacity of power plants in the IPS of Ukraine as of 31.12.2021 is 56.247 GW (excluding energy generation units of the Crimean power system and temporarily uncontrolled territories of Donetsk and Luhansk regions), of which 49.7% are related to thermal power plants (in particular, TPPs, CHPs, modular plants), 24.6% to nuclear power plants, 11.2% to hydropower and pumped storage power plants, and 14.5% to generation units running on renewable energy sources – WPPs, SPPs, BioPPs.

Major generating capacities of the IPS of Ukraine (as of 31.12.2021) are concentrated at:

- 4 nuclear power plants (15 power units, of which 13 units with capacity of 1,000 MW and 2 units with capacity of 415 MW and 420 MW, respectively);
- 10 hydropower plants on the Dnieper, Dniester and Pivdennyi Buh Rivers, as well as on the Tereblia and Rika Rivers (Tereble-Ritska hydropower plant) with a total installed capacity of 4,729.5 MW, and a total number of 101 units. Additionally, there are 3 pumped storage plants with 11 units having a capacity of 1,487.8 MW (with unit capacities ranging from 33 MW to 324 MW);
- 12 TPPs with 75 units having unit capacities of 150, 200, 300 and 800 MW (150 MW – 6 units, 200 MW – 31 units, 300 MW – 32 units, 800 MW – 6 units) and 3 turbo generators, as well as 3 large CHPs with unit sizes of 100 (120) MW – 4 units, and 250 (300) MW – 5 units;

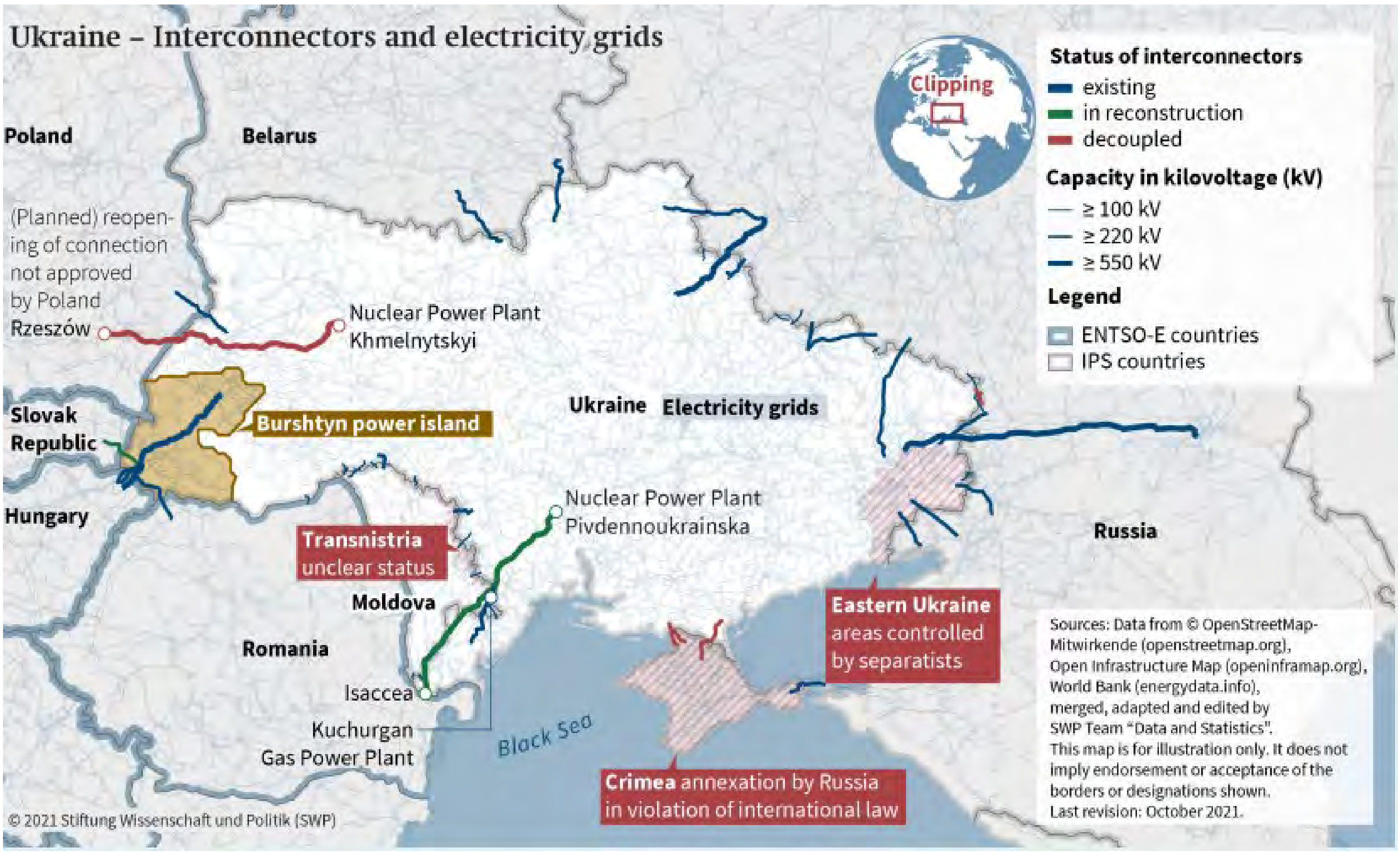

Figure 8 Pre-war transmission system of Ukraine prior to ENTSO-e integration (31

RES plants (including power plants running on biofuels) with a total capacity of 8,148 MW, including Syvaska WPP (the largest in terms of installed capacity of 245.7 MW but for a number of reasons its actual capacity is much lower), Pokrovska SPP (240 MW), Solar Pharm-1 (200 MW), Botievska WPP phases 1-65 (199,875 MW), Myrnenska WPP phases 1–6 (163 MW), as well as a number of power plants with lower capacity.

[31] https://www.swp-berlin.org/publications/products/comments/2021C57_ConnectingUkraine.pdf

Table 2: Renewable energy sector development

RES technology	RES growth compared to the previous year for the period 2016-2021 (in MW)					
	Years					
	2016	2017	2018	2019	2020	2021
WPP	10.9	27.9	60.6	636	86,2	562
SPP	98.9	300.4	466.4	2 565.9	1 807.2	2 222
BioPP	10.2	34.3	1.8	48.3	57	77
Micro-, mini- and small HPP	n/a	5.4	1.9	4.4	6.6	0.9

The development of RE shows a stable upwards trend due to simple and attractive feed-in tariff mechanism, availability of financing by Ukrainian banks, overall sector development progress resulting in multiple success stories. In recent years, there has been a steady increase in the number of commissioned RE facilities.

This dynamic of RE development leads to an increase in the forecast electricity output in the IPS of Ukraine from RE sources (in 2019, electricity generation from RES in the overall production mix reached 3.6% or 5.5 billion kWh; in 2020 generation reached 10.1 billion kWh or 6.8%, in 2021 – 12.5 billion kWh or 8%, and it was expected that in 2022 generation would reach about 14 billion kWh, constituting at least 9% of the total electricity output by all power plants in the IPS of Ukraine).

	2020		2021		+/- as compared to 2020	
	Electricity output, mln kWh	Share in total production, %	Electricity output, mln kWh	Share in total production, %	mln kWh	%
Total electricity output including:	148,854.0	100	156,601	100	7,747	5.2
TPPs and CHPs	52,360.8	35.2	45,843	29.2	-6,517.8	-12.4
TPPs	39,562.6	26.6	37,224	23.7	-2,338.6	-5.9
CHPs	12,798.2	8.6	8,619	5.5	-4,179.2	-32.6
HPPs and PHSs:	7,583.5	5.1	10,172	6.5	2,588.5	34
HPPs	6,026.2	4.0	8,879	5.6	2,852.8	47.3
PHSs	1,557.3	1.0	1,293	0.8	-264.3	-16.9
NPPs	76,202.5	51.2	86,206	55	10,003.5	13.1
RES *(WPPs, SPPs, BioPPs)*	10,862.1	7.3	12,804	8.1	1,941.9	17.8
Block-stations and other sources	1,845.1	1.2	1,576	1	-269.1	-14.5

Source: *NPC Ukrenergo, PU UWEA, 2021*

Figure 9: Pre-war dynamics in production shares by different source of energy

1.3 Present condition of Power Sector in Ukraine

Note: This subchapter does not describe the RE generators as they are included in the chapter on the "Calculation of RES potentials".

Since 2014, the Russian Federation has employed military tactics involving attacks on civilian utilities and energy infrastructures. These tactics intensified on October 10, 2022, leading to significant damage to transmission and distribution (T&D) infrastructure and posing risks to the stability of power systems. Such actions directly affect the operational conditions of renewable energy source (RES) projects. Despite these efforts, as of February 2024, Russia has not achieved its main objective of inflicting continuous and irreparable damage to the infrastructure for political purposes.

The Ukrainian energy sector evaluation and damage assessment prepared by KSE was made in the majority of cases without consideration of the new war strategy[32].However the damage to the energy sector is already exceeding **USD6.8 BLN *(USD 9.1 BLN*** *if utility and district heating are included*) comprising significantly higher losses and rehabilitation needs.

Within 10 months in 2022, Ukraine exported electricity worth USD 542.5 million. The massive attack and consequential damages to the power sector also resulted in the Ukrainian government's decision to stop the electricity export to the EU/ENTSO-E starting from 11 October 2022 (meanwhile lifted again). As of January 2023, Ukraine started importing small amounts of electricity from Western/Central Europe's ENTSO-E. On November 28, 2023, the maximum import capacity from European countries in Ukraine from 1200 MW to 1700 MW. In fact, during the first week of December 2023 commercial electricity imports peaked at only 137 MW during scarce hours due to restrictions on Ukrainian electricity prices.

As a result, Ukrenergo attracted more expensive emergency assistance on December 7 from 11 a.m. to 7 p.m. to almost 700 MW per hour

Figure 10 Russian attacks on Ukrainian IPS (image by texty.org.ua)

As of June 2022, Ukraine's recovery needs were estimated by the World Bank and the European Commission at USD 350 billion. Since then, the estimation may exceed USD 600-750 billion. Ukraine's Prime Minister Denys Shmyhal announced it during the opening of the Rapid Recovery of Ukraine Business Forum held in Luxembourg.

According to the Prime Minister of Ukraine, five priorities have been identified for financing a rapid recovery. The first being energy sector. Also, the Prime Minister of Ukraine, Mr.Denys Shmyhal stated that more than 400 power and heat supply facilities have been damaged as a result of the attacks. Ukraine seeks not only to restore the energy network, but also to decentralize it, which will make it less vulnerable and improve the availability of electricity in Ukrainian homes and businesses.[33]

Tremendous efforts of the Ukrainian energy company NPC "Ukrenergo", with the substantial support of international partners, in order to assure the urgent recovery and re-energization. These continuous efforts allowed, on 28 February 2023, to state that "***the import of electricity in Ukraine is approaching zero***"[34]. This means that the UA power system, even in its current state of significant destruction, is now

[32] European Parliament declares Russia to be a state sponsor of terrorism https://www.eeas.europa.eu/delegations/ukraine/european-parliament-declares-russia-be-state-sponsor-terrorism

[33] https://www.kmu.gov.ua/en/news/denys-shmyhal-enerhetyka-ta-zhytlo-sered-priorytetnykh-napriamkiv-finansuvannia-shvydkoi-vidbudovy

[34] Ukrenergo's telegram https://t.me/Ukrenergo/1932 & https://kyivindependent.com/news-feed/ukrenergo-no-energy-deficit-in-ukraine

producing as much electricity as is needed for consumption. Therefore, there have been no larger power outages in Ukraine till the present time, and deficits are not predicted (depending on future damages).

It shall be noted, that since February 2022 Ukraine has received a lot of help for the power system renovation from different international donors. The major part of it was provided by the Ukraine Energy Support Fund established by the Energy Community Secretariat in 2022.

As of December the 1st 2023

- ENTSO-E officially announced that "Ukrenergo" has fulfilled all necessary technical requirements for the final synchronization of the Ukrainian power system with the European ENTSO-E. This is a wonderful, long-awaited result of the persistent work of energy specialists over the past several years.
- 31 combined heat and power (CHP) and thermal power plants (TPP) are in operation. Among them, 5 TPP units are already operating on gas.
- The total level of coal reserves in the warehouses of Ukrainian CHP and TPP is approximately 860,000 tons.
- All 9 nuclear power plant (NPP) units located in non-occupied territories are operating in the energy system of Ukraine.
- The Dnieper Hydroelectric Power Station (HES) cascade operates based on inflow rates with a gradual economic utilization of the main reservoirs.
- The reservoir levels correspond to the decision of the Interdepartmental Commission on establishing the operation mode of the Dnieper cascade HES and Dniester HES.
- Solar power generation remains at a seasonal level.
- The debt of the National Energy Company "Ukrenergo" to the Guaranteed Buyer for November remains almost unchanged and amounts to UAH 32.57 billion.

1.3.1 Transmission system

The Electricity transmission system, managed by the National Power Company "Ukrenergo," comprises 23,600 km of overhead lines and 141 substations with voltages ranging from 110 to 750 kV. Before Day 1 of the invasion, approximately 25% of these substations were in territories temporarily occupied by Russia, with an additional 12% coming under occupation thereafter. Russian attacks have resulted in the destruction or damage of around 40% of Ukrenergo's transmission substations. Many substations have been targeted multiple times, leading to over 40 overhead lines and 20 substations of 220–750 kV voltage being damaged or disconnected due to ongoing assaults.

The electricity system was divided into two segments. The smaller western region, adjacent to Slovakia, Hungary, Romania, and Poland, was already synchronized with the Continental Europe power system. This area, known as the Burstyn Energy Island (BEI), includes the Burshtyn Thermal Power Plant (2,400 MW) owned by DTEK Zakhidenergo, with a total capacity of 4,700 MW. In 2017, the BEI had 650 MW of transmission capacity connecting it to neighboring ENTSO-E states. However, the majority of Ukraine, including areas under temporary occupation, remained synchronized with the integrated power system (IPS) of the ex-Soviet republics, also involving Belarus, Moldova, Russia, and the Baltic States.

Synchronization with the European grid, a long-standing goal, gained urgency after the Euromaidan and subsequent Russian invasion. Ukraine and Moldova had sought synchronization with ENTSO-E's predecessor as early as 2006. The integration into the European grid became more feasible thanks to the adoption of EU's Acquis Communautaire in Ukraine's energy sector and the country's electricity market reform in 2019.

Currently, Ukraine's system is a key part of the European Network of Transmission System Operators for Electricity (ENTSO-E). The full-scale invasion by Russia on February 24 led to Ukraine's disconnection from the aggressor’s power system. Remarkably, on March 16, 2022, Ukraine and Moldova's power systems were rapidly synchronized with ENTSO-E, marking a significant step in Ukraine’s integration into European energy markets and enhancing the security of its energy sector.

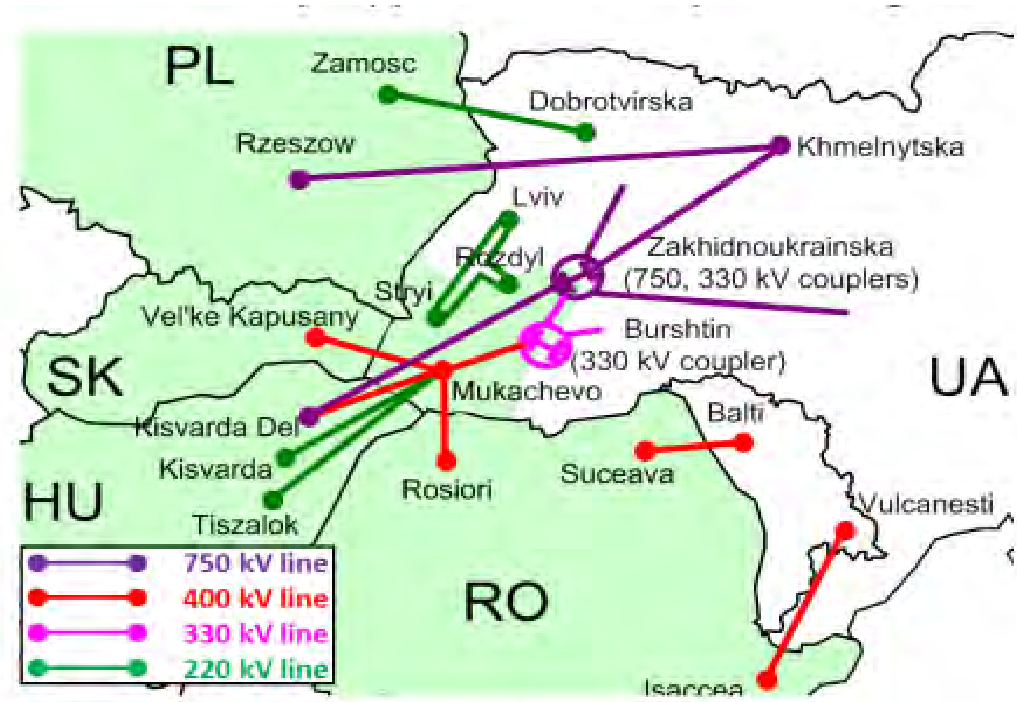

Figure 11 Schematic overview of the Ukrainian and Moldovan power system interconnectors with the surrounding ENTSO-E TSOs (The Rzeszow -Khmelnytsk NPP power line was rehabilitated to 400 kV)[35][36]

Synchronization with ENTSO-E means that:

- Russia and Belarus no longer possess the capability to impact the technical and economic facets of Ukraine's power system operation (excluding extra-systemic intervention such as terrorist attacks or blocking the fuel supply).
- Collaborative partnerships with European counterparts have contributed to enhancing the reliability of the power system operation.
- In instances of excess electricity, Ukraine has the opportunity to export surplus electricity, thereby generating revenue. Conversely, during electricity deficits, Ukraine can import power from the EU, ensuring consistent and reliable electricity supply for Ukrainian consumers.
- The synchronization of the energy sector marks the commencement of comprehensive integration of Ukraine into other EU markets.[37].

On 18 April 2023 and on 20 June 2023, the Transmission System Operators (TSOs) of Continental Europe agreed to increase the electricity trade capacity from Continental Europe to Ukraine/Moldova **to 1,050 megawatts (MW) and 1,200 MW[38]** respectively**,** and from previous trade capacity (**850MW** max. import capacity and 400MW max. export capacity at all hours).[39] This increase became applicable after the interconnection between Ukraine/Moldova and Continental Europe was be reinforced, which happened in May 2023 and taking into account power system stability and security operational learnings[40]. ETSO-E is planning to further increase the interconnection capacity in November 2023[41]. The export potential remains at a level of **675 MW** (excluding Moldova)[42] in contrast to Projections announced at London's Conference (10 000 MW in 2050) or to TYNDP projections.

[35] https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2022/public/RegIP-2022-CCE.pdf

[36] The Rzeszow -Khmelnytsk NPP power line was modernized and switched to 400 kV voltage providing for 200 MW throughput; Despite full synchronization with ENTSEO-E the HV overhead line connections are in principle still valid – just the "green zone" extends now to all UA and Moldova

[37] https://energysecurityua.org/news/how-did-ukraine-synchronize-with-the-eu-s-power-system-and-why-is-it-important-for-the-country-s-energy-security/

[38] https://www.entsoe.eu/news/2023/06/21/press-release-further-increase-in-the-trade-capacity-with-the-ukraine-moldova-power-system/

[39] https://eap-office.ua.energy/pages/bandwidth/public-ntc

[40] https://www.entsoe.eu/news/2023/04/19/further-increase-in-the-trade-capacity-with-the-ukraine-moldova-power-system/

[41] https://www.ukrinform.net/rubric-economy/3775515-entsoe-planning-to-increase-electricity-trade-capacity-in-november.html

[42] https://eap-office.ua.energy/pages/bandwidth/public-ntc

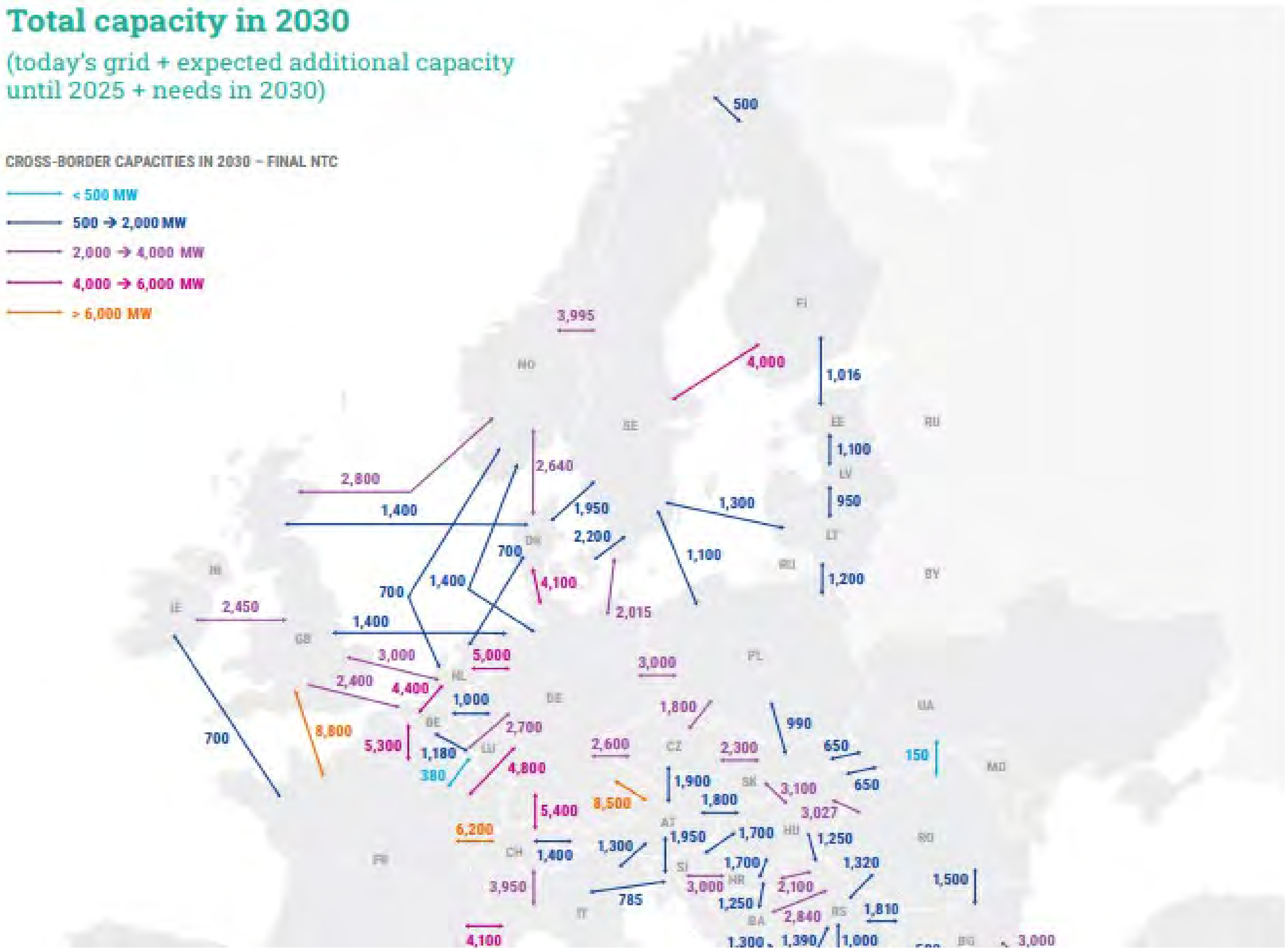

Figure 12: The expected interconnection capacity between Ukraine and ENTSO-E shown in TYNDP[43]
It is different to ambitions 10 000 MW and 35 TWh ephasised at Ukraine Recovery Conference held in London. It is well below the existing 2 500 MW technical export possibility

Furthermore, besides facilitation of the synchronous connection of the Ukrainian transmission system with the Continental Europe system, TSOs of the CCE region have initiated several activities in system development planning:

- PSE (Polish TSO) has started discussion with Ukrenergo on preparations for possible actions on the common profile. The switching of the existing interconnector, which was out of operation between Poland and Ukraine, from 750 kV to 400 kV was performed.
- In 2018 SEPS (Slovakia TSO) and Ukrenergo performed a bilateral common study to evaluate future system needs for the reinforcement of the Slovakia-Ukraine common profile when the lifetime of the current interconnector is reached. Based on additional studies, it will be decided whether the existing line will be either reconstructed as a single circuit line with increased load capacity or as a double circuit line.
- MAVIR (Hungarian TSO) informed that an upgrade of the existing 220 kV line which is not part of the synchronization is foreseen.
- Transelectrica (Romanian TSO) informally agreed with Ukrenergo to include the 400 kV (former 750 kV) OHL Pivdennoukrainska NPP (Ukraine) – Isaccea (Romania) in the next edition of the TYNDP and National Development Plans. This line is already included as a PMI in the Energy Community.

Ukrainian Energy Market experts have conducted an analysis and calculations, taking into account the country's balances and the deficit of specific areas, and have drawn conclusions, defining a complex of measures. As of now, it is an estimation, however it can be implemented by 2035, providing an export interface of up to 6,000 MW.[44]

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[43] https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2022/public/RegIP-2022-CCE.pdf

[44] https://www.epravda.com.ua/columns/2023/10/7/705205/

- 400 kV interconnector Rivne NPP – Kovel – Chelm
- 400 kV interconnector Khmelnitsky NPP – Lviv – Rzeszów (further extension)
- 400 kV interconnector Lviv – Stryi – Mukachevo – Kapushany – Roshior
- 400 kV interconnector Mukachevo – Uzhhorod – Veľké Kapušany
- 400 kV interconnector Chernivtsi – Suceava
- Interconnector 400 kV Artsyz – Isaccea

As confirmed by ENTSO-e on November 28, 2023 the Ukrainian TSO, has achieved compliance with the key technical requirements necessary to enable a permanent interconnection between the power systems of Continental Europe and Ukraine with full implementation of the conditions included in Agreement on Conditions for the Future Interconnection[45]

1.3.2 Distribution networks

The electricity distribution systems in Ukraine includes more than 800,000 km of overhead and cable lines with 0.4 to 150 kV voltage and about 200,000 transformer substations 6-150 kV operated by 32 Distribution System Operators (DSOs). As of the beginning of January 2023, more than 1,000 overhead lines (6-150 kV) and more than 8,000 transformers (6-150 kV) were damaged or disconnected due to continuous Russian attacks (mainly shelling; not including power infrastructure disconnected due to emergencies).

The attacks and damages caused to DSO are ongoing as DSO substations and networks are less protected targets and can often be reached by artillery means (which is way less complicated compared to damaging the highly protected TSO infrastructure). As of December 2023, A total of 408 settlements in Ukraine have been cut off the power grid due to hostilities and technical reasons, the details on the damages are of restricted use.

“DTEK Grids”, one of the main DSO’s, had over 6,000 power facilities damaged in Kyiv, Odesa, Dnipropetrovsk and Donetsk regions and in the city of Kyiv since the beginning of a full-scale war. The company requires further international support for restoration of the entire damaged energy infrastructure.

Another company of the group – DTEK Energy (TPP operator) reported that since autumn 2022, the Russian military has attacked DTEK Energy's energy facilities 35 times. As a result, three power engineers were killed and 28 injured. In addition, contractors and rescuers were killed and injured.

Recently International Arbitration Court in The Hague has fully granted a claim brought by the Ukrainian energy operator DTEK against the aggressor country of the Russian Federation with respect to assets seized in illegally annexed Crimea (DTEK Krymenergo).

The arbitration court ordered Russia to pay the Ukrainian company damages of US$267 million, which includes interest and legal costs at the date of the award. Interest will continue to accrue until the entire amount of losses has been paid in full.[46]

1.3.3 Demand and supply

At the beginning of 2022, there were 17.7 million electricity consumers in Ukraine, 17.2 million households and 0.5 million commercial customers. As a result of the hostilities, electricity demand decreased by 30-35% compared to 2021. The consumption pattern also changed due to the shutdown of industrial enterprises and the massive displacement of consumers from Eastern to Western Ukraine. It is foreseen that the total electricity generation in 2022 will be 25% less than the "pre-war" forecast. Since 24 February 2022, almost all consumers have been temporarily disconnected from the electricity supply. As of 24 January 2023, around 5 million consumers remained without electricity (entirely or partially) due to hostilities or consumption-and-capacity-limiting schedules. Ukrainian TSO and DSOs restore electricity supply where possible, but regular attacks by Russian forces lead to new damages and destruction.

Presently, several thermal power plant units are undergoing maintenance, and solar power plants are unable to operate at full capacity due to dense cloud cover, according to Ukrenergo.

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[45] https://www.entsoe.eu/news/2023/11/28/continental-european-tsos-announce-completion-of-synchronisation-project-with-ukrenergo-and-significant-increase-in-export-capacity-from-continental-europe-to-ukraine/

[46] https://dtek.com/media-center/news/dtek-vigrav-sud-proti-rosii-po-krimskikh-aktivak/

There is currently no electricity export, and imports from Slovakia, Romania, and Moldova are carried out during morning and evening hours, totaling 2,193 MW, with a maximum capacity of up to 589 MW during specific hours.

Since December 1, the technical capability for importing electricity from Europe to Ukraine and Moldova is set at 1,700 MW. A power line in southern Ukraine was damaged in a drone attack, but Ukrenegro repair crews have already restored the line as of the morning of December 8.

Energy operators implemented “emergency measures”, that is emergency import of electricity from Romania, Poland, and Slovakia, from 11:00 to 19:00, Ukrenergo stated on Dec. 7.[47]

- 114 settlements and 134,900 metering points remain without electricity in Donetsk Oblast.
- 63 settlements – about 26,000 consumers – are also without electricity due to hostilities in Zaporizhzhia Oblast.
- A total of 73 settlements remain without electricity in Sumy Oblast and Chernihiv Oblast.
- 16,300 consumers were left without electricity, and the electricity was restored for 1,500 consumers in Kharkiv Oblast. An inspection of networks damaged by new shelling in three hromadas of the region is currently underway (a hromada is an administrative unit designating a town, village or several villages and their adjacent territories – ed.).
- In addition, a medium pressure gas pipeline was damaged. More than 100 consumers remained without gas supply. The gas leak has been fixed. As of the morning, all consumers have been reconnected to the gas supply network.
- The electricity was restored for 302 consumers who had been cut off due to hostilities in Kherson. 3,600 consumers are still without electricity. A total of 45 settlements remain without electricity – more than 26,000 metering points – in the region.

Demand Decrease during Wartime:

Overall demand: Overall national electricity demand in Ukraine has significantly decreased:

- **Population displacement: Millions** of Ukrainians have fled the country or been internally displaced, leading to abandoned homes and businesses and consequently, lower electricity consumption.
- **Economic downturn:** The war has crippled the Ukrainian economy, resulting in reduced industrial activity and commercial operations, lowering electricity demand in these sectors.
- **Infrastructure damage:** Attacks on power plants, substations, and transmission lines have disrupted electricity supply in several regions, leading to forced blackouts and rationing, causing demand to plummet in affected areas.

Increases: local increases in the demand impacting DSO grids and may be a reason for local congestions:

- **Military needs:** The Ukrainian military has increased its electricity demand for powering communication systems, equipment, and facilities.
- **Heating needs**: Increased reliance on electric heating during the harsh winter months, in areas with disrupted gas supplies, can lead to localized spikes in demand.
- **Shelter and humanitarian efforts**: Internally displaced persons residing in shelters and receiving humanitarian aid can contribute to localized increases in demand.

The impact of the ongoing conflict on electricity demand in Ukraine shows significant regional variations. Areas heavily affected by fighting and infrastructure damage experience notable decreases, while others may see increases due to specific circumstances such as military operations or heightened heating requirements during winter.

Moreover, these changes are dynamic, continually shifting in response to the conflict's intensity, the state of infrastructure, and changes in economic and demographic patterns.

The future implications for electricity demand are uncertain, highly dependent on the war's progression, the effectiveness of reconstruction initiatives, and the broader economic recovery of the nation. It is crucial to recognize the inherent challenges in accurately assessing electricity demand during wartime, as security issues and disruptions in infrastructure and data collection systems can result in incomplete or variably accurate data. Please refer to clause 2.1 Methodology for more details.

47 https://english.nv.ua/nation/electricity-consumption-hits-record-high-as-ukraine-seeks-emergency-assistance-from-europe-50374873.html

1.4 Electricity Market Prices vs Prices of neighboring markets

An increasing number of renewable energy producers in Ukraine are expressing readiness to exit the GB's balancing group and participate in the spot electricity market, with the rising electricity prices being a favorable contributing factor. To put it differently, the market price plays a crucial role in influencing renewable energy producers, affecting not only their profitability but also influencing investment decisions and overall competitiveness in the market.

The average price of electricity on the Intraday Market (IDM) of the Integrated Power System (IPS) of Ukraine for the eleven months of 2023 is UAH/MWh 3815.51 [EUR 96.36][48]. The lowest average price was in June 2023 and made up UAH/MWh 2935.68 [EUR 74.14], and the highest average price was in August 2023 - UAH/MWh 4682.10 [EUR 118.24].

As of 5th of December 2023, the price on Intraday Market is UAH/MWh 4594.38 [EUR 116.02]. The average price of electricity on the Day-Ahead Market (DAM) of IPS Ukraine for 9 months of 2023 is UAH/MWh 3553.92 [EUR 89.75]. The lowest average price was in April 2023 - UAH/MWh 2813.74 [EUR 72.54], and the highest average price was in November 2023 - UAH/MWh 4357.80 [EUR 110.05].

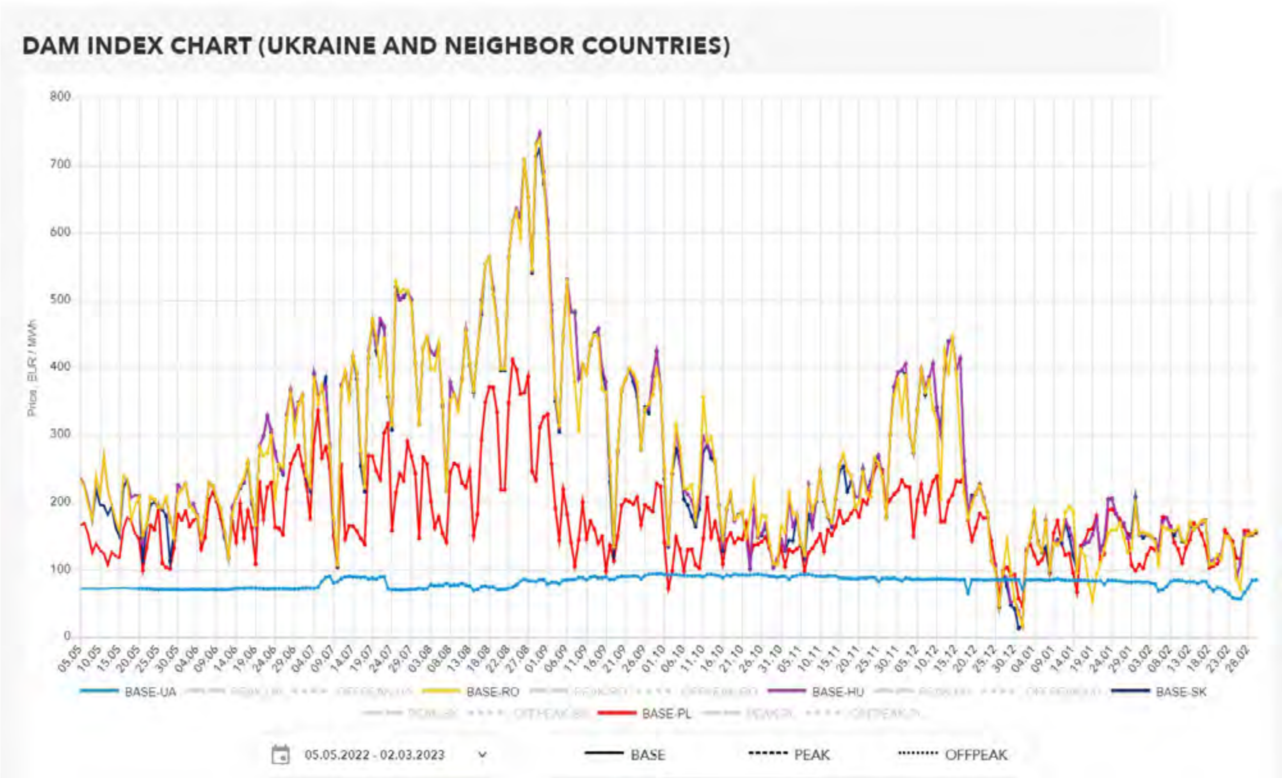

Figure 13: DAM index, electricity trade potential

After the synchronization of the energy system of Ukraine with the network of continental Europe ENTSO-E, which took place on 16 March 2022, the Market Operator started working on accelerating market coupling with EU countries. In 2022, the highest prices for electricity in neighboring countries (for base load) were: Hungary – 206.34 EUR/MWh on 24 Jan. 2023; Slovakia – 208.41 EUR/MWh on 30 Jan. 2023; Romania – 198.89 on 30 Jan. 2023 EUR/MWh; Poland – 186.96 EUR/MWh on 24 Jan. 2023; IPS of Ukraine – 125.33 EUR/MWh on 13 Oct. 2023. As of 05 December 2023, the average price on those countries is 117.8 EUR/MWh.

48 https://www.oree.com.ua/

1.5 Ukraine – EU integration and Green Deal

The Russian invasion has significantly impacted Ukraine's progress towards EU candidate status and the EU's energy security. This situation has prompted the EU to rapidly reduce its reliance on Russian gas and oil by seeking alternative natural gas sources and bolstering green energy production.

Despite efforts to expand domestic green energy production, the EU is still lagging in meeting the targets set by the Fit for 55 initiative and the Energy Community Decarbonisation roadmap. To address this, the EU and its member states are exploring the potential of energy sharing networks with neighboring countries.

Long-term, the EU views renewable energy sources (RES) as key to achieving energy independence. However, to reach full energy independence, the EU needs to further increase its solar and wind energy capacities. Consequently, EU member states are now actively working to establish energy networks with third-party states. Two major hurdles in the EU's green energy future are the development of adequate energy storage and transportation systems. Post-war, a significant focus will be on a comprehensive reconstruction program for Ukraine, incorporating the restoration of damaged infrastructure and services. This reconstruction offers an opportunity to leverage advanced technologies and best practices in alignment with EU energy objectives. Ukraine's EU candidate status is expected to lower the risk-adjusted cost of capital, thereby attracting new investments that will benefit the EU's quest for enhanced energy security.

The European Green Deal, introduced in 2019, is the EU's ambitious strategy to achieve climate neutrality by 2050. It presents a comprehensive plan with actions across various sectors to transform the EU into a sustainable economy. This includes:

- Decarbonization: Embracing renewable energy sources like solar, wind, and geothermal to move away from fossil fuels.
- Energy Efficiency: Optimizing energy consumption in buildings, transportation, and industries.
- Sustainable Mobility: Prioritizing electric vehicles, public transport, cycling to reduce emissions from transportation.
- Biodiversity Protection: Implementing measures to reverse biodiversity loss and restore natural ecosystems.
- Innovation and Research: Investing in clean technologies and research to develop solutions for achieving climate neutrality.

While Ukraine's accelerated renewable energy development is a major stride towards enhancing Europe's energy security, it is not a complete solution. Ukraine's expansive, wind-rich terrain and Black Sea coastline present a substantial wind energy opportunity, beneficial for powering Europe. Additionally, Ukraine's potential in solar and biomass energy could significantly bolster the energy resources available to the EU. This rapid development in renewable energy addresses two critical challenges in the EU's energy transition which are the land requirements and encouraging Eastern Member States

Utilizing Ukraine's renewable energy potential would reduce the EU's vulnerability to external threats concerning the diversion of solar or wind energy, as it provides additional land for necessary energy development while Ukraine's commitment to prioritizing green energy in its development strategy could influence Eastern EU member states to expedite their green transition.

The success of this initiative depends on a sustained partnership, where EU financial and technical support is matched by Ukraine's transparent and welcoming environment for green investments. Though the future holds uncertainties, the potential benefits are substantial. A successful green transition in Ukraine could not only support the EU's Green Deal objectives but also serve as a global exemplar of sustainable post-conflict reconstruction. In essence, the Green Deal has the potential to be a significant instrument for fostering peace, prosperity, and a cleaner future for both Ukraine and Europe.

The details of Ukraine's journey towards implementing EU legislation are further discussed in Chapter 1.6.4.

1.6 Legislative and institutional incentives

1.6.1 Recent pre-war period developments

The renewable sector experienced rapid growth in installed capacity and renewable electricity generation volumes between 2003 and 2014, a development spanning over a decade. This significant progress was made possible by the establishment of a conducive legal, organizational, and economic framework by the state, which enabled private investments to flourish and significantly propel the growth of the sector.

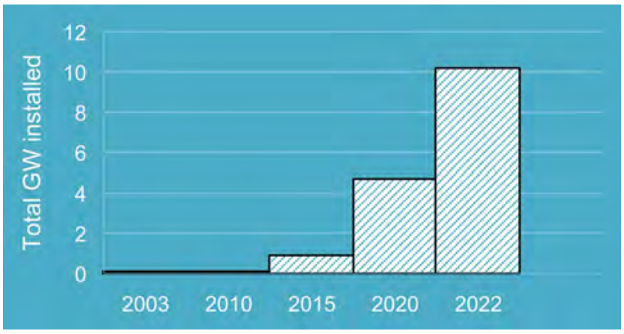

Figure 14: Growth of installed capacity over 10 years

Currently, Ukraine remains highly dependent on fossil fuels, most of which were imported in pre-war time. After beginning of full-scale invasion the State concentrated on decrease in consumption and full refusal from the Russian fossil fuels supply. The supply from the temporary occupied Donetsk and Luhansk became impossible as well. A stable global trend is the increase in the cost of traditional energy sources, which makes the country's economy very sensitive to the conditions of importing natural gas, coal and other energy sources. In 2020, imported gas accounted for about 30% of Ukraine's total natural gas consumption. Ukraine is 85% dependent on imports of oil products.

EU integration obligations and Action Plans

Aware of the urgent need to prevent climate change, Ukraine became one of the first European countries to ratify the **Paris Agreement. The Law of Ukraine "On Ratification of the Paris Agreement" (No. 1469-VIII)** was adopted on 14 July 2016. The Cabinet of Ministers of Ukraine approved the **updated Nationally Determined Contribution of Ukraine to the Paris Agreement by Order No. 868 of 30 July 2021**. Ukraine has set a target to reduce greenhouse gas emissions by 35% by 2030 compared to 1990. The development of RES is one of the main measures to achieve this indicator in the following seven years.

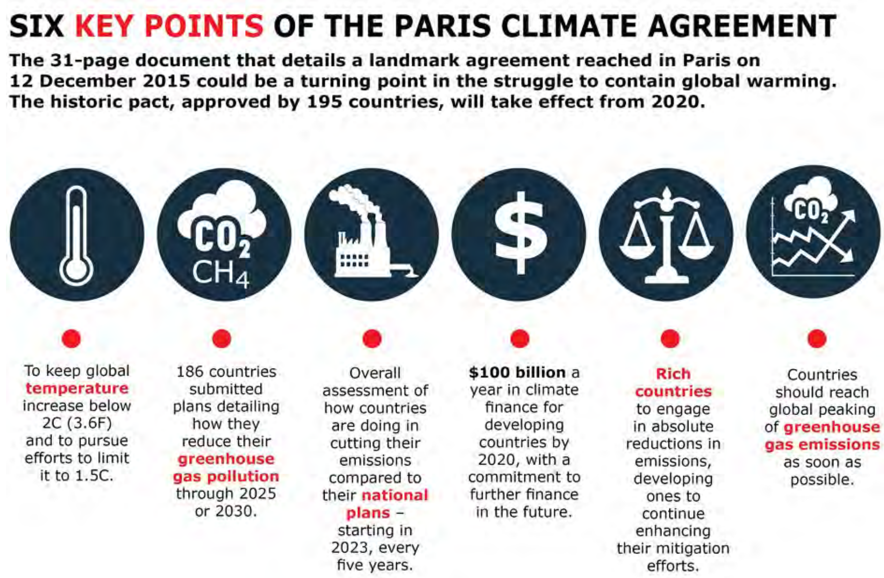

Figure 15: The six key points of the Paris Climate Agreement

The Energy Security Strategy of Ukraine, approved by the Cabinet of Ministers of Ukraine by Decree No. 907-r of 04.08. 2021, defines the strategic goals of ensuring the country's energy security and the tasks for achieving them:

- o Raising the levels of import substitution; in particular through the development of bioenergy, wind energy, justified increases in the extraction of energy resources;
- o Implementation of a set of measures to expand the use of domestic alternative fuels, support the substitution of traditional fuels in transport by the use of electricity and biofuels, implementation of a justified increase in the share of RE sources, considering the requirements for ensuring the operational safety of energy supply systems and the impact on the price parameters of the energy market;
- o Preventing the increase of Ukraine's dependence on external suppliers, ensuring an appropriate level of diversification of energy resources and technologies, in particular through an economically justified increase in the share of RE sources and local energy sources in Ukraine's energy balance.

The National Transport Strategy of Ukraine for the period up to 2030, approved by the Decree of the Cabinet of Ministers of Ukraine as of 30 May 2018 No. 430, provides for an increase in the level of use of alternative types of fuel (biofuel or its mixture with traditional fuel) and electricity (produced from both traditional and renewable sources) up to 50% by 2030.The provisions of Directive 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, set a mandatory target for the use of RE in the transport sector by each country at a level of at least 14% by 2030. **The National Action Plan** includes the strategic objective of increasing the share of electricity generation from RES to 25% of the total electricity generation in 2030, which was established by **the National Economic Strategy** for the period up to 2030 and approved by the Decision of the Cabinet of Ministers of Ukraine of 3 March 2021 No. 179.

The National Action Plan also includes the strategic goals of **the Concept of Implementation of the State Policy in the Field of Heat Supply**, approved by the Resolution of the Cabinet of Ministers of Ukraine of 18 August 2017 No. 569, on achieving the share of the use of alternative energy sources (renewable energy sources and secondary energy resources) in the production of thermal energy by objects in the field of heat supply of 30% in 2025 and 40% in 2035. **The National Action Plan** determines that RE share should reach 27% in 2030.

The target of the National Action Plan is in line with the **Directive 2018/2001**, which foresees a 27% target share of RE-based gross final energy consumption for Ukraine by 2030. In its turn RED III provides for 42.5% by 2030, but aiming for 45%. **Thus the National Action plan is not in line with the RED III provisions**.

According to **the National Action Plan for the Development of Renewable Energy Sources** for the period up to 2020, by the end of 2020 the total installed capacity of solar power plants should amount to 2,300 MW, of wind power plants to 2,280 MW and of bioenergy plants to 950 MW.

At the end of 2020, **the National Action Plan for the Development of Renewable Energy** for the period up to 2020 in the part of solar energy has been exceeded by almost three times. At the same time, the indicators of the development of other alternative energy sources are much lower than those provided for in the specified action plan in terms of wind power - by 40%, in terms of bioenergy - by 80%.

Crisis of old support mechanisms and search for the solution

The "green" tariff model, which was initially adopted to support renewable energy, ultimately proved unsustainable due to its lack of market pricing and feedback mechanisms. Between 2019 and 2020, there was a dramatic increase, over threefold, in electricity production from alternative energy sources. This surge presented economic and technical challenges, stemming from both the high cost of the produced "green" electricity and the limitations of Ukraine's combined energy system, particularly before the integration of renewable energy facilities.[49]

This situation led to a sharp rise in payments to electricity producers under the "green" tariff, necessitating increased subsidies. These were funded through special duties imposed on state companies like "Guaranteed Buyer" and PJSC "NPC Ukrenergo." Consequently, this led to debt accumulation by the state company "Guaranteed Buyer" towards producers at the "green" tariff.

There were also technical risks involved, particularly in maintaining the operational safety of Ukraine's Unified Energy System (UES) with a significant share of RES. The UES lacked the necessary flexible generation capacity to integrate RE facilities effectively, especially given the unpredictable electricity production schedules dependent on weather conditions. This led to inefficient operational modes within the energy system, including restrictions by the Transmission System Operator on the output of electrical energy from RE facilities, costs for which had to be fully compensated under the "green" tariff.

To address these issues, the Ministry of Energy and Environmental Protection of Ukraine initiated public discussions in October 2019. These discussions included a wide range of stakeholders, such as state authorities, institutions, investors, associations, financial institutions, experts, and industry specialists. The Energy Community Secretariat's Dispute Resolution and Negotiation Center participated as a mediator in these negotiations, following the initiative of specialized associations.

After extended discussions and complex negotiations, the Government and the Ministry of Energy reached compromise agreements with renewable energy investors. These agreements considered the interests of various producer groups, the state, and consumers. These agreements were encapsulated in

[49] The Law of Ukraine “On Alternative Energy Sources" No. 555-IV (signed by former president Leonid Kuchma back in 2003.).

the **Memorandum of Understanding on the Settlement of Problematic Issues in the Field of Renewable Energy in Ukraine (referred to as the Memorandum).**

The Memorandum's terms were approved by the Government on June 10, 2020, and subsequently signed by Prime Minister Denys Shmygal, Acting Minister of Energy Olha Buslavets, and heads of the European-Ukrainian Energy Agency and the Ukrainian Wind Energy Association. These bodies represented the interests of renewable energy investors and were key negotiators. The National Commission for State Regulation of Energy and Utilities, in a public hearing, adopted Resolution No. 1141 on June 17, 2020, formalizing the Memorandum, which was also signed by the Chairman of the NEURC and the Head of the Dispute Resolution and Negotiation Center of the Energy Community's Secretariat.

The terms of the Memorandum were implemented in the **Law of Ukraine dated July 21, 2020 No. 810-IX "On Amendments to Certain Laws of Ukraine on Improvement of Conditions for Support of Production of Electricity from Alternative Energy Sources" (hereinafter - the Law No. 810-IX).** The main terms are as follows: on the part of investors, voluntary agreement to reduce "green" tariffs, increase responsibility for imbalances, limit the terms of commissioning solar power plants under the "green" tariff model; on the part of the state, ensuring stable current payment for produced electric energy, repayment of accumulated debts and promotion of further development of the industry on a competitive basis.

Considering the difficult situation in the industry, Ukraine did not opt for unilateral reduction of "green" tariffs, but solved this issue through long negotiations with investors, search for compromises and conclusion of the Memorandum, which became the basis of the relevant law.

Since the adoption of Law No. 810-IX, the level of payments made by SE "Guaranteed Buyer" to producers under the "green" tariff has improved by assuring higher payment rate to RE producers. In addition, the partial repayment of debts to producers under the "green" tariff has begun due to the attraction of loan funds by PJSC "NEC "Ukrenergo", and the issuance of bonds with state guarantees.

Auctions

In order to ensure the further development of RE on a competitive basis, taking into account the best global practices, the Verkhovna Rada of Ukraine adopted **the Law of Ukraine dated 25 April 2019 No. 2712-VIII "On Amendments to Certain Laws of Ukraine on Ensuring Competitive Conditions for the Production of Electricity from Alternative Energy Sources"**, which provides for the introduction of a system of auctions for the distribution of support quotas.

The Cabinet of Ministers of Ukraine adopted Resolution No. 1175 of 27 December 2019 **"On Introducing Competitive Conditions for Stimulating the Production of Electricity from Alternative Energy Sources"**, which approved the procedure for holding auctions for the distribution of support quotas, the procedure for selecting operators of electronic platforms to ensure the conduct of auctions for the distribution of support quotas, and appointed SE "Prozorro.Prodazhi" as the administrator of the electronic trading system in which auctions will be held.

At the same time, considering the difficult financial and economic situation in the industry and the fact that SE "Guaranteed Buyer" had concluded preliminary contracts for the purchase and sale of electricity at the "green" tariff for the installed capacity of RE facilities of more than 10 GW, which would have to be put into operation during 2020-2022, **the start of auctions for the distribution of the support quota was postponed until the resolution of situation.**

Additionally the auctions are addressed by Green Transformation Law described in the following section

Financing and balancing issues

At the same time, the existing model of support for producers under the "green" tariff and auction winners provides that all producers who work under the contracts concluded with SE "Guaranteed Buyer" are members of the balancing group of the Guaranteed Buyer, which is the party responsible for the balance for such producers and is obliged to buy back all the electric energy released by such producers (also for auction winners. Provided by the Law of Ukraine No. 2712-VIII).

A significant amount of RE facilities, concentrated within one balancing group, cannot respond promptly to power system operating modes and market price signals, providing mutual benefit for the transmission system operator and producers of electricity from alternative sources in terms of balancing the power system. This leads to financial losses for SE "Guaranteed Buyer" and an increase in the cost of the service for ensuring an increase in the share of electricity production from alternative sources, which is an integral component of the tariff for the electricity transmission service, which is paid by all consumers. Also, non-involvement of producers of electric energy from alternative energy sources in participating in the electric energy market (including the balancing one) on competitive terms complicates and increases the cost of balancing the operation modes of the power system. …

1.6.2 Legislative incentives during the war period

Storage systems

The Law 2046-IX, enacted on February 15, 2022, establishes a state enterprise called the "Energy Storage Operator." This legislation outlines the operational conditions of the energy storage system and, under specific circumstances, permits energy producers to install power batteries without the need for a license. Anticipated demand for the system capacity ranges from 0.5 to 2 GW. The primary objective of this law is to incentivize energy producers to deploy their battery storage facilities, addressing issues related to imbalances in the system. The key goals include:

- Promote the development of energy storage: The legislation delineates various types of energy storage facilities (ESFs) and outlines the procedures for acquiring licenses and permits to operate them.
- Enhance grid stability and energy security: Energy storage plays a crucial role in mitigating fluctuations in electricity generation from renewable sources, thereby improving grid resilience.
- Attract investment: The law establishes a transparent and predictable regulatory framework, providing an environment conducive to investment in the energy storage sector.

Key points of the law:

- Definition of ESFs: The legislation encompasses a range of technologies, including pumped hydro, batteries, flywheels, and compressed air energy storage.
- Licensing and permits: Operators of ESFs are required to secure a license from the National Commission for State Regulation of Energy and Utilities (NERC). Depending on the technology and capacity of the facility, specific permits may also be mandated.
- Grid access: ESFs are granted the right to connect to the grid and actively participate in the electricity market. They are authorized to engage in buying and selling electricity, providing ancillary services to the grid operator, and participating in balancing mechanisms.
- Tariff regulation: The law permits the implementation of feed-in tariffs or other support mechanisms to encourage investments in ESFs. The specific tariff scheme will be determined by NERC.
- Environmental considerations: ESFs are subject to environmental regulations and must adhere to environmental assessments and permitting procedures.

The Ukrainian government is working on developing regulations and procedures to further clarify the operation and market participation of ESFs.

Improvement on FIT limitations

On 28 March 2022, the Ministry of Energy imposed specific limits on FiT payments to RES producers[50]. The limits were further revised on 15 June 2022[51].Till the third quarter of 2022 the payment limits were calculated as a percentage of the weighted average FiT in 2021, while the remaining payments to RES producers were accumulated as debts:

- 18% - solar & wind,
- 35% - small hydro,
- 40% - biogas, and
- 75% - biomass.

On 26 April 2022, NEURC approved the procedure of payment settlement for prosumers using FiT during Martial Law in Ukraine. The prosumers' payments were linked with the bill collection rate in the region, e.g., if the collection rate is 90%, a prosumer receives 90% of the payment for produced electricity using FiT.

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[50] Order of the Ministry of Energy of Ukraine "About settlements on the electricity market" No.140 dated 28 March 2022.

[51] Order of the Ministry of Energy of Ukraine "On payments under feed-in tariff" No. 206 dated 15 June 2022.

Changes in regards to Virtual PPAs and changes for Electicity market rules

Law on Virtual PPA/Price Minimization Mechanism for RES Producers

The Law No. 2479-IX introduced, among others, a number of amendments that outline a legal mechanism for introducing a service by RES producers to ensure electricity price stability through an Agreement concluded by the RES producer and an electricity consumer[52]. In effect, this mechanism allows for contract-for-difference services between the producer and a consumer without the need for actual exchange of electricity. Only RES producers outside the state support system are eligible for such contracts. The parties determine which RES plant is the subject of such a contract. The contract shall be long-term with a term of at least 1 year, shall not be subject to approval by the regulator or any other authority and may be concluded at any time during the commissioning or operation of the RES system. The TSO shall be notified within 5 days of the conclusion of such a contract, but no confidential information on the terms and conditions of the contract shall be disclosed.

For the period up to 2022, the provisions of some parts of Article 43 of the Law on the Electricity Market have been amended. These were the provisions regulating the use of funds from interconnection access. The use of funds for 2022 has been defined as follows:

Funds received in the period from 1 January to 31 July 2022:

- o 10% of funds for investments and increase of transmission capacity;
- o 45% of funds for the payment of debt of Ukrenergo on balancing market;
- o 45 of funds for the payment of debt of Ukrenergo to the Guaranteed Buyer. The Guaranteed Buyer is to pay these funds to Energoatom and the RES producers in proportion to the respective debts outstanding.

Funds received in the period from 1 August to 31 December 2022:

- o 50% of funds for the payment of debt of Ukrenergo on the balancing market;
- o 50% of funds for the payment of debt of Ukrenergo to the Guaranteed Buyer. The Guaranteed Buyer is to pay these funds to Energoatom and the RES producers in proportion to the respective debts outstanding.

Article 71 of the Law on the Electricity Market was amended with a provision 4-1, which regulates the procedure of exit from and return to the balancing group of the Guaranteed Buyer, for RES producers, which operate under FiT.

Before the Russian invasion in February 2022, the development of RE generation in Ukraine was supported via a Feed-in-Tariff (FiT) scheme, i.e., the Guaranteed Buyer (State Enterprise "Guaranteed Buyer") purchased all electricity produced from RES using FiT.

On 29 July 2022, the legislators introduced an alternative to the FiT scheme and secured an option for RES producers to trade their produced electricity on the power market. Formally this option was made available before the new Law was approved. Yet, the new option was not regulated, and it was not clear whether the RES producers could return to the FiT scheme in the future after switching to direct trading in the power market. Thus, the new Law clarified that the switch would not result in the amendment of FiT levels of the concerned RES producer in case they later decided to return to the FiT scheme.

As of now, RES producers are allowed to trade their electricity on any market segment, whereas other electricity producers shall trade electricity under bilateral agreements only at electronic auctions until 1 April 2023.

Changes to the current laws on energy efficiency: comprehensive thermal modernization

On 09 July 2022, the **Law No. 2392-IX** “On Amendments to Certain Laws of Ukraine Regarding the Creation of Conditions for the Introduction of Complex Thermal Modernization of Buildings” was adopted. Namely the Law introduces changes to two laws in the field of energy efficiency of buildings: The Law of Ukraine “On Energy Efficiency of Buildings” and the Law of Ukraine “On Energy Efficiency Fund”.

Innovations in the legislation will allow the Energy Efficiency Fund to

- o Provide grants for any housing policy programs, including housing restoration;
- o Expand financing as according to the current law, the Fund can finance only complex energy-efficient projects;
- o Reimburse gradually the costs of energy-efficient measures, which reduces the burden on housing cooperatives;
- o Finance additional measures, for example, if it is necessary to strengthen the structure of the coating before its insulation.

Changes to the Law of Ukraine “On Energy Efficiency of Buildings” will allow to:

- o Regulate technical issues of energy certification of buildings. However, the new legislation does not introduce conceptual changes that would stimulate large-scale energy certification of buildings in the country, as it happens in European countries.
- o Introduce the development of a Strategy for thermal modernization of buildings;
- o Place obligations on state bodies to thermally modernize 1% of the heating area of state-owned buildings every year.

Memorandum on strategic partnership in the field of RE-based gases, namely hydrogen and biomethane. Ukraine and the European Commission have signed a Memorandum on a strategic partnership in the field of RE-based (“green”) gases, namely hydrogen and biomethane[53]. According to the Memorandum, cooperation will include sharing information and assessments of scenarios and forecasts on renewable gases demand, developing a suitable regulatory field, harmonizing certification documents in accordance with EU requirements, identifying and eliminating barriers, developing infrastructure, mobilizing financial and investment instruments, and developing "energy clusters" in Ukraine.

The State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEE) has been actively creating conditions for RE-based gas production development and SAEE has already developed a Register for biomethane “Guarantees of Origin”. In addition, the Agency, in cooperation with international partners, has been exploring promising avenues for their circulation in the EU.

Debts settlements prolonged.

On 22 March 2023, the NEURC moved the deadline for the Guaranteed Buyer to pay the outstanding debts to Energoatom and electricity producers under the Feed-in Tariff from 1 April 2023 to 1 July 2023. Currently, the debt of the Guaranteed Buyer to Energoatom amounts to UAH 0.14 billion (ca. EUR 3.5 million), and to the electricity producers under the Feed-in Tariff – UAH 20.1 billion (ca. EUR 500 million)[54].

<u>Energy Strategy of Ukraine until 2050</u>

On April 21, 2023, the Cabinet of Ministers of Ukraine (CMU) approved the **Energy Strategy of Ukraine until 2050.** While the Strategy is yet to be officially published, the Ministry of Energy has outlined that it aligns with the goals of the European Green Deal. It is formulated on the principles of an integrated approach to energy policy development and implementation, aiming to foster sustainable economic growth in Ukraine.

Key elements considered in the Energy Strategy include:

- The impact of the Russian Federation's full-scale war against Ukraine, emphasizing the importance of energy security and the stability of the energy system.
- The integration of the Ukrainian electricity network with the European Network of Transmission System Operators for Electricity (ENTSO-E) and further deepening Ukraine’s power system's integration into the European market.
- The incorporation of cutting-edge technologies, such as hydrogen energy production and utilization, small modular nuclear reactors, energy storage systems, and other technical advancements in the energy sector, reflecting global trends and innovative solutions. It also includes compliance with EU environmental safety regulations and Ukraine's international commitments.

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[53] Memorandum of understanding between the European Union and Ukraine on a Strategic Partnership on Biomethane, Hydrogen and Other Synthetic Gases, 2 February 2023.

[54] Resolution of the NEURC "On amendments to the resolution of NEURC dated 1 September 2021 No. 1460" No. 502 dated 22 March 2023.

- Ukraine's international obligations concerning energy efficiency, renewable energy usage, reduction of greenhouse gas emissions, and other environmental initiatives.
- The decentralization of electricity generation across Ukraine to enhance the stability and reliability of the power supply.

The Strategy was subject to further development, with a detailed presentation at the Ukraine Recovery Conference 2023 in London. However, the Strategy's content and approach have sparked controversy, as further discussed in the subsequent sections.

Critical assessment

The current proposed Strategy appears to be no more than a compilation of overused phrases and slogans borrowed from pre-crisis EU strategies. Despite its crucial significance for the economy, the Strategy's formulation seems to have neglected the viewpoints of market players and technical experts, being endorsed without adequate consultation with the expert community for meaningful discussion, feedback, and assessment.

The announced plan for renewable energy development poses significant inquiries. Ukraine's objective to generate over 90% of its electricity from carbon-free sources by 2050, with a target of 30% for renewable energy by 2030, encounters substantial challenges. The current stance of the Ministry of Energy and the National Commission for State Regulation of Energy and Public Utilities (NEURC), along with existing investor debts, has significantly discouraged recent investments in new RE projects.

Furthermore, the Ministry of Energy has not yet detailed the quota sizes or auction procedures for new renewable energy projects. There are also unresolved issues regarding the required balancing capacities and the implementation of energy storage systems.[55].

Still, the adopted Energy Strategy is a document reflecting the existing international obligations undertaken by Ukraine, forming the path for future development. It has to become fully clear and comprehensive and be properly presented to the expert community and the public. The version of Strategy available for service use was used as a basis for reference scenario is the Chapter 2 "Calculation of RES potentials", please refer to methodology, reference scenario for more detail.

1.6.3 Law 3220-IX Green Transformation of the Energy System of Ukraine

On July 24, 2023, the President of Ukraine signed **Law No. 3220-IX**, aimed at improving support conditions for RE electricity producers. The Law introduces changes to the regulation of "green" auctions, guarantees of origin for electricity and other carries, and contracts for difference. Additionally, new support instruments, such as the market premium mechanism and the self-consumption mechanism, are established. The Law also addresses the extension of the validity period for pre-PPAs and technical conditions for wind energy projects, along with modifications to the operation of the GB's balancing group.

Regarding wind energy projects with executed pre-PPAs at the "green" tariff, the Law stipulates an extension of the commissioning deadline until December 31, 2023. RES producers and the GB must enter into a new PPA under the same terms as the corresponding pre-PPA (considering the new commissioning deadline for wind energy projects).

The extension of the validity period for technical conditions for connection until either December 31, 2024, or December 31, 2025 (in the latter case, the connection service cost must be reviewed). Consequently, RE producers and the distribution system operator must conclude an additional agreement to the respective agreement on connection to the distribution grid, providing for the issuance of new Technical Conditions for grid connection on the same terms as those in effect as of February 24, 2022.

The extension of the commissioning deadline for wind energy projects and technical conditions is possible under the following terms:

- The RE producer concluded a pre-PPA before December 31, 2019.

[55] https://www.epravda.com.ua/columns/2023/02/20/697207/

- The grid connection agreement and technical conditions were valid as of February 24, 2022, with no outstanding obligations for the RE producer under the relevant grid connection agreement.

Simultaneously, the Law prevents the completion of construction and commissioning of wind energy projects located in temporarily occupied territories at the time of entering into the additional agreement to the grid connection agreement as the issuance of new technical conditions with an extension of their validity period is not possible for such projects.

The Law provides support for RE producers who have acquired it through auctions is carried out by guaranteeing the purchase of services through the Feed-in-Premium mechanism by entering into a corresponding contract between the GB and the auction winner. Previously, support for winners of "green" auctions involved purchasing the entire volume of electricity released by such producers at the auction price based on a power purchase agreement.

Additionally, the law shortens the commissioning period for auction winners producing electricity from solar energy from 2 years to 18 months from the date of entering into the Feed-in-Premium service contract. For other RES projects, the commissioning period remains unchanged at 36 months from the date of the corresponding contract.

Furthermore, the support duration for auction winners has been reduced from 20 to 12 years.

The Feed-in-Premium mechanism is a new support mechanism for RES producers who either have a "green" tariff or have acquired support through an auction. Under this mechanism, GB will pay RES producers the difference between the "green" tariff or auction price (considering the surcharge for using equipment from a Ukrainian manufacturer) and the reference price.

The reference price will be determined by selecting the higher value from two indicators:

- o The weighted average value of market price indices for the "day ahead" market for the base load period for the reference month and the preceding month.
- o The weighted average value of price indices for bilateral agreements.

The cost of the Feed-in-Premium service depends on that of the two indicators having the maximum value. Additionally, the calculation takes into account:

- o The "green" tariff or auction price, considering the surcharge for using equipment from a Ukrainian manufacturer.
- o The hourly amount of electricity generated and sold by the RES producer on day ahead market, the intraday market, and through bilateral agreements on the electricity market.
- o The weighted average price of electricity on day ahead market and through bilateral agreements on the electricity market.

If the calculated price exceeds the auction price, including the surcharge, the RES producer is obligated to pay GB for the Feed-in-Premium service for the released electricity from the respective RES project within the specified period (note that this obligation does not apply to RES producers with a "green" tariff).

To receive support through the Feed-in-Premium mechanism, RES producers must enter into the corresponding contract with GB, the standard form of which will be approved by the NEURC. Additionally, RES producers with a "green" tariff must exit GB's balancing group.

Support through the Feed-in-Premium mechanism will be provided to RES producers throughout the entire duration of the "green" tariff or the support period obtained through an auction, which cannot exceed 12 years.

A "contract for difference" is an agreement between a RES producer and another participant in the electricity market, the essence of which lies in compensating for fluctuations in the market price of "green" energy. If the market price of electricity is lower than the indicative price agreed upon in the contract, the contracting party compensates the RES producer for the difference between the indicative price in the contract and the actual market price. Conversely, if the market price of electricity rises, the RES producer compensates the contracting party for the difference.

In Ukraine, contracts for difference are analogous to agreements to ensure the stability of the price for electricity generated from RES.

The Law clarifies the provisions of current legislation regarding the conclusion of contracts for difference by RES producers. Specifically, producers subject to incentives (such as "green" tariffs or auction support) and those not subject to incentives can enter into such contracts.

RES producers subject to incentives who have exited GB's balancing group can also enter into these contracts.

RES producers can now enter into such contracts not only with consumers but also with electricity suppliers or traders.

To confirm that the electricity sold by the RES producer under such a contract is generated from RES, the parties may include conditions for the transfer of guarantees of origin of electricity.

The parties must inform the NEURC about the conclusion of the contract. NEURC, in turn, updates the relevant information in the register of electricity facilities and generating units of active consumers using alternative energy sources for electricity production.

The Law also introduces the mechanism of self-generation – so called Net Billing - and new participants in the electricity market – "active consumers," including those consumers who sell their generated "green" electricity either entirely or partially, meaning excess electricity not consumed for their own needs.

In other words, if, during a month, an active consumer consumes more electricity than they release to the grid, they must pay the difference between the cost of the consumed and released electrical energy to the supplier. Conversely, if the cost of the released electrical energy exceeds the cost of the consumed electrical energy, the supplier will pay the difference to the active consumer in the following month.

The following active consumers can take advantage of the self-generation mechanism:

- Private households with solar/wind installations up to 30 kW;
- Small non-household consumers with solar/wind installations up to 50 kW;
- Non-household consumers with solar/wind/biomass/biogas/hydro/geothermal installations within the allowed capacity;
- Non-household consumers whose generating installations are commissioned by December 31, 2029, within the allowed capacity; and
- Energy cooperatives, energy service customers, and third parties (including RES producers subject to "green tariffs") who connect their generating installations to the networks of an active consumer, provided the latter consumes all the energy they produce.

To implement the self-generation mechanism, active consumers must enter into a contract for the sale and purchase of electrical energy through the self-generation mechanism with a universal service provider, an electricity supplier, or GB (in the case of producers under the "green tariff").

This contract will have a standard form developed by the NEURC and will regulate settlements between the electricity supplier or universal services provider, GB, and the active consumer under the self-generation mechanism.

Active consumers who have the right to sell and purchase electrical energy under the "green tariff" have the right to enter into a contract for the sale and purchase of electrical energy under the self-generation mechanism within the connected capacity of their generating installations. However, simultaneous conclusion of a contract for sale and purchase under the "green tariff" and a contract for sale and purchase of electrical energy under the self-generation mechanism for the same generating installation of an active consumer is prohibited.

The law stipulates that the operation of GB's balancing group will be regulated by the participation agreement in GB's balancing group, the standard form of which will be approved by the NEURC.

It is emphasized that no later than 6 months from the date of the publication of the Law, GB and RES producers participating in its balancing group must conclude an agreement on participation in GB's balancing group.

Furthermore, the Law includes provisions regarding the right of RES producers to exit and return to GB's balancing group without losing the "green" tariff or auction-based support. Consequently, RES producers now have the option to transition to new support mechanisms such as the feed-in-premium and contracts for differences, while retaining the right to return to the "green" tariff or auction-based support.

The Law clarifies that RES producers will not be held responsible for imbalances arising from the deviation of actual hourly electricity supply volumes from the forecasted hourly schedules due to the system operator's commands to reduce load and operational safety commands.

The Law grants GB the right to export electricity in accordance with the procedures defined by the Cabinet of Ministers of Ukraine. The profit generated by GB from electricity exports will be considered in the cost of services for increasing the share of electricity production from RES provided by GB. This is expected to expedite the process of settling GB's debts to RES producers.

The Law introduces a new definition for the guarantees of origin for RES-produced electricity ("guarantees of origin") – an electronic document generated based on information from the registry of guarantees of origin for RES-produced electricity. It certifies that a specified amount of electricity is produced from RES, confirming its environmental value and associated rights related to the positive impact of RES electricity production.

The law introduces several innovations regarding guarantees of origin:

- Guarantees of origin confirm the origin of electricity from RES, produced by (i) RES producers, (ii) consumers who have installed generating facilities for RES electricity production for self-consumption, or (iii) active consumers.
- The NEURC is responsible for issuing, circulating, and retiring guarantees of origin. The NEURC is also responsible for forming and maintaining the registry of objects of the power system and installations of consumers using RES for electricity production. The information from this registry is a component of the guarantees of origin registry.
- A guarantee of origin certifies the volume of electricity supplied to the grid or produced and used for self-consumption and is issued for a volume of 1 MWh.
- Forming more than one guarantee of origin for the same volume of electricity supplied to the grid or for the same volume of electricity produced and used for self-consumption is prohibited.
- The circulation of guarantees of origin occurs within 12 months from the date of producing the electricity volume for which the guarantee is issued, without the right of further circulation after this period.
- The owner of the guarantee of origin must retire it (i.e., use the volume of RES-produced electricity for which the guarantee is issued) within 18 months from the date of producing the electricity volume for which the guarantee is issued.

Consultant’s opinion

In addition to developing new mechanisms and harmonizing legislation in accordance with European integration commitments and introducing new incentive there are still several issues that require attention:

Connection Technical Conditions (CTCs):

In this Law, CTCs are partially regulated, and the continuation of CTCs can be implemented by obtaining new CTCs and amending the connection agreement. Currently, there is a temporary procedure for connection, certain sections of the code are suspended, and developers effectively become hostages to the decisions of the NEURC. However, there is no provision to protect developers from the inactivity of energy companies regarding the implementation of their connection work/delays in commissioning due to delays on the part of the power distribution/transmission system operators (Oblenergo/Ukrenergo). Similarly, there is an issue with the formulation of "the absence of outstanding obligations, the deadline for which has expired under the connection agreement to the power grids" - it is unclear what is meant since with the start of a full-scale invasion, in one way or another, non-fulfilment of obligations by at least one of the parties has occurred.

Power Purchase Agreements (PPAs):

The extension of PPAs can be organized through the GB, with a de facto duration of 4 years from the date of signing the old PPAs. The interests of some developers who are engaged in active construction (including DTEK Renewables, Elementum, and Eco-Optima) have been protected. Still, at the same time, projects located in the occupied areas/affected areas are effectively suppressed to receive a green tariff without taking into account the intentions of the developers. For example, the 288 MW South Ukrainian Wind Power Plant project was at the stage of active construction by a Chinese investor (with equipment delivered to the facility and substation practically completed). Currently, the PPA extension is not available for the developers of this project. This aspect is extremely important for investors and does not contribute to increasing trust in investment security.

Imbalances and the possibility of leaving the balancing group:

In general, the adopted changes correspond to the market's wishes. However, the changes do not cover the effective period of the imbalance's calculation formula, which was recently cancelled by the court[56]. If extended, this would regulate the relationship between RES producers and the Guaranteed Buyer regarding imbalances, as well as between the Guaranteed Buyer and the SE "Ukrenergo" regarding the acceptance of the RES development service. [57] [58]

In September 2022, "green" producers went to court and won a case against NERC, challenging the formula for calculating the share of imbalances that should be reimbursed to them. This formula was set to increase the share of imbalances that "green" producers would be responsible for, from 50% in 2022 to 100% in 2023.

The court's decision to cancel the formula for calculating imbalances has led to a number of problems. First, it has made it impossible to calculate the volume of the service that must be compensated by "Ukrenergo" to Guaranteed Buyer. Second, it has made it impossible for Guaranteed Buyer to fulfill its obligations to pay "green" producers for the electricity they produce.

The situation is a major challenge for the Ukrainian government. The government needs to find a way to resolve the dispute between "green" producers and NERC, and to ensure that "green" producers are paid for the electricity they produce.

The problems of Ukraine's Balancing Market during martial law and the potential risks in 2024 are multifaceted. The Law of Ukraine "On the Electricity Market" defines imbalances in electrical energy as the difference between actual volumes of delivery or consumption, import, and export of electrical energy by the party responsible for the imbalance, and the volumes of purchased and sold electrical energy. These imbalances are calculated according to market rules for each settlement period and can be either positive or negative. A positive imbalance occurs when the volume of electricity supplied is greater than the planned sale volume or when the consumption volume is less than the purchased volume, indicating an excess of produced and unused electricity. Conversely, a negative imbalance arises when the supply volume is less than planned for sale, or consumption exceeds the purchased volume, indicating a shortfall that requires additional purchase.

Regarding the resolution of these imbalances, the TSO handles the payments as follows: in the case of a positive imbalance, the TSO purchases the excess electricity but at a significantly lower price than in other market segments. For a negative imbalance, additional electricity must be purchased at higher prices, with costs borne by the responsible party.

In November this year, many market participants received a letter from PJSC "NEK Ukrenergo" regarding the consideration of the Act of Mutual Homogeneous Requirements/Settlement Document for invoices of November 2022, referring to a decision of the National Security and Defense Council of Ukraine dated 07.11.2023. This decision, aimed at enhancing the resilience of the energy system and preparing the national economy for the autumn-winter period of 2023/24, instructed the Ministry of Energy of Ukraine and the National Commission that carries out state regulation in the fields of energy and utilities to take measures to reduce mutual indebtedness in the electricity market, particularly in the balancing market, the market for auxiliary services, and services for dispatch (operational-technological) management, and to increase export capacities for transborder electricity trade.

However, Ukrenergo was not tasked with implementing this decision of the National Security and Defense Council. Yet, referring to this decision and using its powers as the Settlement Operator and Transmission System Operator, Ukrenergo issues invoices to market participants. If these invoices are not paid promptly, participants are put into "Pre-default" and then "Default", initiating a so-called netting procedure. In this situation, market participants have no choice, as disagreement with the netting results in a full invoice for the reporting period's debt, leading to "Pre-default" and then "Default".

[56] https://lcf.ua/thought-leadership/energy-and-natural-resources/nokaut-vid-nebalansiv/

[57] https://lcf.ua/content/uploads/2023/07/LCF_Draft-Law-9011d-review_UKR_02-07-23.pdf

[58] https://e-b.com.ua/yurii-boiko-energetika-ce-fundament-ekonomiki-koli-v-fundamenti-problemi-nemozlivo-zvoditi-efektivnu-nadbudovu-5969

Furthermore, has reciprocal financial obligations which it still can comfortably ignore without legal consequences. Legal protection in this case is ineffective as, by the time a decision is made, the market participant would have lost its consumers and be driven to bankruptcy. Additionally, all participants of the balancing group suffer in this scenario. Ukrenergo has turned into resolving own financial problems created by inefficient managers at expense of market participants, while the NERC remains aside from this situation.

If this trend continues throughout 2024, the electricity market will likely be left with only monopolies, leading to a decrease in tax payments to budgets, reduced support for the military, and a significant increase in unemployment, which in turn affects tax payments and donations to the Armed Forces. The issue of the funds squandered by PJSC "NEK Ukrenergo" remains unresolved.

To address these issues, several solutions can be proposed. Firstly, there needs to be an independent oversight mechanism to ensure transparency and fairness in the calculation and settlement of imbalances. This can be achieved through proper regulatory reforms and the introduction of external audits. Secondly, strengthening the legal framework to protect market participants from arbitrary and unfair practices is essential. This includes revising the netting procedures and ensuring that Ukrenergo fulfills its reciprocal financial obligations. Thirdly, diversifying the electricity market by promoting smaller distributed suppliers can reduce the risk of monopolization and enhance market stability. Lastly, the government should intervene to resolve the issue of mutual indebtedness and ensure that the financial burdens do not fall disproportionately on certain market participants, potentially through state-backed financial support or restructuring programs as the fastest resolution mechanism.

The European Network of Transmission System Operators for Electricity (ENTSO-E) plays a crucial role in developing and harmonizing the rules and methodologies for imbalance calculation across Europe. This is part of the broader effort to create an integrated European electricity market. Additionally, the European electricity market is increasingly moving towards shorter balancing periods (like 15 minutes) to improve system responsiveness and efficiency. Another important point is assuring accurate nationwide weather/generation forecasting system which can be provided as service by TSO based on actual data collected from market participants, their meteorological stations and actual generation.

Ukrenergo, can leverage a system like GridFox, developed by the Fraunhofer Institute for Energy Economics and Energy System Technology (IEE), to enhance its grid management and integration of renewable energy[59]. This AI-based forecasting tool can enhance the accuracy of renewable energy feed-in predictions, allowing for more effective grid management and stability instead on accusing the produces in improper forecasts. The software enables detailed analysis at the individual plant and consumer group level, crucial for optimizing energy dispatch and managing demand. By aligning with guidelines similar to Germany's “Redispatch 2.0”, Ukrenergo can efficiently use all generation plants, including renewables, for grid balancing. This adoption would not only ensure compliance with modern grid management standards but also improve operational efficiency, maximize the use of renewable energy, and support data-driven decision-making for a more sustainable energy future in Ukraine.

Net Billing

Additionally, the Law stimulates the broad involvement of small and medium-sized businesses in improving Ukraine's energy security by removing barriers for entering the energy market by active consumers - households, small non-household/MSME, and non-residential consumers. Some provisions of the Law raise questions in the market as they are not harmonized with the norms of civil law, particularly regarding purchase and sale agreements. This relates to calculations for the generated electricity being credited virtually, i.e., funds being credited to a personal (rather than a bank) account without the seller being able to freely dispose of them, and the regulator has the ability to determine mechanisms for using the accumulated funds.

Regarding future auctions:

An improved model from 2019 (which was not implemented) with a number of restrictions has been introduced, namely:

- Reducing the support period for auction winners from 20 years to 12 years;
- For auction winners, the auction price is only partially fixed in Euros - but at least 50% of the auction price;
- Shortening the implementation period for auction winners' projects.

[59] https://www.german-energy-solutions.de/GES/Redaktion/EN/News/2020/20200909-ai-forecasting-grid-solution.html

These limitations will reduce the interest of investors in making investments.

As regards the timing of the auctions (as of 1 July 2023), the EnCS considers that for a successful auction to take place, the legal framework should be in place beforehand (including all necessary secondary legislation, long-term schedule for allocation of support, necessary documentation for auctions, etc.). Also, confidence of investors in the Guaranteed Buyer's capacity to transfer the full amount of the support in a timely fashion needs to be restored. Given the low level of payments to the Guaranteed Buyer by the TSO Ukrenergo, the Secretariat has requested that the surcharge for financial support of electricity produced from renewable sources is imposed separately from the transmission tariff and set at a level covering the commitments made towards renewable energy producers. This is also a requirement under the conditions for the certification of Ukrenergo.

Regarding Guarantees of Origin

The provisions of the Law are in scope with the market's expectations. However, it contains certain provisions that require further clarification and alignment with Article 19 of RED III or clarification regarding taxation. The Law partially transposes the RED II and other elements of the so-called Clean Energy Package. At this stage, the Energy Community Secretariat notes that more than the Law will be required to ensure the complete transposition of the Directive[60].

In general, the current version of the Law shows positive dynamics and a threshold for further refinement. It is a significant step forward in resolving the renewable energy market crisis and stimulation of the further development of the sector.

1.6.4 Implementation of EU legislation in electricity sector

The EnC Annual Implementation Report 2023 highlights Ukraine's significant progress in implementing the Electricity Integration Package, despite the ongoing war. Ukraine's achievements in electricity and gas market reforms are notable, with only Serbia showing more advancement in these areas.

A key deadline of December 31, 2023, has been set for incorporating the Electricity Integration Package into national legislation, a major focus of the Energy Community's efforts in 2023. The Secretariat has received drafts of the primary legislation from both Serbia and Ukraine, while other Contracting Parties are still in the drafting phase. The swift and complete adoption of the Electricity Integration Package in compliance with EU standards is essential for integrating into the EU internal electricity market. Full alignment with EU regulations, including granting decision-making authority to the Agency for the Cooperation of Energy Regulators (ACER) over cross-border issues between EU Member States and Contracting Parties, is imperative.

This harmonization is critical for the stakeholders of the Contracting Parties to engage in the EU's electricity market and participate in initiatives like the Single Day-Ahead Coupling (SDAC) and Intraday Market Coupling (SIDC) projects.

Moreover, progress towards integration into the European SDAC and SIDC is heavily dependent on the cooperation among transmission system operators at regional and European levels. This collaboration is a crucial element of the Electricity Integration Package. Effective market coupling necessitates a collaborative approach among operators, as working in isolation risks missing significant economic benefits for their respective economies.

The implementation of certain aspects of the package, such as the Capacity Allocation and Congestion Management (CACM), was already due in 2023. This highlights the urgency and importance of concerted efforts and collaboration for successful integration.

[60] Energy Community Secretariat: Analysis of the Draft Law of Ukraine "On Amendments to Certain Laws of Ukraine Regarding the Restoration and Green Transformation of the Energy System of Ukraine," June 2023.

CLUSTER	IMPLEMENTATION STATUS	2023 HIGHLIGHTS AND NEXT STEPS
Markets and integration	69%	The Law on REMIT was adopted in June 2023 and its implementation started. Ukraine certified its gas storage operator. Ukraine should accelerate transposition and implementation of the Electricity Integration Package as a precondition for the coupling of its short-term markets. Ukraine should re-establish the gas market fundamentals and further strengthen the unbundling status of GTSOU.
Decarbonising the energy sector	44%	Ukraine adopted a law which provides the legal framework for implementing a guarantees of origin registry, introduces a net billing scheme for self-consumption and provides directions for future renewable energy auctions. Ukraine should submit the draft NECP to the Secretariat.
Ensuring energy security	61%	The operation of the electricity system was preserved despite severe energy infrastructure damages caused by the Russian military aggression. Ukraine fulfilled the gas storage targets. Ukraine should improve the risk-preparedness planning starting with the transposition of the Regulation (EU) 2019/941 on Risk-preparedness in the Electricity Sector and the designation of a competent authority. Ukraine should adopt a risk assessment for the gas market and transpose the Security of Gas Supply Regulation.
Improving the environment	52%	In Ukraine, implementation of the environmental acquis is overshadowed by the ongoing military aggression. Nevertheless, compliance is still high.
Performance of authorities	76%	The regulator certified the gas storage system operator in line with the Energy Community gas regulation and adopted a set of secondary legislation acts enabling REMIT implementation. NEURC should adopt the remaining REMIT legislation and launch the relevant investigatory and enforcement actions.

Figure 16: Ukraine's Implementation review

Ukraine has achieved a high score in Unbundling (95%), as confirmed by ENTSO-e, indicating that Ukraine has fulfilled all its obligations under the Agreement on Conditions for the Future Interconnection.[61] The notable progress in Access to System (73%) is influenced by the existence of a temporary connection regulation that suspends the distribution code. While this, along with the transmission code, reflects the majority, but not all, of the integration requirements.

In terms of wholesale and retail markets, Ukraine scored 77% and 73%, respectively. Furthermore, the Public Service Obligation (PSO) regulation, which obligated Ukrenergo to finance electricity generation from coal, was phased out starting from June 1, 2023.

REMIT Regulation (EU) 1227/2011 was transposed in June 2023

The REMIT Law, titled "On Amendments to Certain Laws of Ukraine as to Prevention of Abuse in the Wholesale Energy Markets," holds significant importance. It stipulates that, during the initial two years, the National Energy and Utilities Regulatory Commission (NEURC) is tasked with making decisions, in consultation with the Energy Community Secretariat, regarding penalties for abuses in the wholesale electricity and gas markets.

This law is positioned to play a central role in promoting increased commercial exchanges, collaborative cross-border transmission capacity allocation, and eventual electricity market coupling between Ukraine and the EU.

These developments align with the market integration trajectory outlined in the new electricity Energy Community laws from December 2022 and the Roadmap for Further Market Integration elaborated by the High-Level Working Group on Energy Market Reforms between the EU and Ukraine. Beyond the REMIT Regulation, the REMIT Law introduces amendments related to cross-border capacity allocation,

61 https://www.entsoe.eu/news/2023/11/28/continental-european-tsos-announce-completion-of-synchronisation-project-with-ukrenergo-and-significant-increase-in-export-capacity-from-continental-europe-to-ukraine/

streamlining commercial electricity exchanges between Ukraine and its EU neighbours to create a level playing field, foster cooperation, and enhance efficiency in the interconnected energy market.

The legislation concerning Projects of National Interest in the Energy Sector was presented to Parliament in March 2023 with the objective of implementing the TEN-E Regulation (EU) 347/2013. However, as of now, it has not been formally approved resulting in the score of **88%** in respective regional integration section.

1.6.5 Non-exhaustive list of normative documents considered

The **main** normative documents and Laws underpinning the pathways for the future development of the electricity sector include:

- NSDC[62] Decision dated 02.12.2019 "On urgent measures to ensure energy security";
- Association Agreement between Ukraine, of the one part, and the European Union, the European Atomic Energy Community and their Member States, of the other part, ratified by the Law of Ukraine "On Ratification of the Association Agreement between Ukraine, of the one part, and the European Union, the European Atomic Energy Community and their Member States, of the other part";
- Paris Climate Agreement;
- Ukraine's Second Nationally Determined Contribution to the Paris Agreement;
- Law of Ukraine "On the Electricity Market";
- Law of Ukraine "On the Natural Gas Market";
- Law of Ukraine "On Energy Efficiency";
- Law of Ukraine "On Energy Efficiency of Buildings";
- Law of Ukraine "On Heat Supply";
- Law of Ukraine "On Oil and Gas";
- Law of Ukraine "On Alternative Energy Sources";
- Law 3220-IX Green Transformation of the Energy System of Ukraine
- Law 2046-IX of “On Energy Storage”
- Law of Ukraine "On Alternative Fuels";
- Law of Ukraine "On Land Protection";
- Law of Ukraine "On Critical Infrastructure";
- Law of Ukraine "On the Functioning of the Fuel and Energy Complex in a Special Period";
- Directive 2003/4/EC on public access to environmental information;
- Directive 2003/35/EC on ensuring public participation in the preparation of certain plans and programs relating to the environment;
- Directive 2000/60/EC of the European Parliament and of the Council laying down a framework for Community action in the field of water policy;
- Directive 2009/119/EC obliging Member States to maintain minimum stocks of crude oil and/or petroleum products;
- Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EU and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC;
- Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources
- Directive (EU) 2019/944 on common rules for the internal market for electricity
- Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union
- Regulation (EU) 2019/943 on the internal market for electricity
- Regulation (EU) 347/2013 on guidelines for trans-European energy infrastructure
- Regulation (EU) 2018/1999 on the governance of the energy union and climate action
- Regulation (EU) 2019/942 of 5 June 2019 establishing a European Union Agency for the Cooperation of Energy Regulators
- Commission Regulation (EU) 2016/1719 establishing a guideline on forward capacity allocation

[62] NSDC = National Security and Defense Council of Ukraine.

- Commission Regulation (EU) 2015/1222 establishing a guideline on capacity allocation and congestion management
- Commission Regulation (EU) 2017/2195 establishing a guideline on electricity balancing
- Commission Regulation (EU) 2017/1485 establishing a guideline on electricity transmission system operation
- Commission Regulation (EU) 2017/2196 establishing a network code on electricity emergency and restoration
- Commission Regulation (EU) 2020/1044 supplementing Regulation (EU) 2018/1999 with regard to values for global warming potentials
- and the inventory guidelines and with regard to the Union inventory system
- Commission Implementing Regulation (EU) 2018/2066 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive
- 2003/87/EC
- Commission Implementing Regulation (EU) 2018/2067 on the verification of data and on the accreditation of verifiers pursuant to
- Directive 2003/87/EC
- Commission Implementing Regulation (EU) 2020/1208 on structure, format, submission processes and review of information reported by
- Member States pursuant to Regulation (EU) 2018/1999
- Regulation (EU) 2016/631 establishing a network code on requirements for grid connection of generators
- Regulation (EU) 2016/1388 establishing a network code on demand connection
- Regulation (EU) 2016/1447 establishing a network code on requirements for grid connection of high voltage direct current systems and
- direct current-connected power park modules
- Regulation(EU) 543/2013 on submission and publication of data in electricity markets
- Regulation (EU) 838/2010 on laying down guidelines relating to the inter-transmission system operator compensation mechanism and
- a common regulatory approach to transmission charging
- Regulation (EU) 1227/2011 on wholesale energy market integrity and transparency
- Directive 2009/72/EC concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC
- Directive 2009/72/EC concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC
- RED III Directive 2023/2413
- Directive 2018/2001 on the promotion of the use of energy from renewable sources;
- National Economic Strategy until 2030;
- National Transport Strategy of Ukraine for the period up to 2030;
- EU Hydrogen Strategy until 2050;
- Concept of implementation of state policy in the field of heat supply;
- The concept of implementation of "smart grids" in Ukraine until 2035;
- National program of development of mineral resource base of Ukraine for the period up to 2030;
- Hydropower Development Program of Ukraine for the period up to 2026;
- National plan to reduce emissions from large combustion plants;
- National Energy Efficiency Action Plan until 2030;
- National plan to increase the number of buildings with close to zero energy consumption;
- EU’s Circular economy action plan (not duly considered in the Energy Strategy);
- Guidelines on State Aid for Climate, environmental protection and Energy 2022 - *new document, not considered in strategic documents of Ukraine (Energy Strategy), however important in terms of making projections and avoiding the creation of monopolies.*

1.6.6 Main strategic goals (as set in Energy Strategy)

The main goals or broad directions set in the Energy Strategy include:

1. Reliable and un-interrupted coverage of the electricity supply of residential, commercial and other consumers is fully ensured. Measures were implemented to improve the efficiency of energy use in all areas. The energy intensity of GDP has been reduced by 100% due to an effective policy on using energy resources.
2. The transformation of the energy sector has been carried out, considering the need to ensure physical, engineering, technical and cyber protection of 100% of facilities.
3. Ukraine follows the global trend towards climate neutrality and focuses on its achievement in terms of energy until 2050. 100% of electricity and heat is produced from carbon-neutral sources.
4. A systematic approach to modernizing and improving the efficiency of energy infrastructure has been implemented, taking into account the best available technologies, digitalization and other innovative solutions.

Figure 17: Main strategic goals

5. Full and comprehensive integration with the European natural gas and electricity markets. Legal, technical and economic synchronization is ensured, accompanied by the expansion of the possibility of exchange between neighbouring countries and increased competition in the domestic market. An export-oriented energy industry has been built, which includes:
    - Increase in reserves and production of oil and gas;
    - Export of Ukrainian gas to the EU;
    - Integration of gas storage facilities into the EU network;
    - Production and export of hydrogen and alternative gases;
    - Production and export of equipment and components for the energy sector;
    - Production of small modular reactors and various components for nuclear generation;
    - Complete the nuclear cycle from nuclear fuel production to radioactive waste management.
6. The transformation of the energy sector has been carried out taking into account the need to overcome energy poverty, and protect vulnerable groups of consumers most effectively, without creating restrictions for the development of competitive relations in energy markets.

1.7 Conclusions and Recommendations

Conclusions and general remarks

- Renewable energy continues to dominate as a significant global trend, comprising approximately half of the total industry at USD 318 billion. Notably, Ukraine reflects a consistent upward trajectory in RE development.
- The Renewable Energy Directive III (RED III) mandates a 42.5% renewable energy share in total EU energy consumption by 2030 in contrast to previous goal of 32% according to RED II, with a non-binding aspirational target of 45% . An upcoming directive will revise this existing one, with the amendments becoming legally binding 18 months post-enactment. For specific sectors, the targets include 14% for transport and 40% for heating and cooling. Ukraine, aligning with these commitments, is focusing on enhancing renewable energy and technological advancements. Currently according To Decision Of The Ministerial Council Of The Energy Community and Energy Community Acquis (REDII) Target for share of energy from renewable sources in Ukraine's gross final consumption of energy by 2030 shall reach 27% .As of December 31, 2021, the total installed capacity of power plants in the IPS of Ukraine amounts to 56.247 GW, with thermal power plants representing 49.7%, nuclear power plants 24.6%, hydropower and pumped storage plants 11.2%, and generation units powered by renewable energy sources constituting 14.5% - encompassing WPPs, SPPs, and BioPPs.
- Commencing on February 24, 2022, Russian terrorist assaults targeting civilian utilities and energy infrastructures evolved into an official war tactics on October 10, 2022, resulting in damages surpass-sing USD 6.8 billion (or USD 9.1 billion when accounting for utility and district heating), significantly amplified losses and rehabilitation requirements.
- The Russian invasion on the same day led to Ukraine's permanent disconnection from the aggressor's power system. A pivotal event occurred on March 16, 2022, with the synchronization of the Ukrainian and Moldovan power systems (UA/MD) with ENTSO-E, signifying a momentous stride for the develop-ment and security of Ukraine's energy sector.
- Owing to extensive damages to prominent business consumers, persistent blackouts, and disruptions due to ongoing attacks, electricity demand in Ukraine witnessed a 30-35% decline compared to 2021.
- As of September 2022, approximately 13% of Ukrainian SPP capacities are under occupation, with 6% of the total installed solar capacity destroyed or impaired. Concerning WPPs, the 2023 installed capacity totaled 1.8 GW, with roughly 80% situated in occupied territories, leading to damage or destruction of at least 10 wind turbines - equivalent to approximately 1% of the total installed wind capacity, culminating in 20% of the overall installed RES capacity being affected.
- All Ukrainian hydropower facilities encountered damage or attacks, with the complete destruction of the Kakhovka Hydroelectric Power Plant by Russian troops on June 6, 2023.
- Post the synchronization of Ukraine's energy system with ENTSO-E, the Market Operator focused on expediting market coupling with EU countries and became an official member of ENTSO-e in Decem-ber 2023 by fulfilling all of the obligations
- The Ukrainian Government actively pursues legislative incentives during the wartime period, particu-larly to align the Ukrainian energy market with European standards, with support from the European Secretariat serving as an advisory body for energy market development.
- However, the government's attempts to approve strategic documents and present them to the international community lack the essential coordination with the technical expert community, which is paramount for documents of this nature and complexity

Recommendations

- Development of an Updated Ukraine Energy Strategy:
- An updated Ukraine Energy Strategy shall be developed as corresponding National Energy and Climate Plan (NECP). This strategy should incorporate the opinions and contributions of the expert community, representatives from Transmission System Operators (TSOs), Distribution System Opera-tors (DSOs), power plants, associations, and other key stakeholders in the sector. This incorporation should be the result of thorough public discussions and workshops. The document shall duly reflect the existing bottlenecks such as strengthening of congested grid infrastructure (including previously over-

populated with RES and now significantly damaged Southern Regions). It is essential that only this collaboratively developed version of the strategy be presented

- Feasibility study on the Facilitation of RES Integration/ Implementation of Goals set in the Strategy. A similar study was performed back in 2014 for IBRD in course of Second Transmission project. There is a need for a preparation of such document containing detailed calculations of network modes, reflecting the progress and actual system needs. The expected capacity building and restructuring of the grid has to be re-calculated and analyzed with mandatory coordination by TSO. Priority measures to be identified and structured to enable and plan future procurement.
- Harmonization of Subordinate Plans, Programs and development frameworks:
  In the process of preparing the overall sector strategy, it is imperative to develop and harmonize subordinate/supporting strategic documents for each of the Power Sector components (Nuclear, Hydro, RES, Environment and emissions, Storage, P2X, Grid infrastructure feasibility. These documents should reflect the overall goals and approaches of EU integration and should align with the general Energy Strategy.
- Adoption of Subordinate Laws and Standards:
  Subordinate laws and standards should be adopted to fully correspond with EU legislation. This process should be led and guided by the Energy Community (EnC).
- Specific Recommendations:
  More specific and detailed recommendations are provided in the subsequent chapters of this report. These recommendations should be reviewed and considered as integral components of the strategic planning and implementation process.
- Resolving non-payment issues

To address the present issues, several solutions can be proposed.

- ✓ Firstly, there needs to be an independent oversight mechanism to ensure transparency and fairness in the calculation and settlement of imbalances. This can be achieved through proper regulatory reforms and the introduction of external audits.
- ✓ Secondly, strengthening the legal framework to protect market participants from arbitrary and unfair practices is essential. This includes revising the netting procedures and ensuring that Ukrenergo fulfills its reciprocal financial obligations.
- ✓ Thirdly, diversifying the electricity market by promoting smaller distributed suppliers can reduce the risk of monopolization and enhance market stability.
- ✓ Lastly, the government should intervene to resolve the issue of mutual indebtedness and ensure that the financial burdens do not fall disproportionately on certain market participants, potentially through state-backed financial support or restructuring programs as the fastest resolution mechanism.

2 CALCULATION OF RE POTENTIALS

2.1 Methodology

The Consultant studied the present conditions in the power sector and gathered preliminary information on the current state of the power system. The information was mainly gathered from published data (otherwise the details would usually be confidential). Also, specific attention was given to establishing connections with the main stakeholders and familiarization with existing legislative incentives.

The following approach was taken by the Consultant for detailed data assessment:

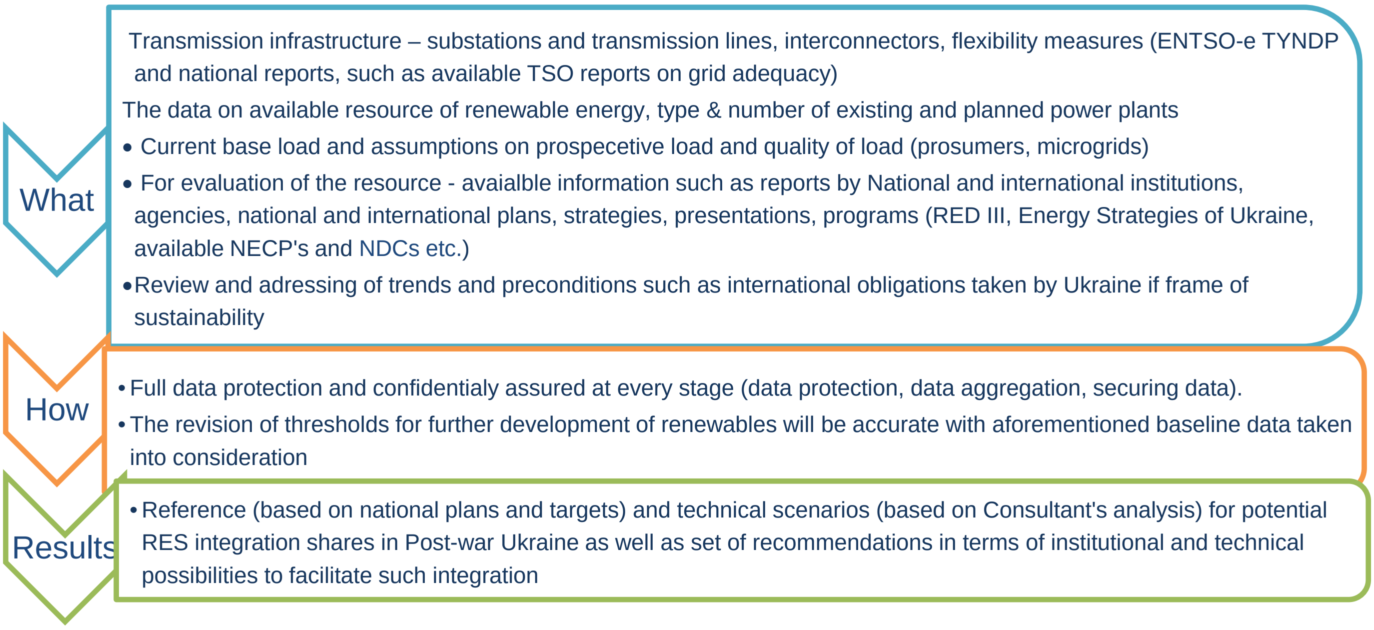

Figure 18: Assessment Approach

2.1.1 Data availability

The quality of data collected remained one of the key challenges for this assignment (taking into account the volatile situation in Ukraine's power system(s), as well as requirements to maintain strict confidentiality on data collected about the system).

The Consultant has reviewed the available open-source data and the data received from stakeholders already completed the familiarization with the available documentation. [63]

Majority of actual and up-to-date documents remain in the "service use" condition not available for expert community the same is applied to the draft Energy strategy, which was a background for recovery plan presented in Lugano[64] . This is the main recent source of information issued by authorities available for the Consultant and having the appropriate extent of justifications to allow proper analysis.

The Strategy presented at the London Ukraine Recovery Conference 2023[65] was not available to the expert community as well as to the system operator's officials (as known to the Consultant). The presentation and the documents provided raised additional doubts in regards to the potential increase in RE generation capacity: (wind up to 140 GW, solar up to 94 GW, energy storage up to 38 GW, nuclear generation – up to 30 GW, CHPs and bioenergy capacities – up to 18 GW, hydrogeneration – up to 9 GW).

The above manifests inconsistency and provides limited possibility for due analysis. The installed capacities of Wind (28,10 GW by 2050) and Solar (17,30 GW by 2050) grew fivefold compared to results presented in Lugano. While Lugano results had some justifications (and quite clear

[63] *It is important to acknowledge that the information and data presented in this report are, with some exclusions, based on sources available as of December 1, 2023. Consequently, the report may not encompass or reflect insights from publications or datasets released subsequent to this date*

[64] https://www.urc-international.com/urc-2022

[65] https://www.urc-international.com/urc-2023-info

justifications in form of subordinate plans, programs and strategies approved by concerned authorities) the London projections were lacking any. For the sake of calculations and Reference Scenario the Consultant is using the version of the Strategy which was available before "for service use" and formed basis for Lugano conference.

The estimation of RES potentials covers both estimates of the available resource and the outlook on possible RES shares in the power system ahead for 2032 and 2050.

With regard to **resource availability** - there is already data from several sources in the literature, in particular from IRENA[66] and IRE - the Institute of Renewable Energy Sources of National Academy of Sciences of Ukraine[67]. The Consultant's task is a critical review of those data or to come up with its own estimates, as a basis for further analysis on policy, legal or possibly technical support requirements for achieving the RE potential to the best extent possible. The following subchapters cover various aspects, also considering the RE development in Ukraine, the actual RE capacities, the development of technologies, the RE development trends including the policy and legal framework, as well as recent strategies.

The calculation for **RES integration** into the power system were arranged on the basis of spreadsheets relying on the available data (pre-war status and postwar assumptions) with limited possibility for full optimization due to lack of measurement data. The calculations included all the available balancing and flexibility solutions in the extent possible today without gathering information from TSO's and DSO's.

The description of calculation scenarios is provided hereunder followed by next subchapters important for proper analysis

2.1.2 Scenarios for calculation

Technical scenario is aimed on revision of the reference scenario provided in Energy Strategy based on the actual situation. The main assumptions are given in the chart below:

Reference Scenario (energy strategy)	Technical scenario (according to international best practices and specific market features)
• Based on national strategies, plans and targets	• Resource reconsidered; • Bottlenecks considered (legislative, land, environmental & social, investment, insurance, logistics, technology, grid topology, as well as local congestions and other grid issues); • Baseline assumptions modified to correspond to the real state of business (GDP growth is considered lower than in strategy (according to Global Trends) and Population change (it is expected that the population will not dramatically drop after the victory of Ukraine due to migration and return of citizens), the tempo of energy sector growth is between 3.5% for a first eight years and 2.6 % till 2050, while Energy Strategy provides for almost 5% growth); • Wider and more practical outlook on available technologies; • The resulting power system can be characterized as a carbon-negative, decentralized, self-reliant smart system, with RES forecasting, P2X compliant with both Ukrainian, EU and global goals; • Consideration of adequate increase of ENTSO-e interconnections • It is considered that the human resource will be sufficient to run all of the activities (as in the reference scenario). **Breakthrough scenario** • Optimistic implementation of technical scenario considerations • Technology breakthrogh (Storage, P2X) • Further advances on decentralization and Smart Grids (*demand response, AI*)

Each scenario is explained in further detailed below.

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[66] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/Apr/IRENA_REmap_Ukraine_paper_2015.pdf
[67] https://www.ive.org.ua/wp-content/uploads/atlas.pdf

2.1.3 **Reference scenario** (Energy Strategy and Lugano Conference presentation)

The Strategy demonstrates a lack of internal consistency and fails to address key aspects, such as recognizing the significance of a circular economy and comprehensively evaluating the impacts of decentralization on grid security and stability. Moreover, its execution could encounter challenges, considering that numerous projected technologies may undermine the driving forces of competition, contradicting the principles outlined in the new CEEAG.

The Strategy frequently relies on costly flexibility options, prioritizing the balancing of renewables with load following over base load nuclear generation, which, if NPPs are state-owned, may result in the establishment of another monopoly. Moreover, the anticipated 17 GW of "semi-peak and peak generation," initially reliant on natural gas and later transitioning to renewable gases, raises concerns, reminiscent of efforts to perpetuate the centralized power system inherited from the post-Soviet era. Mentioning demand side actions or hydrogen production appears incongruent with their effectiveness as measures for enhancing network stability concurrently.

The initiative to build 8 GW of electrolysers for producing hydrogen for export till 2030 also raises doubts in terms of the availability of the technology, the grid topography, and the initiative from DSO and TSO to accommodate such loads in due time (the published extracts do not mention “green” hydrogen).

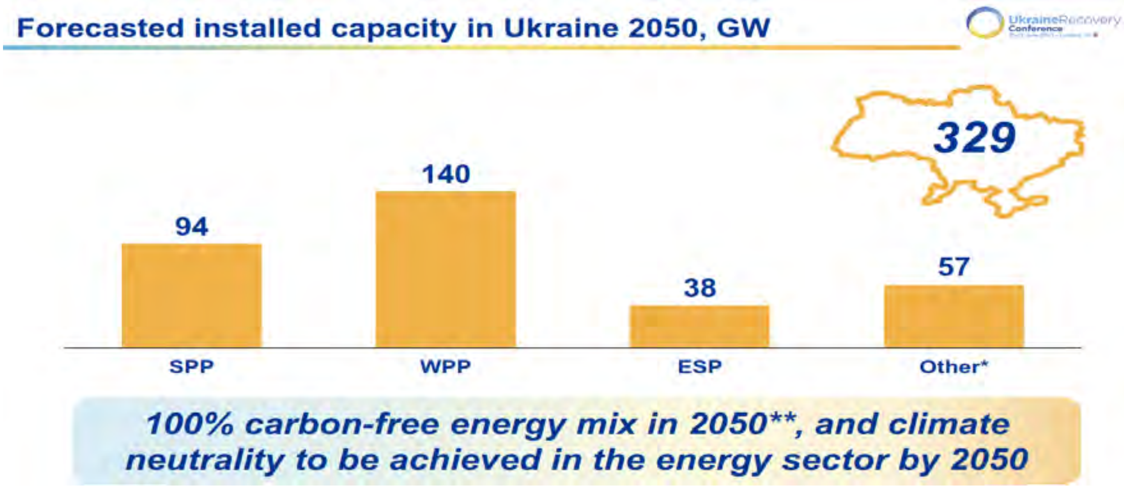

Figure 19: Energy Strategy as presented on the Ukraine recovery conference, London, June 2023[68]

Key findings of the TYNDP 2022 System needs study

In 2030

- 64 GW of capacity increases after 2025 on over 50 borders
- 17 TWh of curtailed energy saved each year
- Dependence on gas for power generation decreases by 9 TWh/year
- 14 Mton of CO_2 emissions avoided each year
- Generation costs decrease by 5 billion euro per year
- Existing transmission projects do not cover all system needs, a 15 GW investment remains

In 2040

- 88 GW of capacity increases after 2025 on over 65 borders, 41 GW of storage in 19 countries and 3 GW of CO_2-free peaking units in 4 countries
- 42 TWh of curtailed energy saved each year
- Dependence on gas for power generation decreases by 75 TWh/year. That's equivalent to 14 % of the EU gas-based electricity generation in 2021.
- 31 Mton of CO_2 emissions avoided each year
- Generation costs decrease by 9 billion euro per year
- Increased security of electricity supply, with 1,6 TWh of avoided energy-not-served
- There are opportunities for new solutions to address the needs throughout all Europe

Capacity increases and generation costs are for the whole area covered by the study, which extends beyond ENTSO-E to include Great-Britain, Ukraine, Moldova and Med-TSO countries bordering the Mediterranean Sea. Avoided CO_2 emissions, avoided curtailment, reduction in gas-based power generation and in energy-not-served are for the ENTSO-E area.

In response to new challenges, the TYNDP also explores real-time system operation needs (voltage and frequency control). These needs are expected to grow in the future as a result of the changing energy generation mix which will include high share of inverter-based generation not providing inertia support to the grid and increasingly responsive energy demand. Results are presented in a separate report on System dynamic and operational challenges.

Figure 20: TYNDP system needs and prospective for European power system development[69]
(for details see next page)

Further the situation became even more unclear and confusing. The Strategy presented at the London Ukraine Recovery Conference 2023 was not available to the expert community as well as to the system

68 https://www.urc-international.com/

69 https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2022/public/high-level-report.pdf

operator's officials (as known to the Consultant). The presentation and the documents provided raised additional doubts in regards to the potential increase in RE generation capacity: wind – up to 140 GW, solar – up to 94 GW, energy storage – up to 38 GW, nuclear generation – up to 30 GW, CHPs and bioenergy capacities – up to 18 GW, hydrogeneration – up to 9 GW (see Figure 20 above).

The Consultant notes that these numbers appear not to be aligned or harmonized with latest available study on the TYNDP's system's needs (for instance referring to increase of capacities as of Figure above).

Moreover, it should be considered that the peak load of whole ENTSO-e in 2022 was at the level of 441,471 GW and the overall NGC (Net Generation Capacity) of 1,057 GW. This is a number for the whole ENTSO-e including non-EU states. Such figures in the Strategy on RE generation capacity appear therefore to be more aligned with a viewpoint backed up by evidence rather than being derived from a technically robust and viable exercise.

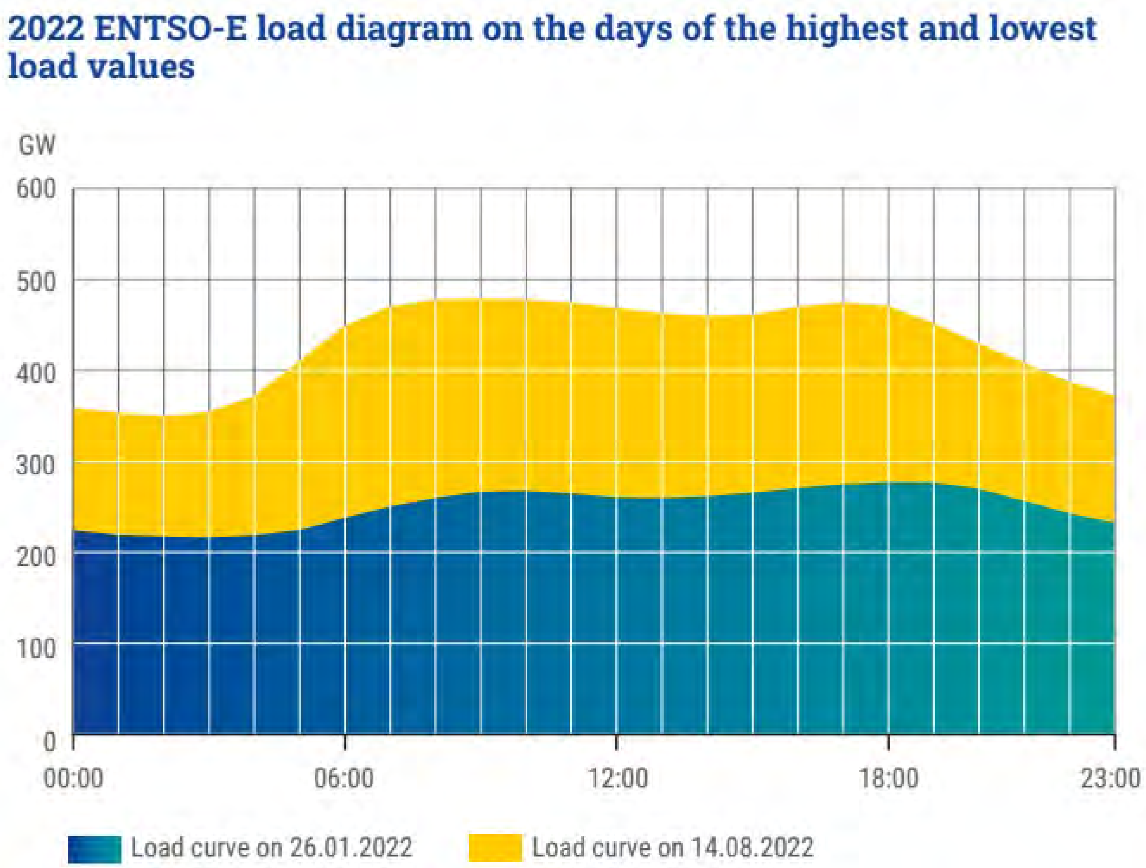

Figure 21: ENTSO-E Peak load of 2022[70]

When considering the reference scenario, One of the debatable assumptions presented in the Energy Strategy is the use of nuclear generation for balancing RES[71] - along with the use of semi-peak/peak generation by newly built gas-fired power plants and a growth of RES consumption by households only 1.9 times along with the introduction of 5 GW prosumer PV. The above concepts do not properly match. While it may appear in line with the fossil phase-out concept even in its reduced form after COP 26 Glasgow conference (which is already being re-considered).

According to the Energy Strategy the RES balancing is arranged by:

- Either balancing and reserve capacities — **multi-fuel TPPs** (natural gas and/or "biomethane") and, in the future other technologies with similar technical parameters;
- Or increasing the capacity of energy storage facilities, including long-term (seasonal) storage using PtX technologies (hydrogen, ammonia, etc.). Storage technologies are already labeled as "practically unavailable in Ukraine (except for hydro)": chemical (0.002 billion kWh[72], 0.5 GW installed), water reservoirs (1 billion kWh hydro and 0.01 billion kWh PSPP – 3.5 GW installed extra) and hydrogen.

[70] https://www.entsoe.eu/data/power-stats/

[71] https://physicsworld.com/a/can-nuclear-be-used-to-balance-renewables/

[72] 1 billion kWh = 1000 GWh = 1 TWh

- In the other part of the Energy Strategy, the RES balancing (possibly the frequency control) was planned to be arranged via highly-load-following nuclear reactors.

It appears that storage, smart technologies, de-centralization and other concepts like cooperation between market players to provide balancing as services are shown in the Strategy only for reference and not used in calculations. This is possibly made with reference to the Glasgow agreements on transient sources (biomethane cannot provide balancing for 17 GW of installed capacities in the short run) instead of doing a proper calculation on the clean and contemporary technologies. Ukraine is planning instead to build new generation based on fossil fuels and rely on them. This does not align with a Green Deal philosophy but prepares the ground for state dominated (if not monopoly) growth instead of open market development.

2.1.4 Technical scenario

The Strategy is strongly considering gas as a transient fuel - which cannot be considered a hypothesis[73].

Natural gas has long been seen as a "transition" fuel for economies depending on coal for their power needs, as it produces lower carbon dioxide emissions than coal but requires similar centralized infrastructure, and gas-fired power stations take only a couple of years to build. Earlier this year, before Russia invaded Ukraine, the European Commission irritated green campaigners by including gas as a "bridge" to clean energy in its guidebook for green investment. High prices for gas, and the plummeting cost of renewable energies such as wind and solar power, have reversed that logic.

This is illustrated in the following Figure based on an analysis from TransitionZero[74] which shows the price level that a CO2 certificate has to have in order to make it economically attractive to switch from coal to gas (black line) and from coal to renewables ("clean", green line) for the period 2010-2022. With the high gas prices in 2022 and moderate prices for coal, the "advantage" of reduced GHG emissions from gas use decreased, while a switch from coal to renewables became more and more attractive due to cost reductions for renewables and RE-based electricity. The cost of switching from coal to renewables **has decreased by 99% since 2010.**

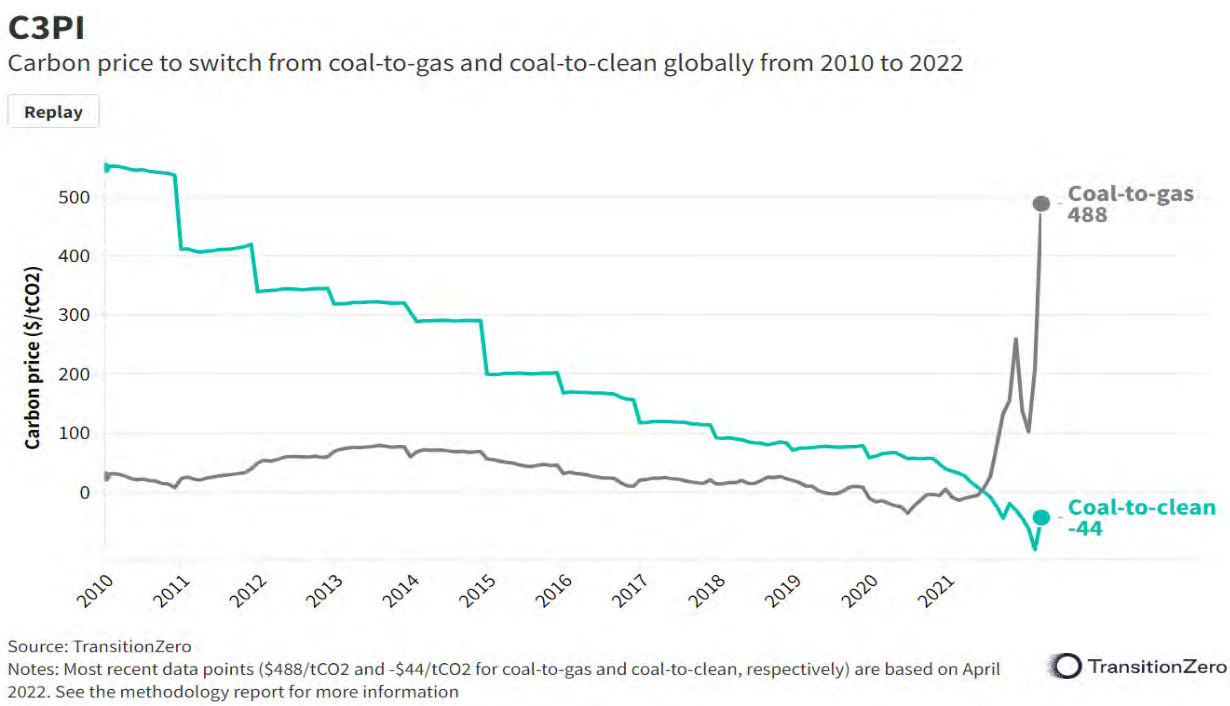

Figure 22: C3PI index: Carbon price level needed to reach same electricity generation costs for coal and gas (black line) and coal and renewables ("clean") for the period 2010-2022 (with gas price high in '22)

Russian invasion has accelerated the process of rethinking this approach. Investments in 17.5 GW of new gas-fired balancing capacities or just reviving outdated thermal power plants, in different words, raises serious concerns regarding compliance with Green Deal targets.

General observations:

[73] https://www.theguardian.com/environment/2022/may/10/avoid-using-gas-transition-fuel-move-clean-energy-study-urges
[74] https://www.transitionzero.org/insights/fuel-switching-coal-to-clean

(i) The Strategy's approach adheres to a (misguided) post-Soviet agenda, advocating for a well-balanced centralized power system, often at odds with renewable energy. Concerns also arise regarding the potential formation of monopolies and the establishment of "large units" such as generation facilities and electrolyzers. A more effective approach suggests the clustering of the power system into self-sustaining blocks capable of confronting both internal and external challenges, while prioritizing the objectives outlined in the Fourth Energy Package.

(ii) The distortion of price discovery in regulated electricity markets is dependent on technology-specific power purchase agreements and the subsidization of coal, gas, and end-user electricity prices. These distortions impede cost-efficient outcomes and hinder the adoption of competitive technologies such as wind, solar, and battery storage.

(iii) Deregulated markets often suffer with a lack of investments due to insufficient demand-side engagement, stemming from the absence of product differentiation and infra-marginal risks arising from high capital costs and lengthy project timelines. These barriers frequently compel zero-carbon originators to shoulder not only technology and market risks but also those associated with policy and political uncertainties spanning multiple election cycles. For optimizing investor behavior, markets and cost-reflective pricing are essential. Differentiated policy support is crucial for ensuring the efficient allocation of capital.

(iv) Both, regulated and deregulated markets urgently need to reform approval processes. While the political will to deploy more capacity is clear, obtaining approvals is a key bottleneck - slowing down the deployment and increasing the cost of zero-carbon sources of electricity generation. According to WindEurope, an industry association, the time to obtain all approvals for onshore wind deployment can take up to 10 years.

	Distributed Energy Higher European autonomy with renewable and decentralised focus	**Global Ambition** Global economy with centralised low carbon and RES options
Green Transition	At least a 55 % reduction in 2030, climate neutral in 2050	
Driving force of the energy transition	Transition initiated at a local / national level (prosumers)	Transition initiated at a European / international level
	Aims for EU energy autonomy through maximisation of RES and smart sector integration (P2G/L)	High EU RES development supplemented with low carbon energy and imports
Energy intensity	Reduced energy demand through circularity and better energy consumption behaviour	Energy demand also declines, but priority is given to decarbonisation of energy supply
	Digitalisation driven by prosumer and variable RES management	Digitalisation and automation reinforce competitiveness of EU business
Technologies	Focus of decentralised technologies (PV, batteries, etc.) and smart charging	Focus on large scale technologies (offshore wind, large storage)
	Focus on electric heat pumps and district heating	Focus on hybrid heating technology
	Higher share of EV, with e-liquids and biofuels supplementing for heavy transport	Wide range of technologies across mobility sectors (electricity, hydrogen and biofuels)
	Minimal CCS and nuclear	Integration of nuclear and CCS

Figure 23: Storylines of the Global Ambition and Distributed Energy scenarios[75] [76]

In contrast to the reference scenario, the technical scenario is considering the combination of Distributed and Global storylines as described by TYNDP 2022 (European Electricity infrastructure ten-year development plan), as shown below. It shall be separately noted that the role and potential of Ukraine appears in the current version of the TYNDP and has to be further coordinated.

The Consultant considers the following mechanisms to ensure required grid stability as a basis laid in the technical scenario (please refer to Chapter 4.3 for wider description):

Modular reactors are a new, not proven technology that shall not be relied on more than any other technology of this kind; in the power sector all possible measures shall be wisely considered while making future assumptions

[75]https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2022/public/high-level-report.pdf
[76] https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2022/public/system-needs-report.pdf

Setting clear market mechanisms making investments in storage and balancing services attractive, as well as introducing storage technologies (0.5 GW till 2032 and 2 GW by 2050), allowing private investors to participate in building up the grid stability and avoid monopoly

Re-thinking PtX(-XtP) as a balancing tool taking into consideration Ukraine's obligation to build 8 GW of electrolyzers and 11 GW of PtX(-XtP) capacities by 2050 – these technologies shall be rendered on a competitive basis and be attractive for investments

Proper consideration of the role of Prosumers (almost 6 GW of solar residential installations). Considerations in regards to inclusion of contemporary RE technologies (please refer to Chapter 4.3 for more details)

Other decentralization (DERMS & Virtual Power plants) and demand-side measures

Extension of ENTSO-e interconnectors

Comprehensive and successful implementation of Hydro Power Plant development strategy

Digitalization and smart solutions such as Forecasting, WAMS, ADMS, renovation of SCADA (inclusion of OMS, MDMS, DERMS and VPPs), V2G and charging stations

Figure 24: Grid stability in technical scenario

When considering technical scenario it's important to acknowledge the constraints identified in the calculations of flexibility and balancing limits for the integration potential of Renewable Energy Sources (RES), as publicly presented by Ukrenergo in its Generation Adequacy Report. These calculations offer a more conservative perspective on the flexibility limits of the pre-war power system. Ukrenergo's report, serving as a crucial reference, outlines the boundaries within which the current energy infrastructure can adapt to and accommodate renewable energy. This conservative estimation highlights the need for cautious and strategic planning in the expansion and integration of RES into Ukraine's existing power system. In addition it is worth mentioning the studies and calculations made by such reputable authorities and providers as USAID (Tetratech)[77], EnC (Trinomics B.V.) [78], Wartsila[79] as well as Consultant's gained experience in modeling and analyzing the UA grid operation during the past dozen of years has allowed to evaluate the possible flexibility limits to allow RE integration in the ambitions extent as presented at least by Ukraine Recovery Plan and further. In following **breakthrough scenario** these limits can be lifted due to technological advance and, as mentioned above, re-thinking of UA power system.

2.1.5 Breakthrough scenario

To effectively enhance renewable energy (RE) in a comprehensive and sustainable way, it's essential to implement multiple improvements beyond the moderate integration of measures already outlined in the technical scenario (as based on the trends and 2023 situation). These further improvements should focus

[77] https://www.energy-community.org/dam/jcr:a39fae7e-4d62-45e6-8ece-11896a87739a/REG092020_USAID.pdf
[78] https://www.energy-community.org/dam/jcr:2db406e5-294f-4285-9209-ec90349ce5cb/Flexiblity_EnCreport_0722.pdf
[79] https://www.wartsila.com/docs/default-source/power-plants-documents/downloads/white-papers/europe/wartsila-flexibility-to-future-proof-the-ukrainian-power-system.pdf

on refining the power system operation concept, as proposed in the technical scenario, to facilitate a smoother integration of renewable energy sources.

Also, the technical scenario, as it currently stands, offers moderate forecasts regarding decentralization and technological progress. It does not anticipate major breakthroughs in technologies (exotic like Cold Nuclear Fusion or quite expected revolutionary advancements in storage technologies[80]). Furthermore, it addresses the challenges faced by the Ukrainian Power Sector, assuming rapid and simultaneous advancements are made. However, even within these constraints, there's significant potential to enhance the integration of renewable energy sources and the resilience of the grid. This advancement is crucial for renewable energy to play a pivotal role in the reconstruction of both the Ukrainian power system and the economy at large.

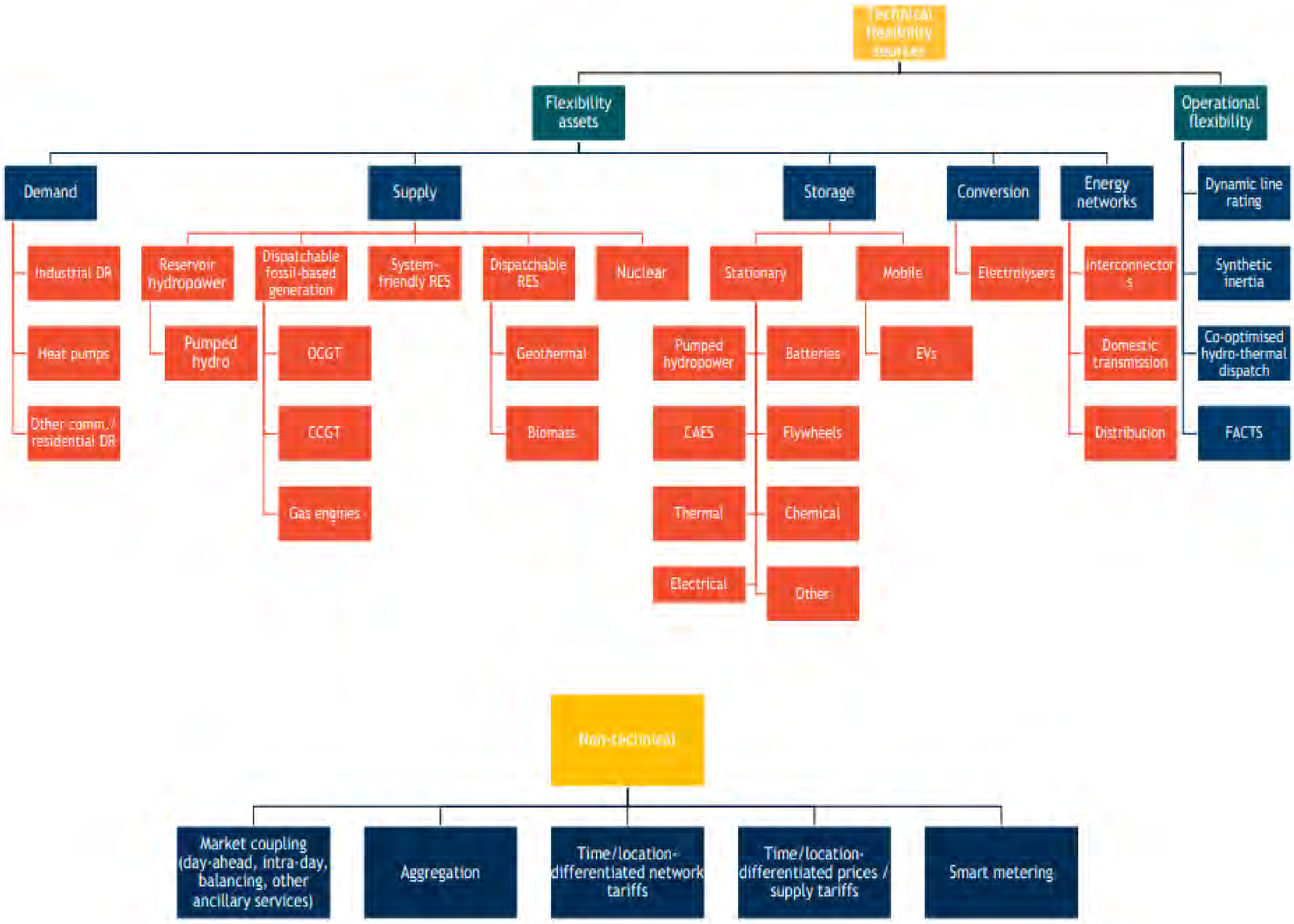

Figure 25 Sources for flexibility improvement according to EnC

Adopting this approach is not limited to just addressing current operational challenges; it also involves tackling broader structural changes in the energy market and shifts in consumer behavior. By embracing these comprehensive strategies, the potential of renewable energy can be fully realized, contributing significantly to the sustainable development of Ukraine's power infrastructure and economy.

1. **Reliable Payment Systems for RE Electricity Generators**. It's essential to establish reliable and prompt payment mechanisms from offtakes to RE existing and future electricity generators – these mechanisms may be supervised by international referees. Non-performance may, for instance result in blocking the EU or state support to the offtakes. This financial stability will encourage future investment in renewable energy projects and ensure the sustainable operation of existing ones. Clear and enforceable contractual agreements along with regulatory support, can facilitate timely payments and reduce the risk for renewable energy providers.

[80] Please refer to Chapter 4.3 for more information regarding the expected technological advances

2. **Expedient settling of the existing debts and malperformance issues**. Settling debt issues, imbalances and limitations imposed on developers. Lifting bureaucratic limiting by establishment of one-stop-shops and transparent development, construction and operation manuals will provide a very clear signal to investors willing to contribute in Ukraine’s “building back better”
3. **AI technologies in balancing and forecasting.** Ukraine is often proclaiming digitalization as one of the main drivers of Economy restoration. However, the power system is still runs on the philosophy of centralized power system killing in the womb any attempt to develop decentralized and deregulated market. TSO and NEURC resist de-monopolisation attempts. when Furthermore TSO shall assist the producers by providing AI based forecasting and balancing tools based on the massive extent of data it operates (gathered from market participants and ENTSO-e members.
4. **Active Support for Prosumers**: Encouraging the concept of "prosumers" – consumers who also produce electricity – is crucial. This approach not only reduces the load on the grid but also promotes local energy generation and consumption. Policies and incentives such as feed-in tariffs, net metering, and subsidies for installing renewable energy systems can stimulate prosumer participation. As the residential sector is a target of this support – a very clear and informational campaign shall start well before the war ends to support prosumers and explain the benefits foreseen. Educational campaigns and technical support can further enhance their ability to contribute effectively to the energy grid. V2G technologies are also in this regard considered.
5. **Grid Reinforcement and Decentralization**: Moving from a centralized system with large generation capacities to a distributed generation model is key. This involves reinforcing the grid infrastructure to support the integration of renewable energy sources from areas most suitable for RE generation to areas with high consumption. Investment in smart grid technologies, which allow for better integration and management of distributed energy resources, is essential. This shift will enable a more resilient and flexible energy system, capable of accommodating diverse renewable energy sources.
6. **Further increasing RE-Electricity Storage (with breaktroughs) & Managing Variable Generation**: Addressing the challenges of energy storage and variable RE generation is critical. While batteries in electric vehicles can contribute to some extent, more comprehensive solutions are needed. Pumped storage capacities, though expensive and geographically limited, offer potential. Green hydrogen and Power-to-X (PtX) technologies are emerging as large-scale options, but issues such as additionality, water supply, and environmental impacts of brine discharge from demineralization plants need resolution. Cost-effective production, financing models, and market incentives are crucial for the widespread adoption of these technologies.
7. **Demand-Side Management and Harmonizing Supply and Demand**: Effective demand-side management is necessary to align variable RE electricity supply with demand. This requires a combination of significant price incentives (varying by factors of 10 or more depending on RE availability), substantial investment in industrial solutions for demand shifts and flexibility, and a profound behavioral change among consumers. To facilitate this shift, an extensive education and awareness campaign starting from kindergarten through to workplace training is essential. Moreover, commonly used appliances should be designed to respond to price signals and forecast data, automatically adjusting operation times or providing cost-based usage suggestions. These smart appliances should have interfaces for receiving and reacting to 24-hour price forecasts based on weather and historical generation / demand data. Wide use of demand response (both industrial and residential) is foreseen.

Implementing these measures will necessitate a collaborative effort between government bodies, energy providers, technology developers, financial institutions, and consumers. The goal is to create an integrated, efficient, and sustainable energy ecosystem where renewable energy sources are not just supplementary but central to meeting the energy demands.

2.2 Current condition of the RES sector

The total installed capacity for RES generation (excluding large hydro power plants) in Ukraine was 9.6 GW as of the end of 2021. The total installed Solar Power Plants capacity (excluding 0.4 GW located in the territories temporarily occupied by Russia before 24 February 2022) reached 7.6 GW or 80% of the total RES installed capacity in Ukraine. As of December 2023, about 13% of Ukrainian SPPs capacities are under occupation, and 6% of the total installed solar capacity has been destroyed or damaged. As for WPPs, the total installed capacity in 2022 was 1.6 GW. As of the end of 2023, approximately 80% of WPPs are located on the occupied territories, and, at least, 7 wind turbines are known to be damaged or destroyed as a result of the hostilities by the army of Russian Federation (about 1% of the total installed wind capacity). Overall, it is 20% of total installed RES capacity that has been damaged or occupied[81]

Figure 26: RES sector damages

According to publicly available information, during the 2022/2023 heating season, Russia damaged 24 power generation facilities, and most of them were attacked multiple times. Due to destruction and occupation, the energy system of Ukraine temporarily lost 43% of nuclear, 78% of thermal generation, at least 48% of the capacity of CHPs, about 80% of wind, and more than 20% of solar generation.[82]

2.2.1 Hydropower

The hydropower development program for the period up to 2026, approved by Decree of the Cabinet of Ministers of Ukraine dated 13 July 2016 No. 552-r, defines the main directions of the development of hydropower for promising projects of new construction and reconstruction of large hydrogen generation capacities.

The current capacity of small hydropower facilities (<10 MW) is 117 MW. Due to its insignificant specific weight in the overall energy balance, small hydropower cannot significantly influence the structure of the country's energy supply.

Figure 27 Small HPP in Turka

Figure 28 Damages to small hydro power plants (excl. large hydro)

All of the Ukrainian hydropower facilities were either damaged or attacked.

During the 2022/2023 heating season, there were more than 30 missile hits on hydropower facilities. According to Public Joint Stock Company (PJSC) "Ukrhydroenergo," the main operator of HPPs and PSPs in Ukraine, the company lost 2,000 MW of generating capacity during the war. The company restored 500 MW, and another 1,500 MW remained damaged or destroyed. Power lines connecting the HPPs with the grid (including reserve ones), could transmit only 50-70% of the installed capacity of operating plants due to the inflicted damages, and also power lines require urgent restoration[83].

Figure 29 Kakhovka Dam destruction

The Kakhovka HPP is the last hydro facility (the lowest position) on the Dnipro River cascade. It is mainly used to control water supply to southern Ukrainian communities for irrigation, and to control the supply water for communities from Zaporizhzhia to Kherson. It consists of a 30 m high dam, creating the Kakhovka reservoir. This reservoir is the 2nd largest in Ukraine by size, with a length of

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81 https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_06_30_UA_sectoral_evaluation_and_damage_assessment_Version_XI__final.pdf

83 Ukrainian energy sector evaluation and damage assessment – IX (as of 24 April 2023), - Energy Charter Secretariat, 2022.

240 km, a surface area of 2155 km², a volume of 18.2 km³[84].

Since the first day of the war, the Russian army has occupied and damaged Kakhovka HPP (343.2 MW or about 5% of installed HPP capacity). Ukrhydroenergo, has already filed a claim at the European Court of Human Rights regarding the damage inflicted on Kakhovka HPP (and the wind power plant in construction on Zmiinyi Island (~40km offshore the coast near the Romanian-Ukraine border). The total amount of the claim is above USD 0.5 billion.

On 6 June 2023, the Russian army set off an explosion in the internal structures of Kakhovka HPP[85]. Due to an explosion inside the machinery hall, the Kakhovka Hydroelectric Power Plant was completely destroyed.

The uncontrolled decrease in the reservoir level threatens the temporarily occupied Zaporizhzhia Nuclear Power Plant (ZNPP) as water from the Kakhovka reservoir is used to fill a pond that supplies water for cooling the turbine condensers, and the fuel rods within the ZNPP safety systems. Currently, the station's cooling pond is filled. The Ukrainian staff at ZNPP continues to monitor critical indicators.

The Energy Community Secretariat assessed the risks resulting from the destruction of the Kakhovka HPP and noted that the dam's destruction resulted in less additional damage to the Ukrainian power system (including large substations (750/330 kV, 330/110 kV and 220/110 kV), and EHV (extra high voltage overhead lines).

Before the explosion Kakhovka HPP was disconnected from the rest of Ukraine's power system and is not controlled by Ukrenergo dispatchers and Ukrhydroenergo. The power supply in unoccupied Ukrainian territories depends on availability of production facilities, their maneuvering (ramping) capabilities, grid connectivity and the transmission network integrity which must be maintained to ensure that the entire power system operates smoothly (without creating smaller electrical islands). Connection with neighboring EU countries and their ability to provide emergency assistance or balance energy consumption is also a critical part of stable system operations.

Destruction of the Kakhovka HPP has led to economic losses as the HPP is no longer able to produce electricity, and important aFRR quantities within the power system have been lost. The losses would need to be replaced by other flexible sources such as Battery Energy Storage Systems (BESS). The loss ranges from around EUR 400 to 75 million/year based on either the current base-load average electricity price at the Hungarian Power Exchange (HUPX) of 391 EUR/MWh (average of September 2022) or the average electricity price at the Ukrainian power exchange (75 EUR/MWh). Investments in new BESS to replace the HPP to provide an aFRR would be around EUR 200 million. It is assumed that other HPPs at the Dnipro cascade would not be affected by the dam's destruction since they are all placed upstream of the dam[86]. Other sources – for example, the Kyiv School of Economics and the Government, have indicated loss estimates of approximately $2 billion[87].

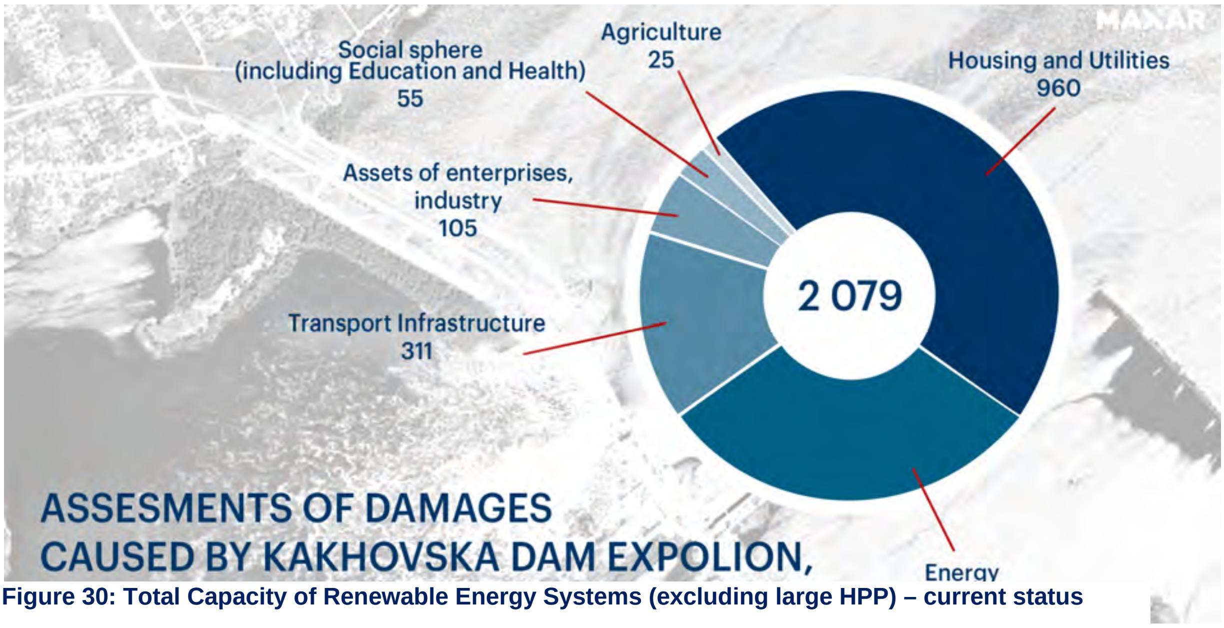


Figure 30: Total Capacity of Renewable Energy Systems (excluding large HPP) – current status

84 Energy Community Secretariat: The role and importance of Kakhovska HPP to the Ukrainian power system: https://www.energy-community.org/news/Energy-Community-News/2023/06/06a.html

85 https://www.president.gov.ua/en/news/prezident-ukrayini-proviv-ekstrene-zasidannya-radi-nacionaln-83417

86 https://t.me/ukrhydroenergo/3606

87 Ministry of Economy Website

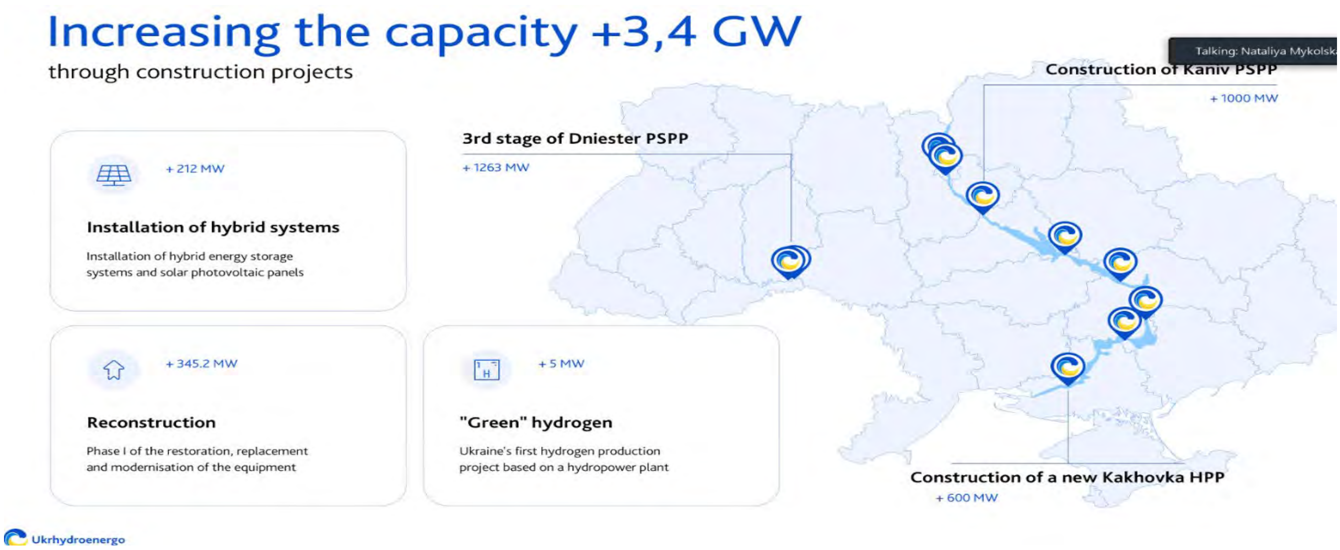


Figure 31: UHE outlooks on development of the generation capacities (28.09.2023) (screenshot from conference)

At the start of 2022, total installed RE capacity (all grid-connected) was 9.5 GW (excluding 0.6 GW of RES capacities located in the territories temporarily occupied by Russia before 24 February 2022) with about USD 12 billion invested in the RE sector during 2009-2021. Currently, 2.5 GW (or 25%) of RE facilities are occupied illegally; about 6% of total installed RES capacity has been destroyed or damaged.

On 28 September 2023, during the EUEA Energy Day held in Vienna, representatives of UHE have mentioned that almost 1.5 GW of existing capacities currently require recovery from damage caused by Russian aggression. Also, the outlook on the HPP potential growth was presented (cf Fig 34 above).

Small hydro (< 10 MW)

There were 177 small hydropower plants (SHPPs) with an installed capacity of 120 MW (excluding one SHPP (0.9 MW) located in the territories temporarily occupied by Russia before 24 February 2022) at the start of 2022 while in 2021, the share of SHPPs in electricity production was 0.1 %. Due to the liberation of Ukrainian territories in November 2022, all SHPPs occupied by the Russian Federation after 24 February 2022 have now been returned to the control of Ukraine.

2.2.2 Solar energy

The photovoltaic (PV) sector attained the highest growth rate among other renewable energy sources in Ukraine during 2019-2021 due to the high rate of provided by the State FIT. In 2022, the total installed PV capacity (excluding 0.4 GW located in the territories temporarily occupied by Russia before 24 February 2022) was 7.6 GW or 80% of the total RES installed capacity in Ukraine (incl. 45,000 prosumer installations with a total capacity of 1.2 GW).

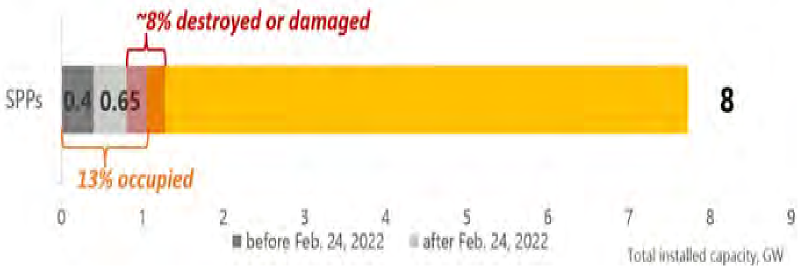


Figure 32 Damages caused to Solar Power Plants

In 2021, Ukraine was ranked 7th in Europe for the development of solar generation (IRENA, 2022)[88].

Currently, about 13% of Ukrainian PV locations are under occupation. About 8% of the solar capacity installed has been destroyed or damaged, including hundreds of prosumer installations. After liberation of territories temporarily occupied by the Russian Federation,

[88] "Renewable Energy Statistics 2022", IRENA, 2022, https://www.irena.org/publications/2022/Jul/Renewable-Energy-Statistics-2022

RES facilities were gradually put into operation[89]. The preliminary inspection results indicate that about 20% of the solar panels at the liberated Tryfonivska SPP with an installed capacity of 10 MW were damaged. As of April 2023, due to the damage to the power grid, the SPP could inject only 20% of its installed capacity into the power system, i.e., 2 MW.

2.2.3 Wind energy

As of December, 2023, Ukraine has an installed wind energy capacity of 1,860 MW[90]. However, 1,317 MW (71%) of this capacity is currently situated in the temporarily occupied territories of Kherson, Zaporizhzhia, Donetsk, and Luhansk Oblasts. The primary operational wind farms are located in Mykolaiv, Odesa, and Lviv Oblasts, with additional smaller stations (housing two or three previously operational turbines) established in Ternopil and Ivano-Frankivsk Oblasts. These are included within the overall statistics.

Three of the largest operational wind power plants are situated in Odesa Oblast: the Yuzhne Energy Wind Farm, the Dnistrovska Wind Farm, and the Ovidiopolska Wind Farm, all owned by the Turkish company Guris.

In Lviv Oblast, the first and second stages of the Staryi Sambir Wind Farm are currently in operation. By December of this year, the wind generators at the Skolska Wind Farm, with a capacity of 54.5 MW, are scheduled to commence operations.

In Odesa Oblast, 40 MW of capacity were energized at the Dnistrovska Wind Farm before the onset of the war, and an additional 60 MW of capacity were built during the military operations.

Moving to Mykolaiv Oblast, the first stage of the Tiligulska Wind Farm, with a capacity of 114 MW, was launched in 2023. Furthermore, it is anticipated that this station will be completed to its claimed capacity of 500 MW by 2024-2025.*Three wind farms with a total capacity of 228.5 MW were built during the wartime.*

Equipment was delivered to the southern regions of Ukraine, to the Tiligulska and Dnistrovska Wind Farms, before the full-scale invasion. However, wind turbines for the wind farm of the ECO-OPTIMA company in Lviv Oblast were supplied during the full-scale aggression. However, the German company Nordex supplied the equipment through Poland on the condition that the Ukrainian company assumes all insurance risks.

Currently, the Russian Federation occupies the south of Ukraine, where the highest wind potential is available. Thus, approximately 80% of wind generation capacities are in occupied territories. As of today, at least ten wind turbines are known to be damaged or destroyed as a result of the hostilities by the Russian army (about 1% of the total installed wind capacity).

Figure 33 Wind Power Plants of Ukraine, according to UWEA

According to preliminary estimates of the Ministry of Energy & the Wind Energy Association of Ukraine, financial losses from the destruction, damages, or theft of wind power plant equipment by the Russian Military Force were estimated at more than EUR 50 million. At the same time, the lost revenue of the Ukrainian wind power industry due to the war was estimated at more than EUR 500 million.[91]

Another WPP the 2nd Stage of the Dnistrovska WPP (Odesa region, 10 GE turbines) was reconnected and passed required approvals for commissioning. It has recently entered the DAM. In addition, the EcoOptima power plant is under construction in the Lviv region of the country.

Ukraine's wind energy sector, though battered by the ongoing war, demonstrates unwavering determination. While European imports remain dominant, domestic production will see a crucial boost with the

[89] Task Force, "Ukrainian energy sector evaluation and damage assessment – VI (as of 24 January 2023)", 2023, https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_01_24_UA_sectoral_evaluation_and_damage_assessment_Version_VI.pdf

[90] https://ua-energy.org/uk/posts/andrii-konechenkov-za-dva-roky-viiny-vvedeno-blyzko-230-mvt-vitroheneratsii

[91] same as above

imminent launch of a relocated factory from Kramatorsk to Zakarpattia. Friendly Wind Technology's facility, dedicated to wind farm equipment, promises to lessen reliance on foreign equipment just like 288 MW of wind turbines to be supplied by GoldWind for the construction of South Ukraine Wind power plant.

Development efforts, spearheaded by national giants like DTEK Renewables, press forward. Completion of the Tiligulska Wind Farm and pre-project work for a large 500 MW project in Poltava Oblast stand as testaments to this unwavering spirit. Smaller initiatives in Transcarpathia, Volyn, and Lviv echo this commitment, focusing on site preparation, wind potential assessments, and environmental impact evaluation those are run by Elementum Energies, Guris, Notus

The U.S. International Development Finance Corporation (DFC) has committed to providing grants for project work related to wind energy development in Ukraine. The European Bank for Reconstruction and Development (EBRD) has also expressed its willingness to invest in the construction of wind farms in Ukraine, but will initially prioritize Western investors. European banks are reluctant to invest in purely national projects in Ukraine until the war is over, as they view the risks of losing their investment to destruction or occupation as too high.

2.2.4 Bioenergy

The dynamics of electricity production from biomass lags behind the generation based on other renewable energy sources. In early 2022, bioenergy power plants had a capacity of 273.9 MW, not counting a 2 MW plant in Russia-occupied areas before February 24, 2022. Bioenergy made up 0.6% of electricity in 2021. Now, 1.3% or 5.7 MW of these facilities are under occupation, with at least four plants damaged from attacks.. to 6.6 TW/h in 2030 (with a total installed capacity of 1.5 GW).

Figure 34 Damages Caused to BioEnergy Power Plants

One of the ways to develop biogas technologies is the production of biogas from solid household waste, of which about 10 million tons are produced annually in Ukraine.

In Ukraine, there are almost 5,500 landfills and solid waste landfills. The largest number of them are in Vinnytsia (741), Poltava (675) and Chernihiv (659) regions. At the beginning of 2021, there are 22 TPPs and CHPs with a total electric capacity of 109 MW producing energy from biomass and operating at a "green" tariff. During 2019-2020, there was a rapid increase in the capacity of such facilities, from 51 MW of electrical capacity at the end of 2018 to 109 MW at the end of 2020.

On 12 April 2023, the first biomethane plant, the Hals Agro plant, was successfully connected to the Ukrainian gas transportation system, injecting the first cubic meters of biomethane gas into the network. This marks a significant milestone for Ukraine, as it becomes the first country in the Central and Eastern Europe (CEE) region to produce biomethane on a commercial scale. According to a statement from the JSC Chernihivgaz, which operates under the brand name of the Regional Gas Company (RGC)[92], the Hals Agro plant will produce around 3 million m3 of biomethane per year. This renewable gas will be consumed by approximately 1,500 customers, including the general population and industry[93] Starting beginning of June 2022, 26 companies that plan to produce a total of 206 million cubic meters have applied to “Operator GTS of Ukraine” LLC (OGTS). m of biomethane per year.[94].

2.2.5 Electricity generation from renewable energy sources by consumers

In 2021, active development was observed in only one segment - residential solar power plants (SPS), the capacity of which increased by 426.1 MW, accounting for 36.4% of the new renewable energy capacities introduced. Thus, the total installed capacity of all household solar systems at the end of the year reached 1,205.1 MW[95]. In contrast to the residential SPS sector, industrial solar energy, on the contrary, demonstrated not the best development indicators, but rather a reduction. In 2021, the capacity of industrial solar generation increased by only 305.5 MW (26.1% of the new renewable energy capacities introduced in 2021), which is 818.1 MW or 3.6 times less than the 2020 figure - 1,123.6 MW. By the end

[92] RGC was founded in 2010 to introduce innovations in the gas distribution industry. 20 gas distribution companies are operating under the RGC brand - https://rgc.ua/ua/about

[93] https://odessa-journal.com/public/the-first-biomethane-plant-in-ukraine

[94] https://euea-energyagency.org/wp-content/uploads/2023/05/April-Review-04.05.23.pdf

[95] https://saee.gov.ua/uk/content/sesd

of the year, the total installed capacity of the country's solar energy sector reached 7,586.3 MW (including residential SPS).

An additional steady increase in the number of private household PV plants under the current "green" tariff model is facing difficulties as of today due to the limited funds for FiT provided through the electricity transmission service tariff. In addition, as the Feed-in Tariff is higher than the (subsidized) market price for households, the existing "green" tariff model does not encourage consumers to primarily produce electricity for own consumption and ease stress on the local grids by bringing generation closer to consumers.

Distributed energy systems enhance the reliability of the entire grid by reducing its vulnerability. Another significant advantage of decentralized installations is a 2.5-fold reduction in the need for additional balancing capacities. The implementation of new energy storage technologies allows for the compensation of imbalances and reduces the requirement for less economically viable reserve capacities of thermal power plants in the context of distributed generation with solar and wind power.

The National Action Plan provides for the further development of RES-based electricity generation by consumers, to a greater extent using PV/solar, within the framework of the new system. This system should combine best global practices and be focused on covering own consumption, avoiding cross-subsidization at the expense of other consumers. A potential model for stimulating renewable generation can be the use of the Net billing system, which considers the difference (“netting the use”) of electricity released to the grid and consumed between the supplier and the consumer in monetary units outlined in the Law 3320-IX.

In reality, the circumstances surrounding residential renewable energy are growing increasingly complex with each day of the invasion. An indicative factor highlighting this complexity is the state of settlements. Upon closer scrutiny, it becomes apparent that the debt situation related to residential power plants, or prosumers, is notably more unfavorable compared to the industry average.

In this context, prosumers refer to ordinary households involved in producing electricity through small-scale solar energy systems for personal use, with any surplus being sold back to the grid. Although the total debt amount in absolute terms is significantly smaller for this category (1.7 billion UAH for the previous year, and as of September 1, 2023 – 3.96 billion UAH), the percentage-wise payments to residential stations lag considerably behind those made to industrial counterparts.

2.2.6 Integration of renewable energy sources into the energy system

In the conditions of the growth of the capacity of *intermittent* solar and wind power plants, the IPS is in urgent need of additional balancing capacities and measures to increase the flexibility of the energy system.

As capacity of renewable generation growth, the balancing of the power system can be achieved by ensuring proper market and technical integration of RES generators into the power system. First of all, this is the creation of conditions for the operation of renewable energy facilities in the electricity market on the same basis as traditional generation, in particular, the transition to the Feed-in-premium model for existing facilities and holding auctions exclusively within this model.

The technical integration of RES into the energy system is facilitated by the synchronization of Ukraine’s unified energy system with the EU ENTSO-E. *More detail on legal aspects of integration and current developments are provided in Chapter 1 – Subchapter 1.6.4* It requires some additional measures such as the construction of highly maneuverable heat generation, including gas turbine plants or gas-piston engines, with the possibility of quick start-up and a significant number of start-stops during the year, construction of new networks, substations and interstate crossings, completion of hydraulic storage power plants, as well as the development and construction of energy storage systems.

The Report on the Assessment of the Adequacy (sufficiency) of Generating Capacities to cover the forecasted demand for electric energy and ensure the necessary reserves in 2020 (approved by the Resolution of the National Commission for State Regulation in the Energy and Utilities Sectors of 16 June 2021 No. 975), determined the need for fast construction of highly maneuverable generation with the possibility of quick start-up in the amount of at least 1 GW and energy storage systems in the amount of at least 0.5 GW.

The active development of balancing capacities and energy storage systems will provide the necessary flexibility and stability to the electricity system.

At the same time, it will strengthen the capacity of the energy system to integrate new capacities from RES and, thus, create the technical possibility for further decarbonization of Ukraine's energy sector following Ukraine's international obligations.

2.2.7 Use of renewable energy sources in heating and cooling systems

For the production of thermal energy from RES in the conditions of Ukraine, it is advisable to use biomass energy, solar radiation energy, aerothermal, hydrothermal and geothermal energy.

In Ukraine, biomass used for heat generation is mainly wood (cod, wood waste, firewood), as well as agricultural waste (straw, sunflower husks).

The share of thermal energy from biomass in Ukraine was about 98% of all renewable thermal energy.

Heat from biomass is mainly generated in the individual sector (domestic boilers and furnaces), as well as in communal, industrial boiler houses, and CHP plants.

In 2020, the gross final volume of energy consumption from renewable sources in heating and cooling systems was 2,869 thousand toe, namely:

- biomass energy - 2816 thousand toe:
- solid - 2797 thousand toe,
- biogas - 19 thousand toe.
- thermal energy through soil/water heat pumps - 52 thousand toe:
- aerothermal (air to water) heat pumps - 36 thousand toe,
- geothermal - 10 thousand toe,
- hydrothermal - 6 thousand toe.
- solar radiation energy - 1 thousand toe.

To stimulate the heat generation from renewable energy sources, the Verkhovna Rada of Ukraine adopted the **Law of Ukraine No. 1959-VIII of 21.03.2017 "On Amendments to the Law of Ukraine "On Heat Supply" on Stimulating the Production of Heat from Alternative Energy Sources"**, which provides for the establishment of an incentive tariff on thermal energy from alternative sources. The tariff for thermal energy from alternative sources is set at the level of 90% of the current tariff for thermal energy from gas (and in the absence of it - at the level of the weighted average tariff for thermal energy from gas by region).

The increase in the production of renewable thermal energy is closely related to the development of bioenergy. According to estimates of the Institute of Renewable Energy of Ukraine's National Academy of Sciences, the technical and achievable potential of biomass for energy use is about 38.2 million tons per year, including solid biomass 35.3 million tons/year, and biogas 1.61 million tons/year. However, it is still required to verify corresponding to the sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels of the EU RED III Directive.

At the same time, for this purpose, conditions for the supply of thermal energy facilities with fuel must be created.

Today, the solid biofuel market has a number of problems, in particular, the instability of biofuel prices, its low quality, and the unreliability of its supply.

The mechanism for the organization of the biofuel market in Ukraine should be using an electronic platform where all interested producers and consumers will trade biofuel. Lithuania may serve as one of the examples (on the Baltpool exchange)[96].

The introduction of the exchange will allow creating a transparent and competitive biofuel market in Ukraine, contribute to the reduction of biofuel prices, provide generating capacity with biofuel, and stimulate the attraction of foreign investments in bioenergy of Ukraine. In addition to available wood biomass, a promising renewable source for the production of thermal energy is energy plants grown on low-productivity lands.

According to the State Geocadastre, there are more than 500,000 hectares of Ukraine's land that need conservation. Provided that energy plants are grown on them with an average yield of 11.5 million tons per year, it is possible to replace up to 2.7 billion m3 of gas per year, while simultaneously restoring fertility. At the end of 2019, only 6.4 thousand hectares of unproductive land were used for energy crops.

[96] https://uabio.org/en/news/uabio-news/11195/

2.2.8 Use of renewable energy sources in the transport sector

The use of RES in the transport sector reduces the dependence from oil imports as well as GHG emissions. Such RES based fuels include liquid and gaseous derivatives of biomass, hydrogen produced using electricity from renewable sources or electric cars using RES-derived electricity.

Figure 35 Solar power plant at E95 (402-407 km, Kyiv-Odessa) for road lighting

In 2020, the gross final volume of energy consumption from renewable sources in the transport sector was 95 thousand toe, namely:

- Bioethanol/ETBE (ethyl tertbutyl ether produced from bioethanol) – 51.1 thousand toe;
- Electricity from renewable sources - 43.9 thousand toe, including:
    - o rail transport (without considering the multiplier factor according to the **Directive 2009/28/EC** – 2.5) – 35.4 thousand toe,
    - o other modes of transport – 8.5 thousand toe.

Initial registrations of electric vehicles in Ukraine in January-September 2023 increased 2.7 times compared to the same period in 2022, amounting to approximately 24.2 thousand units, while the share of new cars increased to 20% from 15%[97]

The transformation of the industry will also be facilitated by changes to Ukraine's *Tax and Customs Codes* regarding the development of the ecological transport industry, which entered into force on 1 January 2022 (in connection with the adoption by the Verkhovna Rada of Ukraine on 15 July 2021 of **Laws of Ukraine No. 1660-IX and No. 1661- IX**).

The changes, which entered into force on 1 January 2022, provide for:

- o VAT exemption for imports of electric vehicles into Ukraine and supply to the customs territory of Ukraine, as well as new vehicles (including those produced in Ukraine) with internal combustion engines with spark ignition, operating exclusively on compressed/liquefied gas natural gas methane or biogas - until 1 January 2026;
- o VAT and import duty exemption for a number of goods by enterprises that have, create or modernize their production facilities for the construction of vehicles with electric motor(s) or vehicles with internal combustion engines with spark ignition that work exclusively on compressed/liquefied natural gas, methane or biogas, or tram cars or subway cars - until 1 January 2031;
- o Profit tax exemption for enterprises that exclusively produce the relevant types of transport and products, provided that the released funds are used for the development of electric transport and such use is related to the activities of the taxpayer, the profit from which is exempt from taxation, until 31 December 2035.

It is planned to further develop the use of Liquefied Natural Gas (LNG), Compressed Natural Gas (CNG) and their biological analogues.

By 2030 the share of RES in the transport sector is planned to be at least 14% equivalent to 961,000 toe.

2.2.9 Use of renewable gases

Biomethane

Biomethane can be used to directly replace natural gas in the production of heat and electricity. In the transport sector, biomethane can be a substitute for various types of motor fuels: compressed natural gas (CNG), gasoline, diesel, liquefied natural gas (LNG), liquefied petroleum gas (LPG). Today, biomethane is not produced in Ukraine, but Ukraine has a significant potential for its production from agricultural waste. There are already many biogas plants used for generation of electricity and heat. The biogas plants are located close to the sources of raw materials that are mainly in rural areas. At the same time, a significant

[97] https://ecopolitic.com.ua/en/news/v-ukraini-kilkist-elektromobiliv-zrosla-vtrichi-za-2023-rik-top-5-na-rinku-2/

amount of thermal energy is not used and thus lost, since there are no significant consumers of thermal energy.

The production of biomethane from biogas can be fed to the gas network and thus transported to areas where biogas-derived heat can be used.

On September 27 2023, the EnC launched the Business Forum on bio-methane and green hydrogen exploring the he development and potential of bio-methane and green hydrogen industries across Ukraine's landscape.

One of the presentations addressing transport sector was prepared by NGVA Europe. While renewable methane production could be ten times higher than current consumption in the transport sector, Ukraine's considerable biomethane capabilities remain largely untapped due to trade restrictions and an underdeveloped market. NGVA Europe indicates that biomethane could eventually fuel about 1.1 million vehicles, substantially reducing diesel-based CO2 emissions by 42 million tons annually. Despite this promising outlook, the existing policy framework in the EU might hinder the full realization of this green energy potential.

According to USAID the following are considerations[98] for biomethane legislative development in Ukraine:

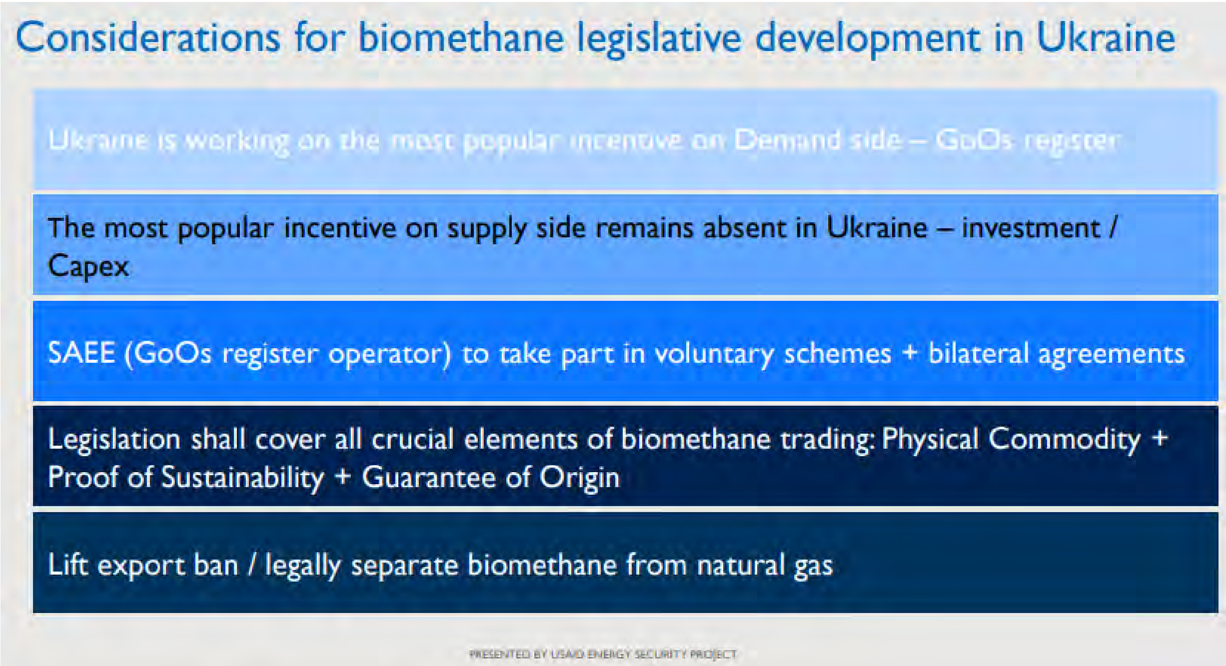


Figure 36 Considerations for biomethane legislative development in Ukraine

The Verkhovna Rada of Ukraine adopted the **Law of Ukraine No. 1820-IX dated 21 October 2021 "On Amendments to Certain Laws of Ukraine Regarding the Development of Biomethane Production"**; its implementation will contribute to the biomethane market development in Ukraine, its export to EU countries and the substitution of natural gas.

"Green" hydrogen

The production and consumption of "green" hydrogen is a new promising area of RES development. The Institute of Renewable Energy of the National Academy of Sciences has calculated the potentially possible

[98] https://www.energy-community.org/events/2023/09/GFUkraine.html

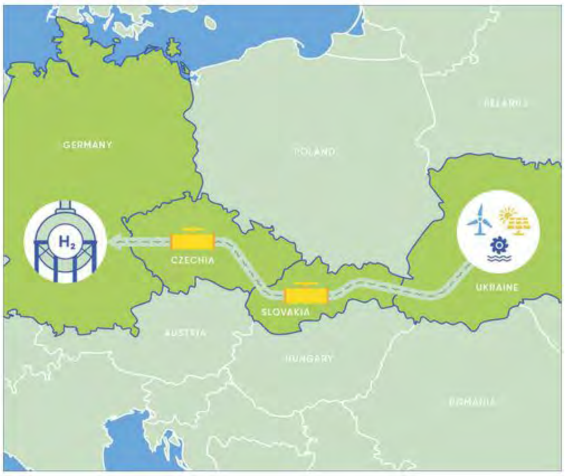


Figure 37 Central European Hydrogen Corridor & / Eastern Corridor

volume of "green" hydrogen production in Ukraine based on wind and PV-derived electricity to an average annual production of "green" hydrogen of 505,132 million Nm3 (~44,957 thousand tons).

Green hydrogen may also be produced using biomethane replacing natural gas in the hydrogen production by Steam Methane Reforming (SMR).

The production and further use of "green" hydrogen will add to the reduction of the use of fossil fuel in various sectors of the Ukrainian economy, thus supporting the decarbonization e.g. in the transport and household sectors, oil refining, chemical and metallurgical industries, etc.

It will also contribute to the further development of renewable generation facilities, improving the reliability of energy supply, and transferring seasonal changes in demand for electricity.

In its **The EU's hydrogen strategy and REPowerEU**[99] plan have put forward a comprehensive framework to support the uptake of renewable and low-carbon hydrogen to help decarbonise the EU in a cost-effective way and reduce its dependence on imported fossil fuels.

The European Union declared an initiative to create 80 GW of electrolyzer production capacity in the middle of the EU and in neighboring countries by 2030, of which 10 GW is assigned to Ukraine. Therefore, Ukraine, using its own potential of RE sources, has the opportunity to become an exporter of "green" hydrogen to EU countries.

The Central European Hydrogen Corridor (CEHC) initiative was launched in 2021 by four gas infrastructure companies (OGE, NET4GAS, eustream, Gas TSO of Ukraine) driven by the vision to develop a hydrogen “highway” through Central Europe. The initiative explores the feasibility of creating a hydrogen pipeline corridor in Central Europe for transporting hydrogen from major hydrogen supply areas in Ukraine via Slovakia and the Czech Republic to hydrogen demand areas in Germany. The hydrogen corridor will also enable the transport of hydrogen between hydrogen production facilities and hydrogen consumers in the Czech Republic and Slovakia.

The priority directions for the production and use of hydrogen in Ukraine will be determined in the **Strategy for the Development of Hydrogen Energy in Ukraine for the period until 2030**. Transmission & Distribution round table published the Hydrogen Supply Corridor Learnbook at the beginning of 2023 summarizing the existing developments[100].

Six corridors looked into include:

- South Central H_2 supply corridor,
- Iberian H_2 supply corridor,
- North Sea H_2 supply corridor,
- Nordic Baltic H_2 supply corridor,
- Eastern H_2 supply corridor *(CEHC route)*
- Southeastern H_2 corridor.

A major driver for the development of the Eastern H2 Corridor is to utilize the potential of renewable hydrogen production in Ukraine. Ukraine is a very promising future major supplier of renewable hydrogen with excellent conditions for large-scale, green hydrogen production development.

Parallel pipelines along the planned project “Central European Hydrogen Corridor (CEHC)” allow for fast and cost-efficient change in the use of dedicated pipelines - without any negative effect on the security of the regional supply of natural gas.

Repurposed pipelines in the Czech Republic and Slovakia will be combined with targeted investments in new dedicated H_2 pipelines in Austria and compressor stations in Slovakia. The Hydrogen storage

[99] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0301
[100] https://www.entsog.eu/sites/default/files/2023-04/web_entsog_230311_CHA_Learnbook_230418.pdf

facilities of RAG Austria in the regions of Salzburg and Upper Austria and NAFTA in Slovakia (IPCEI) will be used to secure and structure the (seasonal) demand of the hydrogen consumers.

The corridor can connect high H_2 supply potential in Ukraine with off takers in Central Europe and southern Germany by 2030. On the corridor additional countries can be connected, i.e. Hungary, Slovenia and Croatia. Besides pipeline transport, the Danube River could be used for the transport of hydrogen derivates from Eastern Europe via ships.

Several recent laws in Ukraine can be considered as incentivizing the Gas Transmission System Operator of Ukraine (GTSOU), each targeting different aspects of its operation and development:

1. Law 9311-1-d on Optimization of the Ownership Structure of GTSOU (July 2023):
   - Abolishes the two-layered ownership structure, simplifying governance and decision-making.
   - Increases transparency and accountability through independent supervisory board and improved reporting requirements.
   - Facilitates potential future privatization or attracting strategic investors.
2. Draft Law 3176 on Amendments to the Law of Ukraine "On Public Procurements" regarding Purchase of Natural Gas (November 2023):
   - Allows GTSOU to purchase gas for balancing needs on the Ukrainian Energy Exchange.
   - Enables participation in short-term gas markets, aligning with EU norms.

Ukraine has not yet fully implemented Regulation (EU) 2017/1938; however, it has a well-established regulatory framework for gas supply security. This framework includes risk assessment, preventive measures, and emergency action plans, although these still require alignment with the gas acquis.

Despite this, Ukraine has successfully incorporated the majority of requirements from Regulation (EU) 2022/1032, meeting obligations related to the storage system operator and trajectory levels of gas in storage. Moreover, both storage and transmission system operators carried out a stress-test to evaluate the feasibility of evacuating gas stored by foreign traders under a warehouse custom regime during a crisis, and Ukraine achieved the specified storage targets.

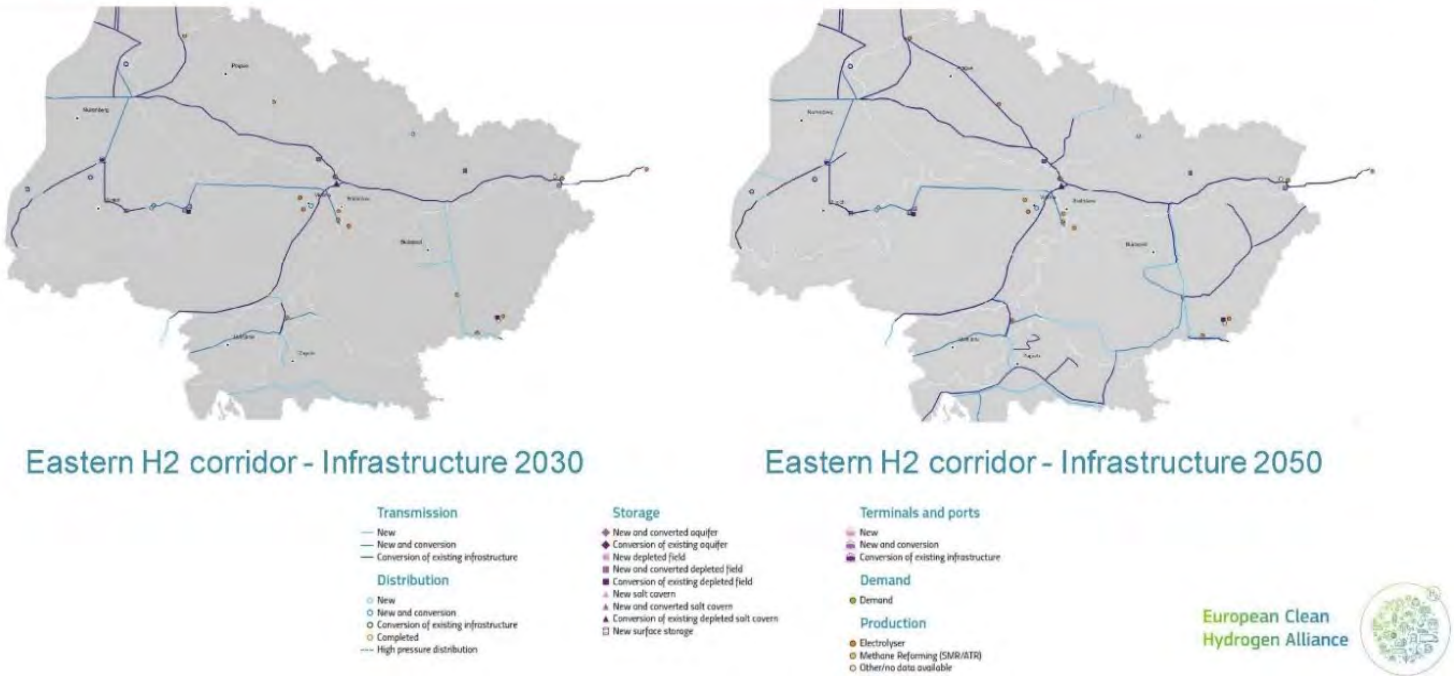


Figure 38 Eastern H2 corridor – Infrastructure. Source: materials of presentation of European Clean Hydrogen Alliance for Business Forum on Ukraine Renewable Gases, 27 Sept. 2023

Improves market efficiency and price discovery for natural gas. With growing demand for "green" energy, the need for the production of RES equipment, energy storage systems, balancing capacities, etc. will grow accordingly, also as such equipment has a finite service lifetime (20-25 years for wind and solar power plants, 7-10 years for energy storage systems). Ukraine is interested in creating capacities for the production of domestic equipment on its territory. This will create new jobs in the middle of the state and reduce import dependence on equipment supplies

2.2.10 Disposal/recycling of equipment that produces energy from RE sources

In addition to production capacities, it is important for Ukraine in the future to create legal, organizational and economic foundations for the disposal, recycling and processing of RES-related equipment including energy storage systems, etc.

The field of renewable energy in Ukraine is young. First renewable energy facilities were built in 2009-2012, with the largest increase in installed capacity during 2019-2020. Given that the average life of solar modules is 25-30 years, the first solar power plants in Ukraine should be decommissioned in 2035, and their mass decommissioning is expected in 2045-2050. Mass decommissioning of wind energy facilities is also expected closer to 2045.

In the future, the production of new equipment for the production of energy from renewable sources will require more resources. Recycling of used equipment will ensure the secondary use of its individual components for the creation of new equipment or other electronic devices, create an effective circular economy and reduce production costs. Therefore, in the next decade, Ukraine plans to form a vision for the state policy on the utilization and processing of equipment that produces renewable energy, energy storage systems, etc.

2.2.11 Promotion of the benefits of using renewable energy sources

Today, RE in Ukraine has a rather negative image as it faces skepticism largely due to its association with oligarchic influence and corruption, as a few powerful individuals are often perceived (by public opinion) to manipulate this sector for personal gain, reminiscent of their control over traditional energy sources, such image started from Kluev's Active Solar scandal[101]. Mismanagement, former lack of transparent policies, and the rapid, disruptive introduction of renewables have further contributed to public mistrust. Additionally, economic dislocation caused by shifting away from traditional energy sectors without adequate transition plans, and the geopolitical intricacies affecting energy policies, amplify the negative perception. This complex backdrop shapes the challenging environment for renewable energy's acceptance and growth in Ukraine. [102]. In order to further use RE sources and alternative types of fuel, it is important to better inform on its advantages, real cost, etc. Relevant work should be carried out at all levels of government and local self-government bodies.

Also, it is important to conduct an informational campaign among the population regarding the use of renewable energy sources and alternative types of fuel in households.

2.2.12 Training of professional personnel in the field of renewable energy

Considering that the volumes of renewable energy production and the installed capacity of renewable energy facilities, energy storage systems, and balancing capacities will grow, Ukraine needs to create conditions to train and retrain Ukrainian professional personnel in the field of renewable energy sources and alternative fuels (construction and operation of facilities, administrative staff, etc.).

Full implementation of the provisions of NECP will require the following actions:

- Increase the level of energy independence of Ukraine;
- Declare long-term state plans for the development of renewable energy sources and alternative types of fuel, determining their scale and the need for investments;
- Optimize / improve regulations in the field of renewable energy sources and alternative fuels;
- Increase the share of energy carriers produced from renewable energy sources and alternative fuels in the structure of total final energy consumption of Ukraine in 2030 to a level of at least 27%;
- Ensure a wider involvement of investments, technologies and intellectual property objects in the process of development of the sphere of renewable energy sources and alternative types of fuel;
- Promote decarbonization of energy, industry and transport, improve the environmental situation in the state as a whole;
- Increase the level of competitiveness of the national economy;
- Optimize the structure of Ukraine's fuel and energy balance;
- Create jobs in energy and other industries;
- Create conditions for further sustainable development of the country and outline strategic guidelines.

In Annex IV of the RED II Directive (EU 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources) as amended by RED III certification criteria for installers are

[101] https://arcrimea.org/en/investigations/2023/06/08/cold-sun-of-occupation-billions-on-green-energy/
[102] https://www.politico.eu/article/ukraines-green-oligarchs-energy-subsidies-electricity-tariffs/

provided. Among others, it is stated that installers should demonstrate the following key competences:

(i) Ability to work safely using the required tools and equipment implementing safety codes and standards and to identify plumbing, electrical and other hazards associated with solar installations;

(ii) The ability to identify systems and their components specific to active and passive systems, including the mechanical design, to determine the correct location of components, and the system layout and configuration;

(iii) The ability to determine the required installation area, the orientation and tilt for the PV and solar-thermal modules, considering any shading/ sun irradiation, structural integrity, the best layout and installation methods for a building and its roof type and the climate conditions; and

(iv) In particular for PV systems, the ability to optimize the electrical design, including design currents, appropriate conductor types and ratings for each electrical circuit, the appropriate size, ratings and locations for all associated equipment and subsystems, and selecting an appropriate interconnection point.

(v) The installer certification validity should be timely limited, so that a refresher seminar or event would be necessary for continued certification.

(vi) would be necessary for continued certification.

2.3 Expected renewable energy deployment

The Consultant's evaluation is grounded in the strategic documents of the Ukrainian Government, the nation's current and future international commitments, and an awareness of prevailing global trends. The primary trajectory for the development of Renewable Energy Sources (RES) in Ukraine is centered on an ambitious objective: ensuring the nation's energy security and safety, and facilitating Ukraine’s integration into the European Union. This approach takes into account the lessons learned during the recent invasion, adheres to the stipulations of Association agreements, fulfills the criteria and obligations as an EU candidate, and aligns with the requirements and advantages associated with market coupling and ENTSO-E commitments.

Furthermore, this strategy incorporates a focus on contemporary technologies and addresses the current challenges within the energy sector. Additionally, it acknowledges the unique aspects of Ukraine's grid topology and energy consumption patterns. The strategy also realistically assesses the actual pace and efficiency of project development, including related construction activities and practical experiences in the field. This comprehensive approach ensures a balanced and pragmatic progression towards Ukraine's renewable energy goals.

The diagram below (sourced from EMBER)[103] shows progress on the increase of RES penetration in the pre-war period:

[103] **Ember** is a UK-based global energy think tank that uses data-driven insights to shift the world to clean electricity.

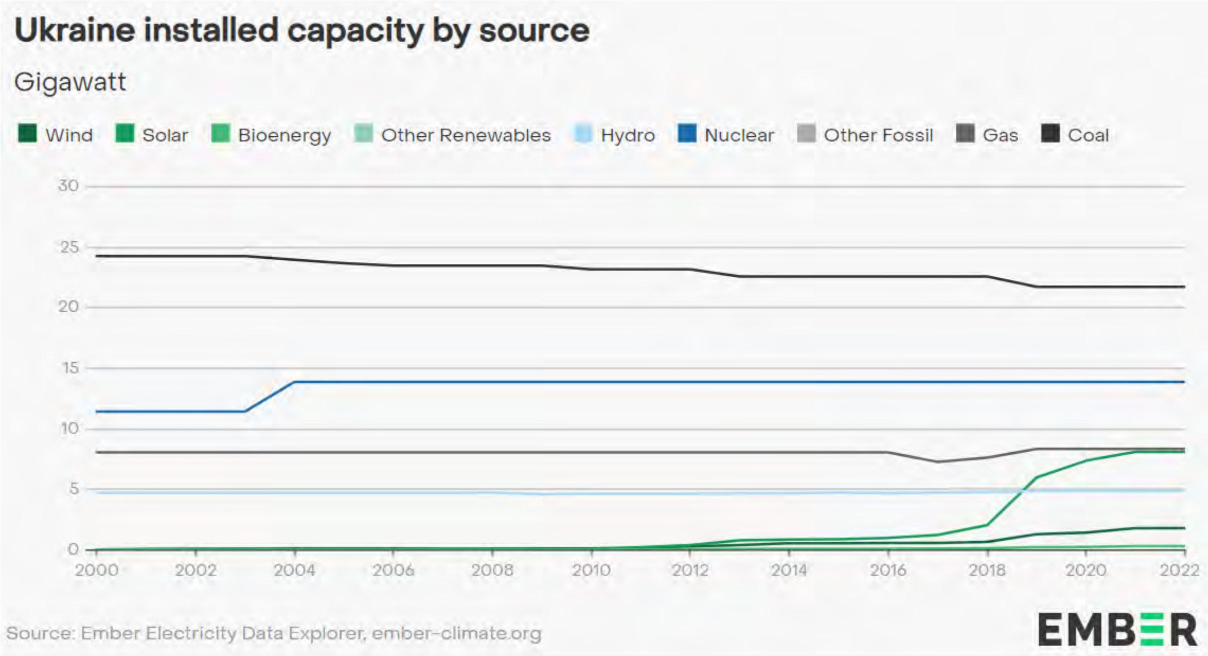


Figure 39: Changes in installed capacities by technology over the last 22 years for Ukraine (in GW)

The following subchapters will provide a vision of the future of the RE sector, its generation capacities, the most relevant current and planned regulations, further needs for incentives and policy support, and potential emission reduction achievements adopting a comprehensive but not excessively granular approach.

2.4 The technical potential for future RES development

2.4.1 Resource estimation and technical potentials

The Consultant verifies the RES resource potential based on the available data. Main sources are:

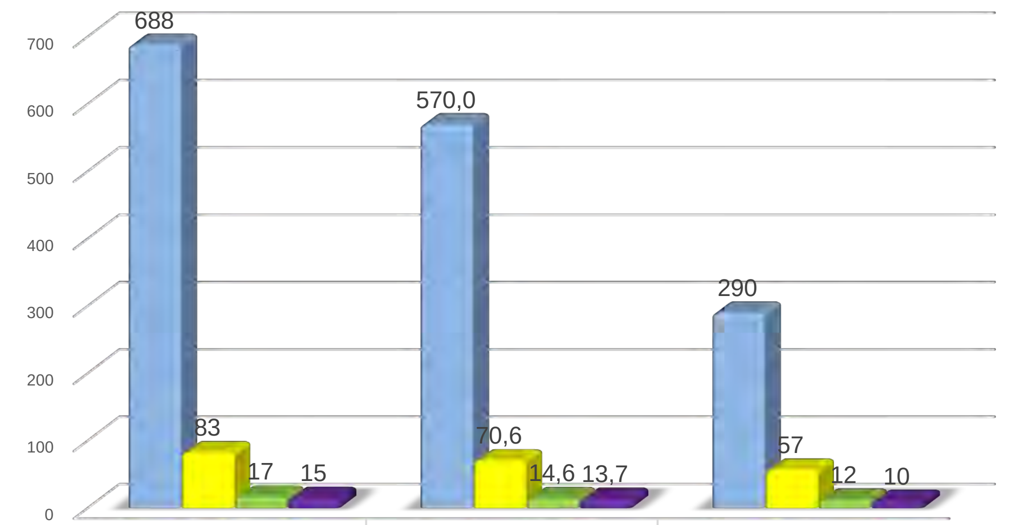
- The Renewable Energy Atlas by the Institute of Renewable Energy of Ukraine (IRE)[104];
- Available data of IBRD and other sources such as the IRENA report (for each technology)[105].

The figure below gives an overview on the RE potential data provided by IRE, IRENA, and the Consultant's estimate (all by RE sources). The majority of sources consider the technical and market constraints quite freely - and significantly overestimate the RES technical potential for some technologies.

The Consultant's estimates are different for all RES for different reasons. In the case of wind potential, IRE considers the whole area of the southern regions to be covered with WTGs, without proper reference to hindering or constraining factors, impacts on the environment and settlements, etc. Numerous other sources further corroborate this survey. In case of biomass, peat as a traditional biomass source is included. However, peat is more a fossil than an RE source. For biogas, it seems as any alternative gases, such as (green?) hydrogen are at least partially included. It shall be noted that implementation of a verification system for sustainability and greenhouse gas emission savings, as mandated by RED II, is indispensable for the credible, equitable, and effective promotion of renewable energy sources. Further details are provided in the corresponding subsections below.

The Consultant has developed its own estimates using the approach commonly used by NREL[106] in estimating potentials. Estimated values represent the high-level outlook on achievable energy generation of a particular technology given system performance, topographic, grid limitations, environmental, land-use (including legal imperfection) constraints to establish the maximum achievable limits of RES potential by source. The Consultant has relied on available information adjusted to reflect more realistic potentials – with the RE potential estimates being less than the estimates provided by IRE and IRENA as shown in the Figure below. In the following sub-sections details are provided regarding the rationale for lower estimates.

[104] https://www.ive.org.ua/wp-content/uploads/atlas.pdf
[105] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/Apr/IRENA_REmap_Ukraine_paper_2015.pdf
[106] https://www.nrel.gov/gis/re-potential.html



	IRE	IRENA	Consultant
Wind	688	570,0	290
Solar	83	70,6	57
BioTPP	17	14,6	12
OTHER RES	15	13,7	10

Figure 40: Estimates for the max RES potential for Ukraine in GW
(see first paragraph/footnotes for source details IRENA & IRE data; own estimates explained in the following text)

Solar:

According to the results of IRE, the theoretical installed capacity of SPPs is 82,768 MW, and the annual potential for generating electricity from SPPs in Ukraine is about 100 billion kWh/year.

However, the above numbers need to be adjusted taking into account various factors, as they neither entirely reflect land use constraints nor provide a proper valuation of the solar rooftop potential. Also, better more realistic and conservative assumptions could be considered when sizing the prospective SPP projects (in terms of the possibility of investors to handle the high cost of grid rehabilitation).

The data by IBRD and SolarGIS, as well as solar resource assessments and operational data from ongoing projects - are considered as more appropriate by the Consultant. In addition, the Consultant existing constraints (as often discovered during the due diligence of actual projects) for a further analysis considered surveys with regard to land availability (nonagricultural land considered as priority) and other s of possible development scenarios [107]

[107] https://documents.worldbank.org/en/publication/documents-reports/documentdetail/466331592817725242/global-photovoltaic-power-potential-by-country

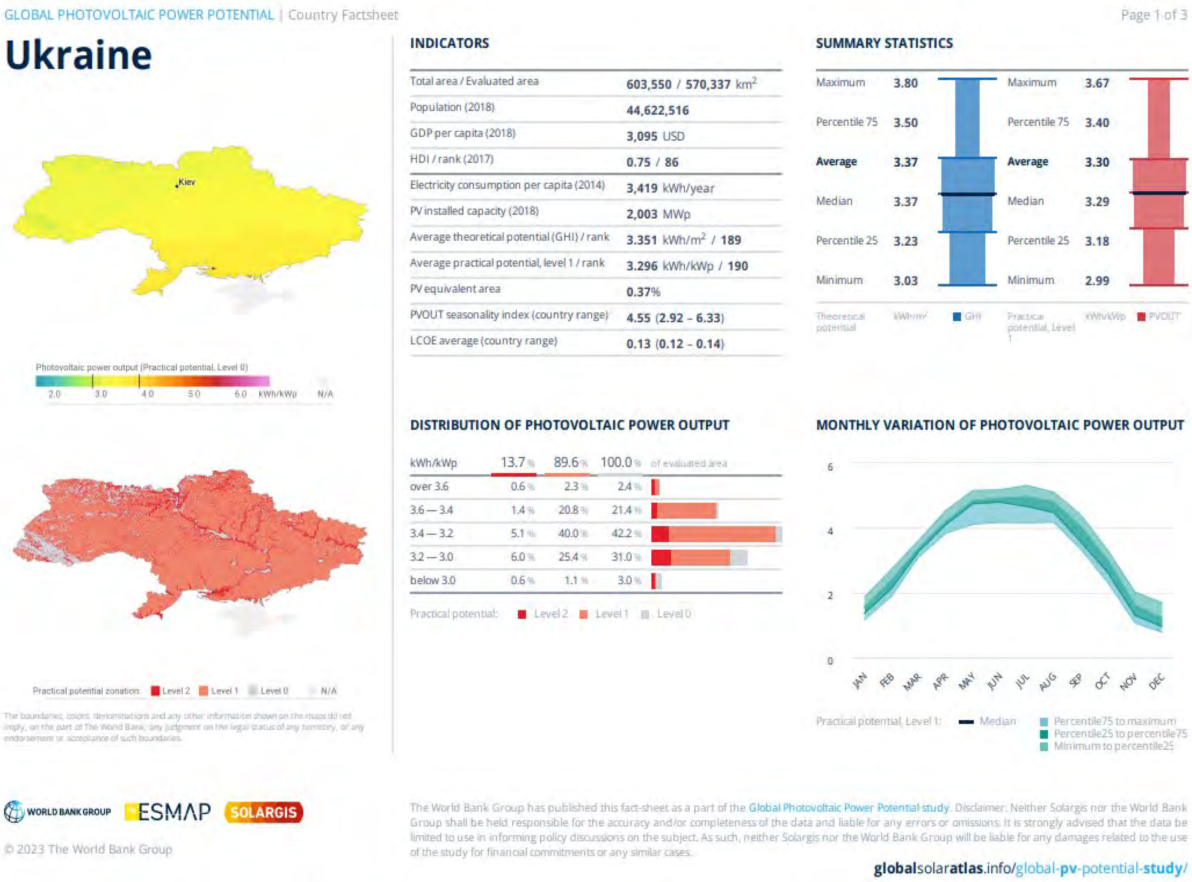


Figure 41: Solar Resource potential according to Global Atlas

All this leads to a reconsidered maximum technical potential for the solar sector as shown below:

Figure 42 Technical Potential of Solar Energy (Consultant)

Wind:

With regards to wind power potential, IRE assumes 688 000 MW and 2 173 770 million kWh/year including 250 MW of the installed capacities of concentrated off-shore (based on 3 MW class turbines). The data and information by IRE is rather illustrative, with approximate calculations, also regarding WTG efficiencies. Land coverage also exceeds any optimistic expectations. In addition, the constraints of regulations and the grid (e.g. transformer capacities and the costs for interconnecting) were not properly considered.

While making its assumptions, the Consultant used data available from the Global Wind Atlas[108] and a report by IBRD regarding the off-shore wind potential for calculating the AEP. The actual data from equipment suppliers on multiple projects was considered with consideration of higher AEP for off-shore wind and with consideration of further development of technology. Also considered were available wind and operational data from the ongoing projects.

[108] https://globalwindatlas.info/en/area/Ukraine

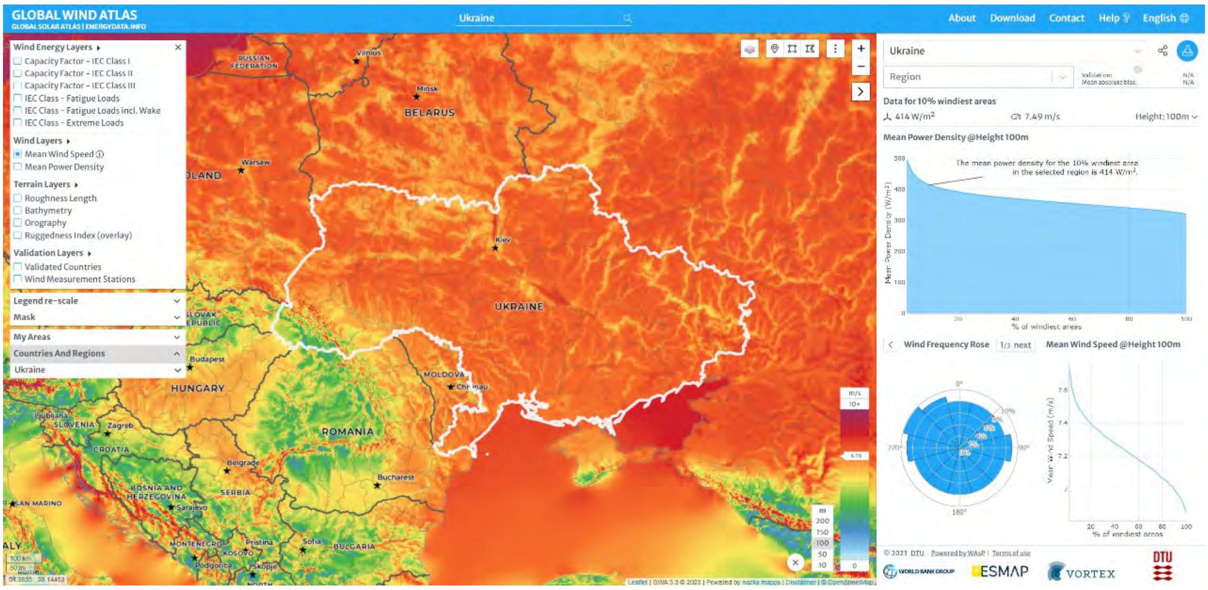


Figure 43: Wind resource potential according to the Global Wind Atlas (screen shot)

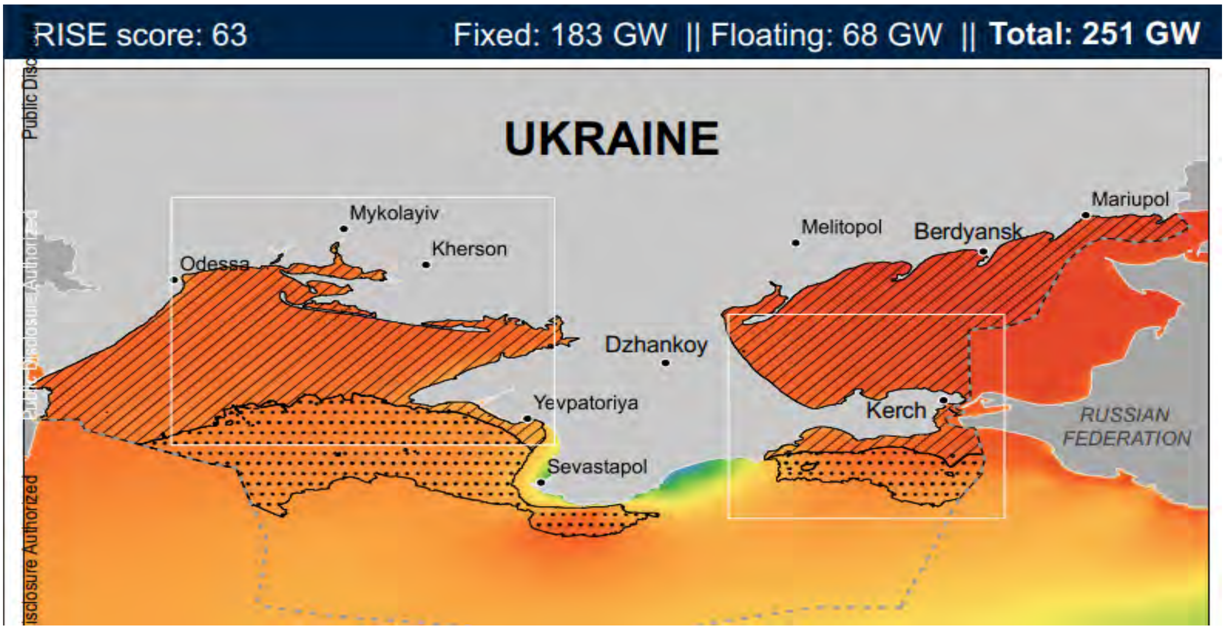


Figure 44: Potential of offshore wind[109]

The offshore wind potential data matches IBRD and IRE sources; however, they still need to be improved by grid constraints and congestions in the southern region of Ukraine, which already existed and were further complicated by Russian invasion damage. Onshore energy facilities (transmission infrastructure) which shall be utilized to evacuate generated power by offshore power plants were severely damaged by Russian strikes. These facilities were already potentially overloaded before the escalation in 2022 and the situation has worsened. Also, due to the temporary occupation of territories (including shores), which has exacerbated risks, and so lessened investors' appetite, it has been impossible to start new full-scale developments in the region. These complications cannot be easily overcome without a long-lasting grid rehabilitation, including i.a. impact assessments. The complexity of the process may be explained by the case of the Novoodesska Artsyz OHL project run by EBRD and Pöyry, a principal project that is a key for

[109] https://documents1.worldbank.org/curated/en/709391586844502062/pdf/Technical-Potential-for-Offshore-Wind-in-Ukraine-Map.pdf

"unlocking" Bessarabia – in development for 20 years, 10 of which passed with the support of EBRD and now on hold due to limitations caused by construction in protected areas.

Figure 45 Technical Potential of Wind Energy (Consultant)

Small Hydro *(all):*

As of the start of 2022, the capacity of small hydropower facilities (SHPP) (less than 10 MW) was 121 MW. The first stage of development of SHPP dates back to the 19th century when SHPPs were built to supply electricity to individual enterprises and in the 20th century, more than a thousand SHPPs were built. By the end of the 1980s, only 49 SHPPs had been preserved. According to IRE, they all have developed an energy resource of 35-70 years and required rehabilitation, allowing them to reach 376 MW total.

The small hydro potential is rather limited, and due to the small share in the overall energy balance, small hydropower cannot significantly affect the structure of the country's energy supply. However, the natural potential of SHPPs has not been fully realized so far. Ukraine has significant potential for using the resources of small rivers, in particular in the western regions. Small hydropower will contribute to the decentralization of the overall energy system, which will solve several problems in the energy supply of remote and hard-to-reach areas in rural locations[110].
This leads to a reconsidered maximum technical potential for the solar sector as shown below:

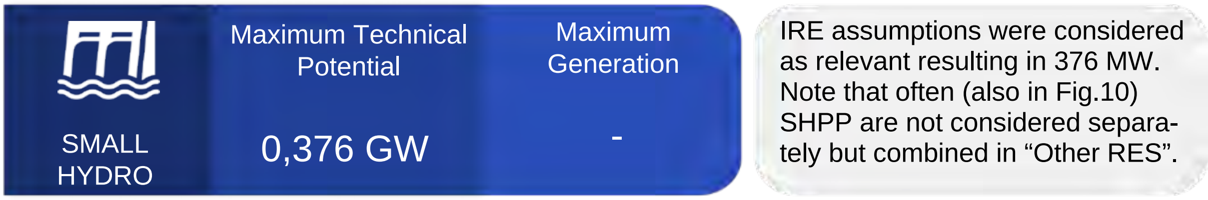


Figure 46 Technical Potential of Small Hydro (Consultant)

Geothermal:

Ukraine has potential for the development of geothermal energy. This is due to the thermogeological features of the terrain and features of the country's geothermal resources. However, in contrast to other renewable energy sources, the growth rate of geothermal energy production capacity in Ukraine is much slower. This is explained by additional initial capital investments, which include not only the costs of energy equipment for the conversion of geothermal energy sources, but also the costs of drilling operations.

Ukraine has a sufficient resource base and developed geothermal technologies for extracting and developing the following types of geothermal energy sources:

- Sub-geothermal - the heat of the upper layers of the Earth up to a depth of 500 m, which is used with the help of heat pump installations;
- Hydrothermal - the heat of deep underground thermal waters and parahydrotherms, which is used with the help of heat and electricity generating units;
- Petro thermal - the heat of superheated "dry" rocks, which is used with the help of borehole heat exchangers or by creating artificial underground permeable collectors.

Hydrothermal resources are the most widespread and currently suitable for technical use as a source of geothermal energy in Ukraine. The Precarpathian (Lviv, Ivano-Frankivsk, partly Chernivtsi Regions) and Transcarpathian (Transcarpathian Regions) depressions, the Dnipro-Donetsk depression (Chernihiv, Poltava, Sumy, Kharkiv, Dnipropetrovsk Regions), Steppe Crimea and the Black Sea coast (Kherson and Odessa regions) are characterized by the most favorable geothermal conditions for the development of hydrothermal resources.

[110] https://www.kmu.gov.ua/news/derzhenergoefektivnosti-rozrobleno-proekt-nacionalnogo-planu-dij-z-rozvitku-vidnovlyuvanoyi-energetiki-na-period-do-2030-roku

Based on data of the Ukraine customs service on imports as well as information on >300 implemented heat pump installations with unit capacities of 6 to 500 kW, the total thermal power of heat pumps used in Ukraine can be estimated to 160 MW.

According to a forecast of the Institute of Geophysics of Ukraine's National Academy of Sciences, the energy potential of heat extraction from upper soil/rock layers on new construction sites is equivalent to 26.8 million toe per year[111].

An intensive exploitation of geothermal resources can lead to a decrease in the temperature in the used soil layers. This needs to be considered for the calculation of the potential low-temperature geothermal resources in different geoclimatic regions of Ukraine. To avoid harming the natural environment and allowing for a longtime geothermal use, extraction of geothermal energy is limited for each region of Ukraine.
For the geothermal potential, available data differs significantly: According to IRE the total geothermal potential is 10 810 MW_{th}. According to NREAP (National Renewable Energy Action Plan) and by commissioning new capacities, around 100 GWh geothermal electricity production can be achieved in 2030 (considering the current situation, conditions and existing potential in Ukraine). This production corresponds to a total capacity of 20 MW_{el} assuming 5000h full load).

Although IRE refers to the geothermal potential and NREAP to a future electricity generation from geothermal energy, IRE includes surface heat pumps in the survey. According to an analysis of customs declarations, the overall heat capacity of heat pumps already in operation in Ukraine as of 2020 is 1500-1600 MW_{th}

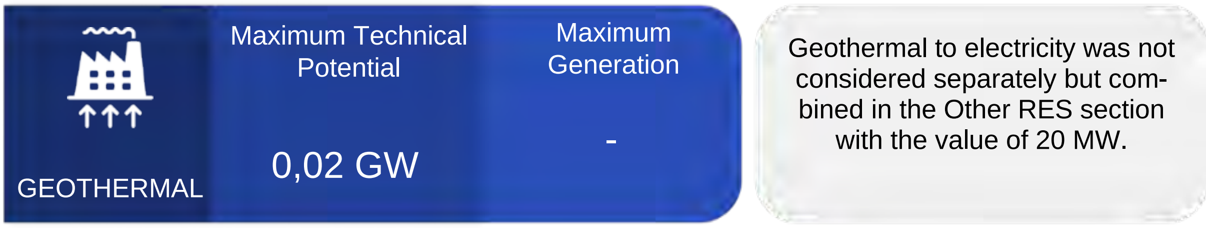


Figure 47 Technical Potential of Geothermal (Consultant)

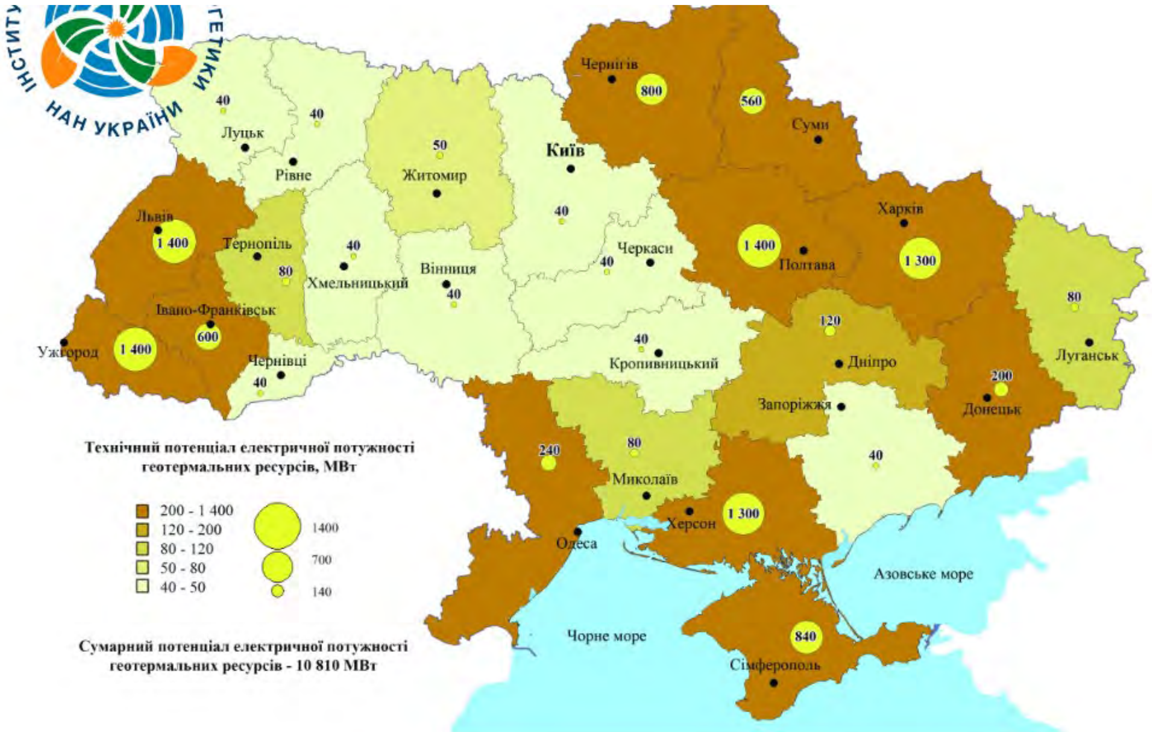


Figure 48 Regions suitable for the development of geothermal energy projects

[111] https://www.ive.org.ua/wp-content/uploads/atlas.pdf.

Biomass:

"Biomass" is often differently defined, such as only solid or "total" (solid, gaseous and liquid) biomass. While biomass from wood is considered as RE, IRE includes also peat (turf) as one of the biomass sources in the calculations. Peat is however not a renewable source and thus not part of the current investigation. Caution is needed if comparing capacities or potentials from different sources.

The State Agency of Energy Efficiency is considered as one of the most reliable sources; their data for the what is achievable potential is estimated at 25-31 million toe[112], 10 of which stands for capacities suitable for generating electricity, the rest – for heat[113].

The electricity production from biomass in Ukraine can be increased to 6.5 billion kWh in 2030 (with a total capacity of about 1.4 GW according to NREAP, the recently adopted Energy Strategy assumes up to 4.1 GW). This estimate is based on construction and commissioning of new bio-generation capacities using most recent technologies as already used in EU countries with similar conditions.

So far, the targets of the National Action Plan for the Development of Renewable Energy for the period until 2020 in terms of the development of bioenergy and the projected generation profile of this segment of renewable sources, is widely under-achieved. Therefore, the State Agency of Energy Efficiency and Energy Conservation of Ukraine Project envisages within the National Action Plan till 2030 the intensive development of electricity generation using biomass and biogas[114].

The Renewable Energy Directive (RED II) represents an integral regulatory measure adopted by the member states of the European Union, aiming to bolster the adoption of energy from renewable sources. This directive is expansive, covering a variety of raw materials and fuels, including agricultural and forest biomass, as well as waste, residues, and other non-food biomass components, which are critical for the production of biofuels, bioliquids, and biomass fuels.

RED II ensures that biomass production adheres to stringent environmental standards, preventing adverse impacts and maintaining public trust in renewable initiatives. Such a system also levels the playing field in the market, encouraging fair competition and innovation, while providing a framework for continuous improvement in line with evolving scientific understanding and technology. Moreover, it aligns the EU's renewable energy goals with broader international commitments to sustainability and climate change mitigation, ensuring that the shift towards renewable sources contributes positively to global environmental objectives.

Moreover, RED II is strategically oriented towards promoting the sustainable production of energy, notably through the incorporation of recycled carbon fuels. This initiative is designed to further the diversification of energy sources and facilitate the decarbonisation of the transport sector, encompassing both liquid and gaseous fuels derived from non-renewable waste streams or by-products. The directive meticulously ensures the sustainability of fuel production processes and mandates significant greenhouse gas emissions reductions. To uphold these standards, RED II imposes stringent requirements for tracking greenhouse gas emissions, applicable to all actors within the supply chain, ranging from raw material production to the final distribution of biofuel products. This comprehensive approach ensures a thorough evaluation of the biofuel production's environmental impact, aligning with the European Union's broader commitment to sustainability and reduced carbon emissions.

Further the EU RED III Directive (EU 2023/2413 of 20 Nov. 2023 on the promotion of the use of energy from renewable sources) provides the Sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels[115]. NECP's legal framework should incorporate the criteria based on the Article 29 of this Directive in order to comply with the EU requirements in the biofuels, bioliquids and biomass development area.

Another potential for increasing the share of renewable energy sources in electricity is the use of bio-energy at existing facilities of conventional generation - through their conversion or co-firing of biomass. At present, some 230 power and combined heat and power (CHP) plants use co-firing, mostly in Northern Europe and the United States, with a capacity of 50-700 MWe. The Global Bioenergy Partnership (GBEP) and other organisations are in the process of finalising indicators, as well as certification processes, to ensure the sustainability of biomass production. Biomass cofiring based on residues and wastes has been recognised by the UNFCCC (United Nations Framework Convention on Climate Change) as a technology

[112] 1 toe = 11.63 MWh => 1 million toe = 11.63 million MWh = 11.63 TWh

[113] https://saee.gov.ua/uk/activity/vidnovlyuvana-enerhetyka/potentsial

[114] https://saee.gov.ua/uk/content/elektronni-consultatsii?fbclid=IwAR0ReeuARnxoPKbeE5aDq25z9Vw_XRg9RTD4t1Vf_L_Dmm4AKcxvuWrSbmg

[115] https://www.energy-community.org/dam/jcr:78fd6b72-436f-45e7-aef5-5ade1d53f92a/Directive_2018-2001.pdf

to mitigate GHG emissions so that countries can sell carbon credits associated with their co-firing projects. Other policies to support co-firing include CO2 emissions trading schemes (e.g. the EU Emissions Trading System or EU ETS), the removal of fossil-fuel subsidies, incentives for converting power plants into co-fired CHP plants, and mandatory co-firing quota schemes. Supporting policies are in place in EU countries (i.e. Austria, Denmark, Finland, the Netherlands, Sweden), the UK, and the United States. Emerging economies with large productions of agricultural waste and coal-based electricity (e.g. China and India) are also well-positioned to implement cofiring[116]. An additional potential offers the use of biomethane instead or blended with natural gas in gas-fired boilers.

Considering the experience of implementing bioenergy installations by European countries like in Sweden, Denmark, Lithuania, etc., in Ukraine, the biomass-based electricity generation can be increased

Biomethane development is essential for the post war economy of Ukraine, as it possesses important advantages:

- Biomethane is absolutely ready for injection into the gas network today. No investment is required in the modernization of gas networks (GTS and GDS) and equipment (gas burners, engines, turbines).
- Ukraine can compete with any country in the production of biomethane. Ukraine can offer the cheapest raw materials for biomethane production. Ukraine has the largest area of agricultural land in Europe, and, accordingly, one of the world's best potentials of agricultural raw materials for biomethane production.
- Biomethane plants, in addition to biomethane, generate digestate, which can become the main organic fertilizer needed for the revival of Ukrainian soils.
- Today it is the cheapest of the possible renewable gases.
- The EU adopted ambitious plans for the production of biomethane (REPowerEU): 35 billion m3/year in 2030. Ukraine can potentially provide up to 20% of this need[117].

Figure 49: Technical Potential of Biomass Energy (Consultant)

Biogas:

The overall electrical potential of TPP operating on biogas is 984 MW electric and 1044 MW thermal, so roughly 1 GW for electricity production, and 1 GW for heat only boilers, with biogas mainly from agricultural residues and landfill gas. In future strategies, biogas is foreseen as a future replacement for natural gas and as one of the sources for future so-called "semi-peak and peak generation" according to the Energy Strategy; however, expectations of 17.5 GW, reflected in the Strategy are excessive. The Consultant notes that, as current biogas sources cannot be arbitrarily increased, such peak/semi peak gas demand will be covered mostly by H2/PtX - otherwise there is no clear concept in switching from natural gas. Even green H2 is not biogas and needs to be accounted for separately (see below). The pure biogas potential is included in the biomass potential shown in the previous subsection.

Liquid Biofuels:

Liquid biofuels so far play a minor role with an annual technical potential estimated by IRE in the order of 606 thousand tons/year of bioethanol and 620 thousand tons/year of biodiesel[118]. Any substantial increase might be based on green H2/PtX; however, as green H2 is produced with RE-derived electricity this will not account for an increase in the RES potential (on the contrary, conversion/efficiency losses

[116] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/IRENA-ETSAP-Tech-Brief-E21-Biomass-Co-firing.pdf?rev=29f866731c4d4f12922f8b3e4a22c6df

[117] From the materials of the presentation of UABIO at the Business Forum on bio-methane and green hydrogen Business to Businees/Europe to Ukraine (EUB2BUA) NH Danube City, Vienna, 27 September 2023

[118] The energy content (heat value) of 1 kg of diesel is approx. 11.8 kWh/kg (~10 kWh/ltr), of ethanol approx. 7.4 kWh/kg (~5.85 kWh/ltr). Bioethanol and Ethanol are similar while Biodiesel is chemically different from diesel with a 14% reduced (lower) heat value (37 vs 43 MJ/kg).

need to be considered). The ***additional*** RE potential of biofuels is considered as relatively minor not adding substantially to the RE potential of biomass as shown on the previous subsection[119].

Hydrogen impact on RES integration, P2X potential:

No hydrogen production, also not green H2, is adding to the RE potential - as in the most sustainable (best) case RE-based electricity is consumed. Nevertheless, (green) hydrogen plays an important role for a sustainable RE-based zero emission strategy, such as for long-term energy storage, for technical use e.g. in steel or chemical industry (with RE electricity being no alternative), and to possibly use potential natural gas infrastructure. Therefore green H2 is discussed here as well.

The Energy Strategy foresees 10 GW of electrolysers with an annual production of 1.7 million tons of H2 up to 2050 (8 GW by 2030). The hydrogen production potential is foreseen at the level corresponding to the potential of wind energy estimated by IRE – approximately 40 million.

The initiative to build 8 GW of electrolysers to produce hydrogen (*the publicly available extracts do not mention "green" hydrogen*) for export till 2030 is also questionable. At present there are still some challenges that Ukraine needs to overcome, to create an efficient hydrogen market, such as:

- **Barriers** that hinder the development of the hydrogen economy need to be addressed, such as high production costs, insufficient resources for hydrogen production, and the complexity of hydrogen storage and transportation.
- **Incentives and investment climate**: A system of incentives for investors and consumers is essential to create an effective hydrogen market and investment climate. This can include subsidies, incentives for innovation and new technologies, a favourable investment climate, and investments from the public and private sectors.
- **Partnerships:** The most successful development of the hydrogen economy is possible through collaboration between countries, research institutions, industrial companies, and other stakeholders. This can involve supply agreements, joint research and development of new technologies, and the exchange of expertise and knowledge.
- **Infrastructure development:** An appropriate infrastructure is necessary for a functioning hydrogen market, including hydrogen (re-)fuelling stations, pipelines for hydrogen transportation, charging stations for hydrogen fuel cells, and more.
- **Regulations:** Regulatory bodies should establish appropriate standards and norms governing hydrogen quality, storage and transportation, and the safety of hydrogen use. It is also important to develop regulatory mechanisms to stimulate the development of the hydrogen market, including providing government incentives and discounts for hydrogen and hydrogen technologies.
- **Interaction with other sectors:** The development of the hydrogen market should involve collaboration with other sectors of the economy, such as industry, transportation, energy, construction, and more. Cooperation between these sectors will enable the development of comprehensive approaches to hydrogen utilization and ensure maximum benefits from hydrogen as energy carrier.
- **International cooperation**: Creating favourable conditions for international trade in hydrogen and hydrogen technologies, developing common standards and norms, and facilitating the exchange of expertise and technologies between countries is essential.
- **Skills and education**: Highly-skilled professionals understanding hydrogen technologies and their applications are needed. Therefore, providing appropriate education and training for experts in the field of hydrogen is crucial.
- **Creating consumer demand**: There should be demand for hydrogen as a clean fuel. Therefore, increasing consumer awareness of the advantages of hydrogen, hydrogen technologies, and fuel cells, as well as promoting successful case studies of hydrogen utilization in the auto/transport industry, power generation, and producing industry is necessary.
- **Research and development**: Ukraine's tremendous scientific potential should be utilized to study hydrogen technologies, research on cost reduction and quality improvement of hydrogen, and explore new directions for hydrogen applications.

[119] Additional info: According to the National Transport Strategy the level of application of alternative fuels (biofuels or their mixture with traditional fuels) and electricity (produced from both traditional and renewable sources) is up to 50 percent by 2030.

Furthermore, hydrogen and synthetic fuels are considered as one of the aspects of PtX technologies (power-to-ammonia, power-to-chemicals, power-to-liquid/fuel (e.g. synfuel/ethanol), power-to-gas (e.g. methane, syngas)... Electric vehicle charging, space heating and cooling, and water heating can be shifted in time to match generation, forms of demand response that can be called power-to-mobility and power-to-heat). P2X is a powerful mechanism for assuring flexibility and reaching the decarbonization targets in the post-transient fuel period (excluding nuclear).

Figure 50 Technical Potential of Power to X (Consultant)

2.4.2 Alternative estimations

(i) The estimation by IRE is used as a basis for further optimization while considering the actual market conditions. (The IRE report does not consider several limiting factors and is based on the 3 MW machines).

(ii) International Renewable Energy Agency (IRENA) surveyed Ukraine's renewable sector and potential in 2015.[120]. In 2017 a report on Cost-competitive renewable power generation was published by IRENA, providing the following conclusion: *Ukraine possesses a cost-competitive wind potential of up to 119.2 GW. This is despite the high cost of capital assumed. A further potential for wind (up to 200 GW) and solar PV (up to 70 GW) can be unlocked by 2030 if more stable frameworks are provided. In addition, opportunities for further investment in SHPPs, particularly in western regions, may be investigated. Ukraine also has sufficient high-temperature geothermal deposits (120-180°C) to produce geothermal electricity.*

Adding biomass, biofuels, biogas and hydro resources, Ukraine's **technical renewables potential is estimated to be 415 GW** (see Table below at the right lower corner) excluding offshore wind. (This can be compared to IRE estimate at 874 GW including offshore WPP ~ **625 GW** excluding off-shore).

Technologies	2009	2015		2020 (NREAP)	Additional cost-competitive potential			Technical potential	
	MW	MW	GWh	MW		MW	GWh	MW	GWh
Solar PV	0.0	825.0	859.0	2,300.0	2016	0.0	0.0	70,611.6	88,370.6
					2030	53,264.7 - 69,785.8	67,655.6 - 87,451.0		
					2050	69,785.8	87,451.0		
Wind	76.0	513.9	1,363.2	2,280.0	2016	231.3 - 119,083.8	1,197.6 - 350,875.2	320,580.9	858,452.3
					2030	318,583.5 - 319,891.1	855,048.0 - 856,898.9		
					2050	320,022.2 - 320,067.0	857,045.8 - 857,089.2		
Hydro	4,549.0	5,703.5	8,487.0	5,350.0		5,578.5	13,733.0	8,950.0	21,500.0
≤ 10 MW	49.0	88.0	274.5	150.0		n.a	n.a	3,750.0	8,500.0
> 10 MW	4,500.0	4,581.0	8,213.0	5,200.0		n.a	n.a	5,200.0	13,000.0
Pumping	n.a	1,034.5	n.a	n.a		n.a	n.a	n.a	n.a
Biomass	0.0	51.4	136.4	950.0		1,696.8	10,278.0	14,643.0	78,389.0
Biogas	0.0	16.2	46.1	290.0		1,696.8	10,278.0	8,565.0	51,389.0
Solid Biomass	0.0	35.2	90.7	660.0		0.0	0.0	6,078.0	27,000.0
Biowaste	n.a	n.a	n.a	n.a		0.0	0.0	n.a	n.a
Geothermal el.	0.0	0.0	0.0	20.0		0.0	0.0	n.a	n.a
Total (2016)	4,625.0	7,093.8	10,845.6	10,900.0	2016	7,506.6 - 126,359.1	25,441.8 - 375,119.4	414,785.5	1,046,711.9

Figure 51: Ukraine Renewables potential according to the International Renewables Energy Agency in 2016

[120] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/Apr/IRENA_REmap_Ukraine_paper_2015.pdf

2.4.3 Decentralized and residential RES

In 2021, decentralized and residential renewable energy source (RES) installations, particularly solar, gained popularity as an economically viable option, largely due to the attractive feed-in tariffs (FiT) for residential setups. This trend continued into 2022 and 2023, further fueled by the desire for individual energy security and autonomy, especially in response to the Russian military's attacks on energy infrastructure. Special focus has also been placed on maintaining grid stability, taking into account the potential addition of new photovoltaic (PV) capacities by prosumers, estimated at around 5 GW.

Additionally, the Ten-Year Network Development Plan (TYNDP) gives distinct consideration to the Distributed Energy scenario, which envisages a markedly different future for Europe's energy system compared to the National Trends scenario outlined in the TYNDP 2022 system needs study. The Distributed Energy scenario envisions a path to achieving carbon neutrality in the EU27 by 2050, with a minimum of 55% emission reduction by 2030. This scenario is underpinned by societal willingness to attain energy autonomy, leveraging widely accessible indigenous renewable energy sources. It signifies not just a shift in energy production but also a broader transformation in lifestyle, marked by a strong, decentralized push towards decarbonization through local initiatives by citizens, communities, businesses, and the support of authorities. This scenario leads to maximized renewable energy production within Europe and a significant reduction in energy imports. .[121]

2.4.4 .Other sectors

Ukraine aspires to continue its active development of RES also in other sectors (besides electricity generation). The indicative RES consumption goal in 2030 is 27% in the energy mix in Ukraine. This corresponds to the following shares of RES in the main sectors: power industry - 25%; heating and cooling – 35%; and transport - 14%. These targets were approved on 15 December 2022 by Decision of the Ministerial Council of the Energy Community (Decision 2022/02/MC- EnC).

2.5 Grid & environmental aspects: Assessment/calculation of impacts

Before the war, the rapid increase in renewable generation capacity caused grid imbalances and a growing need for balancing capacity and storage. The Ukrainian government had estimated that the grid would require around 2 GW of new peak-generation capacity and about 500 megawatts (MW) of energy storage capacity by 2025. Initial projects in grid-scale battery storage had seen significant private sector and international involvement before the war. DTEK, the largest private investor in Ukrainian renewables, completed a 1 MW storage project in the city of Energodar at the start of 2022 with the support of Honeywell and SunGrid. Creating partnerships between Ukrainian renewable and grid companies and U.S. and international companies can further advance the country's reconstruction plan.

Expanding renewable energy will depend on the interconnection and export capacity between the Ukrainian and EU electricity grids. Integrating the Ukrainian grid with Europe's will be ongoing during and after the war. Following the emergency synchronization of the two networks at the beginning of the war, Ukrenergo (the Ukrainian grid operator) and ENTSO-E connected their grids, but interconnection levels remained low. In the Ukraine Recovery Plan, the country hopes to reach a transfer capacity between Ukraine and Europe of 3.6 GW by 2030 and 6.2 GW by 2040.

121 https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2022/public/system-needs-report.pdf

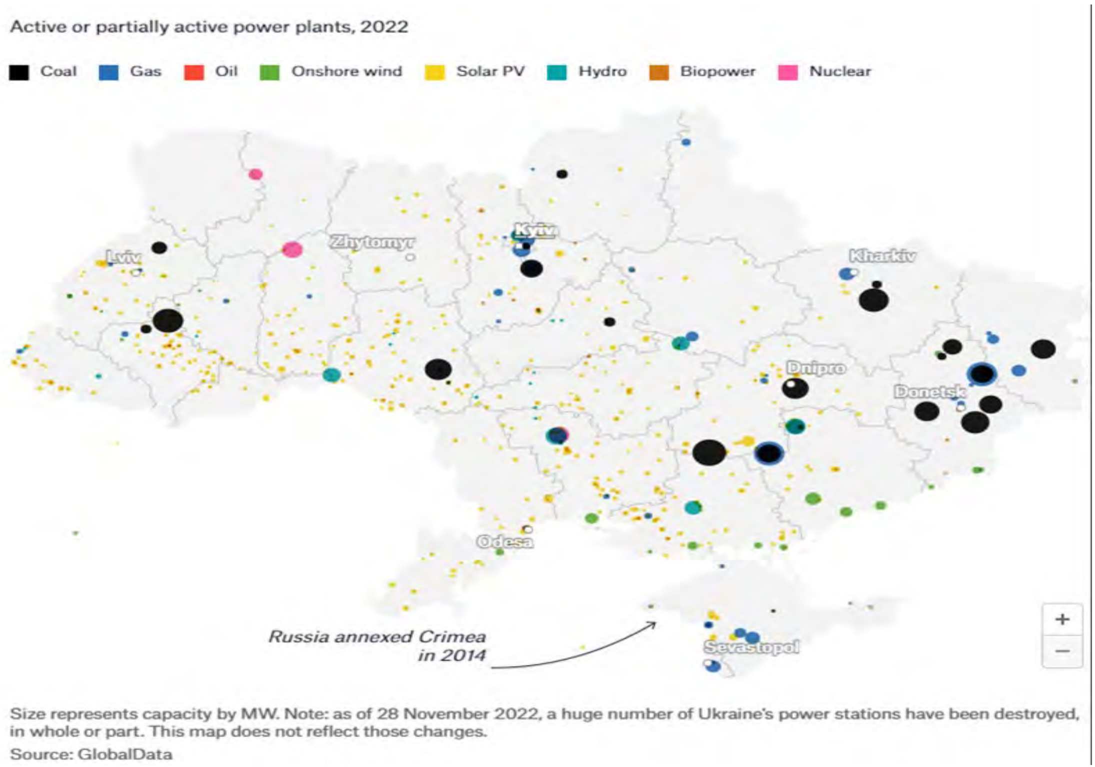


Figure 52: Power Plants in Ukraine

Expanding interconnection will depend on rehabilitating the Rzeszow-Khmelnytskyi line between Ukraine and Poland and upgrading segments of the Ukrainian grid to meet European energy regulations.

Rolling out renewable generation will enable Ukraine to support the European Union's climate ambitions through green electricity exports. Before the latest disruptions in the nuclear energy sector, some 55% of power generation in Ukraine came from nuclear. Renewables can potentially displace coal and natural gas in the sector using P2X technologies. Full integration with the European grid will require progress on regulations and technology, underscoring the importance of clear steps forward throughout the war and in the initial reconstruction phase.

2.5.1 **The role that renewables can play in decarbonization** (incl. coal phase-out)

Decarbonization, the process of reducing greenhouse gas emissions, is highly relevant for Ukraine for several reasons:

- Ukraine is one of the most vulnerable countries in Europe to the effects of climate change, experiencing more frequent and severe heatwaves, droughts, and floods. Decarbonization would help mitigate these impacts, protecting Ukrainian citizens, ecosystems, and infrastructure.
- Ukraine currently relies heavily on fossil fuels, including imports from Russia. Decarbonizing its energy sector would reduce this dependence and enhance energy security, making Ukraine less vulnerable to geopolitical disruptions.
- The transition to a low-carbon economy can create new jobs and industries in Ukraine, particularly in renewable energy, energy efficiency, and sustainable technologies. This can boost economic growth and diversification.
- Decarbonization is a central pillar of the European Green Deal and a key requirement for EU membership. By aligning its decarbonization efforts with the EU, Ukraine can strengthen its ties with the bloc and facilitate its future accession

Based on the recent Implementation Report by EnC, the works on NECP is ongoing and the progress is considered as 29% at the moment, however the success with Greenhouse Gas 2020 target and related policies is missing – no reporting obligations were included in legislation. The long-term strategy shall be adopted to reflect 2050 climate neutrality objective.[122]

The transition to zero emissions will drive innovation and economic growth, and create new jobs. It will improve living standards – particularly in developing economies – through reduced local air pollution and

[122] https://www.energy-community.org/implementation/report.html

related health impact; lower energy bills for households, thanks to cheap electricity and more efficient buildings; provide more flexible mobility services; and produce higher-quality, more durable consumer goods.

Decarbonisation requires a major shift from carbon-intensive fossil fuels to clean energy. Direct electrification will be the primary route to decarbonisation, since it is the cheapest and most energy-efficient option in most applications, so scaling up zero-carbon electricity provision is thus the most important priority.

However, in some applications, this is not currently feasible; while in others, it is not cost effective. Therefore, total decarbonisation of all sectors of the economy will also require three additional technologies:

- **Hydrogen** – an energy carrier whose energy density, storability and suitability for high-heat applications make it superior to electricity in some specific applications. Low or zero-carbon hydrogen can be produced through electrolysis ("green hydrogen") or derived from methane combined with CCS ("blue hydrogen"). Hydrogen can in turn be used to produce hydrogen-based fuels (e.g., ammonia and synfuels);
- **CCS (Carbon Capture and Storage)** – which, aside from its potential use in making blue hydrogen, can also be applied to multiple industrial processes, and to thermal power plants that continue to provide flexible power supply within primarily renewable power systems. Its cost-effective use will depend on local availability of suitable and safe storage capacity;
- **Biomass** – which in principle can meet a wide variety of applications, including industrial heat, chemical feedstock, flexible thermal power supply and transport fuels; but the total scale of its use across all sectors must reflect the limited potential supply of truly sustainable biomass.

It is not possible to forecast precisely what the global energy mix will be in a zero-carbon emissions economy. But all feasible scenarios for a zero-carbon emissions economy involve a massively expanded role for direct electricity use (reaching 65% to 70% of final energy demand, versus 19% in 2020), and a very significant expansion of the role of hydrogen (accounting for another 15% to 20% of final energy demand, with an increasing proportion produced from electrolysis).

The four forms of clean energy described above will make it technically possible to reach net-zero emissions by mid-century across all sectors of the economy, with the potential exception of agriculture. In many sectors, direct electrification will dominate, due to its inherent efficiency. In others – in particular, in industry and buildings – a portfolio of solutions exists, and the appropriate decarbonisation route will vary by region depending on local resource availability and prices:

- Already electrified sectors – such as household appliances, lighting, cooling, water heating, computing, machinery movement in manufacturing and rail – just have to ensure that the electricity they use is zero carbon.
- Surface transport is likely to become electric, in either battery or hydrogen fuel cell electric form, well before 2050 and far faster than many projections suggest, due to the inherent energy efficiency advantage of electric engines. For light-duty vehicles, it is likely that even the upfront capital costs of buying EVs will fall below those for Internal Combustion Engine (ICE) vehicles by the mid-2020s. For medium and heavy-duty vehicles, decarbonisation will likely entail either battery-based electrification or use of hydrogen in fuel cell EVs, with the former dominating shorter-distance intra-city applications and the latter dominating longer distances.
- In the shipping and aviation sectors, battery-based electrification and hydrogen will also play a significant role in short-distance journeys. But the limited energy density of batteries and the low volumetric density of hydrogen may make the use of liquid fuels necessary for long distances for the foreseeable future. These fuels could come from either a low-carbon, sustainable bio-feedstock (e.g., alcohols, biofuels) or from a power-to-liquid production route (ammonia in the case of shipping and synfuels in the case of aviation).
- In heavy industry sectors – steel, cement, chemicals and aluminium – a combination of clean energy sources and carbon capture can remove both energy-based emissions and emissions resulting from the chemical processes themselves. The most cost-competitive option is likely to vary by region, and depending on the brownfield or greenfield nature of each site.
- Residential and commercial building heating is already electrified in many regions and could be electrified further through the use of electric heat pumps or resistive electric heating. Alternatives include the combustion of hydrogen or bio-methane using existing gas grids and district heating systems. The optimal solution will vary by region, depending on resource availability and existing infrastructure. Better insulation of buildings is particularly important to reduce peak demand and make

this fuel switch – in particular, electricity-based options – more manageable from an energy system perspective.

- In agriculture, emissions from fossil fuel use can be eliminated by clean electrification or use of e-fuels. However, nitrous oxide and methane emissions from agricultural processes will be more difficult to eliminate. Some supply-side technologies could help to reduce these emissions – in particular, changes in agricultural practices; but major changes in diet will likely also be necessary[123].

Figure 53: Key innovation areas to fully decarbonise the economy[124]

Phasing out coal constitutes a fundamental change to the electricity sector not only in Ukraine, but also in those EU Member States that still rely strongly on coal. Major infrastructure investments will have to be taken to replace coal fired power plants. Many EU Member States use coal to generate electricity, though only a few countries still have large active coal-based power plants infrastructure. Lignite and hard coal capacities are still installed in various EU Member States, with very large capacities in Germany (over 45 GW) and Poland (over 30 GW), Czech Republic (around 10 GW) and Spain (around 10 GW) (Figure 51).

[123] https://www.energy-transitions.org/wp-content/uploads/2020/09/Making-Mission-Possible-Executive-Summary-English.pdf
[124] https://www.energy-transitions.org/wp-content/uploads/2020/09/Making-Mission-Possible-Executive-Summary-English.pdf

Especially for several Central and Eastern European Member States, replacing lignite and hard coal is challenging because they still constitute a substantial share in installed total power plant capacity: in Poland (71%), Czech Republic (46%), Bulgaria (35%), Slovenia (25%).

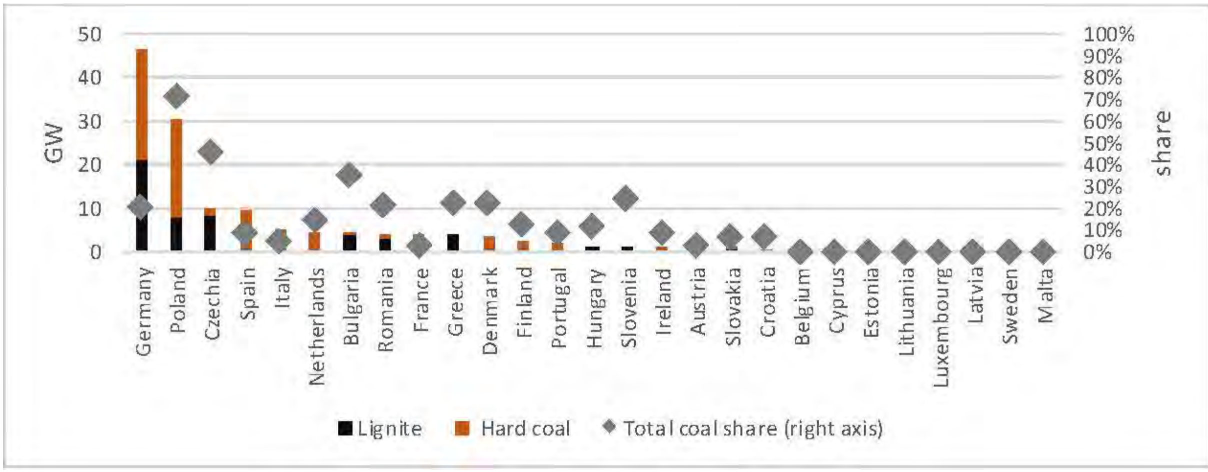


Figure 54: Installed capacity of coal-fired power plants in 2019 based on ENTSOE transparency platform data[125]

Higher energy efficiency and much a higher share of RE are the two pillars of energy transition. Renewable energy and energy efficiency measures can potentially achieve 94% of the required emissions reductions by 2050. The remaining 6% would be achieved by the other options for reduction of energy related CO2 emissions, i.e. fossil fuel switching, continued use of nuclear energy and carbon capture and storage (CCS)[126].

Between 41% and 54% of the total reduction can be directly attributed to renewables. The range indicates the contribution of electrification based on increased use of renewable electricity, which simultaneously raises energy efficiency and RE shares. Potential for CCS is only considered for the industry sector where some emissions from energy-intensive sectors are very challenging to mitigate, such as iron and steel or cement production. CCS is not considered as an option for the power sector.

The global energy transition and stronger overall economic growth according to the REmap Case could create around 19 million additional direct and indirect jobs in 2050 in the renewable energy, energy efficiency and grid enhancement and flexibility sector. Job losses in the fossil fuel sector (7.4 million) would be completely offset by new jobs in renewables alone, with more jobs being created by energy efficiency activities. Thus, the global energy transition results in 11.6 million additional direct and indirect jobs in the energy sector[127]. These include the millions of additional jobs that will be created in other sectors of the economy related to activities of deployment and maintenance of renewables, construction, implementation of energy efficiency measures, manufacturing of required equipment, and bioenergy supply.

[125] https://transparency.entsoe.eu/generation/r2/installedGenerationCapacityAggregation/show

[126] http://www.irena.org/DocumentDownloads/Publications/Perspectives_for_the_Energy_Transition_2017.pdf

[127] IRENA. Global Energy Transformation. A Roadmap to 2050, - IRENA, Abu Dhabi (2018)

2.5.2 Emissions

Ukraine has made good progress in its electricity transition, committing to a phase-out of coal and achieving rapid increases in wind and solar capacities.

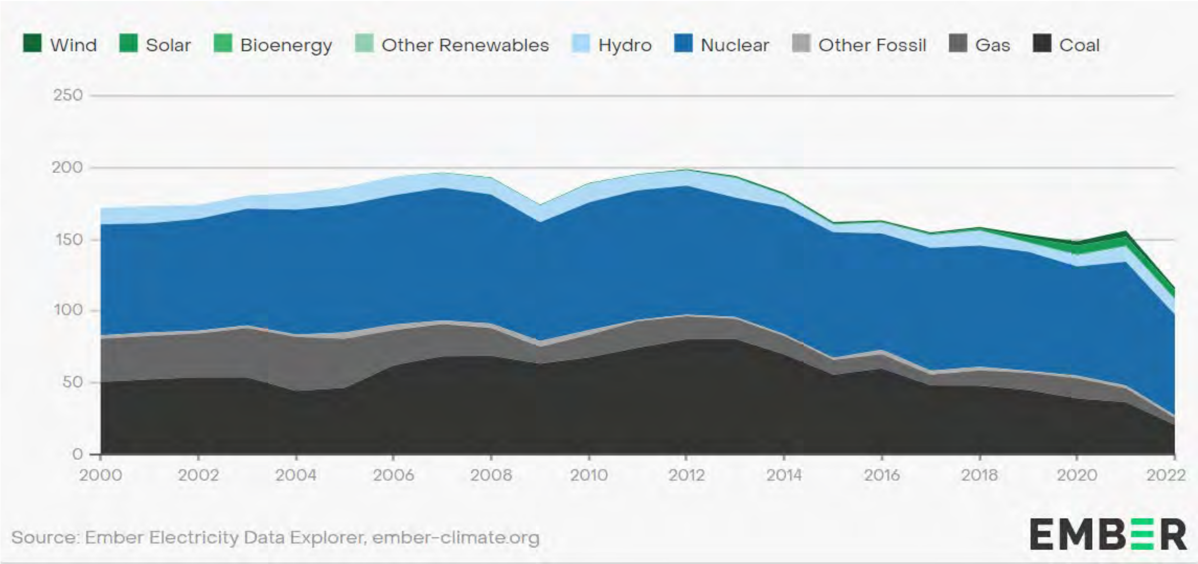


Figure 55 Ukraine's electricity generation by source (in TWh)

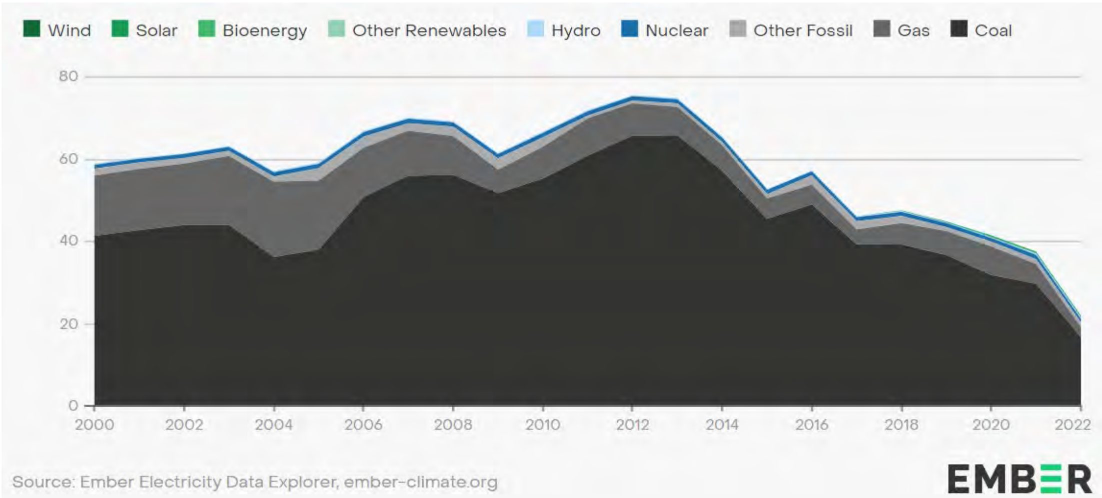


Figure 56 Ukraine’s power sector emissions by source (in Mega tonnes of CO2eq)

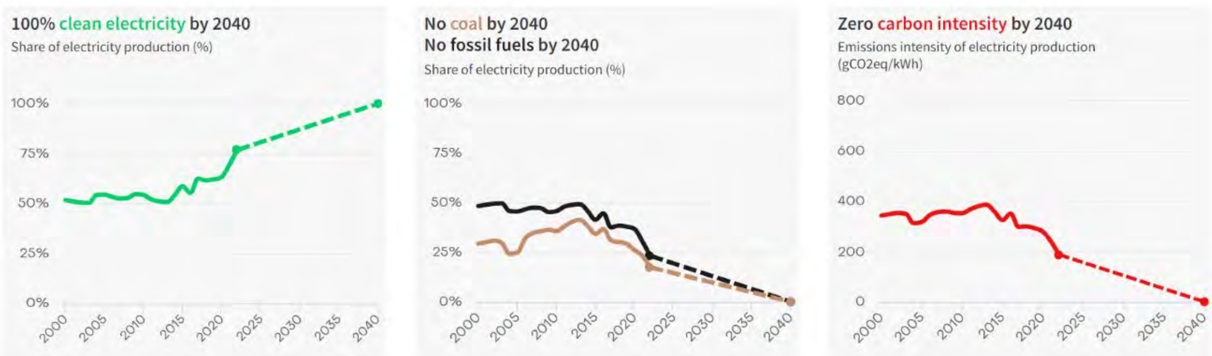


Figure 57 Ukraine’s Progress towards clean power targets 2000-2040

However, Russia's invasion of Ukraine in 2022 dramatically changed the landscape of the country's energy transition, with wind and nuclear power severely affected and a concerted attack on grid infrastructure. In 2022, Ukraine saw a dramatic fall in power sector emissions as power plants stopped generating or were damaged, and electricity demand collapsed.

Ukraine's power sector emissions by source (in Mega tonnes of CO2eq)

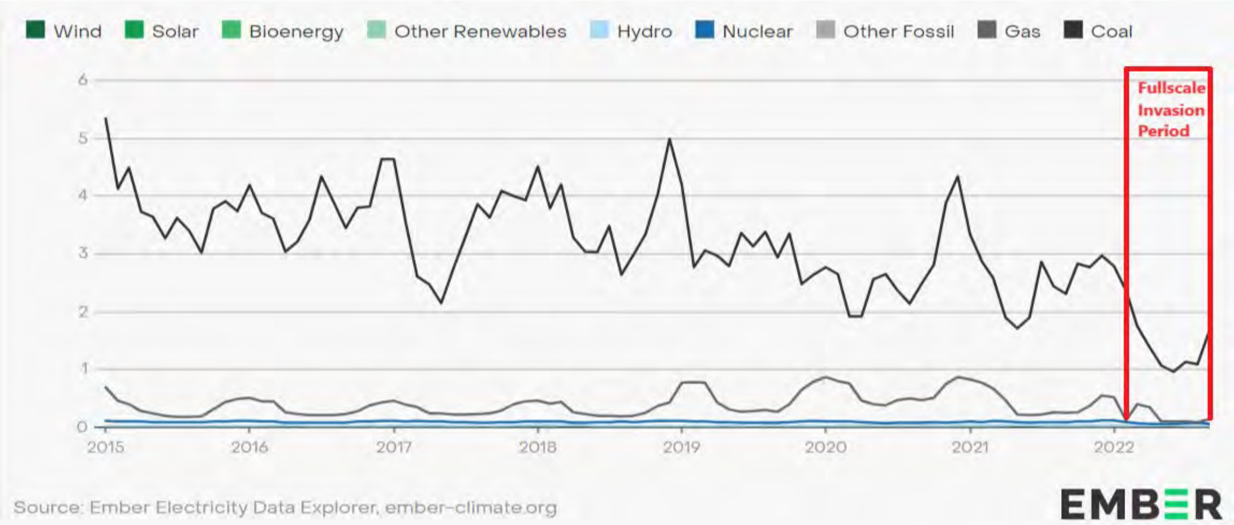


Figure 58 Ukraine's power sector emissions by source (in Mega tonnes of CO2eq)

Ukraine will continue to follow the global trend of decarbonization. Thus, it is planned to achieve climate neutrality in the energy sector by 2050 by:

- Using low-carbon energy sources;
- Developing generation running on renewable energy sources;
- Reducing and further eliminating coal generation;
- Implementing projects aimed at Carbon Capture and Storage (CCUS), which will neutralize the existing residual volume of emissions in 2050.

By 2030, the Strategy anticipates reducing GHG emissions by 65% from 1990 levels (following NDC2).

Ukraine ranks first among the 45 Parties in Annex I to the UNFCCC regarding achieved reductions in GHG emissions (excluding the LNG sector) **and fourth in terms of reduction in GHG emissions, considering the LNG sector compared to 1990**. Thus, GHG emissions in Ukraine decreased 62.4% from 1990 levels (excluding LFR) and 64.8% from 1990 (excluding the LNG sector).

In 2021, at the UN International Climate Conference (COP26) in Glasgow, it was decided to accelerate global actions to achieve climate neutrality - the Glasgow Climate Pact. More than 40 countries have agreed to phase out the use of coal. Large coal-consuming countries, including Canada, Poland, Ukraine, Vietnam and others, will gradually stop using coal for electricity production. Achieving climate neutrality is planned, in particular, by stimulating the use of renewable resources and introducing tools for regulating greenhouse gas emissions, including an Emissions Trading System (ETS) and a CO2 tax.

Emissions Trading System (ETS)

The ETS is the world's first and largest cap-and-trade system for greenhouse gases, stands as a cornerstone of the European Union's ambitious climate action strategy. Launched in 2005, the EU ETS operates in phases, with each setting a cap on the total amount of certain greenhouse gases that installations covered by the system can emit.

This approach provides a financial incentive for companies to decrease their emissions since it becomes more economical to reduce emissions than to purchase additional permits. The EU Emissions Trading System (ETS) encompasses over 11,000 installations throughout the EU, representing approximately 45% of the total greenhouse gas emissions in the EU.
These installations include power plants, refineries, steelworks, and other industrial facilities. The system is presently in its fourth trading phase (2021-2030), featuring a significantly reduced cap compared to previous phases, underscoring the EU's commitment to achieving more profound emission reductions.

The EU ETS has demonstrated success in reducing emissions within its covered scope. Verified emissions covered by the system decreased by 43% between 2005 and 2020. However, critics argue that the system requires further reform to truly enhance its effectiveness.

After a transition period, the ETS should replace the carbon tax as the fulfilment of the EU requirement laid down in CBAM (*Carbon Border Adjustment Mechanism*). Also, one of the factors ensuring the reduction of emissions is the implementation of state policy in the field of ensuring environmentally friendly public transport (for example, in Sweden, the entire underground transport system runs on electricity from renewable energy sources, and since 2017 all buses operate on renewable fuel sources).[128]

The Carbon Border Adjustment Mechanism (CBAM) of the EU is a policy crafted to ensure fair competition for European companies contending with counterparts in countries with less rigorous carbon pricing. CBAM achieves this by introducing a financial charge on imports of specific goods, determined by their embedded carbon emissions.

The primary objective of CBAM is to encourage global producers to adopt cleaner production practices and diminish their carbon footprint. While CBAM carries substantial potential for global climate action, its application to Ukraine introduces intricate considerations, particularly in the context of the ongoing war and the country's aspirations for EU membership.

Potential Impacts of CBAM on Ukraine:

- Increased Costs for Ukrainian Exporters: Ukrainian industries like steel, cement, and fertilizers, which are among the sectors targeted by CBAM, could face significant cost increases due to the carbon charges. This could potentially lead to higher prices for consumers and reduced competitiveness for Ukrainian exports in the EU market.
- Challenges for Adaptation and Compliance: Implementing the necessary systems and procedures to comply with CBAM could be a significant burden for Ukrainian businesses, especially amid the ongoing war and economic challenges. Technical assistance and financial support from the EU would be crucial to facilitate a smooth transition.
- Opportunities for Green Transformation: CBAM could act as a catalyst for Ukrainian industries to modernize and invest in cleaner technologies. This could not only help them comply with CBAM but also contribute to Ukraine's long-term climate goals and enhance its overall competitiveness.
- Special Measures for Ukraine: Recognizing the unique circumstances of Ukraine, the EU could consider temporary exemptions or reduced charges for Ukrainian exports under CBAM. This would help alleviate the immediate economic pressure and provide space for Ukraine to adapt to the new requirements.
- Supporting Ukraine's Green Transition: The EU could provide targeted financial and technical assistance to help Ukraine build the necessary infrastructure and capacity to comply with CBAM and accelerate its green transition. This could include investments in renewable energy, energy efficiency, and carbon capture and storage technologies.
- Maintaining Open Trade and Dialogue: Open communication and collaboration between the EU and Ukraine are crucial to ensure a smooth implementation of CBAM that does not hinder bilateral trade relations. Finding a balance between environmental protection and economic considerations is key.

It's important to note that the situation is still unfolding, and the specific details of how CBAM will be applied to Ukraine are still being discussed. However, the considerations outlined above provide a framework for understanding the potential impacts and opportunities of this policy for both Ukraine and the EU.

The active work of the Decarbonization Fund[129] will be an important tool for stimulating the achievement of climate neutrality. A part of the carbon dioxide tax will provide revenues to this fund, which will exclusively support projects that lead to CO2 emissions reductions, increasing energy-efficiency, and having positive environmental and social effects.

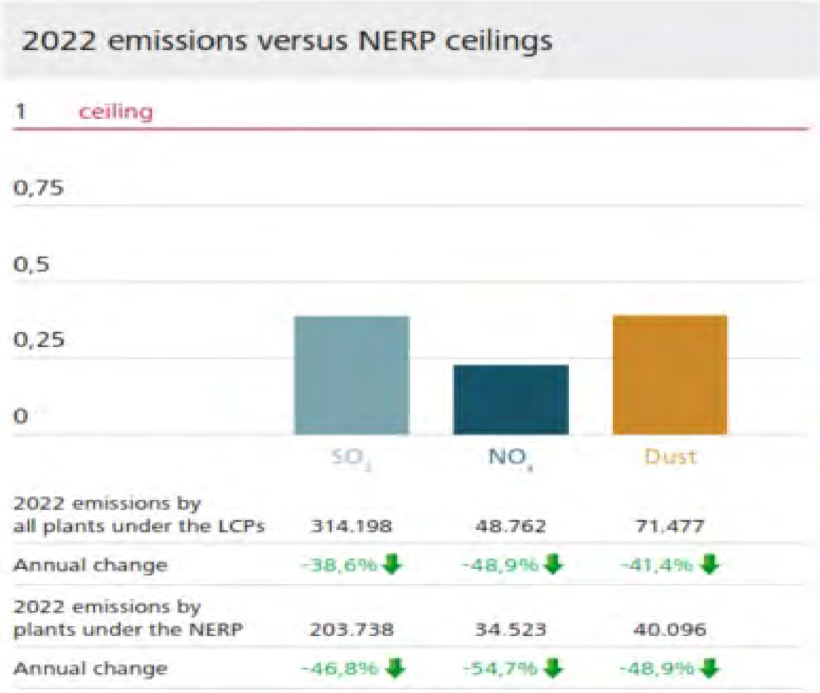
Ukraine has fulfilled its reporting obligations in line with the Large Combustion Plants Directive by promptly submitting its emissions data. The focused implementation of the National Emission Reduction Plan

128128

[129] Established in pursuance of the provisions of the Draft Law No. 8433 adopted on 11.04.2023 "On Amendments to Section VI "Final and Transitional Provisions" of the Budget Code of Ukraine on the use of funds from accounts in support of Ukraine".

continues. In the reporting year of 2022, emission ceilings for all three pollutants were met, demonstrating a significant reduction in emissions for each.

This achievement is linked to the unavailability of several plants subjected to attacks and uncertainties surrounding the data from plants situated in occupied territories.[130]



	SO_2	NO_x	Dust
2022 emissions by all plants under the LCPs	314.198	48.762	71.477
Annual change	-38,6% ⬇	-48,9% ⬇	-41,4% ⬇
2022 emissions by plants under the NERP	203.738	34.523	40.096
Annual change	-46,8% ⬇	-54,7% ⬇	-48,9% ⬇

Figure 59:2022 emissions versus NERP ceilings

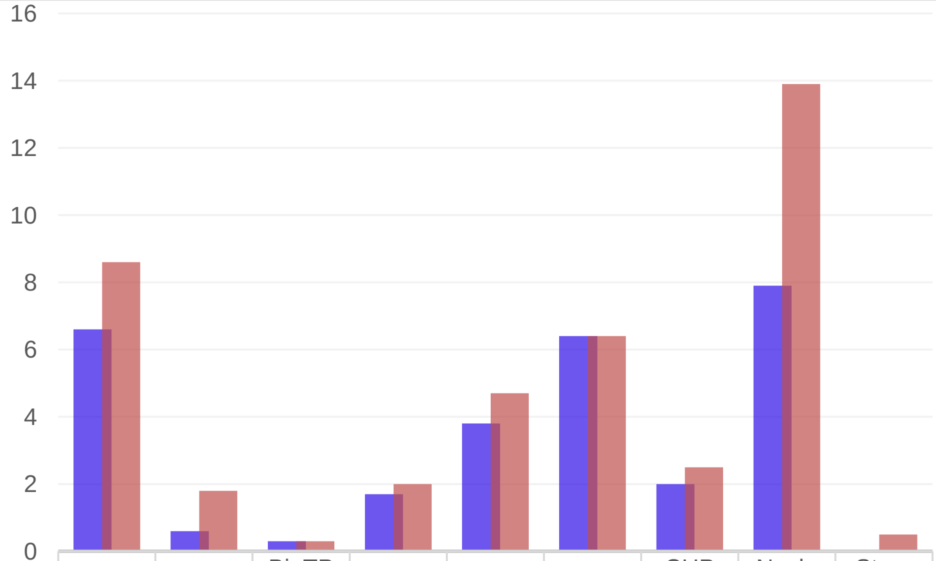
Note: Due to the methodology used by the European Environment Agency (EEA) for the historical dataset, the values do not include CO2eq emissions from biomass combustion or upstream and infrastructure / supply chain emissions.

Both scenarios consider a significant decrease in emissions. However, the more ambitious technical scenario is achieving a carbon-negative power system in 2050 and approaching zero carbon by 2035. The reference scenario, in contrast, still foresees the use of fossil fuels and further compensation via CCUS in 2050.

[130] https://www.energy-community.org/implementation/report.html

2.6 Summary of the Results

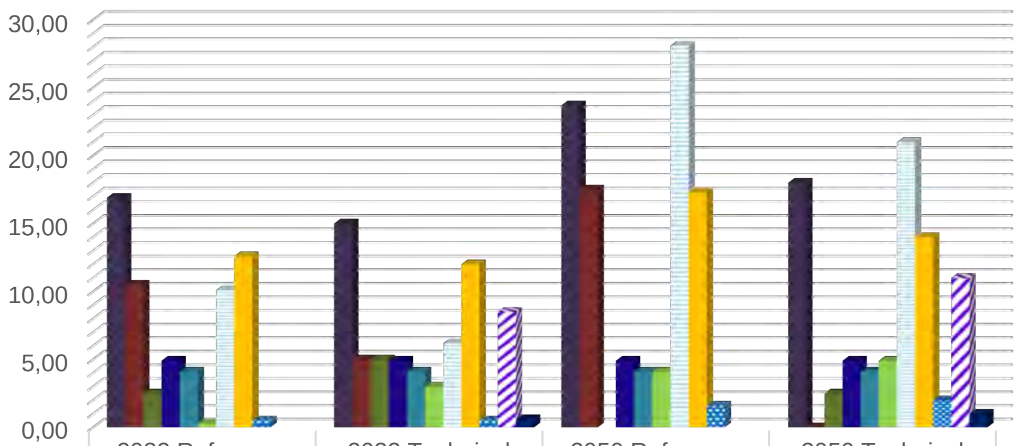
The Energy Strategy provides a relevant vision of the power sector capacity in the post-war period.



	Solar	Wind	BioTPP	PSPP	HPP	TPP	CHPP	Nuclear	Storage
2023 (wartime, plan)	6,6	0,6	0,3	1,7	3,8	6,4	2	7,9	0
2025 (postwar)	8,6	1,8	0,3	2	4,7	6,4	2,5	13,9	0,5

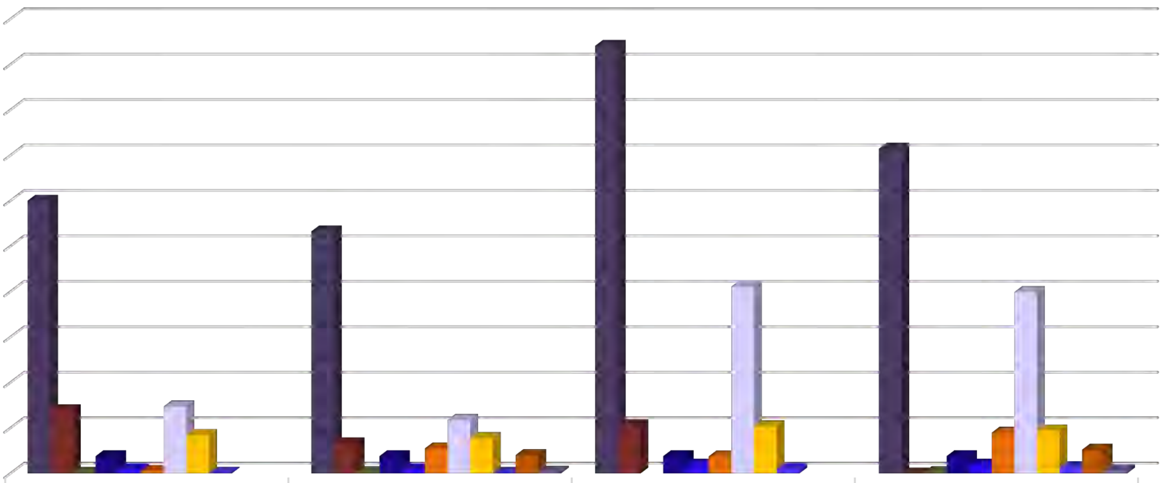
Figure 60: Installed generation capacities (wartime and post-war acc. to Energy Strategy, in GW)

The Consultant has reached the following results on the installed capacities of different sources in the grid (both scenarios are shown - reference and technical).



	2032 Reference	2032 Technical	2050 Reference	2050 Technical
Nuclear	16,90	15,00	23,70	18,00
TPP	10,50	5,00	17,50	0,00
CHPP	2,50	5,00		2,50
HPP	4,90	4,90	4,90	4,90
PSPP	4,10	4,10	4,10	4,10
BioTPP	0,30	3,00	4,10	4,90
Wind	10,10	6,20	28,10	21,00
Solar	12,60	12,00	17,30	14,00
Storage	0,50	0,50	1,60	2,00
P2X - X2P		8,50		11,00
OTHER RES		0,60		1,00

Figure 61: Installed capacity projections (in GW)

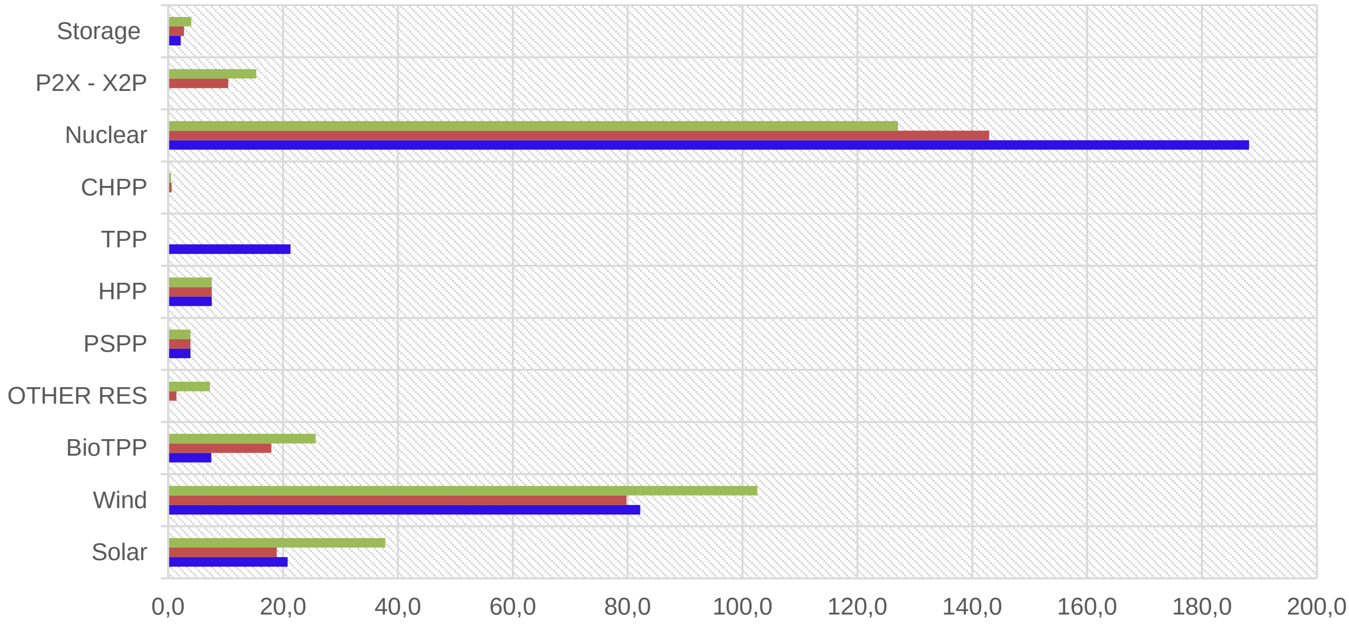


	2032 Reference	2032 Technical	2050 Reference	2050 Technical
Nuclear	120,0	106,5	188,2	142,9
TPP	27,8	13,2	21,3	0,0
CHPP	0,3	0,6		0,6
HPP	7,6	7,6	7,6	7,6
PSPP	2,0	2,0	3,9	3,9
BioTPP	1,1	11,0	7,5	18,0
Wind	29,5	23,6	82,2	79,8
Solar	16,9	15,6	20,8	18,9
Storage	0,3	0,3	2,2	2,8
P2X - X2P		8,1		10,5
OTHER RES		0,7		1,5

Figure 62: Electricity generation for 2032 and 2050 based on the installed capacities of the 2 scenarios of Fig. 2 (in billion kWh)[131]

[131] The hydropower values were included from available version of energy Strategy. We also consider more intense pumping regimes and | and integration of P2X-X2P technologies at PSPPs (such as ones currently tendered by IBRD)- BESS. This results in more electricity without increase of generation capacities, the provisions in Strategy are verified as acceptable in this regard. This note will be introduced in calculation results to avoid confuse

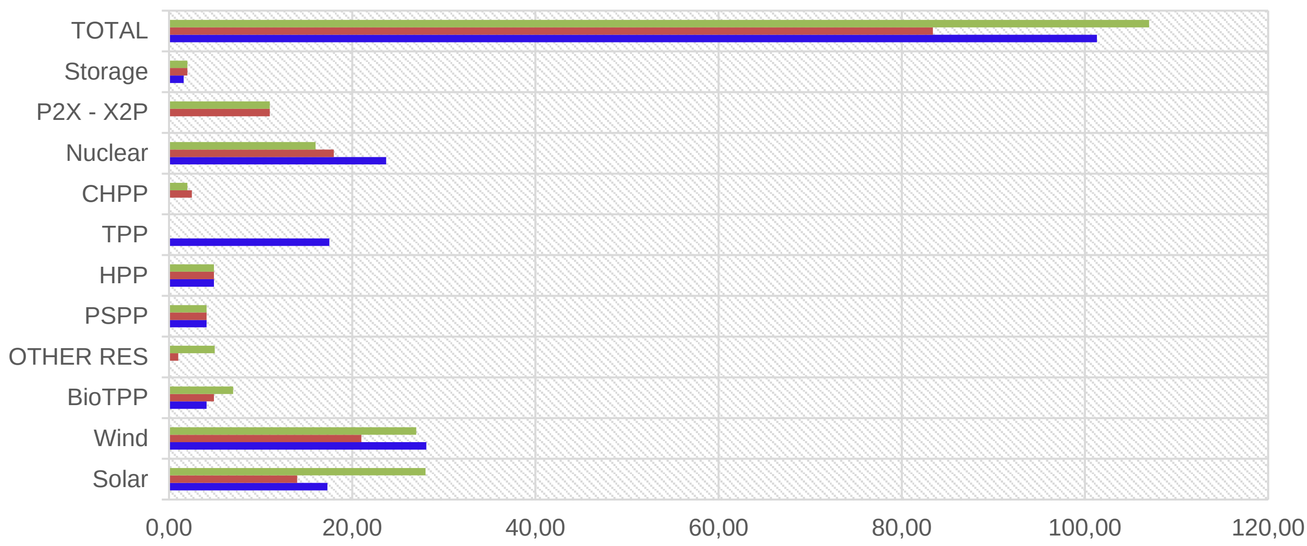
Planned Energy Generation, billion kWh



	Solar	Wind	BioTPP	OTHER RES	PSPP	HPP	TPP	CHPP	Nuclear	P2X - X2P	Storage
2050 Breaktrhough	37,8	102,6	25,7	7,3	3,9	7,6		0,5	127,1	15,4	4,0
2050 Technical	18,9	79,8	18,0	1,5	3,9	7,6	0,0	0,6	142,9	10,5	2,8
2050 Reference	20,8	82,2	7,5		3,9	7,6	21,3		188,2		2,2

2050 Breaktrhough   2050 Technical   2050 Reference

INSTALLED CAPACITIES, GW



	Solar	Wind	BioTPP	OTHER RES	PSPP	HPP	TPP	CHPP	Nuclear	P2X - X2P	Storage	TOTAL
2050 Breakthrough	28,00	27,00	7,00	5,00	4,10	4,90	0,00	2,00	16,00	11,00	2,00	107
2050 Technical	14,00	21,00	4,90	1,00	4,10	4,90	0,00	2,50	18,00	11,00	2,00	83,4
2050 Reference	17,30	28,10	4,10		4,10	4,90	17,50		23,70		1,60	101,3

Figure 63 Comparison by source, all scenarios

2.7 Conclusions and Recommendations

The development of RES integration is expected to be slower at first due to the imperfection of the legal and investment framework. The technical scenario considers the phase-out of coal and gas generation by 2050 to the maximum possible extent, success with implementing HPP construction, the wide introduction of contemporary technologies (including modern wind turbines), storage and PtX.

Conclusions

The Consultant presents two scenarios of RE development – a reference scenario (according to the recently adopted Energy Strategy) and a technical scenario (incorporating international best practices and specific market features). However, expanding renewable energy will depend on the interconnection and export capacity between the Ukrainian and EU electricity grids and readiness for deep integration of P2X technologies.

Storage, smart technologies, de-centralization and other concepts like cooperation between market players to provide balancing as services are shown in the Strategy only for reference and properly reflected in calculations. This is possibly made with reference to the Glasgow agreements on transient sources (biomethane cannot provide balancing for 17 GW of installed capacities in the short run) instead of doing a proper calculation on the clean and contemporary technologies.

The analysis confirms the possibility to reach and sometimes exceed the current targets in sustainable energy generation and emission reductions as set in a frame of international agreements signed by Ukraine. This included among other things, obligations in the frame of the European Green Deal. A key assumption behind reaching the targets is that the following are in place:

- Legislative, technical, and financial measures;
- Availability of human capital;
- Technical skills and financial resources.

Recommendations

- Preparation of the Feasibility Study on Facilitation of RES integration/ Implementation of Goals set in the Strategy. Similar study was previously conducted in 2014 for the International Bank for Reconstruction and Development (IBRD) as part of the Second Transmission Project. In light of the stabilization of the military situation, it is necessary to prepare a similar document. This document should be based on DigSilent/PSS-e or similar grid models and provide detailed calculations of network modes, accurately reflecting both the advancements and the needs of the system to accommodate the desired volumes of RES with due account to parallel operation with ETNSO-e. Furthermore, it is imperative to re-calculate and analyze the anticipated capacity building and rehabilitation of the grid. This process must involve obligatory coordination with the Transmission System Operator (TSO) and should be based on the most reliable and specific measurement data as well as link to Strategic documents of the sector and whole industry. Additionally, it is essential to identify and systematically structure priority measures. This structuring is critical to facilitate and plan future procurement processes effectively. Such a formalized approach will ensure that the developments in the grid infrastructure are in alignment with the evolving requirements and strategic objectives of the energy sector.
- Unification of the resource estimation methodology for RES. The resource estimation methodology varies in every of the analyzed sources including the International Renewable Energy Agency (IRENA), the International Bank for Reconstruction and Development (IBRD), the National Renewable Energy Laboratory (NREL), the and the Institute of Renewable Energy of Ukraine. In order to ensure consistency and accuracy in the identification of resources, the unification process should culminate in the adoption of a uniform methodology that will be universally applied across all relevant entities engaged in resource estimation.
- Inclusion of technical experts, TSO, ENTSO-e Currently the processes ongoing with power sector remain unclear for expert society and international community, wider discussions and workshops are required to properly address all of the existing issues. The publication of non-discussed and properly elaborated documents is not recommended, the documents shall comply with EU plans and strategies.

3 Assessment of Barriers & Opportunities

This chapter provides a comprehensive analysis of the prevailing challenges confronting the renewable energy sector (RES) in Ukraine. It examines both pre-existing issues that accumulated before the full-scale aggression of the Russian Federation and those directly imposed by the aggression itself. The chapter then outlines a spectrum of targeted plans, options, and opportunities aimed at overcoming these bottlenecks and propelling the RES sector forward.

Special attention is given to existing recovery plans and approaches designed to accelerate RES development and capitalize on available investment opportunities. The recently vetoed Ukraine facility is also discussed within this context.

- Before the escalation of the war, Ukraine was making strides toward meeting its renewable energy implementation targets. However, the 2023 EnC report on implementation progress indicates a significant shortfall in RES sector development (36% overall) due to various factors, including:Imperfections in quality support schemes and grid operator (GO) practices.
- Non-compliance of the biomass sector with REDII regulations.
- Low utilization of RES in heating and cooling applications.

These issues, alongside other identified bottlenecks, are explored in further detail throughout the chapter.

3.1 Pre-war challenges

Regarding the conditions of the RES sector, it is noted that the full onset of war is the largest but not the only challenge the sector was facing in 2022. A whole set of challenges existed well before 24 February 2022. These challenges continue to raise major concerns for investors and asset owners and have already contributed to a slowdown of RES investments. They can be divided into three issues – **technical, legal, and economic.**

Technical issues:
Difficulties for interconnection of future projects, even more critical due to huge war damages. The surplus of projects with "booked" interconnection and relevant obligations for grid rehabilitation which were never implemented. Such projects "on hold" are still considered during calculations. Future developments are depending on the above, decreasing the projects feasibility due to high expenditures on interconnection. At the same time the willingness of investors to proceed with the construction of projects "on hold" is unpredictable. Another technical challenge is the conservatism of Ukrainian developers and lawmakers who are very technology-cautious and rely on proven approaches without proper consideration of most contemporary technologies (often due to complexity of financing) combined with unjustified relying on such technologies during the year 2023[132].

Legal issues:
Retrospective FiT cuts, an absence of the “green” auctions announced in 2020, the absence of approved mechanisms for Guarantees of origin, and PPA mechanisms that are complicating sales of renewable electricity around the country as well as exports to the EU. There is also no clarity on finalization of the ongoing construction works (**the Draft Law No. 8191** was registered in November 2022, the provisions of which are partially adopted in the Law 3220-IX). Reoccurring governmental underperformance of the undertaken obligations.

Economic issues:
The non-substantiated transmission tariff providing funds for FiT, lack of clear and viable mechanisms for investments in new technologies such as hydrogen and storage. Problems with debts restructuring and deficit of FiT payments for the purchased “green” energy aggravated with imbalance payments. The Regulator, NEURC, tries to maintain a balance between the need for higher electricity tariffs and overseeing the fulfilment of FiT obligations. Such a strategy has resulted in a systematic underfunding of the guaranteed FiT. It needs a better mechanism for the provision of funds for FiT support, and fulfilling obligations to RE electricity producers, assuming that there will be no extra funds from exports of electricity this and possibly next year. Keeping existing investors willing to maintain their existing investments will be critical for further and new investments in the post-war economy.

[132] as shown during review of RES penetration figures of London conference

A significant amount of RE facilities, concentrated within one balancing group, cannot respond promptly to power system operating modes and market price signals, providing mutual benefit for the transmission system operator and producers of electricity from alternative sources in terms of balancing the power system. This leads to financial losses for SE "Guaranteed Buyer" and an increase in the cost of the service for ensuring an increase in the share of electricity production from alternative sources, which is an integral component of the tariff for the electricity transmission service, which is paid by all consumers. Also, non-involvement of producers of electric energy from alternative energy sources in participating in the electric energy market (including the balancing one) on competitive terms complicates and increases the cost of balancing the operation modes of the power system.

- The intermittent nature of RES and uncoordinated issuance of technical conditions by TSO/DSOs led to an overabundance of prospective projects without a clear picture of investors' actual plans. Lack of proper system planning, leading to an "RES bubble" with several ambitious but technically infeasible projects (due to cumulative grid impacts and interference with other projects);
- Lack of forecasting capabilities and imbalance payments as a mechanism to cover the financial weakness of the TSO, resulting in significant challenges with debt coverage and future debt financing;
- Retroactive tariff cuts and complex permitting procedures have reduced international investment flows (lack of clarity on timelines for completion, commissioning and operation of power plants and interconnections has led to significant challenges in project planning and financial modeling, limiting the ability of international investors to enter the market);
- Uncertainty in both auctions and PPAs makes proper financial planning for post-tariff periods impossible. The lack of clear incentives and success stories for storage projects leads to lack of investor interest in storage projects;
- Insurance challenges due to the above factors;
- Wind projects located in Western Ukraine faced serious logistical problems due to the inability to ship equipment across the border with Poland (oversized tower sections had to be transported from the port);
- Legislation: negative progress in terms of simplification led to significant investor discomfort and did not allow for proper modeling, risk and contingency assessment.

Settlements of payments for RE-based electricity generation

- As of 22 May 2023, the level of payments to RES producers since the start of 2023 is almost 60%; for April 2023, payments for electricity amounted to 56.3%; for the first ten days of May 2023 = 49.9%.
- The debt of the National Energy Company "Ukrenergo" to the Guaranteed Buyer for November remains almost unchanged and amounts to UAH 32.57 billion.[133].
- As of 16 May 2023, the GB has received only six applications for suspending contracts from 1 June 2023. As noted by the GB, since the beginning of the full-scale war, 42 entities with a total capacity of 227 MW have joined the balancing group of the "Guaranteed Buyer." Among them, five companies returned after the termination of the contract. "This shows that the counterparties tried to enter the free market on their own, assessed the results, and decided that it was more profitable for them to return. Also, since the start of 2023, the Guaranteed Buyer has concluded 19 agreements with counterparties[134].
- The share of non-performing loans in the RE industry increased to 51% at the start of May 2023 from less than 3% before the beginning of the invasion. According to the NBU, the share of "green" energy loans in the gross loan portfolio is almost 4%. In some banks, the share of the portfolio reached 13%, according to the Report on financial stability for June 2023 of the National Bank of Ukraine. As mentioned by NBU, the lack of a safety margin may lead to a new wave of company defaults once the regime of temporary relaxation of debt payments ends[135].
- In September 2023[136] Energoatom has finally started to cover PSO obligations, 22 billion 726 million UAH were transferred to Ukrenergo and plans to pay almost 2,5 billion more till the end of 2023 to cover the debt. Energoatom's costs for the PCO service account for 64% of its income. The company

[133] https://www.gpee.com.ua/news_item/342

[134] https://expro.com.ua/novini/za-pvmsyacya-garantovaniy-pokupec-otrimav-lishe-6-zayav-na-timchasoviy-vihd-z-balansuyucho-grupi?fbclid=iwar3l-agzhmxtr8q1449pd278ry8ekzxm86tnytvfcwjotxpk8dssjtpqmjq

[135] https://bank.gov.ua/admin_uploads/article/FSR_2023-H1.pdf?v=4

[136] https://ua-energy.org/uk/posts/enerhoatom-voseny-splatyv-maizhe-23-mlrd-hrn-za-posluhu-pso-27-10-2023

has accumulated a debt of UAH 18.429 billion for the PCO service due to the war. The debt can only be repaid through government compensation.

Price caps

The Department of the Energy Market proposes to set the following limit prices on the day-ahead and intraday markets (November): 00:00-07:00, 23:00-24:00 - 3000 UAH/MW*h; 07:00-08:00, 11:00-17:00, 22:00-23:00 - 5600 UAH/MW*h; 08:00-11:00 - 6900 UAH/MW*h; 17:00-22:00 - 7500 UAH/MW*h. Liberalisation of price caps will allow imports from other Member states and Contracting Parties of ENTSO-e hence improving energy Security of Ukraine. It is recommended to develop a strategy for further price caps liberalization is developed, to reflect the sequence of markets and include an automatic mechanism for adjustment of the price caps based on a transparent methodology.

3.2 War-implied challenges

Figure 64 Drivers and Challenges in UA RES sector

- Decrease in system stability and balancing capacity, need for forecasting and curtailment lead to the fact that even operational RE are in a very challenging situation even with huge energy deficit & energy demand (sometimes leading to misguided dispatcher commands);
- All TPPs of the country are damaged, requiring larger reserves from ensuring the system adequacy. In this condition, RE development becomes a limiting factor;
- Direct damage to the backbone networks leads to impossibility of ensuring the n-2 criterion, normal operation of RES is possible only after full restoration of the power system, which may take years and may not be reasonable to a large extent;
- The risk of further escalation remains a limiting factor for all projects with payback periods of RES projects;
- EBRD does not provide loan facilitation or relief, despite wartime conditions killing existing projects;
- The Ministry of Energy has limited payments to "green producers" to 15% (18%) of the average Feed-in-Tariff, and the payment of the remaining part of the planned revenues is not yet defined in any other document;
- All debts are not considering the inflation (28% in 2022 and up to 25-30% in 2023), these losses are fully on RES OBJECT OWNERS with loans in currency;
- Due to the above facts, some of the asset owners even planned the full relocation of the assets to other country;
- There is no clarity on how to proceed with projects that were under construction at the beginning of 2022 – not a fully clear guideline.

For the majority of RES objects - these are not considered as critical infrastructure. Thus, the staff cannot be reserved from mobilization to the armed forces.

3.3 Cost-effective options for accelerated renewables deployment

Accelerating the deployment of renewables is crucial for transitioning to a more sustainable and low-carbon energy system. Cost-effective strategies can help facilitate this transition.

The typical cost-effective options are following:

- **Power Purchase Agreements (PPAs):** Establishing long-term PPAs with fixed prices for RE can provide investors with revenue predictability, which encourages project development. These mechanisms can help reduce financing costs and make renewables more attractive to investors. For Ukraine it may allow to implement EU-wide standardized PPA templates and guidelines for different RE technologies, simplifying negotiations and reducing legal costs. Establish a centralized platform to connect RE developers and potential buyers.
- **Competitive Auctions:** Implement competitive bidding processes, where RE projects compete to provide electricity at the lowest cost. Auctions can lead to price reductions and drive down the cost of RE; For Ukraine this can result in auctions for large-scale RE projects, ensuring transparency and competition across member states. Introduce diverse auction formats (e.g., technology-specific, capacity-based) to cater to various project types and market needs
- **Financial Incentives:** Offer financial incentives such as tax credits, grants, or subsidies to reduce the upfront costs of RE projects. These incentives can stimulate investment in renewables. This may foresee Tax Breaks and Project Finance for developments based on contemporary and innovative technologies (excluding for instance projects without proper forecasting and flexibility) and in particular energy deficit locations (to avoid congestions in War-Affected southern regions). The cooperation with both IFI's and large private investors (see clause PPP below);
- **Net Billing and Feed-in-Tariffs for Small-Scale Installations:** Encourage small-scale RE installations on homes and businesses by implementing favourable net metering policies and FiTs. This enables customers to sell excess energy back to the grid, improving the economics of rooftop solar and other distributed renewables, the existing law 3220-IX sets the framework for this however the initiative requires further tuning;
- **Grid Modernization**: Invest in grid infrastructure and modernization to accommodate a higher share of variable renewable energy sources. A smart and flexible grid can integrate renewables more effectively and reduce the need for expensive grid upgrades. Such grid developments shall be planned and justified based on relevant studies (proper grid modelling) to be approved by Ukrenergo and comply with ENTSO-e and Strategic obligations;
- **Storage Integration:** Promote energy storage technologies like batteries to mitigate the intermittency of renewables. Energy storage can improve grid stability and enable renewables to provide reliable power even when the sun is not shining or the wind is not blowing – this is one of the critical components to assure grid resilience. Project finance, tax incentives and other financial incentives shall be foreseen for the first projects of the kind in sector the framework for this is set in Law on Energy Storage (2046-IX) however it may require additional support for the first projects due to high initial investment costs for ESFs also the concerned regulations to be finalized by the Government;
- **Research and Development (R&D):** Investments in research and development (R&D) are crucial for the development and commercialization of advanced renewable energy (RE) technologies. Achieving breakthroughs in efficiency and cost reduction is essential for significantly accelerating the deployment of these technologies. It has been observed that the Institute of Renewable Energy, along with similar institutions in Ukraine, is currently facing a shortfall in resources necessary for actual research activities and experiments. To address this issue, two primary approaches are recommended:
    - *Enhancement of R&D Attractiveness*: Implementing relevant incentives to increase the attract-tiveness of R&D for young specialists is vital. Such incentives are expected to foster greater interest and involvement in the field of renewable energy research.
    - *Expanded Participation in International Programs*: Encouraging broader participation of Ukrainian scientific organizations in international programs such as Horizon Europe and the Innovation Fund is imperative. This will facilitate the integration of Ukrainian research within the wider European scientific community.

  Additionally, attention should be directed towards establishing cooperation with the European Investment Bank (EIB) and Invest EU, organizations that provide financial support for R&D initiatives.

Further collaboration between Ukrainian R&D and European counterparts through Knowledge and Innovation Communities (KICs), the European Sustainable Biomass Partnership (ESBP), the European Photovoltaic Technology Platform (EPVTP), and other mechanisms is also recommended. Such collaborative efforts are essential for enhancing the research capabilities and technological advancements in the field of renewable energy within Ukraine.

- **Streamlined Permitting and Licensing**: Simplify and expedite the permitting and licensing processes for RE projects. Delays in approvals can increase costs and deter investors, one stop shop may be one of the solutions – it is addressed further in the last chapter of this report;
- **Public-Private Partnerships (PPPs):** Collaborate with the private sector to finance and develop RE projects. PPPs can leverage private sector expertise and funding to accelerate deployment 0 wider inclusion of large Private developers. This allows combining public policy support and incentives with private sector technology, innovation, and investment and has proven itself as an efficient mechanism in other countries. The primary legal framework for PPPs in Ukraine is established under the Law of Ukraine "On Public-Private Partnership," which provides the legal basis and defines the mechanisms for implementing PPP projects. Ukrainian PPP legislation shall undergo amendments and updates to align with international best practices and to address specific economic and social challenges. Keeping abreast of the latest legal changes is crucial for stakeholders involved in PPP projects;
- **Community-Based Renewable Energy:** Encourage community-based RE projects, which can foster local ownership and support. Community involvement can help reduce opposition and streamline project approval, this may also refer to microgrids development, “Energy Cooperatives” and similar iniciatives. The war in Ukraine has cast a long shadow over the country's energy landscape, highlighting the vulnerabilities of centralized systems and the urgent need for diversification. Community-based renewable energy (CBRE), a promising avenue for fostering local energy resilience, independence, and sustainability, the legal framework for CBRE is still evolving, requiring further clarity and streamlining of procedures;
- **Energy Efficiency Programs:** Implement energy efficiency measures to reduce overall energy demand. Lower demand can make it easier to meet energy needs with renewables and reduce the required capacity;
- **Education and Outreach:** Raise public awareness about the benefits of renewables and provide information on incentives and financing options. Informed consumers are more likely to invest in RE technologies;
- **Long-Term Planning:** Develop comprehensive, long-term energy plans that prioritize renewables as a core component of the energy mix. Clear policy direction provides stability and confidence to investors;
- **Economies of Scale:** Encourage large-scale RE projects that benefit from economies of scale, driving down the cost of energy production;
- **Carbon Pricing:** Implement carbon pricing mechanisms like carbon taxes or cap-and-trade systems, which can make fossil fuels more expensive and renewables more competitive. For instance the EU Emissions Trading System **(EU ETS**) and **CBAM** further addressed in Clause 2.5.2,

3.4 EC approaches on accelerating the RES development

On 9 November 2022, the European Commission proposed a **temporary emergency regulation on accelerating the deployment of renewable energy**. Its main aim is to simplify permit-granting procedures for RE projects, in particular for solar installations, heat pumps, and projects involving the repowering of RE plants. Accelerating the rollout of renewables is considered one of the main measures that could help the EU address the current energy crisis, improve security of supply and reduce energy prices. The regulation comes in response to the European Council conclusions of 20-21 October 2022, which called for the 'fast-tracking of the simplification of permitting procedures to accelerate the rollout of renewables and related grids'. It complements several other regulations adopted in 2022 to mitigate the energy crisis, such as the regulations on gas storage, gas demand reduction and on addressing high energy prices.

The RED III Directive 2023/2413, formally known as the Renewable Energy Directive, is a game-changer for the European Union's energy landscape. **This ambitious legislation sets a binding target of at least 42.5% renewable energy in the EU's final energy consumption by 2030, with an even more ambitious aspiration of 45%.** This translates to a significant increase from the current 21% share, marking a crucial step towards a sustainable and [137]climate-neutral future. To achieve this ambitious goal, RED III introduces several key measures:

- Accelerated deployment of renewable energy: Member states are required to develop ambitious national renewable energy action plans, with clear targets and timelines for deployment across various sectors, including electricity, heating and cooling, and transport.
- Streamlined permitting procedures: RED III aims to simplify and expedite permitting processes for renewable energy projects, reducing administrative burden and fostering faster project approvals.
- Focus on innovation and advanced renewables: The directive encourages investments in next-generation technologies like offshore wind, advanced biofuels, and solar photovoltaic, recognizing their crucial role in future energy systems.
- Enhanced sustainability: RED III promotes the use of sustainable biofuels and addresses the issue of indirect land-use change (ILUC) emissions associated with certain bioenergy sources.

RED III is not just about setting ambitious targets; it's about creating the enabling environment for Europe to harness its vast renewable energy potential. By streamlining regulations, fostering innovation, and ensuring environmental sustainability, the directive paves the way for a cleaner, greener, and more energy-independent Europe.

In essence, RED III is a bold call to action, demanding a collective effort from governments, businesses, and citizens to build a sustainable energy future for the EU. Its ambitious targets and comprehensive measures signal a clear commitment to renewable energy and provide a roadmap for Europe to become a global leader in clean energy technology and innovation.

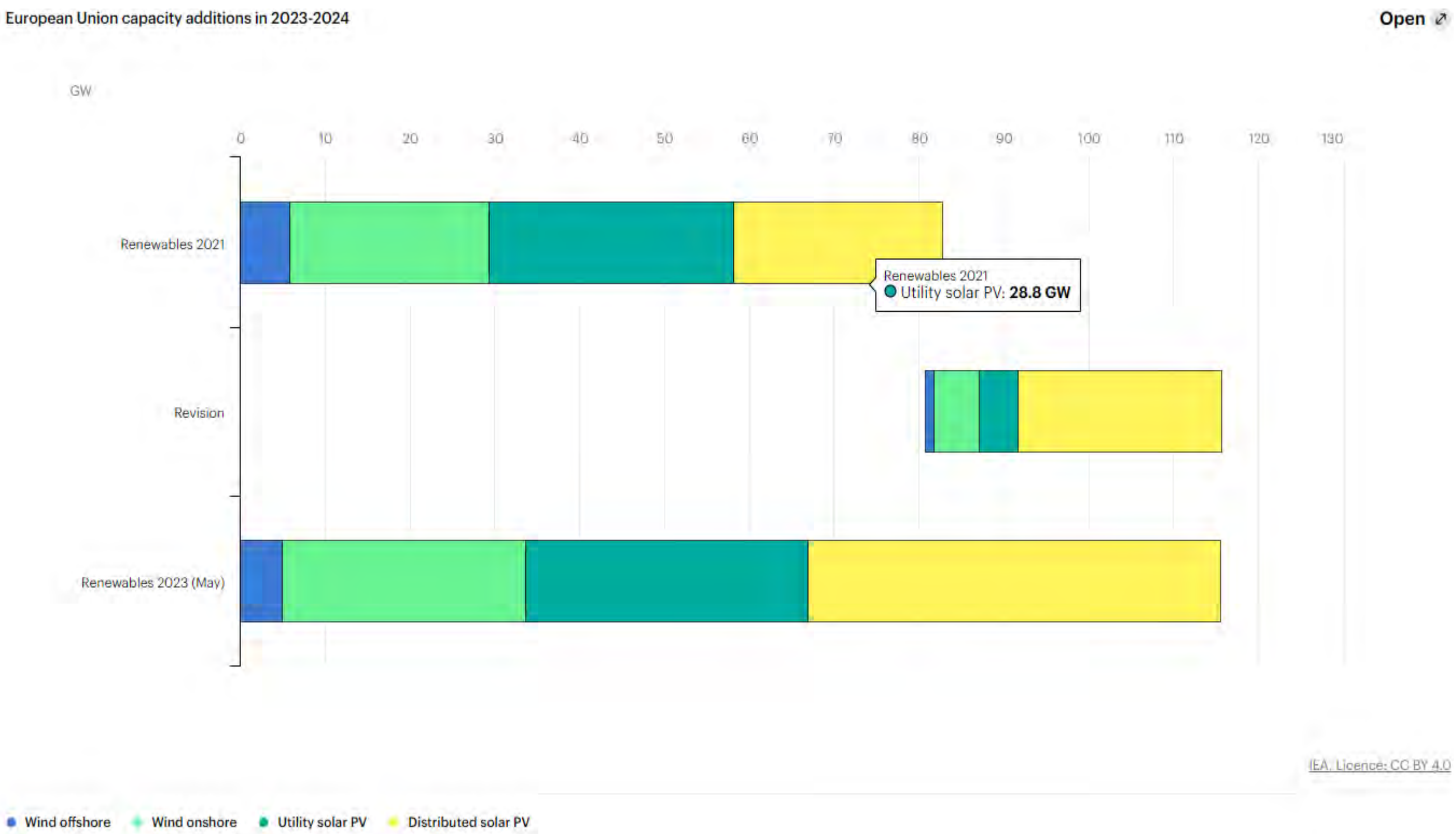


Figure 65: EU capacity additions in 2023-2024

European countries introduced more policy and regulatory changes to ease permitting in the last 18 months than over the entire previous decade. While permitting has become a key policy focus in Europe to accelerate the deployment of large-scale wind and solar PV and early benefits are starting to be visible, the proposed policy changes are expected to have limited impact on the deployment of renewables in 2023 and 2024 compared with other drivers, such as installations of small-scale residential and commercial solar PV.

[137] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023L2413

EU electricity consumers are set to save an estimated EUR 100 billion during the 2021-2023 period thanks to newly-installed solar PV and wind capacity. Accelerating RE deployment in Europe since 2021 has mitigated the economic impact of the energy crisis. Low-cost wind and solar PV are on course to displace an estimated 230 terawatt-hours (TWh) of expensive fossil fuel generation over the 2021-2023 period, helping to reduce wholesale electricity prices in all European markets. Without these capacity additions, the average wholesale price of electricity in the EU in 2022 would have been 8% higher, hurting consumers, businesses and government budgets.

Renewables could help Europe displace more natural gas for heating buildings next winter. Last year was the second warmest winter on record in Europe, which helped the EU use less gas for heating buildings. Projected growth of RE such as clean electricity, bioenergy boilers, heat pumps, and solar thermal and geothermal technologies could displace almost 8 bcm of EU buildings-related gas consumption annually in 2023 and more than 17 bcm in 2024. This would represent a significant contribution to cover increasing gas demand, should harsher winters and hotter summers occur over the course of 2023-2024[138].

3.5 Available investment plans for renewable energy sector (public and private)

3.5.1 European Investment Plans

The European Commission has established the first list of renewable energy **Cross-Border (CB RES) projects** under the Connecting Europe Facility (CEF). The list marks the start of the implementation of the window of CEF Programme, dedicated to renewable energy and decarbonization.

CB RES projects are identified by the CEF Regulation and aim to promote cross-border cooperation between Member States (and between Member States and non-EU countries) in the field of planning, development and cost-effective exploitation of RES. In addition, CB RES projects may facilitate RES integration through e.g. energy storage or hydrogen production facilities with the aim of contributing to the EU's long-term decarbonisation strategy. CB RES projects need to be set-up by a cooperation mechanism as defined in RED III.

This first list comprises three projects, relevant for a total of seven Member States. These are a hybrid offshore wind park between Estonia and Latvia, a cross-border district heating grid based on RES between Germany and Poland, and a project to produce renewable electricity in Italy, Spain and Germany for conversion, transport and use of green hydrogen in the Netherlands and Germany.

The realisation of the projects in the first CB RES list makes an important contribution to the increased renewable energy ambition under the European Green Deal, as well as to the objectives of the REPowerEU. The European Commission, with the support of CINEA, will monitor the implementation of the CB RES projects and will soon make available information on the status of the projects via a public portal.

On 5 August 2022 the Commission awarded EUR 300.000 for two studies that support pioneering actions representing diverse options of cross-border cooperation. These studies aim to help the beneficiaries to advance their project concepts and develop them into successful applicants for a status of a CB RES project later on. The first study will investigate the feasibility of a supra-regional supply of district heating in the regions of southern Germany (Bavaria) and Austria (Upper Austria and Salzburg). The second one will support the environmental impact assessment of a project for up to 2GW of cross-border offshore wind farms in the Gulf of Riga area located in Estonian and Latvian waters.

The Delegated Regulation establishing the list of CB RES projects will go through a standard procedure of 2 months scrutiny period by the European Parliament and the Council, after which it will enter into force.

The projects which are included in the list were able to apply for the call for proposals for works & studies under CEF Energy launched in November 2022.

The three projects that made it to the list are:

- **Climate-neutral district heating in the European city Goerlitz-Zgorzelec**

  Goerlitz (DE) and Zgorzelec (PL) will invest into RES heat generation and connect its district heating networks with a cross-border pipeline, to jointly supply the European city with climate-neutral district heating based on a RES generation of 160 GWh per year. A feasibility study is currently being carried

[138] IEA 2023 Renewable Energy Market Update - June 2023, https://www.iea.org/reports/renewable-energy-market-update-june-2023/executive-summary.

out; the next step is to develop a concept for the transformation of the heat supply of the cities of Goerlitz and Zgorzelec respecting CO2 neutrality. Scenarios are to be developed and the use of regenerative technologies that can replace the currently used heat supply systems will be investigated. The project is expected to be realised by 2026.

- **CEO-Alliance cross-border-European green hydrogen value chain**
  The core of the project is to build new, additional renewable power plants in Italy, Spain and Germany and then convert the green power produced to green hydrogen and/or ammonia. Part of the ammonia will be used for off-takers directly in the Netherlands, but the bulk part will be converted to hydrogen and transported to Germany for further utilisation, including in hard to electrify industries, what is necessary to make the low-carbon transition a success story.
- **ELWIND – Estonian-Latvian joint hybrid offshore wind project**
  The ELWIND project is an offshore wind project, involving Estonia and Latvia, comprising an hybrid grid connection with interconnector and transmission lines to connect the two countries and aiming for an annual renewable electricity output of about 3 to 3.5 TWh per year. The plan is to build two offshore wind parks, one in Estonian and one in Latvian waters. The aim is to pilot a cross-border hybrid project concept in the Baltic-Sea for replication in other locations and to improve the security of supply in the region[139].

Two projects have been selected under the 2021 CEF Energy call for preparatory studies for cross-border renewable energy projects. The funding for these projects amounts for around EUR 300.000 and will support pioneering actions representing diverse options of cross-border cooperation that the renewable sector offers.

The *first project selected*, promoted by Regionalwerk Chiemgau-Rupertiwinkel, is the Eneregio SOBOS study, which will receive EUR 200.000 to investigate the feasibility of a **supra-regional supply of district heating**. The geographical scope of the study covers parts of southern Germany (Bavaria) and Austria (Upper Austria and Salzburg).

The aim is to analyse the potential and feasibility of a cross-border heating system that would be supplied by waste energy from local industry, geothermal and bioenergy plants. As a result of the Eneregio SOBOS study, a cross-border RE project will be defined, relying on data collection of heat sources and sinks/heat demands in the industry and customer sectors.

If the expected potential is confirmed, the supra-regional district heating could lead to over 2 TWh of heat being supplied from sustainable sources. The transnational network of heat sources and heat sinks from different processes via a district heating transport system will tap into the geological potential for RE deployment and enable the cross-border and year-round use of CO2-free heat for the supply for the entire districts, thus leading to the diversification of the heat supply, reduction of regional reliance from fossil fuels and ultimately of the dependence on energy imports from outside the EU.

The *second project selected* will be carried out by Eesti Energia, whose goal is to develop, build, and operate, together with partners, up to 2GW of **cross-border offshore wind farms** in the Gulf of Riga area located in Estonian and Latvian waters. The project will receive an EU grant of EUR 99.000 to conduct a study that will support the ongoing environmental impact assessment with technical data regarding turbines, foundations, connection cable lines, construction methodologies and other necessary data. Moreover, the study will update the cost estimate as well as operational expenditure estimate of the wind farm.

If the study's outcome is positive and the project will be ultimately carried out, the hybrid offshore wind farms with a RES capacity of up to 2 GW and interconnecting Estonia and Latvia could start their commercial operations by 2030. This will significantly improve both countries' energy supply security[140].

Scaling up renewables in line with their potential to meet energy security and climate objectives requires significantly larger investment than currently forecasted. While the bulk of investment will need to come from the private sector, public capital providers (such as multilateral and national development institutions) have an important role to play in terms of mobilizing **private sources.**

Although RE investment trends are mostly positive, there are persistent barriers that prevent the private sector from accessing many of the existing investment opportunities.

[139] https://cinea.ec.europa.eu/news-events/news/commission-adopts-first-list-renewable-energy-cross-border-projects-2022-08-30_en
[140] https://cinea.ec.europa.eu/news-events/news/cef-energy-eu-invests-around-eur-300000-studies-future-cross-border-renewable-energy-projects-2022-08-30_en

- Scaling up investment volume through streamlining solar project documentation. The existing contractual framework for RE projects is over-complicated and originally designed for large-scale and technically complex conventional power generation. The overwhelming contractual documentation requirements result in high transaction costs and prolonged project development and finance timelines; hindering further increase in global renewables capacity.

  As a response to the need for a simplified and streamlined contractual framework to unlock greater investments in renewable energy, IRENA and the Terrawatt Initiative ("TWI") jointly launched the Open Solar Contracts Initiative. By simplifying and streamlining contracts for solar PV, the Initiative aims to reduce project review time and transaction costs, and provide a basis for aggregating and securitizing assets to scale up investment volume. The initiative provides a comprehensive and universally-applicable standardized contractual solution for solar power projects.

  The standardised contracts include: (i) Power Purchase Agreement, (ii) Implementation Agreement, (iii) Supply Agreement, (iv) Installation Agreement, (v) Operations and Maintenance Agreement and (vi) Finance Facility Term Sheet; and cover most of the contractual requirements for a solar power project[141].

- Enhancing national capacities for implementing and financing renewable energy. The capacity constraints to take projects from concept to implementation and to lend to RE projects represent two major barriers to enhanced fund flows to RE projects. In response to this need, IRENA initiated capacity building programs for domestic financing institutions and public institutions with the initial pilots in Small Island Developing States (SIDS).

  These capacity building programs, for project development and for project financing, are being implemented with in-house expertise as well as in partnership with international, regional and local stakeholders, to gain from their experience and from best practices globally[142].

  As mentioned during the conference in Vienna, from the Ukrainian perspective it is important to emphasize that it took more than 1.5 years for establishment of guarantee mechanisms for IFI financing in regards to RES projects. It is expected that the process will be over by the end of 2023.

3.5.2 Plans for restoration and further development in Ukraine

As with broader reconstruction efforts, the RE sector will require significant financial support from both public and private partners. Creating a market that can attract capital and compete with other countries pursuing RE will require improvements in Ukraine's RE policy framework. Expanding renewable generation will depend on significant grid modernization efforts and increased storage and export capacity to manage variable generation throughout the system. Two examples on recovery plans are provided in the following sections.

3.5.3 Ukraine's National Recovery Plan

Ukraine has outlined plans that would significantly increase renewable generation capacity as part of the reconstruction effort. Ukraine's National Recovery Plan, unveiled at the Lugano Conference in July 2022, calls for spending about USD 130 billion (equivalent to 65% of Ukraine's GDP in 2021) to achieve energy independence and develop green energy over two recovery phases (2023-2025 and 2026-2032). RE is emphasized in the second phase, with the goal of adding 5 to 10 GW of solar and wind capacity (USD 15 billion), localizing the production of RE equipment (USD 2 billion), building more than 30 GW of RE for hydrogen production (USD 38 billion), and constructing smart grids (USD 5 to USD 10 billion). The scale of these goals is ambitious, to say the least and it was even exceed at the London conference in 2023.

[141] https://www.irena.org/Energy-Transition/Finance-and-investment/Mobilising-Private-Investment
[142] https://www.irena.org/Energy-Transition/Finance-and-investment/Mobilising-Private-Investment

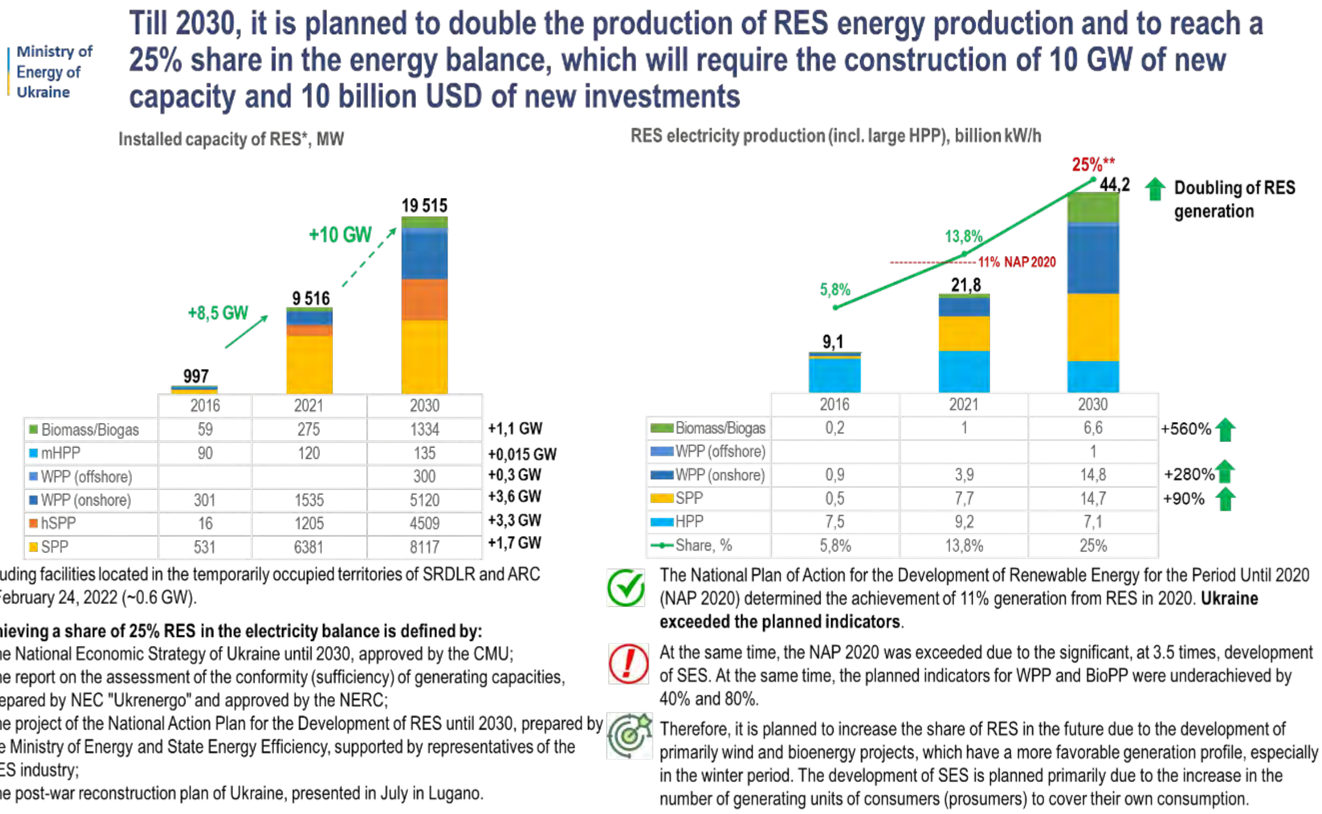


Figure 66 Ukraine National Recovery Plan for RE sector (Lugano)

The plan also calls for increasing interconnection with the EU to up to 6 GW by 2032. While the plan is extensive, it is important to realize that there is a need for a substantial working order to coordinate the work of donors, ensure transparency, adhere to the "build back better" principle, and implement regulations consistent with the green transition and decarbonization course. According to the officials, the main source of reconstruction funds should be the confiscated assets of Russia and Russian oligarchs which is considered to be the easiest mechanism available in case of political will. The other sources would be grants, low-interest loans from international financial organizations, and investments from the private sector.

Unfortunately, the highest potential for RE is concentrated in regions that have been or are currently under Russian control. The development of RE, particularly wind and solar, depends on Ukraine's successful recapture of these territories. The level of destruction in these regions could hinder any new investment or development, as enabling infrastructure such as roads and power grids may need to be rebuilt. Existing installations may also have been damaged. Approximately 66% of solar and wind installations are located in five regions: Odessa, Zaporizhzhia, Mykolaiv, Kherson, and Dnipro. These sites may require additional maintenance and repair as Ukraine reclaims territory.

At the same time when ensuring the further development of renewable generation, it is important to consider the geographical potential of the territory of Ukraine and the peculiarities of the energy system as well as plans for restoration of economic potential and future demand, and economic activities.

By 2021, the vast majority, about 55%, of RE facilities were built in five southern regions (Dnipropetrovsk, Zaporizhzhia, Kherson, Mykolaiv, Odesa). In the next 10 years, priority for the development of RE should be given to regions with insufficiently developed RE capacities and energy deficit regions, mainly northern ones. This will be facilitated by holding of auctions in certain regions (areas), which is provided for by the amendments introduced by Law No. 810-IX to the Law of Ukraine "On Alternative Energy Sources".

Considering the Economic Development Strategy of Donetsk and Luhansk Regions for the period until 2030, approved by the Cabinet of Ministers of Ukraine **Decree No. 1078 of 18 August 2021**, special attention will be paid to the development of renewable electricity in Donetsk and Luhansk Regions[143].

A favorable area for the development of RE is the exclusion zone of the Chernobyl NPP, which has a developed electric power infrastructure and is located in an energy deficit region.

[143] National Action Plan on RES development till the period until 2030.

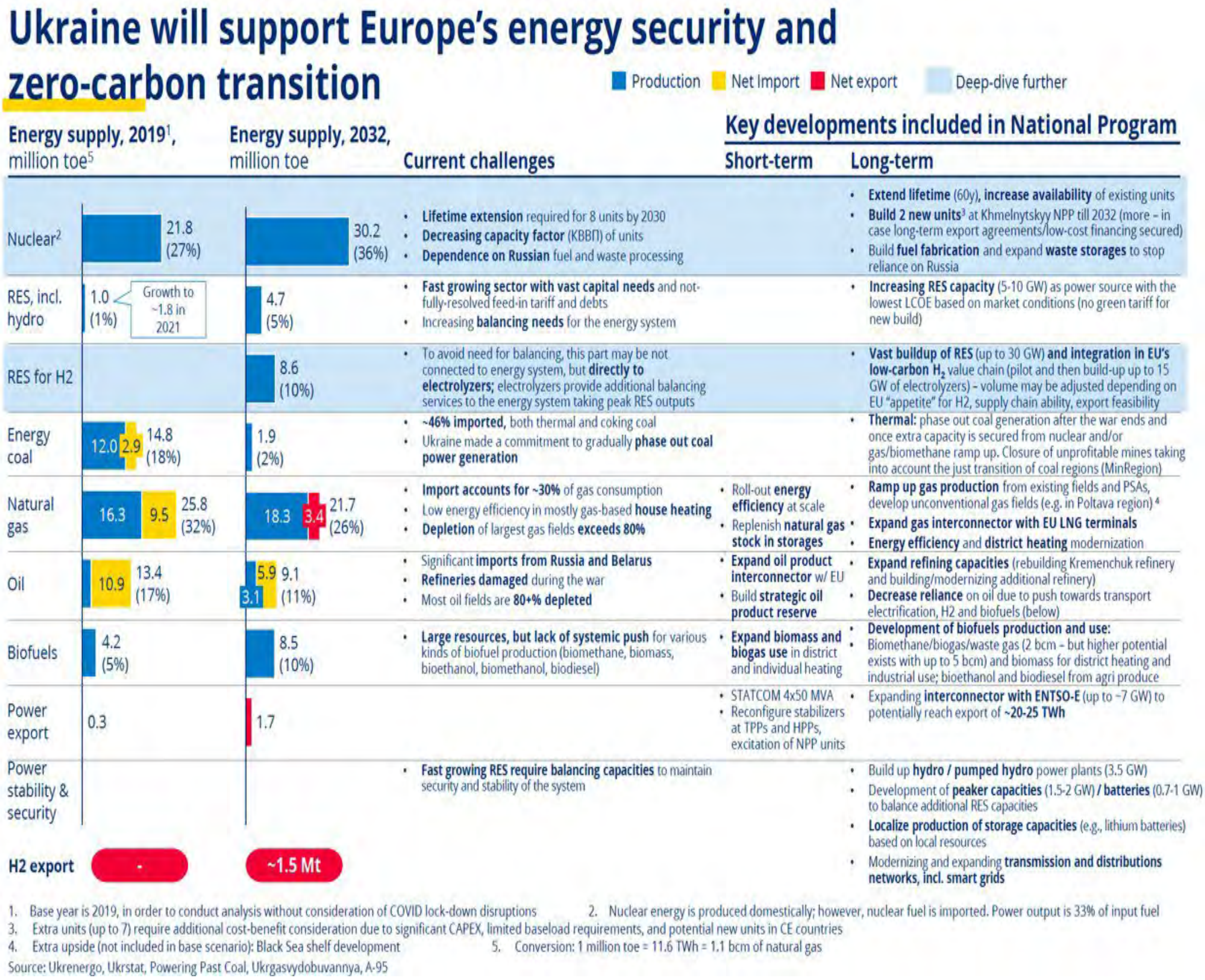


Figure 67: National program No.4 of National Recovery Plan - Energy security and zero-carbon transition

The expansion of RE will also depend on the interconnection and export capacity between the Ukrainian and EU power grids. Integrating the Ukrainian grid with the European grid will be an ongoing effort both during and after the war. After an emergency synchronization of the two systems at the beginning of the war, Ukrenergo (the Ukrainian system operator) and ENTSO-E have connected their systems, but interconnection levels remain low. In the Ukraine Recovery Plan, the country hopes to reach a transfer capacity between Ukraine and Europe of 3.6 GW by 2030 and 6.2 GW by 2040. Expanding interconnection will depend on rehabilitating the Rzeszow-Khmelnytskyi line between Ukraine and Poland, and upgrading segments of the Ukrainian grid to comply with European energy regulations.

At the same time, lawmakers are working on new conditions for RE facilities to keep them financially attractive. These include Contracts for difference, Corporate PPAs, Guarantees of origin and Net billing mentioned above.

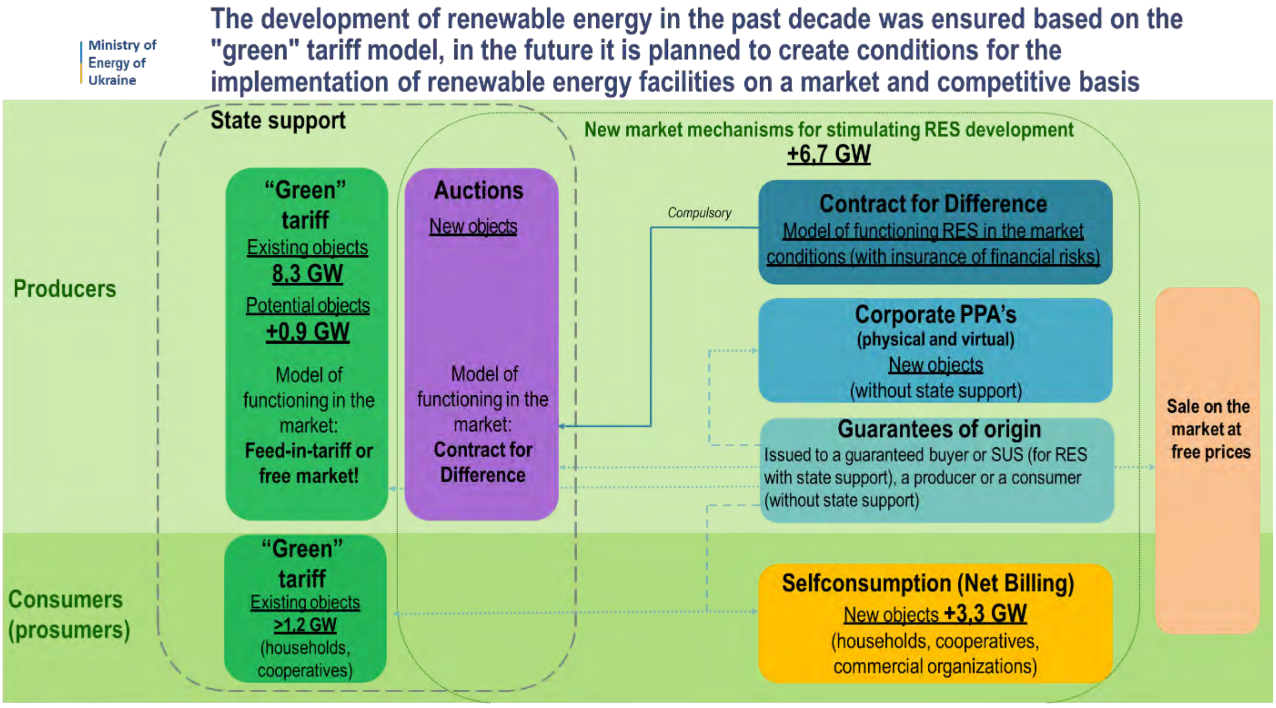


Figure 68 New market mechanisms

Table 3: The components of Energy Security Program

			Capex, bln USD	Duration
Low carbon energy	Nuclear	Increasing nuclear capacity (prolongation, higher utilization of existing capacities, and 2 GW new units at Khmelnytskyi NPP)	~14	2023-25
		Localizing nuclear value chain (uranium mining, plant for fuel production, waste storage)	1.3	2023-25
	RES	Build out 5-10+ GW RES (depends on the export capacity)	~11.5	2026-32
	Balancing	Build out of 3.5 GW hydro and pumped hydro capacities	~3.5	2023-32
		Build 1.5–2 GW peaker and 0.7–1 GW of storage	~2.8	2023-25
	Supporting supply chain	Localize RES equipment production (towers, transformers, cables, solar panels, electrolyzes, Li batteries, etc.)	~2+	2026-32
	Biofuels	Developing biofuels (bioethanol, biodiesel, bio-methane, biomass) production from agroproduced residues and waste	~4.2	2022-25
	Infra-structure	Expanding interconnectors with ENTSO-E to ~6 GW (multiple projects)	0.6	2022
		Smart grids	~5-10	2026-32
		Re-build damaged/destroyed energy objects (CHPs, networks)	~0.4	2022-25
H2	RES	Build 30+ GW RES for H2 production	~38	2026-32
	Infra-structure	Build out ~15 GW electrolyzer capacities	~7	2026-32
		Test and develop H2 transport infrastructure	~2	2026-32
Gas	Production	Increase gas production from existing fields, develop unconventional gas fields (not including Black Sea shelf development~ USD 11 billion)	~18	2023-32

			Capex, bln USD	Duration
	Infra-structure	Modernize gas transmission and distribution networks	~2.5	2023-32
		Securing gas supplies/storage for EU and Ukraine (e.g. extension of Świnoujście/Gdansk LNG and/or inter-connect or import from Turkey/Italy/Germany)	0.7	2023-27
	Stock	Natural gas stock replenishment	~5	2022
Oil	Infra-structure	Expanding oil refining capacity post-war (rebuild, build or modernize 2 facilities) + oil pipeline Brody-Adamova Zastava	~2.5	2023-25
		Expanding oil products interconnectors with EU refineries and ports	0.7	2022
	Stock	Oil, oil products emergency stock for 30+ days (protected storages)	1.2+	2022
Total			**>128**	

3.5.4 Ukraine Facility

The European Commission has proposed the establishment of a new instrument, the Ukraine Facility, aimed at providing consistent financial support for Ukraine from 2024 to 2027. The Facility is designed to address both the short-term state and recovery needs, as well as the medium-term reconstruction and modernization of Ukraine. In response to the challenges of supporting a country at war, the Facility emphasizes predictability, transparency, and accountability of funds.

The Ukraine Facility will consist of three pillars. Pillar I focus on financial support to the Ukrainian state through grants and loans, ensuring stable and predictable funding. To receive support, the Government of Ukraine must develop a detailed 'Ukraine Plan,' endorsed by the EU, outlining its vision for recovery, reconstruction, and modernization, along with planned reforms for EU accession. Pillar II involves a Ukraine Investment Framework to attract public and private investments using guarantees and blended finance. Pillar III encompasses technical assistance and supporting measures, including expertise on reforms, assistance to municipalities, civil society, and other forms of bilateral support.

The first version of Ukraine Plan is delivered to EC on November 3 and contains the following major blocks, according to the Head of Government:

- Macroeconomic scenarios, including the establishment of quality recovery institutions.
- Foundational reforms, encompassing the reform of state governance, measures for managing state finances, anti-corruption efforts, and reform of the judicial system.
- Economic reforms, focusing on improving the business climate, managing state assets, developing human capital, and regional policy.
- Key sectors of the economy that will help Ukraine grow both now and, in the future, including the energy sector, agricultural sector, logistics, IT, critical materials, and manufacturing industry.[144]

The overall budget for the Facility is proposed to be up to €50 billion from 2024 to 2027, provided through a combination of grants, loans, and budgetary guarantees. The newly proposed Ukraine Reserve, part of the Multiannual Financial Framework mid-term review, aims to provide at least €2.5 billion annually for grants and guarantees. Loans will be guaranteed by the 'headroom,' representing the difference between the own resources ceiling and the funds needed by the Commission.

The Facility aligns with the EU's commitment to play a significant role in Ukraine's macro-financial and recovery support. It encourages other donors, including third countries, international financial institutions,

[144] https://www.radiosvoboda.org/a/news-shmyhal-kabmines-plan-ukraine-facility/32669073.html

and organizations, to contribute to the implementation of the Ukraine Plan. Despite uncertainties arising from Russia's war of aggression, the Facility is designed to provide flexibility and programmability, adapting to Ukraine's evolving needs. The Regulation also allows Ukraine to request amendments to the Ukraine Plan if pre-established conditions become unachievable due to objective circumstances.

As of 16.12.2023 the decision on allocation funds for Ukraine facility **was blocked**[145] by a decision of Viktor Orbán, prime minister of Hungary. All 26 EU countries except Hungary, had come to an agreement on "all components" of the budget revision, including the funds for Ukraine. Leaders will get a second chance to strike a deal at an extraordinary summit expected to be held in Brussels in January 2024.

The principle of unanimity, the rule that any decision in the European Union (EU) must be approved by all member states may become another critical bottleneck for Ukraine's EU integration and survival of nation in general. This means that any one country can veto any proposal, regardless of how many other countries support it (even all the rest as with Ukraine facility fund).

3.5.5 Streamline of financing

In 2019, Ukraine entered the top-10 countries in the world in terms of RE development, and in 2020 - in the top-5 European countries in terms of solar energy development[146]. Since 2019, investments in new RE projects in Ukraine have been consistently higher than in fossil fuel projects. In the past 10 years, international and Ukrainian RES investors invested more than USD 12 billion in the Ukrainian economy, and the share of foreign investors in the installed RES capacity as of the end of 2021 exceeded 35%. Today, the list of the largest international creditors and investors in the RES sector in Ukraine includes the European Bank for Reconstruction and Development, the Black Sea Bank for Trade and Development, the American International Development Finance Corporation, the Federal Land Bank of Bavaria BayernLB, the Investment Fund for Developing Countries, NEFCO and many others. Investments in the Ukrainian RE power plants came from China, the USA, Great Britain, Germany, the Netherlands, Sweden, Denmark, Norway, France, Luxembourg, Belgium, Spain, Canada, Turkey, etc.

International funding has long been an important source of capital for Ukraine's energy sector. Development banks will play an important role in unlocking private sector investment potential in the RE sector. MDBs can provide essential loan and risk insurance products to enable both short- and long-term investment. This involvement would build on in-country experience. The European Bank for Reconstruction and Development (EBRD) has played an important role in the renewable energy and broader energy sectors in Ukraine. In 2009, the Bank launched the Ukraine Sustainable Energy Lending Facility (USELF) to support hydropower, biomass, wind and solar projects. The program provides loan-based financing as well as technical advice and training to enable project development. More recently, the EBRD offered EUR 149 million (USD 158 million) to Ukrenergo to upgrade Ukraine's power transmission system and further efforts to synchronize with the European grid. Lessons from these earlier projects can be used to tailor interventions during the reconstruction process, including combining financing instruments with opportunities for technical advice and input. Institutions with expertise in Ukraine's energy sector should work with Ukrainian and international actors to target project funding and provide technical assistance where needed.

U.S. development banks will also be important partners for investors in the RE sector. USAID has significant experience in Ukraine's energy sector, having led U.S. efforts to assist in the war. Fostering partnerships with the United States and other Western countries to address immediate damage to the power sector can lead to effective partnerships for reconstruction. The U.S. International Development Finance Corporation (DFC) has also increased its activities in Ukraine and Eastern Europe; as of October 2022, the organization had more than a dozen projects in the country worth USD 700 million. The DFC can provide technical assistance grants and feasibility studies to accelerate project identification, planning and financing. Political risk insurance can also help reduce project risk for investors. The DFC offers political risk insurance that covers up to USD 1 billion in losses caused by political violence, including war, terrorism, and hostile actions by national or international forces. This support is likely to be essential throughout the reconstruction process to attract investment and manage project risk.

Currently, investment flows for Ukraine's reconstruction are significant, exceeding half of Ukraine's GDP in 2022, and these are not just humanitarian investments.

[145] https://www.euronews.com/my-europe/2023/12/15/hungarys-orban-blocks-eus-50bn-long-term-financial-support-to-ukraine

[146] https://mcl.kiev.ua/en/otsinka-vplivu-na-dovkillya-dlya-pidpriyemstv-yaki-zajmayutsya-himichnim-virobnitstvom-ta-pratsyuyut-v-galuzi-himichnoyi-promislovosti/

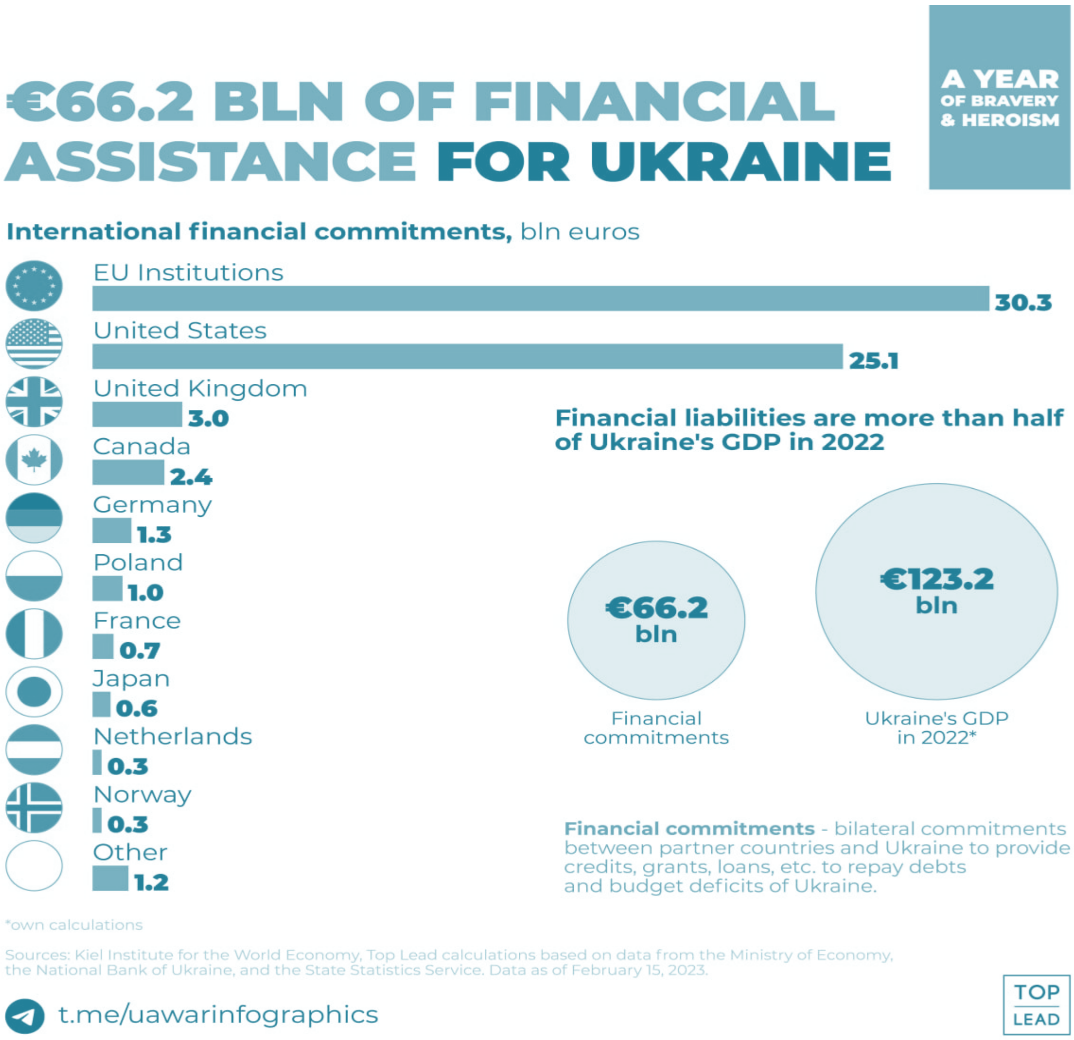


Figure 69: Investment flows

Europe will play an important role in Ukraine's reconstruction as the country moves forward in the EU accession process. It will be important to identify areas of cooperation between U.S. agencies and financial institutions and their European counterparts. These initial plans and relationships should be developed today.

Ukraine's renewable energy sector, despite the ongoing war, is receiving a boost from international support. The U.S. DFC has committed project work grants, creating a pathway for future wind farms. While the EBRD remains cautious due to war risks and will initially prioritize Western investors, it stands ready to support national projects in the future.

This international support is crucial for Ukraine, which is rich in wind resources and actively seeking sustainable energy solutions. Wind power aligns with the country's climate goals and serves to reduce dependence on imported fuels, a strategic priority post-war. Despite challenges such as infrastructure damage and the need for large-scale financing, Ukraine's future in wind energy appears promising, thanks to both international backing and the inherent advantages it possesses.

Energy Support Fund for Damage Recovery

In agreement with the European Commission the Ministry of Energy of Ukraine, the Ukraine Energy Support Fund was established to counteract the impact of the Russian attacks targeting critical energy infrastructure. The Fund enables governments, international financial institutions and international organizations as well as corporate donors to provide financial support to the Ukrainian energy sector's efforts to repair that damage and keep functioning.

The procurement is conducted by an external procurement agent, Tetra Tech ES, Inc., implementer of the USAID funded Energy Security Project. The process is overseen by the Energy Community Secretariat. Whilst the procurement agent selects the supplier and negotiates the terms and conditions of the Supply Agreement, the Secretariat, acting as manager of the Fund, is responsible for the payment of the said goods and/or services. A contract is concluded directly between the supplier and the Ukrainian energy company.

- Contributions amounting to a total of EUR 30,124,821 have been transferred by 9 donors to the Special Purpose Account, adding up to a total of EUR 165,892,812 by altogether 14 donors since the establishment of the Fund in 2022;
- Essentially all funds credited to the Special Purpose Account have been committed to finance items requested by 42 different Ukrainian Counterparties;
- Procurement resulted in the conclusion of 53 Purchase Agreements, the total value of items contracted amounting to EUR 32 million.

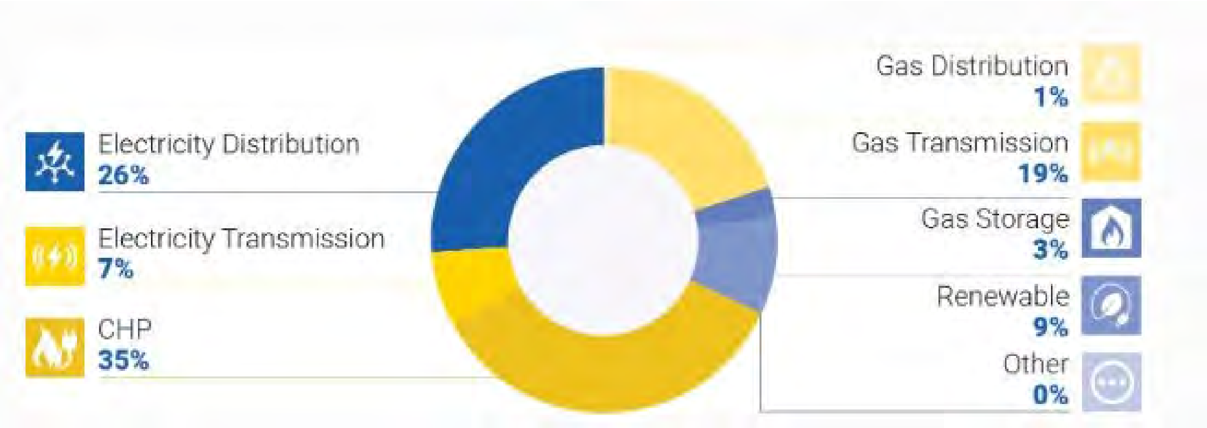


Figure 70: Activity of Ukrainian Counterparties supported through the Fund, in % on the basis of the value of the items requested[147]

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[148] Proofs may be the booked capacity and payments under Grid connection Agreement, financial closure documents and proofs from financial institutions on ability to finance or progress with Civil works and delivered equipment or other similar mechanisms to be foreseen by legislation

3.6 Conclusions and Recommendations

Conclusions

The full-scale Russian invasion of Ukraine is the largest challenge of the sector. The other important challenges are the technical, legal and economic issues. Among pre-war challenges are the intermittent nature of RE, uncoordinated issuance of technical conditions by TSO/DSOs, lack of forecasting capabilities, retroactive tariff, uncertainty in RE auctions and PPAs, insurance challenges, logistics in Western Ukraine and negative progress in simplification of legislation.

War-implied challenges are as follows: decrease in system stability and balancing capacity, need for forecasting and curtailment, damage of all TPPs, damage to backbone networks, risk of further escalation, limited payments under FIT.

The cost-effective options for accelerated renewables deployment are as follows: FIT(s) and PPAs, competitive auctions, financial incentives, Net Metering and FITs for small-scale installations, grid modernization, storage integration, R&D, streamlined Permitting and Licensing, Public-Private Partnerships, Community-Based Renewable Energy, Energy Efficiency Programs, Education and Outreach, Long-Term Planning, Economies of Scale, Carbon Pricing.

The transition to zero emissions will drive innovation and economic growth, and create new jobs. It will improve living standards – particularly in developing economies – through reduced local air pollution and related health impact; lower energy bills for households, thanks to cheap electricity and more efficient buildings; provide more flexible mobility services; and produce higher-quality, more durable consumer goods.

Currently, alternative clear, transparent, predictable and reliable financial and managerial framework will create a basis for private investors to proceed with financing and future development of the RES sector in Ukraine.

Recommendations

- Extension and implementation of legislative framework: the Law 3320-IX has to be further amended based on feedback from RES sector and concerned stakeholders, secondary legislation to be developed allowing to revitalize the sector
- Elimination of debts to producers: One of the foreseen solutions – introducing clear zero-deficit tariff for Ukrenergo and relevant communication producers assuring further streamline of financing
- Elaborate mechanism for covering military risks: The issue of covering military risks has not yet been resolved significantly limiting any investment activity
- Use of successful institutional experience of other countries: Instead of creating something new from the scratch many incentives can be integrated from the experience of such countries as Denmark, Netherlands and Germany, to do so negotiations with these countries are ongoing. For example, in terms of approvals associated with grid connection – these further may be on paid basis to avoid flow of unrealistic developments limiting the grid access for the projects ready to invest.
- Utilize the Cost-effective options for RES development: Please refer to the list of actions foreseen in Clause 3.3
- Extension of Technical Conditions Investors who were ready to build there objects before the full scale invasion started shall be able to proceed with their plans so a very clear and transparent extension of Technical Conditions shall be arranged – 5 years for projects which are proven to be built[148]

[148] Proofs may be the booked capacity and payments under Grid connection Agreement, financial closure documents and proofs from financial institutions on ability to finance or progress with Civil works and delivered equipment or other similar mechanisms to be foreseen by legislation

4 FURTHER DEVELOPMENT OF RENEWABLES

This Final Chapter delves into various strategies, mechanisms, regulatory frameworks, pricing instruments, and complementary technologies that are pivotal for fostering the growth of the renewable energy sector. The focus is on creating a conducive environment for renewables to thrive, considering the multifaceted nature of the energy sector. Key areas of exploration include risk insurance mechanisms, corporate PPAs options, market and regulatory processes, technologies that support the integration of renewable energy into the grid. This includes smart grid technologies, energy storage solutions like batteries and pumped hydro storage, and demand-side management tools. The role of emerging technologies such as hydrogen fuel cells and advanced bioenergy solutions is also explored. Planning instruments to optimise the electricity generation mix linked to demand-side measures and infrastructure development are also assessed along with options for streamlining permitting procedures for renewable energy projects. Each of these elements plays a crucial role in shaping a resilient, sustainable, and economically viable renewable energy sector, aligned with global climate goals and local developmental needs.

4.1 Insurance mechanisms to mitigate risks and allow financing of new renewables projects

Providing war-related risk insurance to private investors is key to Ukraine's resilience.

The European Bank for Reconstruction and Development (EBRD), European Commission, Norway, Switzerland, TaiwanBusiness - EBRD Technical Cooperation Fund and Ukraine signed a Statement of Intent for relaunching the private insurance market to support resilience and reconstruction of Ukraine on 21 June 2023 at the Ukraine Recovery Conference in London.

Russia's war on Ukraine has all but closed this market, yet making insurance available to private investors is key to ensuring resilience in wartime and a successful reconstruction later.

Insurance is a crucial area of endeavor to support Ukraine's economic resilience. The latest needs assessment for Ukraine, carried out by the World Bank and partners and published on 24 February 2023, showed the country had suffered physical damage of USD 135 billion after a year, and would need USD 411 billion to rebuild over a 10-year period. While international finance to Ukraine thus far has largely been from countries and international organizations, given the enormous needs of reconstruction the private sector will also need to play a major role going forward.

The challenge is providing the right insurance for these private-sector investors.

Agreeing that a public-private partnership approach is necessary to develop the market at the required reasonable scale, the signatories agreed to work together to achieve this goal. The signatories will explore the possibility of cooperating on establishing a Ukraine Recovery Guarantee Facility, in partnership with leading international private-sector institutions, aiming to facilitate the provision of private-sector insurance against war-related risks in Ukraine. This would initially focus on trade but have the potential to expand to other segments of the insurance market[149].

As mentioned by UHE specialists during the 14th European-Ukrainian Energy Day 2023 conference in Vienna on 29 September 2023 currently the problem exists in terms of provision of insurance during the wartime allowing the recovery of Ukraine. For instance, impossibility to provide insurance for the international staff working in Ukraine (the cost of such insurance is extremely high) is blocking the possibility for expedient re-building projects foreseeing the on-site presence of international experts.

In order to get financing from IFIs it is required to get bankable projects, which includes among others reliable insurance coverage of the critical risks associated with the project.

Similarly, project insurance mechanisms are necessary to ensure EPC services by credible contractors and international equipment manufacturers. The absence or non-availability of relevant insurance products makes it challenging for local developers to engage credible international partners in Ukrainian projects.

[149] https://www.ebrd.com/news/2023/international-move-to-unlock-war-insurance-for-ukraine-investments.html

For instance, due to this situation, local developers of renewable energy facilities under construction in 2023-2024 had to halt construction. They were compelled to negotiate remote commissioning with international EPC contractors and agree on the involvement of local subcontractors, leading to additional delays and resource allocation for the projects.

Therefore, Insurance mechanisms can play a crucial role in mitigating risks associated with RE projects and attracting financing in Ukraine. These mechanisms provide a level of financial security for investors and project developers, making RE projects more attractive. Here are several insurance mechanisms that can be implemented:

War Risk Insurance:

War Risk Insurance is critical to unlock construction of RE facilities and associated infrastructure in the nearest future. The war risk shall include any damages directly or indirectly caused by the military activities and armed aggression including but not limited to the property and equipment damages, logistic interruptions, and damages to the grid infrastructure, which impair the launch of the project.

The agencies providing War Risk Insurance are summarized below in the Political risk section.

Political Risk Insurance (PRI):

PRI protects against losses arising from political events, such as regulatory changes, government actions, or currency exchange rate fluctuations. In Ukraine, where political stability can be a concern, PRI can provide confidence to investors.

Political risks refer to the uncertainties and potential negative outcomes for investors due to governmental actions. These can include loss or devaluation of assets due to war, revolutions, or government seizures, as well as restrictions on profit repatriation. To mitigate these risks, investors may opt for political risk insurance (PRI), which transfers the risk burden to third parties such as insurance agencies. PRI is typically offered by international organizations like the **Multilateral Investment Guarantee Agency (MIGA)** [150]or by state-sponsored export credit agencies (ECAs). PRI generally covers risks like currency inconvertibility, confiscation, political violence, and default on financial obligations. However, the availability of PRI is variable, as indicated by most credit agencies freezing limits for Ukraine, with exceptions like MIGA, DFC (USA), UKEF (UK), and others considering or providing coverage. The need for specific types of PRI, such as war risk insurance, might vary over the duration of an investment project[151].

In efforts to attract and protect investors amidst military risks, Ukraine's government has been actively engaging with the Multilateral Investment Guarantee Agency (MIGA). In 2022, MIGA disbursed $30 million for a pilot investment insurance project in Ukraine and received an application from Raiffeisen Bank International for a €50 million expropriation of funds cover. However, by early 2023, MIGA faced challenges in processing applications due to reinsurance limitations and its products were not available to Ukrainian companies. To address the broader needs of post-war recovery and economic support, MIGA introduced the Support to Ukraine’s Reconstruction and Economy (SURE) Trust Fund, initially funded by Japan and expected to grow significantly. This initiative aims to provide trade finance guarantees, support liquidity for SMEs, and cover essential imports and real sector projects, preparing for the country's reconstruction in sectors like transport, housing, and energy once the conflict stabilizes.

As mentioned couple of times previously, the **DFC**[152] offers political risk insurance that covers up to USD 1 billion in losses caused by political violence, including war, terrorism, and hostile actions by national or international forces. DFC has introduced measures in Ukraine to bolster private investment, offering capital insurance up to 85% and full debt insurance. It is ready to provide direct lending alongside credit and political (military) risk coverage. The credit risk insurance entails that insured borrowers can seek loans from commercial banks or other financial institutions. As of February 23, 2023, DFC has shown increased commitment to insuring Ukrainian businesses, including those initiated by Ukrainian investors, although it faces limitations and requires refinancing to expand its capabilities.

On the 8th of June 2023, **the United Kingdom** initiated the formulation of a sophisticated war-risk insurance scheme, intended to entice corporations within the investment, technology, energy, and

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[150] https://www.miga.org/support-ukraines-reconstruction-and-economy-trust-fund-sure-tf

[151] https://www.bdo.ua/getmedia/1ab1237f-ad6f-4f3b-af07-53d6b9db228f/Investor-s-Roadmap12_12_2023-2.pdf

[152] https://www.dfc.gov/what-we-offer/our-products/political-risk-insurance

defense sectors to contribute substantially to the reconstruction efforts of Ukraine. The objective is to manifest tangible advancements in this scheme within the current month, as conveyed by knowledgeable individuals.

It is anticipated that while national governments will commit to a certain degree of direct financial aid for Ukraine, the facilitation of private capital investments, bolstered by governmental underwriting, is being considered a more financially prudent approach to amass further monetary support for Ukraine's rehabilitation.[153]

Following a favorable decision by the Export Insurance Policy Committee and backed by the Polish government, **KUKE** reinstated insurance coverage for receivables from goods exported to Ukrainian buyers on June 13, 2022. However, service export insurance might face limitations due to a payment moratorium initiated by the National Bank of Ukraine on February 24, 2022.[154]

On April 26, 2023, Italy's Export Credit Agency, **SACE**, announced its readiness to recommence operations in Ukraine, marking a significant indication of support for Italian businesses. In addition to an earlier pledge of €500 million, SACE has committed an additional €1 billion to bolster trade and financial activities with Ukraine.[155]

Other national Agencies such as German[156], Japanese (NEXI)[157], EKSFIN[158] (Norway) and others are considering insurance coverage for Ukraine.

Currency Exchange Risk Insurance:

Given the potential volatility of the Ukrainian hryvnia, insurance against currency exchange rate fluctuations can protect foreign investors from unexpected losses.

Property and Equipment Insurance:

Standard insurance policies covering property damage, equipment breakdown, and other physical risks can safeguard RE assets like solar panels and wind turbines from damage or loss due to unforeseen events.

Force Majeure Insurance:

This type of insurance covers project interruptions caused by force majeure events, such as natural disasters or extreme weather conditions, ensuring that projects can recover from such setbacks.

Revenue Guarantee Insurance:

These policies can guarantee a certain level of revenue for RE projects, protecting investors from fluctuations in energy prices or unexpected drops in energy production.

Completion Guarantee Insurance:

Completion guarantees assure lenders and investors that a project will be completed on time and within budget, mitigating construction and development risks.

Performance Guarantee Insurance:

Performance guarantees can cover the energy production output of renewable projects, ensuring that they meet specified performance standards. If performance falls short, the insurer may compensate for the loss in energy generation.

Environmental Liability Insurance:

This insurance can cover the costs associated with environmental damage or pollution caused by a RE project, helping mitigate potential legal and financial liabilities.

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[153] https://www.bloomberg.com/news/articles/2023-06-08/uk-eyes-war-risk-insurance-scheme-for-ukraine-s-reconstruction
[154] https://kuke.com.pl/en/news-and-insights/kuke-restores-insurance-cover-for-ukraine
[155] https://www.pravda.com.ua/eng/news/2023/04/26/7399531/
[156] https://eba.com.ua/en/nimetskyj-uryad-nadaye-garantiyi-dlya-novyh-nimetskyh-investytsij-v-ukrayinu/
[157] https://www.nexi.go.jp/en/topics/newsrelease/202311130149.html
[158] https://nucc.no/supporting-ukraine-through-partnership-a-recap-of-outlook-ukraine/

Insurance for Off-taker Default:

In cases where RE projects have Power Purchase Agreements (PPAs) with off-takers, insurance can protect against defaults by the off-taker, ensuring a predictable income stream.

Construction Risk Insurance:

During the construction phase, this insurance can cover risks related to delays, cost overruns, or construction defects.

Insurance for Transmission and Grid Connection:

Grid connection and transmission risks can be substantial. Insurance can protect against delays or disruptions in connecting the project to the grid.

Insurance for Technology Performance:

Some insurers offer coverage for the performance of specific RE technologies, helping mitigate technology-specific risks.

Customized Insurance Solutions:

Work with insurers and risk management experts to develop tailored insurance solutions that address the unique risks of each RE project in Ukraine.

To effectively implement these insurance mechanisms, Ukraine should work on creating a regulatory environment that encourages insurers to offer such policies, and it should provide support and incentives to make insurance more affordable for RE project developers. Additionally, collaboration with international financial institutions and organizations experienced in risk mitigation and insurance can be valuable in developing and implementing these mechanisms effectively.

On 22 November 2023 the Verkhovna Rada of Ukraine adopted the Law On amendments to the Law of Ukraine “On financial mechanism for promoting export activities” regarding insuring investments in Ukraine against military risks (draft law No. 9015 dated 14 February 2023).

The law expands the authorities of the Export-Credit Agency of Ukraine (hereinafter - the “ECA”). From now on, the ECA has the authority to conduct the following activities:

Insurance and reinsurance of loans of Ukrainian commercial entities, related to investments into objects and infrastructure, required for development of processing industry and export of goods (works, services) of Ukrainian origin against military risks; insurance and reinsurance of direct investments into Ukraine against military risks.

The Law will enter into force on 1 January 2024 subject to its signing by the President of Ukraine and official publication*[159]*. However, while the law creates the legal framework for state insurance of the war risks, its efficiency will be directly linked to availability of funds for such insurances which shall be involved from IFIs, international donors and other sources.*

4.2 Options for fast implementation of corporate PPAs

Despite possibly the most turbulent year in recent history for the European energy markets, the number and volume of PPAs in the European markets remained impressively stable. 2022 saw disclosed contracted volumes of 8.4GW – a 21% decrease with respect to 10.7GW in 2021. Deal count increased 4.5% year-on-year, with a total of at least 161 deals in lieu of 154 the year before.

Corporate PPAs accounted for an impressive 80% of deal count (129 out of 161), and 83% of contracted volumes (7 GW out of 8.4 GW). Activity increased at least 20% by disclosed contracted volumes, which in 2022 scaled to 7 GW with respect to 5.8 GW in 2021. In terms of deal count, increase rate reached around 29%, with 129 deals in lieu of 100 in 2021.

Hedging against rising and volatile prices was one of the main drivers of this year’s corporate PPA ‘miracle’. – **Instead of procuring power for the near-term future, as energy-intensive corporates typically do, they spread the high front-year costs by the means of a long-term PPA** to achieve an averaging effect and to be shielded from sky high front-year contracts.

[159] https://www.pwc.com/ua/en/publications/tax-and-legal-alert/2023/war-risks-insurance-law.html

Information Technology (IT) kept its first spot for largest procurement volumes in MW. – With a total of 1.9 GW disclosed capacity, across 14 deals the likes of Meta (Facebook), Amazon, Equinix, Google, Microsoft and more ensured IT remained as the 'hungrier' corporate segment. Metals & Mining observed the largest year-on-year growth, and came to a close second position.

Balancing costs, the tendency to link PPA prices to inflation and spot prices and counterparty/credit risk were the most notable observations in this year's PPA deal making. – In 2022, spiking costs became a notable issue for Balancing Responsible Parties (BRPs), with many sellers facing lengthy work to close terms for such agreements. Amid a volatile environment, market participants' imagination and willingness to strike more flexible price terms were noted. Counterparty risk was one of the most prominent reasons PPA negotiations did not succeed.

The year experienced extreme volatility levels throughout, but two spikes are the ones to be remembered the most: January 2022, and September 2022 where volatility reached up to 230%. From January 2022 to December 2022, the monthly average EURO Composite Index increased by 23%.

Extreme backwardation led to price disparity between short- and long-term PPAs. – As contracts for deliveries in the near term started getting priced significantly higher compared to longer dated ones, the forward curve lost its flat shape. As a result, short-term PPAs were priced significantly higher than long-term ones.

The turmoil led to significantly increased spreads in PPA price bids with regards to benchmark prices. – Risk appetite, portfolio benefits, risk metrics, funding cost differences and decreased competition in utility offtakes gave rise to utility off-takers quoting a wide range of prices for the same transaction.

The leverage of short-term PPAs was the risk management play of the decade. – Extreme backwardation offered lucrative opportunities for sellers to take advantage of the liquid price horizon, especially 1-3 years ahead. Whenever the regulation allowed, there was also a rush among nimble players to opt out from subsidy schemes – either permanently or temporary – to capitalize from the attractive sales opportunities on the open market. A prime example was Germany's EEG market segment.

Merchant appetite led to innovative financing structures. – Prices at times were at such high levels, that certain financings could be arranged on the basis of such comparatively very short tenors. Increased availability of debt construction facilities allowed flexibility of asset owners to make sales decisions outside the 10-year PPA. Some IPPs pre-financed merchant assets on an equity basis, refinancing them on portfolio basis comprised of assets with long-term revenues, taking advantage of portfolio effects.

Certain assets under Baseload PPAs faced agonising losses due to unmanaged positions. – Rising prices did not benefit all projects. High prices, cannibalization and unforeseen deviations from production forecasts created the perfect storm for eye-popping cash outflows and losses for assets with the wrong risk assessment, especially in the Nordics' area.

Evolving regulatory environment will play a key role in which markets will experience healthy activity in 2023. Regulatory uncertainty is having an impact on PPA revenues and investor return expectations, while significantly increasing reporting requirements.

In the first half of 2023 Ukrainian Parliament has passed the legislation which removed significant regulatory restriction unlocking some potential for the PPAs. This means removed provisions allowing the Regulator to limit the maximal duration of the PPAs executed by the RE producers, amended regulation of virtual PPA, defined the aggregator's legal regime in the electricity market and created legal framework for implementation of guarantees of origin.

In Ukraine, PPA could be deemed as the most desirable instrument for utility-scale renewable energy development subject to the unpredictable electricity market, low-reliability of the RES support schemes proposed by the Government[160] and adverse regulatory practices by NEURC[161].

However, due to the reasons stated below PPAs remain tailored and limited-available instrument for the vast majority of Ukrainian power producers and consumers.

The following options and strategies should be considered to expedite the adoption of corporate PPAs in Ukraine:

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[160] According tot he information provided by the SE "Guaranteed Buyer" cumulative debt before the RES producers under the FiT is ammountin to UAH 31,7 billion.

[161] https://www.energy-community.org/dam/jcr:4c176023-d2cf-4dda-956d-fe65308b7503/Note17_NEURC%2024102023.pdf

4.2.1 Establish Competitive Market

The energy market of Ukraine has been reformed during the last couple of years. In the context of renewable energy and corporate PPAs, an established competitive market refers to an environment where multiple RE producers can generate electricity from renewable sources and offer it for sale to corporate consumers. A consistent regulatory environment reduces the perceived risks associated with investing in RE projects and requires to be detailed in form of secondary legislation following the approved 3220-IX draft (please refer to Ch. 1.6.2 for more details).

Most of the PPA models envisage pricing formula which is based on the market price indexes of the electricity. However, Ukraine lacks reasonable market-based pricing subject to the following factors:

- PSO mechanism for households which impairs pricing and decreases competition by reducing demand in the competitive market segments;
- large share of the state-owned or state-controlled power generation in the electricity market;
- unpredictable regulatory policy by NEURC;
- large volume of debts in various segments of electricity market.

Reasonable Non-Regulated Pricing Policies: In a competitive market, pricing should be driven by supply and demand forces, with minimal government interference in setting prices. However, it is important to strike a balance to ensure fairness and affordability for both RES producers and corporate consumers. Reasonable pricing policies mean that prices should reflect market dynamics, but they should not be excessively high, ensuring that energy remains accessible to consumers.

Incentives for Risk Mitigation: To encourage RES producers to enter into corporate PPAs, there should be mechanisms in place to mitigate risks associated with the offtake of renewable energy. These risks can include fluctuations in energy production due to weather conditions, technological issues, or grid constraints. Corporate consumers, on the other hand, may be concerned about price volatility. Incentives, such as financial instruments or government support, can help mitigate these risks and encourage more corporate PPAs.

Transparency: A competitive market should prioritize transparency in pricing, transactions, and contracts. This transparency builds trust among stakeholders and helps ensure fair dealings.

4.2.2 Streamline Regulatory Processes:

Streamlining regulatory processes refers to the effort of making it easier, faster, and more efficient for businesses and RE producers to engage in these agreements. The objective is to reduce bureaucratic hurdles and complexities associated with obtaining approvals and permits for such agreements. Ukraine is actively moving forward to limiting bureaucratic procedures in different spheres of life. New electronic services were developed by the Ministry of Digital Transformation in order to simplify the time consuming permitting procedures in civil construction etc.

However, the regulations in energy market are still require major attention of the Government. E.g. on September 8, 2022, the Supreme Court has invalidated NEURC resolution implementing amendments to RES imbalance settlement formula which caused the industry approx. UAH 5 billion damages in 2021-2022[162]. Despite existence of the relevant court decision the updated formula has not been adopted as of the date of this report.

Regulatory Reforms: Advocating for regulatory reforms involves working with relevant government agencies to revise and update existing regulations or create new ones that are more conducive to corporate PPAs. These reforms should aim to simplify and expedite the approval process for entering into corporate PPAs. This may involve changes in legal and regulatory frameworks that govern energy procurement and distribution. In addition more actions to ensure regulatory capacity and independence of NEURC are required.

Complex Price Formulas: Allowing the use of complex price formulas in PPAs can provide flexibility for businesses and RE producers to structure agreements that suit their specific needs. This flexibility can

[162] See resolution of the Supreme Court in case no. № 640/4069/21 - http://iplex.com.ua/doc.php?regnum=106140918&red=1000039c0aaf3377bba4d7d02d9a89c83959eb&d=5

enable parties to adapt to market conditions, changing energy demand, and evolving technologies while ensuring fair pricing.

Simplified Provisions: Simplified provisions for physical PPAs, often referred to as 'direct line' agreements, can reduce the complexity of contractual arrangements. These provisions outline the terms and conditions of energy supply in a straightforward manner, making it easier for businesses to understand and navigate the contractual relationship with RE providers.

Cable Pooling: Cable pooling involves sharing the costs and benefits of connecting RE projects to the electrical grid. Advocating for the implementation of cable pooling can help reduce the costs associated with grid connection, making it more attractive for RE producers to supply electricity to corporate consumers.

Tradable Derivatives: Introducing tradable derivatives for electricity can create additional opportunities for risk management and hedging in corporate PPAs. These financial instruments can help parties manage price fluctuations and uncertainty in the energy market, adding stability to long-term agreements.

4.2.3 Support Mechanisms:

Market support mechanisms are tools and policies that governments can introduce to create a more favourable environment for RE investments and corporate PPAs. These mechanisms are designed to incentivize the production and consumption of clean and sustainable energy sources. The listed below market support mechanisms create an environment where renewable energy becomes economically viable, competitive, and aligned with corporate sustainability goals. This, in turn, encourages corporations to pursue PPAs with renewable energy producers as part of their energy procurement strategies.

Taken together the latter mechanism shall be aimed to increase value and demand of the electricity originating from renewable energy sources, as well as to mitigate producers' long-term risks to ensure bankability of the projects in Ukraine.

With regard to RED III Directive (EU/2023/2413) entered into force on November 20, 2023 the following support mechanisms could be considered to support and boost RE investments in Ukraine:

Feed-in Premiums: Feed-in premiums are incentives provided to RE producers in addition to the market price for electricity. These premiums are often higher than the market price and are intended to make RE projects more financially attractive. By encouraging the government to introduce feed-in premiums, RE producers are more likely to invest in new projects, leading to increased capacity for clean energy generation. The Law of Ukraine No. 3220-IX introduced a market feed-in premium mechanism, however, as of the date of this report, the subordinate acts for the implementation of this mechanism are still not developed.

Guarantees of Origin: Guarantees of Origin, also known as Renewable Energy Certificates (RECs), are tradable certificates that represent a specific amount of renewable energy generated. Encouraging the use of green certificates in Ukraine can create a market where RE producers can sell these certificates to corporate consumers or utilities. Corporate consumers can then use these certificates to demonstrate their commitment to using renewable energy. The Law of Ukraine No. 3220-IX introduced the Guarantees of Origin in Ukraine. The Law provides for the procedure for issuing, circulating, and redeeming guarantees of origin to be approved by the Cabinet of Ministers of Ukraine separately. As of the date of this Report, the procedure have not been issued.

Emission Taxation: Increasing emission taxation can create a financial incentive for businesses to transition to renewable power sources. Higher taxes on emissions from fossil fuels make RES comparatively more attractive from a cost perspective. This can drive demand for renewable power, which can be secured through corporate PPAs. As of the date of this Report, the lowest carbon tax rates in Europe can be found in Ukraine (€0.75, $0.82)[163].

Renewable Energy Targets: Setting clear and ambitious RE targets can provide a strong policy signal to the market. These targets can mandate a certain percentage of energy to come from renewable sources by a specific date. This regulatory framework can drive investments in RE projects and create a

[163] https://taxfoundation.org/data/all/eu/carbon-taxes-in-europe-2023/

larger pool of renewable energy for corporate PPAs. The targets, provided by the Strategy 2050 are not available to the public yet, so this point is to be further studied.

Tax Incentives: Providing tax incentives, such as tax credits or deductions, to businesses that engage in corporate PPAs or invest in RE projects can reduce the overall financial burden and make such initiatives more attractive from a cost perspective. The 2018 tax incentives provided VAT release for import of PV modules and inverters for solar producers. The initiative was cancelled in May 2020.

By encouraging the government to introduce these market support mechanisms, Ukraine can create a more favourable and financially attractive environment for RE investments and corporate PPAs. These incentives can accelerate the transition to clean energy sources, reduce greenhouse gas emissions, and attract businesses interested in sustainability and renewable energy procurement.

At the same time, with regard to Article 264 of the Association Agreement between Ukraine and EU[164] any reforms shall be designed and implemented with regard to EU state-aid law and regulations incl. Articles 93, 106,107 of the Treaty on Functioning of European Union and Guidelines on State aid for climate, environmental protection and energy 2022 (Communication from the Commission C/2022/481).

4.2.4 Other incentives

The following incentives shall be also considered as productive options for fast implementation of corporate PPAs:

- Off-take insurance is an innovative financial instrument designed to mitigate the risk associated with the payment and performance of off-takers in corporate PPAs. In the context of RE projects, especially in emerging markets like Ukraine, where many businesses may not have strong international credit scores or the financial capacity to provide guarantees, off-take insurance can play a crucial role.
- Renewable energy auctions are a structured and transparent mechanism through which RE projects can sell their electricity to corporate buyers.
- Advocate for incentives, tax breaks, or subsidies for businesses engaging in corporate PPAs, making them more economically viable.
- Raise awareness among businesses about the benefits of corporate PPAs, both in terms of cost savings and environmental responsibility. Offer educational resources and case studies to illustrate successful implementations.
- Develop the necessary infrastructure for RE projects, including grid connections and storage solutions, to ensure reliable energy supply for corporate buyers.
- Promote the use of third-party aggregators or intermediaries/traders that can help match corporate buyers with RE projects, simplifying the procurement process, load balancing and decrease regulatory burden.
- Develop standardized contract templates for corporate and virtual PPAs, which can reduce negotiation time and legal costs. These templates should comply with local regulations and industry best practices.
- Collaborate with RE associations and organizations (EUEA, UWEA, ASEU, UABIO etc.) to lobby for favorable policies and engage in public-private partnerships to advance renewable energy adoption.
- Encourage businesses to seek green energy certifications, such as guarantees of origin, to verify the renewable energy origin of their purchased electricity.
- Seek guidance and support from international organizations and partners with experience in implementing corporate PPAs in other countries. Learn from global best practices.
- Advocate for government agencies at all levels to adopt RE procurement targets, which can stimulate demand and attract investors. The legislation on public procurement procedure shall be amended to comply with electricity market practices and demands, allowing price-formula and foreign-currency-based contracts.

[164] See https://zakon.rada.gov.ua/laws/show/984_011?lang=en

o Pilot Projects:

Launch pilot projects with select businesses to demonstrate the feasibility and benefits of corporate PPAs in Ukraine. Successful case studies can encourage wider adoption.

o Engage with Utilities:

Collaborate with utility companies to explore innovative billing and metering solutions that facilitate corporate PPAs and provide grid stability.

o Financial Instruments:

Explore financial instruments like green bonds or project finance to fund RE projects, making it easier for businesses to access renewable energy through PPAs.

Fast implementation of corporate PPAs in Ukraine will require a coordinated effort involving government bodies, businesses, RE developers, and advocacy groups. By working together to create a conducive regulatory environment and raise awareness, Ukraine can unlock the potential of corporate PPAs as a tool for sustainable energy transition and economic growth.

4.3 Innovative solutions for renewable energy

There are many innovative solutions for renewable energy that aim to address the challenges associated with transitioning to cleaner and more sustainable energy sources. The condition and current developments in the RES sector of Ukraine are detailed in Chapter 0. Here are some notable examples considered as a part of Technical scenario in Chapter 2 hereof:

4.3.1 Power to X and X to power

"Power-to-X" (PtX) is a term that refers to a group of technologies and processes used to convert surplus electrical energy (power) into other forms of energy or valuable products. The primary goal of Power-to-X technologies is to store and utilize excess renewable energy, particularly electricity from sources like wind and solar, when it is available in abundance. This surplus energy can be converted into various forms to address energy needs in different sectors of the economy and to facilitate the integration of RE into the broader energy system.

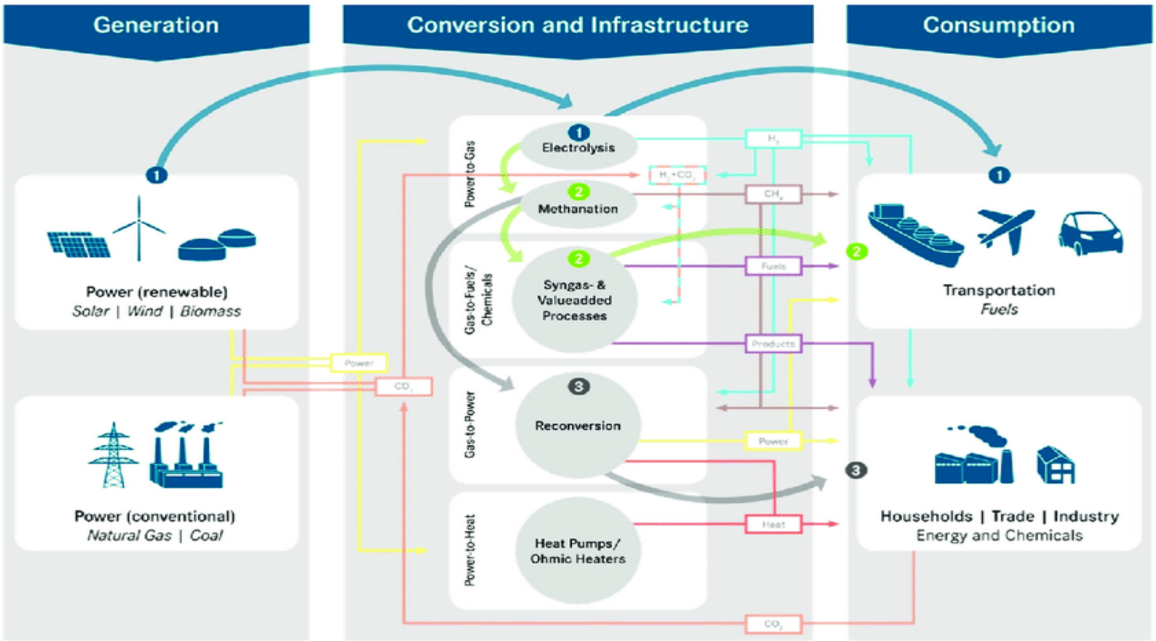


Figure 71: Applications of Power-to-X technologies

Ukraine having significant potential for renewable and alternative energy sources, and leveraging X-to-Power technologies can help diversify the energy mix while reducing greenhouse gas emissions. However, the successful implementation of these technologies requires supportive policies, investments, and regulatory frameworks to encourage development and integration into the energy system. Additionally, international collaboration and expertise can play a significant role in advancing these technologies in Ukraine.

Also in the transition phase, natural gas reforming may be required. This is a carbon-neutral resource if carbon capture technology is utilized. The reforming of hydrocarbons is seen as a kick-starter to the provision of sufficient hydrogen supply at short notice, enabling the creation of the necessary hydrogen infrastructure. This includes investment into gas grids. Meanwhile, existing assets and infrastructure can be used with adapted gas turbine technology to reduce the carbon footprint of power generation and oil & gas. The scalability of gas turbines from small decentralized to large centralized systems offers enough flexibility in terms of production capability and local storage requirements.

Some major P2X and X2P technologies which can be applied in Ukraine are listed hereunder:

Power-to-Hydrogen (PtH2):

In this process, surplus electricity is used to electrolyze water (H2O) into hydrogen gas (H2) and oxygen (O2). Hydrogen can be stored and used as a clean energy carrier for various applications, including transportation, industrial processes, and energy storage.

With little modifications, a blend of hydrogen and natural gas can be transported within the existing gas infrastructure. A new or retrofitted piping infrastructure, though, would be necessary for 100% hydrogen transport. Combusting hydrogen at the point of production could solve this problem during the initial phase of the transition.

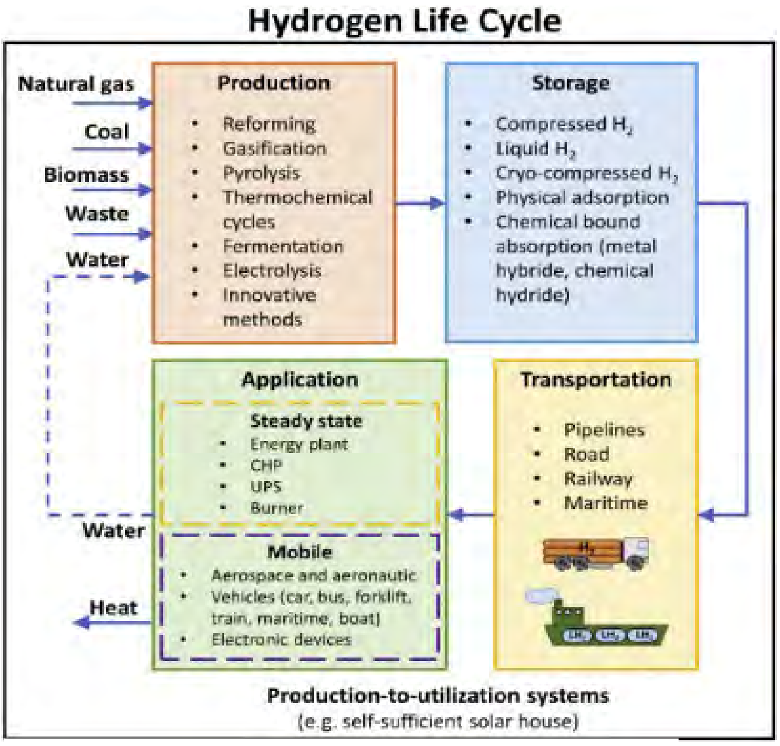


Figure 72 Hydrogen Lifecycle

Turbine innovation

The current turbine fleet is optimized for natural gas but can probably handle up to 5% hydrogen without modification. Fuels with higher hydrogen content or pure hydrogen demand modifications to the combustion system, greater fuel flexibility and improved safety measures.

Technologies were developed for Integrated Gasification Combined Cycle (IGCC) plants that can burn gas mixtures with high amounts of hydrogen. However, they typically use dilution agents such as water or nitrogen that reduce efficiency, increase complexity and add costs. Some industrial scale gas turbines are under development that can burn gas mixtures with high hydrogen content (up to 100%) without dilution. However, they may not offer sufficient fuel flexibility. This is an area ripe for turbomachinery innovation.

With little to no modification, a blend of hydrogen and natural gas can be transported within the existing gas infrastructure. A new or retrofitted piping infrastructure, though, would be necessary for 100% hydrogen transport. Combusting hydrogen at the point of production could solve this problem during the initial phase of the transition.

- ***Power-to-Methane (PtMethane)***

Power-to-Methane technology involves the conversion of excess electricity and carbon dioxide (CO2) into methane gas (CH4) through chemical reactions. Methane can be used as a renewable natural gas for heating, electricity generation, or transportation.

- ***Power-to-Syngas (PtSyngas)***

Syngas (synthesis gas) is a mixture of hydrogen (H2) and carbon monoxide (CO) produced through the gasification of carbon-containing feedstocks like biomass or waste. Power-to-Syngas technologies use renewable electricity to generate syngas, which can be used in various industrial processes or as a fuel.

- ***Power-to-Ammonia (PtAmmonia)***

Ammonia (NH3) is a compound that can be produced from hydrogen (H2) and nitrogen (N2) and is primarily used in the fertilizer industry. Power-to-Ammonia involves using renewable electricity to generate hydrogen and then combining it with nitrogen to produce ammonia.

- ***Power-to-Liquid (PtL)***

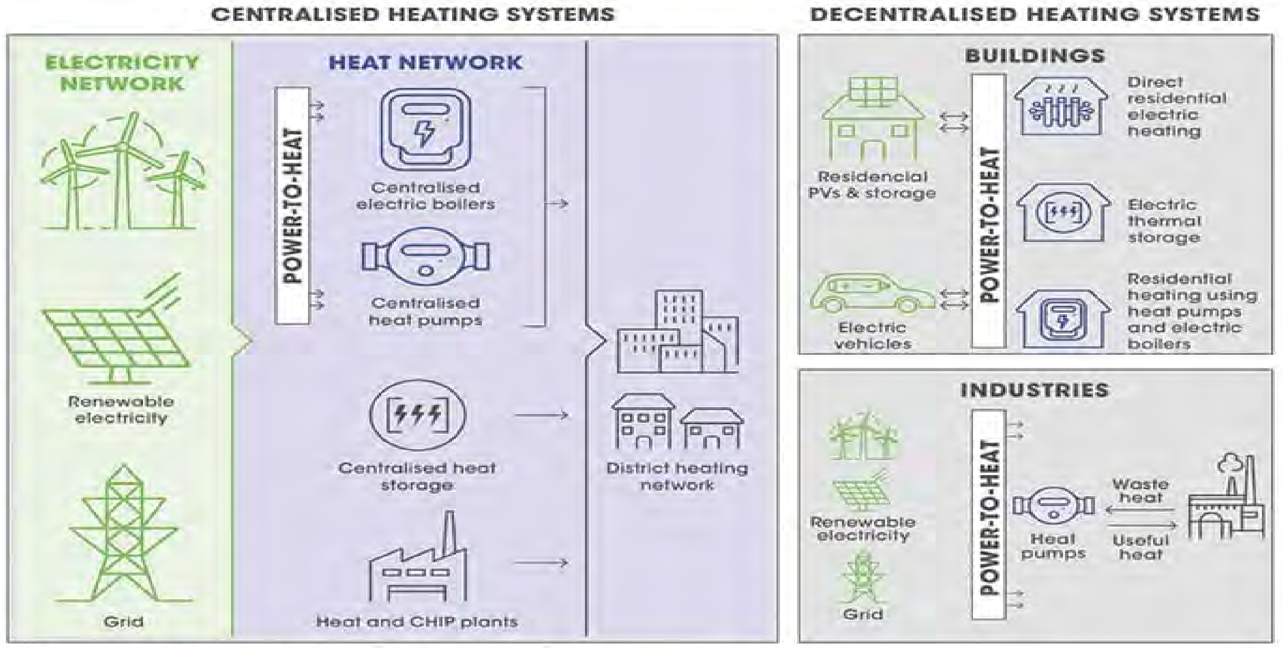
Power-to-Liquid technologies aim to produce synthetic liquid fuels (e.g., synthetic gasoline, diesel, or jet fuel) from renewable energy sources. These fuels can be used in existing internal combustion engines and aircraft.

- ***Power-to-Chemicals (PtChem)***

Power-to-Chemicals processes involve using renewable electricity to power chemical reactions that produce various chemical compounds. This approach can lead to the production of chemicals, including ethylene, propylene, and other valuable compounds.

- ***Power-to-Heat (PtH)***

Power-to-Heat[165] involves converting excess electricity into thermal energy, typically through electric heating elements or heat pumps. This can be used for district or space heating, and industrial processes.



CHP = combined heat and power; PV = photovoltaic.
Based on: Bloess et al. (2018).

Figure 73: Centralised and decentralized power-to-heat applications according to IRENA

- ***Power-to-Cooling (PtC)***

Similar to Power-to-Heat, Power-to-Cooling technologies convert electricity into cooling or refrigeration, often through electric chillers. This is useful for air conditioning and refrigeration applications.
Power-to-X technologies are critical for achieving energy transition goals, improving grid stability, and reducing greenhouse gas emissions. They enable the storage and distribution of clean energy in versatile forms, addressing the intermittency and seasonality of renewable energy sources. Additionally, Power-to-X can contribute to the decarbonization of sectors that are otherwise challenging to electrify directly, such as heavy transportation and certain industrial processes.

165 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Power-to-heat_2019.pdf?la=en&hash=524C1BFD59EC03FD44508F8D7CFB84CEC317A299

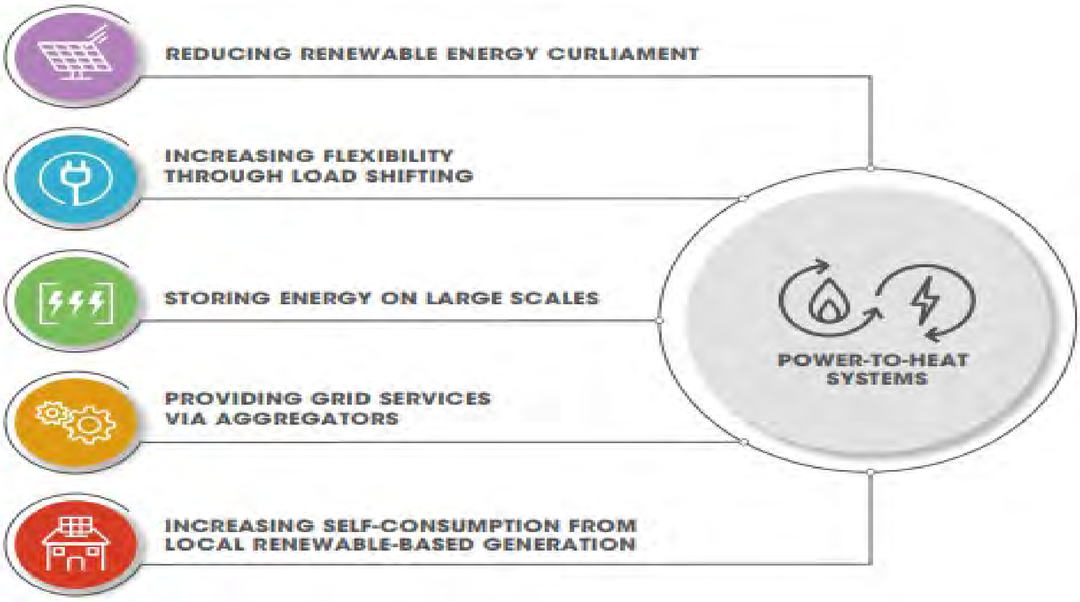


Figure 74: Power-to-heat systems support VRE integration[166]

Moreover, PtC and PtH systems can help integrate greater shares of VRE by using heat pumps and electric boilers as a source of demand-side flexibility in power systems. These electric loads can be used to reduce curtailment of surplus renewable generation, to load shift to coincide with renewable energy generation, and to provide grid services.

Considering the results & conclusions of Chapter 2 and taking into account the ambitious plans and obligations undertaken by Ukraine in terms of a European integration, the a large potential in RE and finally the existing gas infrastructure for export, green H2 and its derivates are offering a very promising potential for UA to achieve ambitious goals in own supply as well as export to the EU of a green alternative to natural gas..

4.3.2 Advanced Solar Technologies:

Floatovoltaics and Solar Canals

Floating photovoltaic (PV) solar installations, also known as floating solar farms or floating solar panels, are an innovative and sustainable solution for countries like Ukraine, which has a significant need for renewable energy sources to reduce its dependence on fossil fuels and promote energy security.

Figure 75: Typical Floating PV system

[166] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Power-to-heat_2019.pdf?la=en&hash=524C1BFD59EC03FD44508F8D7CFB84CEC317A299

Ukraine boasts numerous water bodies, such as reservoirs, ponds, and water treatment facilities, which can be repurposed for floating PV installations. These installations can make efficient use of otherwise unused or underutilized spaces.

Unlike many land-based solar plants, floating arrays can be unobtrusive because they are hidden from public view. They can achieve higher efficiencies than PV panels on land because water cools the panels. The panels can have a special coating to prevent rust or corrosion

Floating PV can help reduce water evaporation in reservoirs, which can be particularly beneficial in regions with water scarcity issues. The shade provided by the solar panels can slow down the evaporation process. As Ukraine is a densely populated country with valuable agricultural land, floating PV can help save land resources by utilizing water surfaces instead. This is especially important for preserving fertile land for food production. Ongoing advancements in floating PV technology, such as improved float materials, mooring systems, and panel design, have made these installations more reliable and efficient[167]. Advantages of floating solar over land-based systems include higher energy yield, reduced evaporation, and improved water quality, among others. Combining floating solar with hydropower plants is of particular interest. Flexible hydropower output can be used to smooth the variability of the solar generation, while making better use of existing transmission assets, particularly beneficial in countries with weak grids. With a global estimated potential of 400 gigawatts, under conservative assumptions, floating solar could double the current global installed capacity of solar PV. Although the market is still nascent and challenges in deployment remain, the floating solar market is set to accelerate as the technologies mature[168].

Developing a clear regulatory framework for floating PV projects is essential to attract investment and ensure proper environmental management. Ukraine can learn from the experiences of countries with successful floating PV deployments

Same system may serve to cover the canals watering the agricultural lands of Southern Ukraine, cooling reservoirs at power plants and partially be utilized in course of agrivoltaics (see below).

Figure 76: Solar canals could save water and generate power

Agrivoltaics

Agrivoltaics, also known as "solar farming" or "solar sharing," is a sustainable agricultural practice that involves the co-location of solar photovoltaic (PV) panels with agricultural activities on the same land. This

167 https://www.sciencedirect.com/science/article/pii/S1876610219302243?via%3Dihub

168 https://documents.worldbank.org/en/publication/documents-reports/documentdetail/579941540407455831/where-sun-meets-water-floating-solar-market-report-executive-summary

approach allows farmers to generate renewable electricity while continuing to use the land for crop cultivation or animal husbandry. In Ukraine, agrivoltaics could offer several advantages:

- **Optimized Land Use:** Ukraine has vast agricultural lands, and agrivoltaics can optimize land use by simultaneously generating electricity and crops or livestock products. This can enhance overall land productivity and income for farmers.
- **Reduced Land Competition:** As the demand for renewable energy infrastructure grows, there may be competition for land between solar farms and agriculture. Agrivoltaics provide a solution by allowing both activities to coexist harmoniously.
- **Improved Energy Security:** Ukraine can increase its energy security by generating clean electricity through agrivoltaics, reducing its reliance on imported fossil fuels and promoting energy independence.
- **Crop Protection:** Solar panels provide shade, which can help protect crops from extreme heat and excessive sunlight, leading to improved crop yields and quality. This shade can be particularly beneficial for sensitive crops.
- **Water Conservation:** The shading provided by solar panels can reduce water evaporation from the soil, thus conserving water resources and making irrigation more efficient.
- **Diversified Income Streams:** Farmers can benefit from diversified income streams by generating revenue from both electricity sales and agricultural products. This can help stabilize income, especially during periods of low crop prices.
- **Environmental Benefits:** Agrivoltaics contribute to reduced greenhouse gas emissions and promote sustainable land use practices, aligning with Ukraine's commitment to environmental sustainability.
- **Grid Stability:** Distributed solar installations like agrivoltaics can enhance grid stability by generating electricity close to where it is needed, reducing transmission losses and grid congestion.

Agrivoltaics is not popular in Ukraine at the moment. There are only several companies pioneering in this sphere, and their activity cannot be considered the classic agrivoltaics of growing crops under the PV modules.

TeslaAgro LLC is using sheep and organic lawnmowers at the Solar Park “Ganska SES” located near the city of Berdychiv in the Zhytomyr region of Ukraine. They also grow blueberries and strawberries on the free from PV installation land plots of the solar park[169].

Figure 77 Sheep at Ganska Solar Park, Berdychiv, Ukraine

Solar installations are also utilized by farming and berry-growing companies in Ukraine. With the onset of full-scale Russian aggression, fresh dairy and berry producers incurred substantial losses due to power outages. Solar installations are employed to supply electricity to refrigerators, ensuring the freshness of products. While not classified as traditional agrivoltaics, producers are contemplating its adoption for risk mitigation and additional cash flow generation[170].

[169] https://east-fruit.com/en/horticultural-business/stories/solar-farming-and-agrivoltaics-instead-of-gas-and-coal-examples-of-their-use-in-ukraine-and-globally-photo/

[170] https://uaberries.com/novyny/novyny-sektoru/ahrovoltaika-maibutnie-ukrainskoho-fermerstva

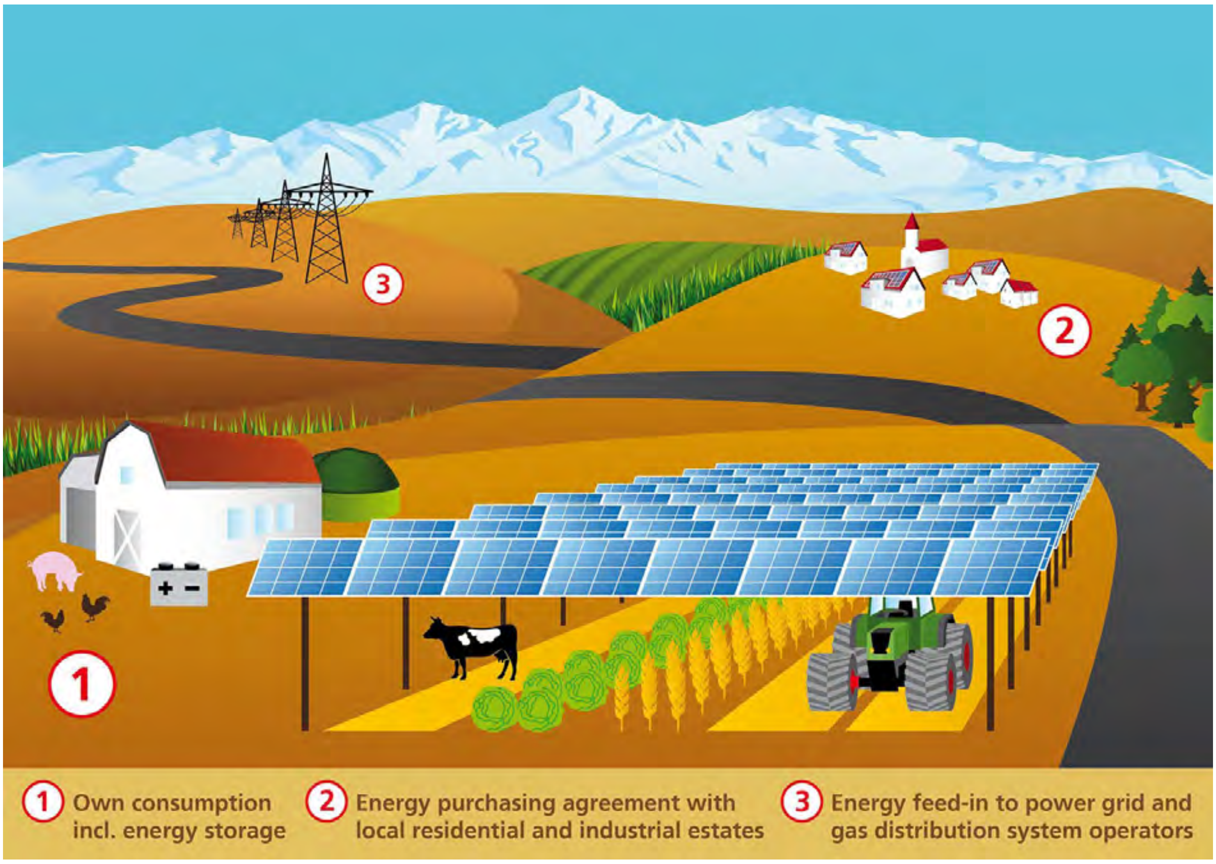


Figure 78: Example of an Agrivoltaic farming[171]

If solar panels can be added to greenhouses, the results could be especially transformative. Greenhouse-based farming reportedly produces 10 times more food than growing in an open field, but it can require 10 times as much power.

A pilot project is also under way in France, with more than 5,000 solar panels being placed over a farm in the north-eastern town of Amance. The panels are expected to be connected to the grid in December 2022, and they could produce 2.5 megawatts of power at peak times, Euronews reports.

Increasing the world's solar energy capacity will be a big part of solving the sustainability equation. At the same time, the UN estimates that the global population is set to rise by an estimated 2 billion people in the next 30 years, and land is at a premium. Agrivoltaics is one way of using the same area of land to produce more food while also rolling out more sources of renewable energy.

Perovskite Solar Cells:

These are a promising alternative to traditional silicon-based solar cells, offering higher efficiency and lower production costs. However, this technology is still struggling to outcome the cell stability problems. Even though power conversion efficiency has already reached 25.8%, poor stability is one of the major challenges hindering the commercialization of Perovskite Solar Cells (PSCs). Several initiatives, such as structural modification and fabrication techniques by numerous ways, have been employed by researchers around the world to achieve the desired level of stability however until now no major breakthrough is achieved and some researchers recommend to focus on alternative materials[172].

Solar Paint, Solar Tiles, Transparent panels and Solar Windows:

These technologies integrate solar panels into everyday materials, such as paint and windows, making it easier to generate solar power in urban environments. Solar paint, also known as photovoltaic paint or solar coating, is an emerging technology that allows surfaces to generate electricity from sunlight. While it holds potential for various applications, including Building-Integrated Photovoltaics (BIPV) and unconventional surfaces, its utilization in Ukraine would majorly depend on cost-effectiveness and R&D progress in regards to durability and efficiency (perovskite considered above was mainly considered as one of the most promising opaque solar cells for BIPV however the same limiting factors in regards to

[171] https://metsolar.eu/blog/what-is-agrivoltaics-how-can-solar-energy-and-agriculture-work-together/

[172] https://pubs.rsc.org/en/content/articlehtml/2023/ra/d2ra05903g

durability are applied). As an alternative to perovskite Flexible and Thin-Film[173] amorphous silicon Solar Panels can be considered as well as developments in copper indium gallium selenide, cadmium telluride and gallium arsenide[174].

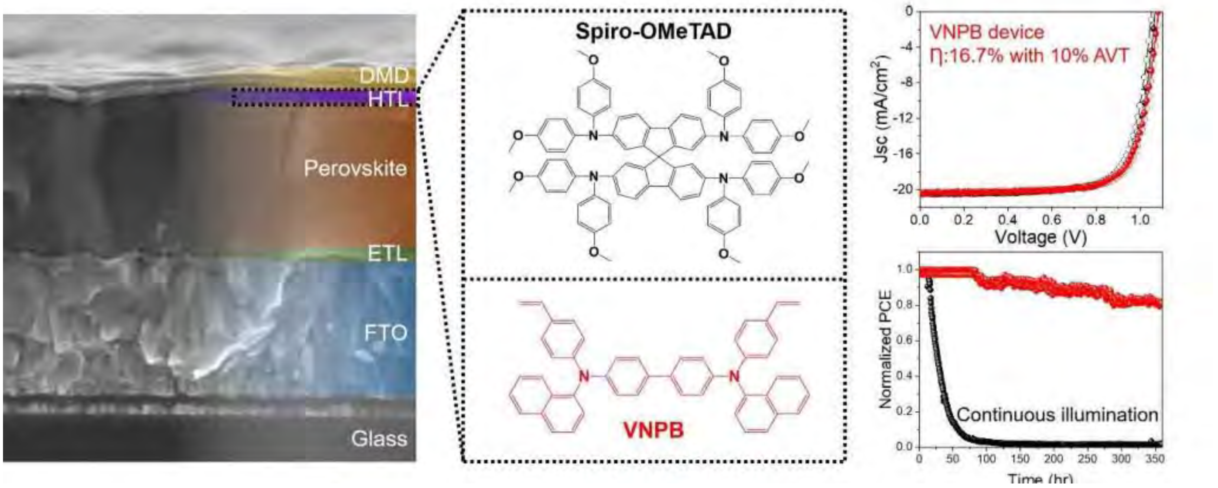


Figure 79: A schematic depicting the semi-transparent solar cell design.

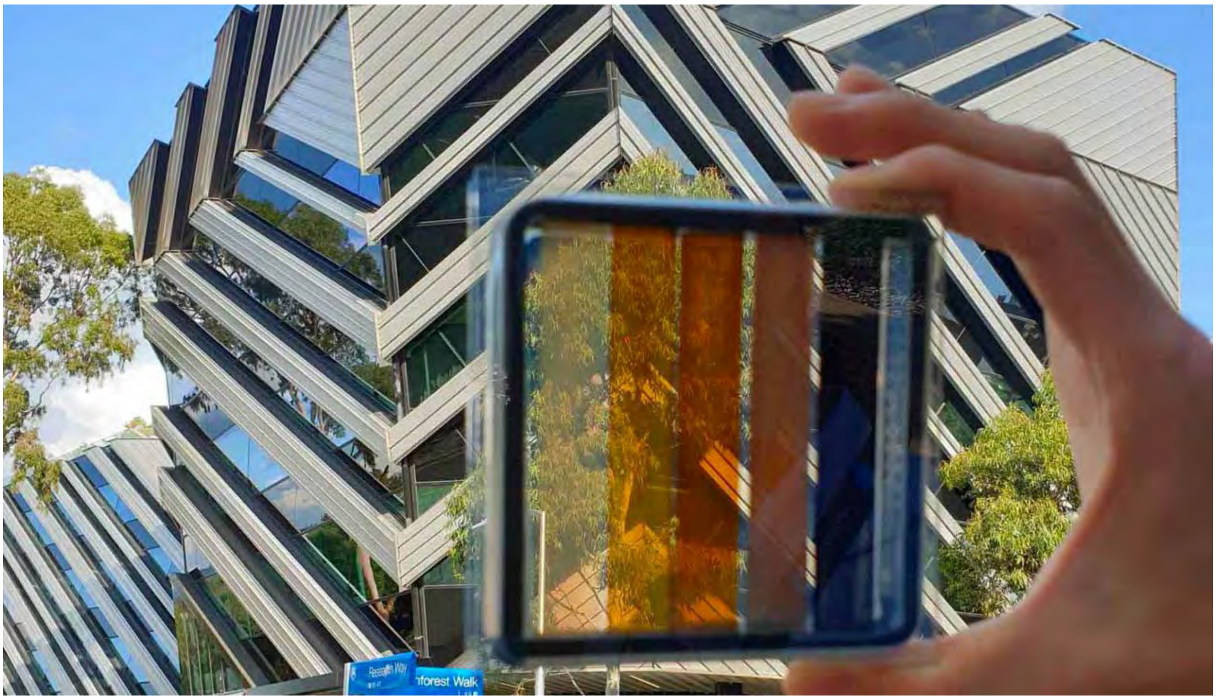


Figure 80: Hand holding a transparent solar panel towards the sun

[173] https://www.cnet.com/home/energy-and-utilities/what-are-flexible-solar-panels-the-lightweight-alternative-solar-option/
[174] https://arena.gov.au/blog/transparent-solar-panel-breakthrough-puts-the-future-of-solar-in-clear-view/

4.3.3 Wind Power Advancements

Vertical Axis Wind Turbines (VAWTs): Vertical Axis Wind Turbines (VAWTs) are a type of wind turbine in which the main rotor shaft is oriented vertically, and the blades rotate around this axis. VAWTs differ from the more common Horizontal Axis Wind Turbines (HAWTs), where the rotor shaft is horizontal, and the blades rotate like a traditional fan. These turbines are more compact and can capture wind from any direction, making them suitable for urban and residential settings. Despite these challenges, VAWTs have their niche applications, particularly in situations where their advantages, such as omnidirectional wind capture, low wind speed operation, and aesthetic appeal, align with specific project requirements. They are often used for off-grid or distributed energy generation. There is some potential use in offshore applications as shown in the image below and they can be integrated into urban or rural settings where HAWTs may face greater acceptance challenges.

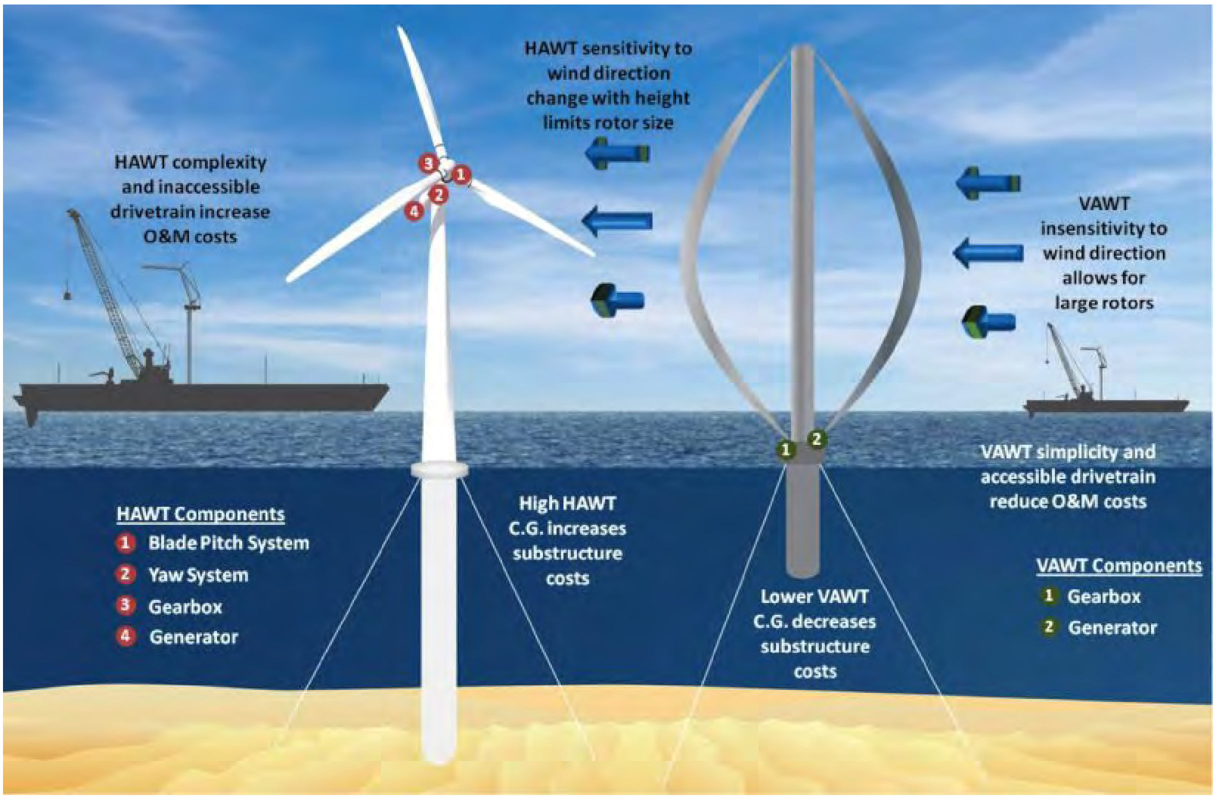


Figure 81: Advantages of VAWT for offshore applications

Offshore Wind Farms: Installing wind turbines offshore can harness stronger and more consistent winds, but it also presents engineering and logistical challenges. According to the World Bank the Offshore wind potential in Ukraine can reach up to 251 GW[175].

(figure continued next page)

175 https://documents1.worldbank.org/curated/en/709391586844502062/pdf/Technical-Potential-for-Offshore-Wind-in-Ukraine-Map.pdf

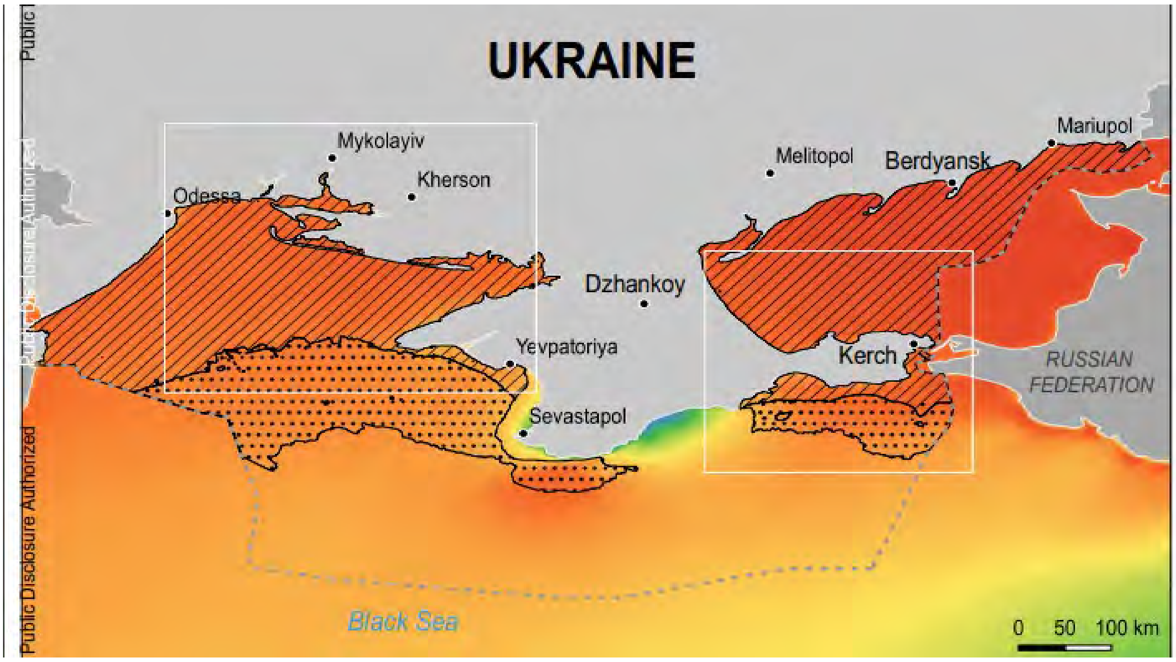


Figure 82: Offshore wind potential in Ukraine, IBRD

4.3.4 Energy Storage

- **Advanced Batteries:** Developments in lithium-ion and solid-state batteries are enabling better energy storage solutions for both grid-scale and residential applications. Advanced energy storage technologies play a crucial role in modernizing the energy sector and enabling the widespread adoption of RES. These technologies help store excess energy generated during periods of high RE production and make it available when demand is high or when renewable sources are not generating power. Amongst promising chemical storage technologies the advance is expected in Li-Ion, Solid state and Flow batteries. Ongoing research in materials science is leading to the development of new materials for energy storage, such as high-capacity anode and cathode materials for batteries.

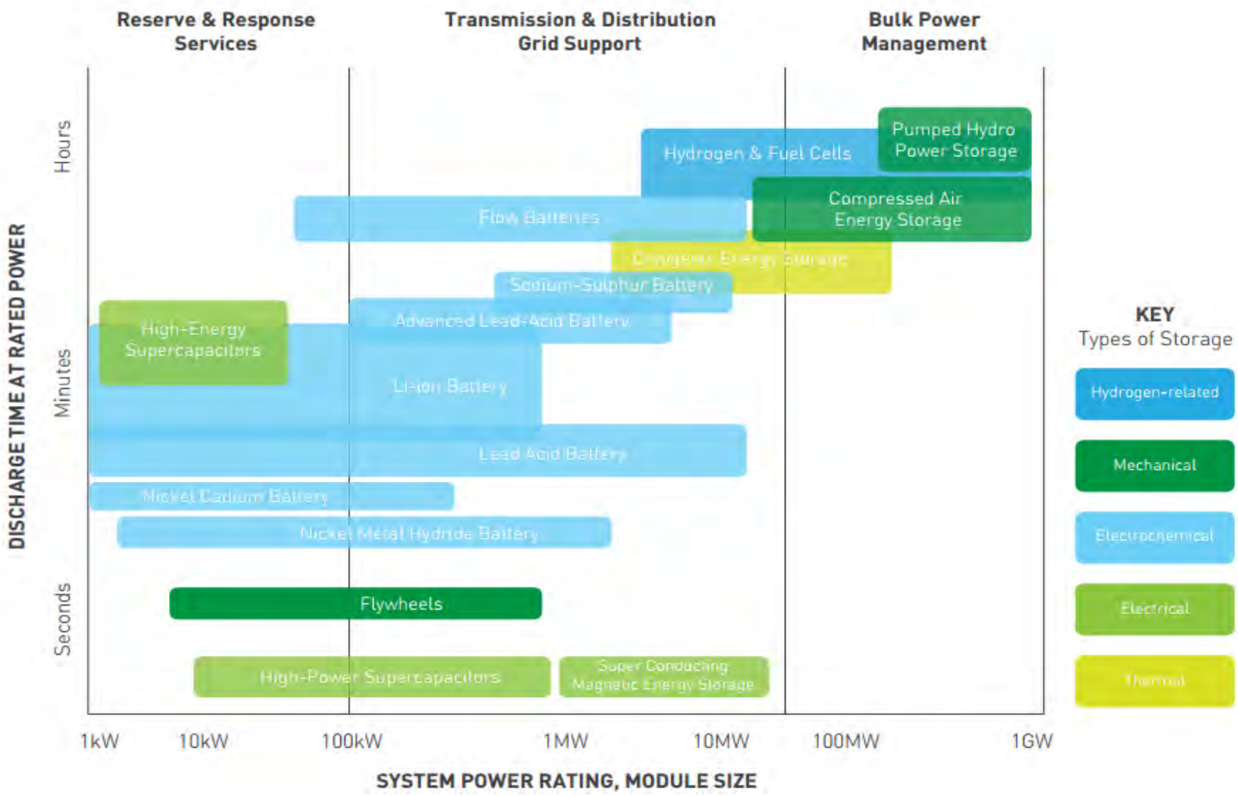


Figure 83: Storage technologies comparison

Non-chemical types of storage:

- Supercapacitors: Supercapacitors, or ultracapacitors, store energy electrostatically rather than chemically like batteries. They offer high power density, rapid charging and discharging, and a longer cycle life. They are often used in applications requiring quick bursts of energy, such as regenerative braking in hybrid vehicles.
- Thermal Energy Storage: Thermal energy storage systems store heat in materials like molten salt or phase-change materials. This stored heat can then be used to generate electricity or provide heating and cooling. These systems are often used in concentrated solar power plants.
- Hydrogen Storage (please refer to PtH2 above): Hydrogen can be used as an energy carrier and stored for later use. Advanced hydrogen storage technologies include compressed hydrogen storage, liquefied hydrogen storage, and solid-state hydrogen storage materials.
- Flywheel Energy Storage: Flywheel energy storage systems use a spinning rotor to store kinetic energy. When energy is needed, the rotor's kinetic energy is converted back into electrical energy. Flywheels are known for their fast response times and long cycle life.
- Advanced Compressed Air Energy Storage (A-CAES): A-CAES systems store energy by compressing air and then expanding it to generate electricity when needed. They often incorporate advanced technologies like isothermal compression to improve efficiency.
- Gravitational Energy Storage: Gravitational energy storage systems use heavy objects or masses to store potential energy. These masses are raised when excess energy is available and lowered to release the stored energy when needed.
- Electrochemical Capacitors: Also known as "supercapacitors", these devices store energy electrostatically, like traditional capacitors, but with much higher energy densities than standard capacitors.
- Hybrid Energy Storage Systems: Combining multiple energy storage technologies can provide more flexible and efficient solutions for various applications. For example, pairing batteries with supercapacitors can provide high power and energy density.

The choice of energy storage technology depends on factors like the application, required energy capacity, response time, and cost-effectiveness. Advancements in these technologies are ongoing, and they are crucial for building a more sustainable and reliable energy infrastructure.

Currently one of the most notable advancements in this field is the **"Improving Power System Resilience For European Power Grid Integration Project** (Installation Of Hybrid Systems For Electricity Production In Ukrhydroenergo)" by IBRD[176] foreseeing **BESS with PV plants and EMS for provision of ancillary services which will foresee** finance for installation of BESS and solar PV plants, and an energy management system.

In total, 197 MW of BESS will be installed at selected hydro power plants (Kyiv HPP/PSHP, Kaniv HPP, Kremenchuk HPP, and Seredniodniprovska HPP). Additionally, 35.9 MWp of solar PV plants will be installed. All facilities including connection power lines will be installed within the precincts of UHE's HPP territories.

These sites are identified based on land availability and transmission capacities. The BESS will provide ancillary services to the grid, particularly FCR and a-FRR. Those BESSs will be under coordinated operation with HPPs and solar PVs through a newly installed EMS so that a wide range of grid services is provided seamlessly, and charging/discharging operation is optimized.

The total size of the BESS is determined to meet the FCR requirement for ENTSO-E synchronization and then allocated to each site taking into consideration the connected HPP unit sizes as well as land availability. The proposed BESS will provide the necessary ancillary services to the grid, which will improve flexibility of UkrES.

Therefore, the proposed investment will enable synchronization with the ENTSO-E, improve integration of VRE sources, and increase power system reliability through creating the most reliable source of system flexibility that is not contingent on the availability of resources (water, coal, gas) and the working status (in/out of operation) of the provider. PV plants will be used mainly to supply electricity to the battery storage facilities and also cater to auxiliary consumption within the HPP facility.

The PV plants will be developed and operated by UHE and not subject to the FiT scheme. To meet the timeline for synchronization, the subcomponent will be developed in a short period of time, targeting early commissioning.

[176] https://documents1.worldbank.org/curated/en/803731625364161631/pdf/Ukraine-Improving-Power-System-Resilience-for-European-Power-Grid-Integration-Project.pdf

The Cabinet of Ministers of Ukraine, by **the Resolution No. 550 dated 2 June 2021**, approved the investment project for the construction of Ukrhydroenergo PJSC energy storage systems with an installed capacity of 197 MW. This hydro storage system is planned to provide auxiliary services for frequency regulation and active power, in particular, the frequency support reserve and the frequency restoration reserve.

After lengthy discussions, the Committee of the Verkhovna Rada of Ukraine on Energy and Housing and Communal Services registered, and agreed with market participants the **Draft Law of Ukraine "On Amendments to Certain Laws of Ukraine Regarding the Development of Energy Storage Systems" (reg. No. 5436-d of 17 September 2021**), which provides for the regulation of the legal, economic and organizational foundations of the functioning of energy storage systems in the electricity market. Adoption of the said bill will create conditions for the implementation of projects for the construction of energy storage systems in Ukraine, including at renewable energy facilities.

As of today, the process of implementation of energy storage system projects including construction has already begun in Ukraine.

The first energy storage system in Ukraine, with a capacity of 1 MW and a capacity of 2.25 MW/h, was commissioned in May 2021 by the DTEK Company in the city of Energodar on the territory of the Zaporizhzhia TPP, which is currently under Russian occupation. Plans for the construction of an additional 50 MW storage system were also announced.

In July 2021, the Vinnytsia City Council issued urban development conditions to the KNESS Company for the construction of an energy storage system with a capacity of 1 MW and a capacity of 1 MW/h, fully developed, designed, and manufactured in Ukraine.

PJSC “NEC Ukrenergo”, together with the French consulting company RTE International (the consulting branch of the French transmission grid operator), developed a Feasibility Study and a "Roadmap" for the construction of energy storage systems with a capacity of 200 MW.

In April 2020, the agro-industrial holding "Myronivskyi Khliboprodukt" began the development of a 25 MW energy storage system.

4.3.5 Enhanced Geothermal Systems (EGS)

EGS involves injecting water into hot rock formations to create steam and generate geothermal power, potentially expanding geothermal energy's reach beyond regions with naturally occurring hot spots.

- Drilling: Deep wells are drilled into hot rock formations, typically several kilometres below the Earth's surface.
- Hydraulic Fracturing: Cold water is injected into the well under high pressure to create fractures or stimulate existing fractures in the hot rock.
- Heat Extraction: The injected water circulates through the fractures, absorbing heat from the surrounding rock. It then returns to the surface as hot water or steam.
- Electricity Generation: The hot water or steam is used to drive turbines, which generate electricity. Alternatively, the hot fluid can be used directly for heating applications.

The EGS technology is still in the experimental and demonstration phase in many parts of the world, but it holds promise for expanding geothermal energy production. Continued research and development efforts are essential to address technical challenges and reduce costs, making EGS a more commercially viable energy source.

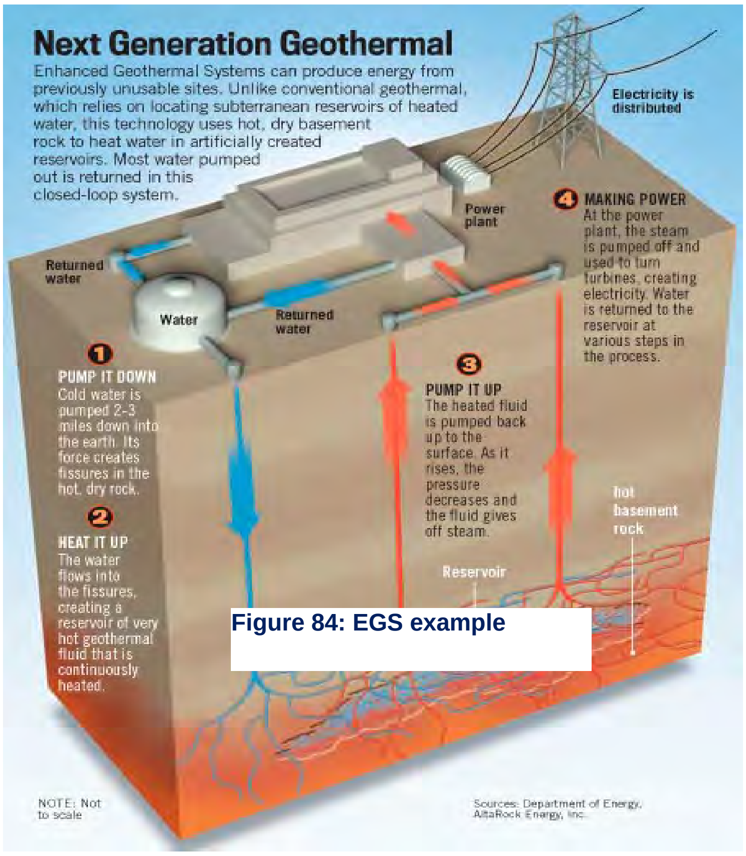


Figure 84: EGS example

4.3.6 Biofuels

Algae. Algae can be cultivated to produce biofuels, providing a more sustainable alternative to fossil fuels. Ukraine's geography, which includes the Black Sea and various inland water bodies, provides opportunities for cultivating algae for biofuel production. Algae can grow in different types of water environments, such as ponds, lakes, or wastewater treatment facilities, and they can use nutrients from agricultural runoff. The technology is still lacking financial attractiveness for private investments and require high use of fertilizers.

Anaerobic Digestion.

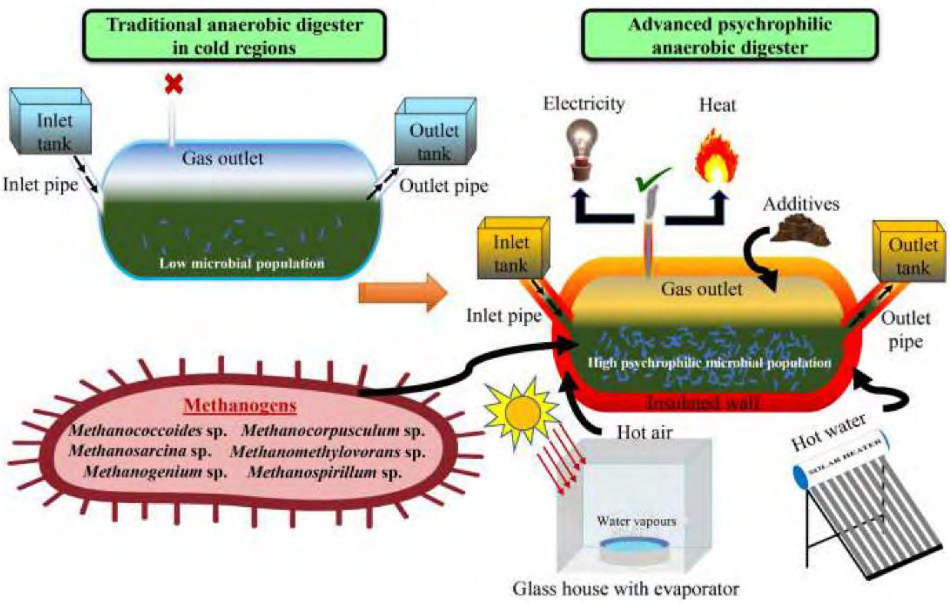


Figure 85: Features to improve biomethanation under low temperatures.

Anaerobic digestion is a biological process that breaks down organic materials, such as agricultural waste, food waste, and wastewater, in the absence of oxygen to produce biogas (a mixture of methane and carbon dioxide) and nutrient-rich digestate. Biogas can be used as a RES, while digestate can serve as a valuable fertilizer. Ukraine has a significant agricultural sector, which generates substantial amounts of organic waste, including crop residues, livestock manure, and food processing waste. Anaerobic digestion can help convert this waste into renewable energy and nutrient-rich fertilizer. Biogas produced through anaerobic digestion can be used for electricity generation, heat production, or as a vehicle fuel. It provides a renewable and sustainable energy source, helping to reduce greenhouse gas emissions.

In Ukraine the dominant type of waste that tend to increase are almost unchanged. They include sewage sludge, industrial sewage sludge, animal feces, urine and manure, plant wastes. In the future, this will make it possible to focus on solving the problems of waste disposal and the achievement of environmental goals, as well as to counteract emergencies at agricultural enterprises by using the efficient bioenergetic potential of organic waste[177].

One of the projects, co-founded by EU is aimed at in-situ biological methanation in Ukraine, 12 MW unit located in Ladyszhin, Vinnytsia region, currently in Demo – stage.[178]

The Verkhovna Rada adopted the Law No. 4558 "On the handling of pesticides and agrochemicals", which for the first time defines the term "digestate formed in biogas plants" and abolishes the requirements for its state registration. This will allow the use of the valuable organic fertilizer digestate as a specific product. The document defines this term as residues of raw materials, by-products and waste of animal or vegetable origin, mixed or not, resulting from a controlled process of anaerobic digestion with the release of biogas[179]. Such a digestate complies with the requirements laid down by Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules for placing on the EU market of fertilizers and amending Regulations (EU) 1069/2009 and (EU) 1107/2009 and repealing Regulation (EC) 2003/2003. Digestate can be used as a component of fertilizers, which improves yields and helps maintain proper soil moisture.

There were a number of anaerobic digestions startups in Ukraine in the beginning of 2022[180] and the technology is expected to grow.

4.3.7 Smart Grids and Microgrids

Smart Grid Technology: Integrating digital communication and automation into power grids improves efficiency, reliability, and the integration of renewable energy sources.

By intelligently integrating the actions of all electricity generators and users connected to it, a smart grid increases the efficiency of electricity supplies. It is doing so by employing innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

- Better facilitate the connection and operation of generators of all sizes and technologies;
- Allow consumers to play a part in optimizing the operation of the system;
- Provide consumers with greater information and choice of supply;
- Significantly reduce the environmental impact of the whole electricity supply system;
- Minimize electricity loss between power plants and consumers;
- Avoid costs of building new power plants related to reduced peak demand;
- Deliver enhanced levels of reliability and security of supply.

[177] https://science.lpnu.ua/ep/all-volumes-and-issues/volume-6-number-3-2021/potential-organic-waste-substrate-anaerobic

[178] https://www.energy-community.org/events/2023/09/GFUkraine.html

[179] https://ecopolitic.com.ua/en/news/v-ukraine-razreshili-ispolzovat-organicheskie-udobreniya-iz-othodov-biogazovyh-ustanovok-2/

[180] https://anaerobic-digestion.com/anaerobic-digestion-in-ukraine/

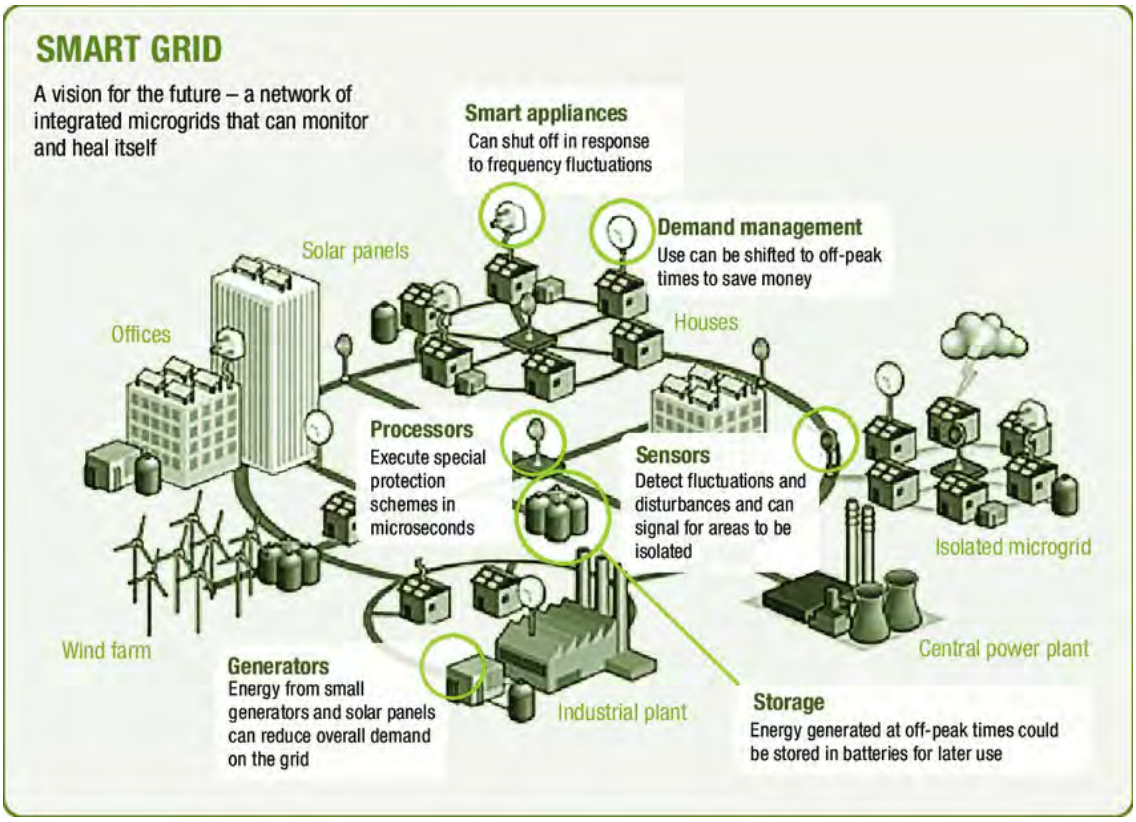


Figure 86: Set up of a smart grid network

One of the outstanding features provided by smart grids and microgrids (horizontally balanced resilient grids able to operate in islanding mode) is top level of energy security and ability to withstand damages, threats and terrorist/military attacks.

Microgrids can be an effective measure to enhance the resilience and security of a power system and protect it from various threats, including terrorist attacks. Microgrids are small-scale, localized energy systems that can operate independently or in conjunction with the main grid.

Here's **how microgrids can contribute to power system security**:

Isolation and Independence: Microgrids can be designed to operate autonomously, separate from the main grid. This isolation can prevent disruptions in the event of an attack on the main grid. Even if the main grid goes down due to a terrorist attack, microgrids can continue to provide power to critical facilities, such as hospitals, military bases, and emergency response centers.

Redundancy: Microgrids can serve as a redundant source of power. In case of an attack on the main grid, power can be seamlessly shifted to the microgrid to maintain essential services without interruption.

Grid Resilience: Microgrids are designed to withstand and quickly recover from disruptions. They often incorporate RES, energy storage systems, and advanced control systems, making them more resilient to outages caused by physical attacks or cyberattacks.

Distributed Generation: Microgrids typically include distributed generation sources, such as solar panels, wind turbines, and combined heat and power (CHP) systems. This distributed generation diversifies the energy supply and reduces dependence on centralized power plants, which may be vulnerable to attacks.

Energy Storage: Microgrids can include energy storage systems, such as batteries, which can store excess energy during times of low demand and release it during high demand or emergencies. This provides a buffer against sudden disruptions.

Grid Monitoring and Control: Microgrids are equipped with advanced monitoring and control systems that can detect anomalies and respond quickly to restore power. These systems can help identify and mitigate the effects of cyberattacks on the microgrid.

Community Resilience: In addition to protecting critical infrastructure, microgrids can also enhance community resilience by providing power to homes, schools, and businesses during emergencies, including those caused by terrorist attacks.

Load Shedding: Microgrids can implement load shedding strategies to prioritize power supply to critical loads while temporarily reducing power to less critical loads during high-demand or emergency situations.

Cybersecurity Measures: Microgrids can incorporate robust cybersecurity measures to protect against cyber threats. These measures include firewalls, intrusion detection systems, and secure communication protocols.

Remote Operation: Some microgrids are designed to be remotely operated and monitored, allowing for rapid response and control in emergency situations, even from off-site locations.

While microgrids offer significant advantages in enhancing power system security, they require careful planning, investment, and ongoing maintenance. Additionally, regulatory and policy frameworks may need to be adapted to facilitate the deployment of microgrids and ensure their integration with the main grid. Nonetheless, microgrids represent a valuable tool in protecting power systems from various threats, including acts of terrorism.

Artificial Intelligence and Machine Learning: Artificial intelligence (AI) and Machine Learning (ML) have the potential to significantly benefit the RE sector in Ukraine, as in many other countries. These technologies can enhance the efficiency, reliability, and sustainability of RE systems and contribute to Ukraine's energy transition.

AI and ML can improve the accuracy of renewable resource assessment and forecasting, particularly for solar and wind energy. These technologies can analyze historical weather data, satellite imagery, and local weather conditions to predict energy generation, helping grid operators better manage variable renewable sources.

Also, AI can play a crucial role in integrating RES into the grid more effectively. It can optimize the operation of grid assets, predict and manage power fluctuations, and ensure grid stability. AI-driven demand response systems can also balance supply and demand efficiently. They can determine the most cost-effective times to charge and discharge energy storage units, taking into account variable energy prices and grid demand.

One of the examples can be the use of a system like GridFox, developed by the Fraunhofer Institute. This AI-based forecasting tool can enhance the accuracy of renewable energy feed-in predictions, allowing for more effective grid management and stability. It enables detailed analysis at the individual plant and consumer group level, crucial for optimizing energy dispatch and managing demand.

Also, AI and ML can be used for predictive maintenance of RE infrastructure and planning its future development by analysis of digital twins. Also, by analyzing sensor data from wind turbines, solar panels, and other equipment, these technologies can detect anomalies and recommend maintenance actions before major failures occur, reducing downtime and repair costs. ML algorithms can analyze energy consumption patterns in residential, commercial, and industrial sectors to identify opportunities for energy savings. This information can guide energy efficiency programs and policies.

AI can enhance the security of the energy grid by detecting and responding to cyber threats and intrusions. It can help protect critical infrastructure from cyberattacks and ensure the integrity of the grid.

Current developments:

A large project on the smart grid integration is being developed at TSO level within **Second Transmission project** financed by IBRD and CTF (330 + 48,425 million USD total) foreseeing balancing market reform, rehabilitation of backbone of substations, Introduction of Smart Grid through purchase and installation of Smart Grid solutions including: (a) modernization of the telecommunications network between renewable energy sources, key substations of transmission networks and system operator control centers; and (b) modernization of the regional and national system of load distribution and organization of control centers. The similar processes for inclusion of DSO-level technologies are developing fast after it became clear that smart grids have another advantage - providing high level of energy security.

On 14 October 2022[181], the government approved the Concept of Smart Grid Implementation in Ukraine until 2035. The document, developed with the support of the World Bank, envisages the development of the energy system on modern principles.

The Concept aims to gradually reduce electricity losses in networks, reduce CO_2 emissions, increase investment in power grid modernization, and improve the quality and reliability of power supply for electricity consumers.

Figure 87: Second Transmission Project

As a result of the implementation of the Action Plan for the implementation of the Concept until 2035, it is planned to reduce electricity losses in power grids in Ukraine as a whole from 11.6% to 7.5% or by 6 billion kWh, which is equivalent to 3 million tons of burned coal at thermal power plants.

It is also expected that the cost of operational maintenance of power grids will decrease by a total of at least UAH 8.3 billion, and the actual level of the index of the average duration of long power outages in the system (SAIDI) will be reduced from 1700 to 100 minutes in 2035, which will correspond to the average European level.

With financial support from the Lithuanian government, **Mykolaivoblenergo** power distribution company has already started developing a pilot project for building a Smart Grid[182]. The International Energy Cluster has completed the development of the project "Renovation of the energy infrastructure of JSC Mykolaivoblenergo with the transfer to the voltage class of 20 kV".

DTEK Grids, is seeking EUR 2.4 billion of funding in a 10 year-project to transform the region's power infrastructure. The plans, which must be approved by Ukraine's Ministry of Energy, envisage building a smart grid with 20,000 km of new overhead and underground cables, 250 substations, 6,000 transformers and almost a million smart meters[183].

[181] https://www.kmu.gov.ua/news/uriad-skhvalyv-kontseptsiiu-vprovadzhennia-rozumnykh-merezh-v-ukraini-do-2035-roku

[182] https://en.interfax.com.ua/news/economic/865138.html

[183] https://dtek.com/media-center/news/dtek-grids-will-develop-a-concept-of-smart-grid-in-the-kyiv-region-in-cooperation-with-the-biggest-european-power-companies-/

- A resilient smart grid infrastructure that still works even if one segment is damaged or destroyed.
- Stronger connectivity to power produced from renewables.
- Digital Twin technology allowing engineers to model how the upgraded network will function.
- A flexible system enabling consumers to become contributors through ‘home-grown’ energy from household solar panels or even by de-charging car batteries.

Figure 88: Videowall at dispatching center

DTEK Grids is planning to test the new grid concept in a **three-year pilot** phase across Irpin-Bucha-Borodyanka, an area 15 miles from the capital that suffered now-infamous attacks after Russia’s full-scale invasion in February 2022. The company is seeking to attract initial funding of EUR 145 million for the pilot.

4.3.8 Energy Efficiency Technologies

Technologies like energy-efficient HVAC systems, LED lighting, and smart building management systems reduce energy consumption in residential and commercial buildings. Moreover, Ukraine has historically had high energy intensity, meaning it uses more energy to produce a unit of economic output compared to more energy-efficient countries. Addressing energy intensity is a critical goal to improve overall energy efficiency.

Ukraine has developed a legal framework to promote energy efficiency, including the Law on Energy Efficiency of Buildings, the Law on Energy Efficiency Fund, and the National Energy Efficiency Action Plan. These policies set targets and regulations for energy efficiency improvement. All of the attempts on energy efficiency in industrial or residential sector shall be relying on integration of contemporary technologies.

While Ukraine has made progress in improving energy efficiency, there is still substantial potential for further enhancements. Challenges include restoration priorities, funding constraints, infrastructure upgrades, and the need for continued policy support. To continue advancing energy efficiency, Ukraine may benefit from increased investment, technological innovation, and ongoing commitment to energy-saving measures.

4.3.9 Hybrid Renewable Systems

Combining multiple renewable energy sources, such as wind and solar, with energy storage can provide a more stable and consistent power supply. Mixed solar/wind rooftop units: one of the exaples is a technology presented by Uneole[184] startup. These systems are designed to overcome the intermittency and variability associated with individual renewable sources and to maximize energy generation while minimizing reliance on fossil fuels. They can be customized to suit specific energy needs and can be particularly valuable in remote or off-grid locations where a consistent power supply is essential. Designing and integrating hybrid systems can be complex, requiring careful planning, monitoring, and control systems to optimize their performance.

[184] https://uneole.fr/

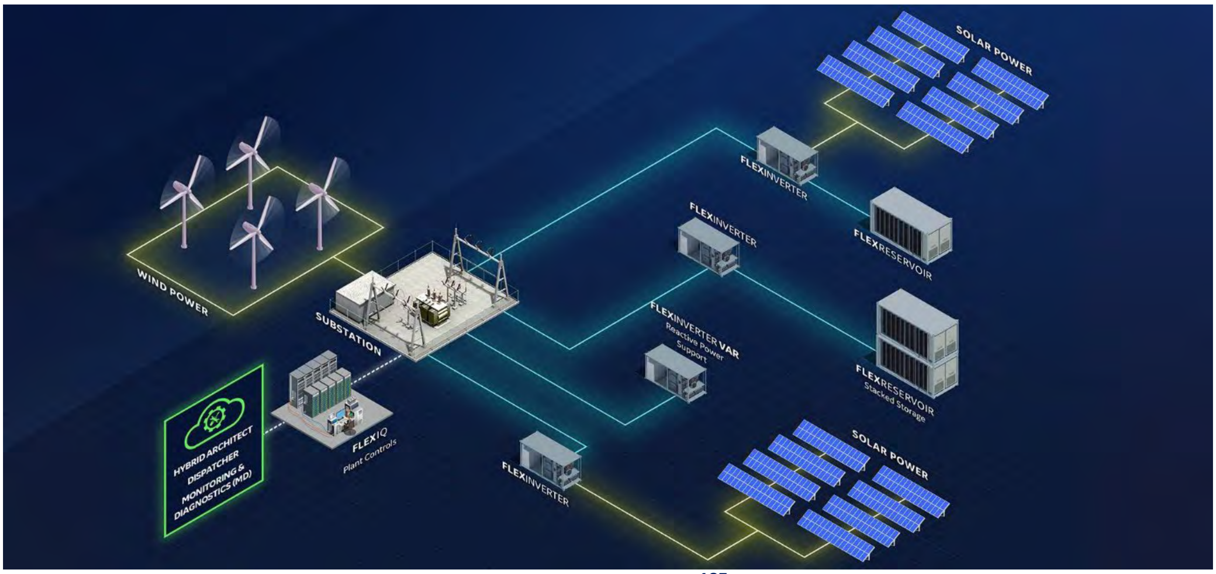


Figure 89: GE solution on the hybrid PV/Wind/Storage system[185]

4.3.10 Circular Economy Approaches

Recycling and reusing materials in the production and maintenance of RE infrastructure can reduce environmental impact and resource depletion.

Out of the three principles of a circular economy:

- Eliminate waste and pollution,
- Circulate products and materials (at their highest value),
- Regenerate nature – eliminating waste is the one most consistent with Ukraine's current needs.

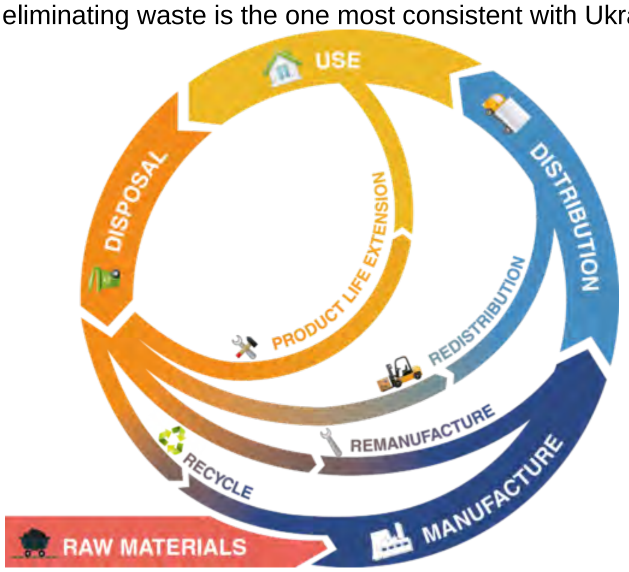


Figure 90: Circular economy principles

Prior to Russian aggressions, Ukraine was already facing waste management issues despite having developed several national strategies, reforms, and policies to combat the effects.

The main purpose of the waste management reforms targets the sporadic landfills which constitute Ukraine's current management practice. Wartime has also exacerbated the situation by greatly increasing the amount of construction, demolition, and hazardous waste materials, which, in turn, is treated poorly due to no appropriate scheme for categorizing different types of waste.

In 2021, over 90% of Ukrainian household waste was disposed of at landfill sites, only 7% was recycled, and 1.7% burned. Out of the 6000 operational landfills; 824 did not meet environmental standards, 371 required renovation, 230 were overcrowded. Moreover, Ukraine was the only European country without extended producer responsibility (i.e., "no polluter pays" principle). Therefore, eliminating waste and

[185] https://www.ge.com/renewableenergy/solar-storage

pollution has been – and remains – a salient issue for Ukraine which must be adequately dealt with. So, what is being done?

Subsequent developments such as the attempt at European Union (EU) accession through compliance with the European Green Deal (EDG) have revealed weaknesses in the current state of affairs concerning Ukraine's policy and legislative area of waste management and CE implementation[186].

At the same time, implementing a circular economy approach in the RE sector in Ukraine can help maximize resource efficiency, reduce waste, and promote sustainability. A circular economy aims to minimize the use of virgin resources, reduce waste generation, and keep materials and products in circulation for as long as possible. Some ways Ukraine can promote a circular economy within its RE sector:

***Resource Efficiency in Manufacturing*:** Encourage the use of recycled materials and components in the manufacturing of RE equipment, such as solar panels and wind turbines. This can reduce the need for virgin resources and minimize the environmental impact of production.

***Product Design for Reuse and Recycling*:** Promote eco-design principles for RE products, ensuring they are designed with disassembly and recyclability in mind. Extended Producer Responsibility (EPR) policies can incentivize manufacturers to take back and recycle their products at the end of their life cycle.

End-of-Life Management: Develop recycling and disposal facilities for RE equipment that has reached the end of its useful life. Proper recycling processes can recover valuable materials and reduce waste.

***Remanufacturing and Refurbishment*:** Encourage the refurbishment and remanufacturing of RE equipment, extending its lifespan and reducing the need for new equipment. This can create job opportunities in the repair and maintenance sector.

***Batteries and Energy Storage*:** Implement recycling and repurposing programs for energy storage systems, such as lithium-ion batteries used in solar installations. Recovering valuable materials from old batteries can reduce the environmental impact and lower costs for new installations.

***Circular Supply Chains*:** Develop circular supply chain practices, such as refurbishing and reusing components and materials from decommissioned RE systems in new installations.

***Digital Technologies*:** Implement digital technologies like the Internet of Things (IoT) and blockchain to track the life cycle of RE equipment and ensure traceability for recycling and reuse purposes.

***Circular Business Models*:** Promote circular business models, such as Product-as-a-Service (PaaS) or leasing, which encourage manufacturers to retain ownership of their products and incentivize their longevity and efficient use.

Waste Reduction: Implement waste reduction and recycling programs at RE project sites to minimize construction and operational waste.

To reach EU member status, legislative reform is actively followed in Ukraine both locally and globally, aimed at stimulating businesses to transition to the latest production methods, including CE. The innovative management approach begins by treating "waste" as an opportunity, not a problem.

In June 2022, Ukraine took a significant step towards modernizing its waste management system, which had been previously inadequately regulated and fragmented, with the adoption of the "**Waste Management Law**" (WML). This law, inspired by EU directives such as the EDG, establishes a comprehensive legal framework for waste management and marks a pivotal shift in Ukraine's approach to this sector. The WML, effective from July 9, 2023, provides a grace period for regulators and businesses to acclimate to the new regulations. Key features of the WML include:

Implementation of a New European Waste Management Hierarchy: Establishing a systematic approach to waste management at local, regional, and national levels, aligning with European standards.

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[186] https://www.circularinnovationlab.com/post/the-present-state-of-the-circular-economy-in-ukraine

- Polluter Pays Principle and Extended Producer Responsibility: Obligating manufacturers to manage the disposal of packaging and products they introduce to the market, thereby promoting accountability and sustainable practices.
- Streamlined Information System: Enhancing the efficiency of waste management through improved accounting, reporting, and authorization processes.
- Publicly Accessible Subsystem of Registers: Increasing transparency by providing public access to information on issued permits, Extended Producer Responsibility (EPR) producers, and their products.
- Standardized Waste Collection and Recycling Procedures: Outlining protocols for the collection, removal, processing, and recycling of household waste.
- Special Provisions for Current Geopolitical Challenges: Addressing waste disposal issues arising from bombardments and the closure and rehabilitation of outdated landfills.
- Modern Waste Recycling Infrastructure: Facilitating the development of a state-of-the-art recycling infrastructure in Ukraine that aligns with European directives, thereby attracting investors and laying the groundwork for a Circular Economy (CE).

The adoption of the WML and the move towards a circular economy approach signify Ukraine's commitment to reducing environmental impact, generating economic opportunities, decreasing reliance on imported resources, and contributing to a more sustainable and resilient energy sector. Effective collaboration among the government, industry, and civil society is crucial in driving this transition and fostering a holistic circular economy in renewable energy.

4.3.11 Electrification of heating and transport based on renewable energy

RE-electrification is a particularly powerful strategy because it takes advantage of potential synergies between electrification and renewable energy, and between sectors of the economy. At the same time, however, it a very complex undertaking, since steps taken in one sector can have major impacts on other sectors and their infrastructure requirements. The impacts will be seen not only on the power grid, but also on the gas and thermal network infrastructure, as well as on building stocks, recharging stations for EVs and other end-user infrastructure. Each of the three major areas of the economy would play a significant role in achieving the RE-electrification transition, both through major growth in their use of electricity as a fuel, and in offering opportunities for significantly increasing the flexibility of that use.

Buildings

Buildings now use about 120 exajoules (EJ) of energy globally per year, about 30% of global final consumption. More than half of that energy is supplied by natural gas, oil, coal, biomass. Homes and other residences consume about 70% of buildings energy, while commercial and government buildings use the rest.

Currently, electricity supplies about 24% of the energy used in residential buildings and 51% of that for commercial and public buildings. Those shares can be increased using the following technology pathways:

- Switch to heat pumps for space heating and hot water. Heat pumps are three to four times more efficient than other forms of space heating. However they typically have higher capital

Figure 91: BIPV system

costs and require major building retrofits when applied to old properties. In some Nordic countries heat pumps already account for more than 90% of the sales of space heating equipment.

- Use electricity directly for resistance heating in boilers and furnaces, typically to heat water that is circulated to provide heating, and for space heaters. As there is no efficiency gain in this option, for economic reasons it is better suited to well-insulated buildings or mild climates. Switch to electric stoves and ovens for cooking where applicable. In addition to the direct electrification of building energy needs, using synthetic fuels produced with clean electricity may present another pathway to reduce fossil fuel use and emissions in buildings:
- Use electricity to produce fuels such as hydrogen or synthetic methane that can be supplied to homes and commercial buildings through existing or new natural gas distribution pipelines. Countries with colder winters face a particular challenge in electrifying buildings while meeting high demand for heat. In France, for example, the current typical peak demand for electricity and gas combined is four times higher in the winter than in the summer.

A separate solution is in increasing the use of district heating systems, which can take advantage of waste heat, heat from sewage or water, or renewable heat as sources for heat pumps. The heat can also come from biomass and geothermal sources, combined with cogeneration to produce heat and power, and storage systems.

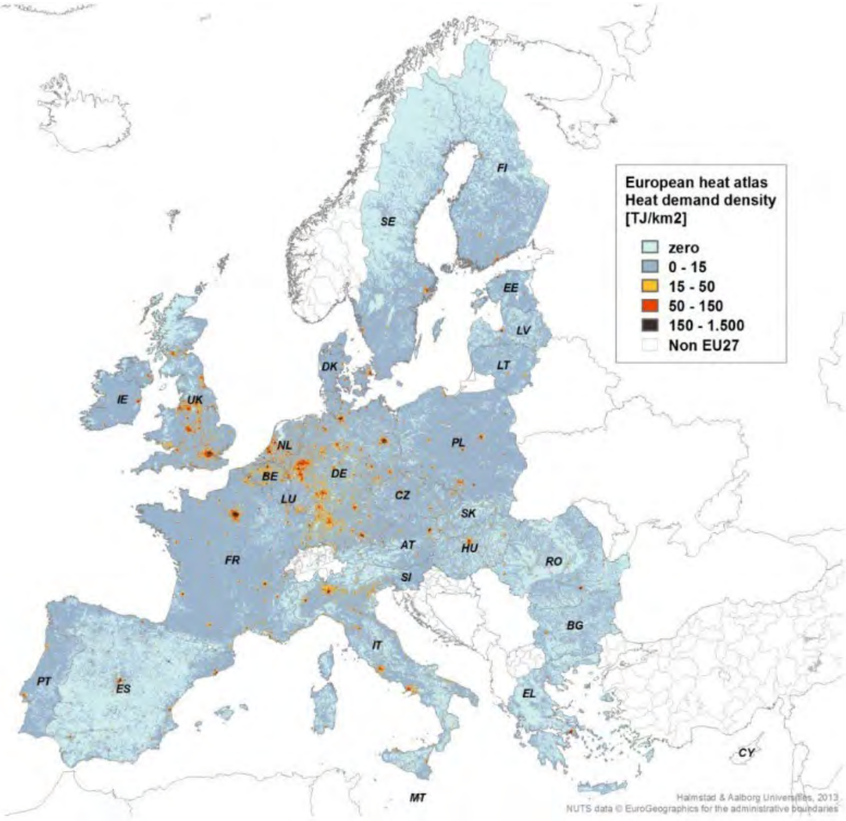

Figure 92: European heat demand density

The Heat Roadmap Europe project found that using such systems to supply half of Europe's total demand for heat (using excess industrial heat, large-scale heat pumps and cogeneration) could cut carbon emissions by 89% in 2050 compared to 2015[187]. District heating systems can also be combined with thermal storage systems. In addition to existing solutions, demonstration projects are exploring even more innovative approaches. In Sweden, for example, E.ON's Ectogrid technology enables a number of buildings to be connected to a thermal grid, using heat pumps to supply the necessary heat. Heat or cooling flows as needed among the buildings, controlled by a cloud-based management system. The approach reduces heating bills by 20% (Ectogrid, 2018). In northern England, the so-called HyDeploy project was launching a four-year trial to inject hydrogen produced via electrolysis into a number of existing gas grids, to reduce cooking and heating emissions without the need for new end-use appliances[188]. Achieving greater electrification of energy use with renewable power in buildings requires a careful combination of multiple approaches, which balance the needs of different infrastructure requirements. Particular attention must be paid to avoiding excessive new investment in power distribution grids to meet the winter peak demand[189].

Transport

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187 http://vbn.aau.dk/files/288075507/ Heat_Roadmap_Europe_4_Quantifying_ the_Impact_of_Low_Carbon_Heating_and_Cooling_Roadmaps..pdf

188 www. hydeploy.co.uk/

189 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jan/IRENA_RE-Electrification_SGCC_2019_preview.pdf

Currently, only about 1% of total energy use in transport – which includes passenger and cargo transport by road, rail, maritime shipping and aviation – is supplied by electricity. More than two-thirds of that is used for rail transport globally, and much of the rest is used by tram and subways. The electricity consumption of the estimated millions EVs now on the road is negligible. Strong policies are therefore required to accelerate the profound transformation of the transport sector called for by decarbonisation targets and concerns over local air quality.

The technology paths for achieving a major transformation include:

- Increase the share of EVs on the road. Such vehicles offer a number of advantages, including improved air quality and reduced maintenance and operating costs. Adoption rates will depend heavily on both public policies and continuing declines in the cost of batteries. Bloomberg New Energy Finance estimated that battery costs would drop quickly enough to make EVs cost-competitive without subsidies by 2024[190]. Especially in urban environments, the air pollution benefits of EVs can make a decisive difference. As a result, an increasing number of cities have put in place regulations that favour electric driving. Anticipated changes in transport, such as autonomous vehicles and more shared rides, which are expected to increase the usage rates of vehicles, could reinforce the deployment of EVs.
- Use renewable electricity to make hydrogen to power fuel cell vehicles (FCVs) and trains for use over long-distances, for example, where battery capacities limit the range of EVs, or in cases where the cost of building new overhead electric lines is high. Though currently expensive to buy, studies show that in the long run FCVs may offer well-to-tank costs comparable to the Internal Combustion Engine (ICE) equivalent, subject to future changes in oil prices and tax schemes.
- Use renewable electricity to make synthetic gas or oil (hydrogen derivatives) to replace fossil-based transport fuels. Studies show that even in the long run, the economic prospects for such fuel use in ICE vehicles may not be positive in comparison to EV or FCV options. However, such fuels can be used for applications where no alternatives exist, such as heavy-duty marine and aviation applications. The extent to which the use of hydrogen and its synthetic fuel derivatives penetrate may largely depend on the future performance and cost of batteries. With sufficiently low battery costs, electricity can increasingly be used for rail travel and freight, and perhaps in aviation. For example, Avinor, the public operator of Norway's airports, has a goal of using electric aircraft for all flights of up to 1.5 hours long by 2040[191]. Ships are being electrified and batteries have been introduced on ferries in Norway, for example, while hydrogen is being considered for Rhine River freight shipping. The future role of hydrogen for transport applications requires further debate. The electrification of transport is in many ways an ideal use of renewable power, given the variable output of sources such as solar and wind. Road vehicles are parked about 90% of the time, allowing their charging schedules to be optimised using smart power management tools to accommodate (or even take advantage of) those variations in power generation. German research finds that adjusting charging rates up or down to match the changes in wind and solar generation, in combination with price-sensitive smart charging systems, can more than double the share of renewable energy used by EVs[192].
- EVs also offer the potential of so-called vehicle to grid (V2G) services (often considered as a part of Smart Grid package). When parked and connected to the grid, their batteries can help regulate voltage and frequency, or supply electricity to meet spikes in demand. The vehicle capacities are significant: car battery capacity already far exceeds the capacity of all other electricity storage. However, this V2G potential has not yet been widely taken advantage of, outside of certain pilot projects.

  V2G pilot was considered as one of possible scenarios within Second transmission project in Ukraine, however taking into account it was developed mostly on TSO level – the actual impact and scalability was doubtful. Also, one of the challenges of V2G/G2V is a level of battery derating due to operation in balancing mode. The technology has still not approached the feasibility margin. However, it may be considered for isolated areas and in terms of high energy security in case of blackouts. It was considered by the Consultant as a part of P2X/X2P concept of the technical scenario.

[190] https:// about.bnef.com/electric-vehicle-outlook
[191] www.avinor.no/ en/corporate/community-and-environment/ electric-aviation/electric-aviation
[192] https://www.oeko.de/fileadmin/oekodoc/ Assessing-the-status-of-electrification-ofthe-road-transport-passenger-vehicles.pdf

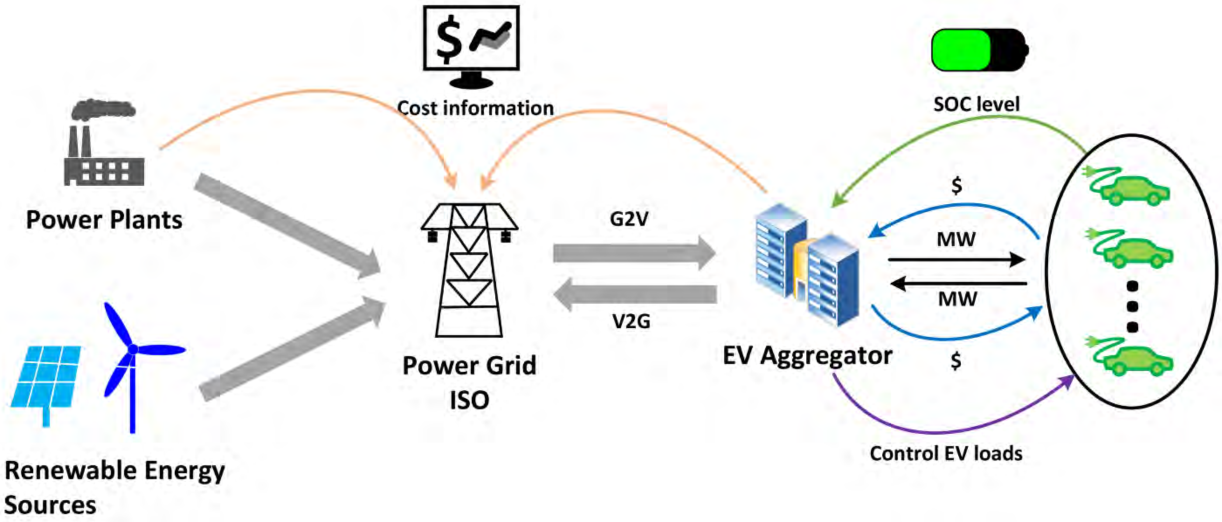

Figure 93: Vehicle to grid / Grid to vehicle mode

Flexibility can also come from using electrolysis to produce hydrogen, which then can be used in FCVs. Not only can the electrolysis process be quickly ramped up or down to match supply variations, but the resulting hydrogen also functions as a means to store temporary surpluses of energy. Realising these potential synergies requires intelligent grids and smart power management strategies. This is especially important to avoid the massive investment in upgrading distribution networks that would be required if EV charging were uncontrolled. Pilot projects and experiments are already demonstrating the benefits of smart electrification strategies in transport. In the Netherlands, grid operators and Renault have built 1 000 public solar-powered smart charging stations with battery storage, decreasing peak load by 27-67%[193]. In California, Pacific Gas & Electric (PG&E) and BMW have paid car owners for the right to draw power from their plugged-in cars, cost-effectively helping to meet peak loads (PG&E, n.d.).

Given the intricate interrelationships between generating power and using it for transport, and between market forces and public policy, the electrification of transport with renewable energy is a daunting and complex task. Making the transition requires careful planning. For example, the necessary transport infrastructure – especially for road transport, whether it is EV charging stations or hydrogen distribution networks and fuelling stations – must be rolled out at a scale to ensure that consumers can have confidence in choosing new types of vehicles or transport. Furthermore, the implications of transport electrification for clean power demand, and for the potential need for hydrogen production capacity, need to be better understood. Some studies indicate that the full electrification of the transport sector would require renewable generation capacity several factors larger than what is currently envisaged. Expansion of electrification without the corresponding expansion of renewable energy will result in higher emissions from the power sector, even though emissions from the transport sector significantly reduce.

National goals, such as banning sales of fossil fuelled vehicles entirely (as France, Norway, the United Kingdom and others plan to do) or setting EV targets (as in China, Germany, the Republic of Korea, and others), must therefore be complemented with clear plans for implementation of measures such as charging infrastructure and the use of smart charging.

For example, to ensure that the five million zero-emission vehicles mandated to be on the road in California by 2030 can be supplied with electricity, the state has earmarked USD 2.5 billion over eight years to install 250 000 charging stations[194].

[193] https://doi.org/10.1016/j. apenergy.2015.04.092.
[194] www.arb. ca.gov/msprog/zevprog/zevprog.htm

Industry

Industry is the most challenging of the three major sectors to decarbonise because of its unique dependencies on fossil fuels for both fuel and feedstocks, and because of the lack of cost-effective substitution (in contrast to transport, where ICE vehicles can be replaced by already available EVs).

For high-temperature industrial processes, there is no significant efficiency gain from a shift to electricity. Today, electricity supplies only about 27% of the energy used in industry, powering everything from pumps and motors to heating and cooling units.

Technologies and strategies for RE-electrification include:

- Increase the use of efficient heat pumps for low-temperature heat. IRENA estimates that the number of such heat pumps could rise from one million today to 80 million in 2050, which would supply about 7% of the global demand for industrial heat. Combined with waste recovery, heat pumps offer significant cost reductions, as Kraft Foods in the United States found when it captured waste heat from refrigeration systems to heat water. The company saved more than 14 million gallons of water and USD 260 000 annually[195].
- Adopt electric boilers or hybrid boilers that can switch instantly between electricity and natural gas. The hybrid boilers allow companies to not only take advantage of fluctuating electricity prices, but also to help balance supply and demand on the grid as renewable power generation varies. High-temperature electric furnaces for commercial applications are not yet available.
- Replace natural gas fuel and feed stocks with hydrogen or its derivatives produced with renewable power. Direct use of hydrogen as feedstock, for example in ammonia production, has good economic prospects among all the hydrogen applications.
- Use of circular economy approaches (see Ch.4.3.10).
- Relocate industrial facilities to regions with low-cost renewable electricity. Aluminium smelters have in some cases moved to Iceland because of inexpensive hydropower. Switching to electricity in industry is easier and cheaper for new plants, given the high cost of retrofitting existing plants. In many cases electrification of industrial processes could be made cost-effective with a price on carbon. However, areas with good renewable sources, or industries where processes can be made flexible to better match the variable generation from these sources, could already have potential to maximise the benefit of cheap and clean power generated by renewables. For example, the output of an aluminium production process developed by Germany's Trimet Aluminium SE and New Zealand's Energia Potior Ltd can rise or fall by 25%, creating a virtual storage capacity of about 1 120 megawatt hours (MWh) – similar in size to a medium-sized pumped-storage plant[196] . Electrification permits quick and substantial reductions in industry's carbon emissions. The reason is that the bulk of energy use is in just a few energy-intensive industries, such as metals and chemicals. Using smart public policy to target the production of the few energy-intensive commodities can have a major impact. The Swedish Energy Agency is co-financing a pilot initiative called HYBRIT that will use hydrogen from hydro and wind power to make steel, for example. The goal is to make the production of steel fossil-free by 2035, at a cost that is competitive with traditional steel production. That initiative alone has the potential to cut Sweden's total carbon dioxide emissions by 10%[197].

[195] www. climate.emerson.com/documents/kraft-foodsrelies-on-heat-pump-en-us-3222734.pdf
[196] www.iea.org/publications/ insights/insightpublications/Renewable_ Energy_for_Industry.pdf
[197] www.hybritdevelopment.com

4.4 Planning instruments to optimise the electricity generation mix linked to demand-side measures and infrastructure development

To ensure an optimal mix of generation capacities and their efficient integration with demand-side measures and infrastructure development in the energy sector, comprehensive planning instruments and strategies are essential. Here are some key planning instruments and considerations for achieving this:

- **Integrated Energy Planning:** Develop an integrated energy planning framework and plan that considers all available energy sources and technologies, including fossil fuels, renewables, nuclear, emerging technologies. This holistic approach ensures that energy generation, transmission, and consumption are optimized together. The Smart Grid measures shall be implemented to sufficient extent allowing to build a technical background to achieve this goal.
- **Diversified Energy Portfolio:** Aim for a diversified energy portfolio that includes a mix of energy sources, such as solar, wind, hydro, natural gas, and nuclear power. This diversity can enhance energy security and resilience by reducing reliance on a single source.
- **Demand-Side Management (DSM):** Implement demand-side measures to reduce energy consumption during peak periods and optimize energy use. This may include energy efficiency programs, time-of-use pricing, smart grids, microgrids, and incentives for consumers to reduce energy consumption during high-demand times.
- **Infrastructure Development**: Plan for infrastructure development that accommodates various generation capacities and efficiently transmits energy from different sources to demand centers. This includes upgrading and expanding transmission and distribution networks as well as incorporating energy storage solutions.
- **Energy Storage:** Incorporate energy storage technologies, such as batteries, pumped hydro, or thermal storage, to balance supply/demand, store excess energy from intermittent sources, provide grid stability.
- **Flexibility and Grid Management**: Develop grid management systems that can adapt to fluctuations in energy supply and demand. This includes real-time monitoring, grid automation, and the ability to integrate distributed energy resources like rooftop solar panels.
- **Environmental and Regulatory Considerations**: Ensure that planning takes into account environmental and regulatory requirements, including emissions reduction targets, air quality standards, and land use regulations. This may influence the choice of generation technologies and locations.
- **Market Mechanisms:** Implement market-based mechanisms, such as capacity markets, renewable energy auctions, and carbon pricing, to incentivize the development of the most cost-effective and reliable generation capacities.
- **Stakeholder Engagement**: Engage with stakeholders, government agencies, utilities, industry representatives, and the public, to gather input, address concerns, and build consensus on energy planning decisions.
- **Long-Term Planning**: Develop long-term energy plans with a horizon of several decades to ensure stability and predictability in the energy sector. Long-term planning allows for the phased integration of new technologies and gradual retirement of older, less efficient generation capacities.
- **Risk Assessment**: Conduct risk assessments to evaluate potential challenges and uncertainties, such as fuel price volatility, extreme weather events, and technological advancements that may impact energy planning decisions.
- **International Cooperation**: For Ukraine it is crucial to collaborate with neighbouring countries including ENTSO-e member states and regions to facilitate cross-border energy trade, share resources, and enhance energy security.
- **Monitoring and Evaluation**: Establish mechanisms for ongoing monitoring and evaluation of the energy system's performance, including the effectiveness of demand-side measures and infrastructure investments. Adjust the plan as needed based on real-world outcomes.

Optimizing the mix of generation capacities and integrating them efficiently with demand-side measures and infrastructure development is a complex and dynamic process. It requires careful analysis, forward-looking planning, and adaptability to changing technologies and market conditions. Additionally, it is crucial to align energy planning with broader sustainability goals, including reducing greenhouse gas emissions and promoting clean energy sources.

4.5 Options for streamlining permitting procedures for renewable energy projects (one stop shop)

Creating a market that can attract capital and compete with other countries pursuing renewable energy will require improvements in Ukraine's RE policy framework. Expanding renewable generation will depend on significant grid modernization efforts and increased storage and export capacity to manage variable generation throughout the system.

In this light Ukrainian government shall consider international best practices to streamline permitting procedures for development of so-called one-stop shop for RE development.

Danish experience by Danish Energy Agency could be considered as the relevant example.

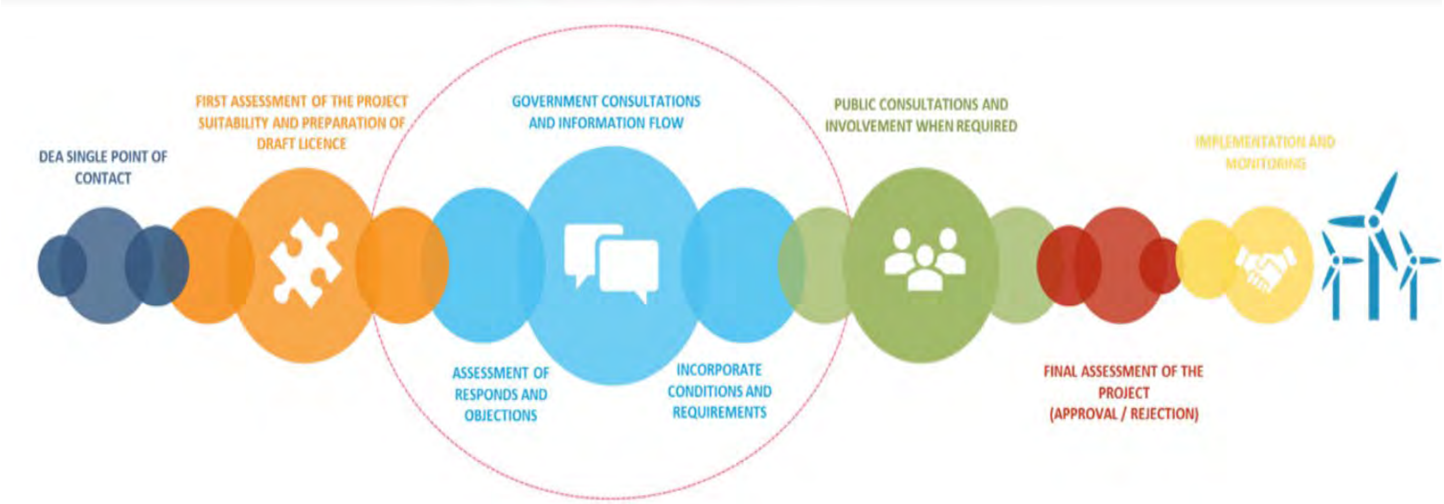

Figure 94: Flow of involved authorities and the number of steps during the procedure (DEA)

Energistyrelsen (Danish Energy Agency, DEA) serves as the main liaison between developers and the various other authorities involved with granting licenses for the development of offshore wind parks. Even though the number of required permits is not reduced, the authorizations processes are coordinated with other authorities through a single authority (DEA). Thus, DEA can grant collective authorization on behalf of several authorities, with conditions formulated by the individual authorities. This is called 'one-stop-shop'.

Consequently, the project developer has a relatively high degree of certainty as it can expect the project to be implemented if all conditions are respected. These joint authorizations do not completely exclude the need to obtain authorizations from other authorities. In these cases, the DEA acts as a relay for information between the RES developer and the other authority. In other words, the RES developer provides information to and hears back from the DEA, even if the DEA is not involved in the particular decision-making process. However, once the relevant authorities have cleared the project to proceed the system provides a high degree of certainty for investors that the project will be carried out. It also simplifies the administrative process as there is only one point of reference, the DEA[198].

With regard to Ukrainian experience, 'one-stop-shop' concept could be applied to permitting procedures which could be performed at basic conditions without significant involvement of the investor, such as land allocation and development, electricity grid development, infrastructure and logistic development (e.g. road construction) as well as certain components/stages of environmental impact assessment.

At the same time, in **Ukrainian reality the regulatory framework of the one-stop shop solution shall be adjusted to allow the developer taking over development responsibility to perform it by its own resources** where the capacity of the state-appointed agency is limited or inadequate to ensure rapid and quality development of the project. Please refer to Clause 3.3 and 4.2 for additional measures to be foreseen for enabling this.

[198] https://resmonitor.eu/en/dk/best-practices/100/

Ukrainian legislation provides for several mechanisms/instruments which could serve as a basis for the ‘one-stop-shop’ such as:

Designation of the land plots for ‘green’ auctions. Within the scope of the ‘green auctions’ governmental authorities could define and pre-development (including issuing of the technical conditions for the grid connection) land plots proposed for construction of the RE facilities[199].

Subject to respective amendments proposed mechanism could be used for development of complicated tailored RE projects such as offshore wind, hydroelectric, hydrogen etc.

Public-private partnership. According to the applicable law within the scope of the public-private partnership (PPP) projects public partner (i.e. municipal or national government) could be responsible for the development of the project proposed for subsequent investments[200]. Additionally, the relevant projects could receive other types of support from the state, such as infrastructure and grid connection, loans, financial guarantees, guarantees of offtake and feedstock supplies etc.[201].

However, development and implementation of the PP projects has complicated long-lasting procedure and requires significant capacity from the public authority i.e., either by national or local government. In this regard such approach could be used for pilot or large-scale national projects.

Industrial parks. According to applicable legislation industrial parks could be established at the municipal and state-owned land to ensure fast industrial development of the region/community[202]. Within the borders of industrial park the land and infrastructure could be allocated for RE projects.

In addition to that industrial parks could create and operate their own ‘small distribution systems’[203] to develop distributed generation from renewable sources and establish reliable electricity supplies.

Support for significant investment projects. Significant investment projects legal regime (known as ‘Investment nanny’ support)[204] provides for state support for certain projects, including bioenergy projects including construction of the grids, other infrastructure as well as reservation of the land plots and facilitation of the communications with national and local permitting authorities. Subject to minor technical amendments proposed legal regime could be applied to other RE projects.

Based on the above-mentioned, Ukrainian legislation contains provisions and mechanisms which subject to minor amendments could be used for establishment of the ‘one-stop-shop’ permitting approach to boost RE development in Ukraine.

At the same time, such projects are reasonably subject to complicated procedural requirements to ensure state-aid compliance and control for just distribution of the resources. Due to this fact, such projects on the one hand require significant capacity from public authorities and, at the same time, make private investment dependent on the mentioned capacity and project management by public authorities.

Therefore, in order to ensure fast and large-scale decentralized development of RE projects Ukrainian legislation should leave the gap and opportunity for individual developments which are not dependent or coordinated by public authorities.

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[199] See Article 9-3 of the Law of Ukraine On Alternative Energy Sources.

[200] See Law of Ukraine On State-Private Partnership.

[201] See Article 18 of the Law of Ukraine On State-Private Partnership.

[202] See Law of Ukraine On Industrial Parks.

[203] See Chapter 9 of the Distribution Grids Code, approved by NEURC Resolution no. 310 as of 14 March 2018.

[204] See Law of Ukraine On State Support of Investment Projects with Significant Investments in Ukraine.

4.6 Conclusions and Recommendations

CONCLUSIONS

- Providing war-related risk insurance to private investors is key to Ukraine's resilience.
- Currently the problem exists in terms of provision of insurance during the Wartime allowing the recovery of Ukraine. For instance, impossibility to provide insurance for the international staff working in Ukraine (the cost of such insurance is extremely high) is blocking the possibility for expedient re-building projects foreseeing the on-site presence of international experts.
- To effectively implement the necessary insurance mechanisms, Ukraine should work on creating a regulatory environment that encourages insurers to offer such policies, and it should provide support and incentives to make insurance more affordable for RE project developers.
- Advanced RE technologies are critical for achieving energy transition goals, improving grid stability, and reducing greenhouse gas emissions and their use was considered while developing the technical scenario.
- DEA can serve as a guidance of one-stop-shop for Ukraine, At the same time, in Ukrainian reality the regulatory framework of the one-stop shop solution shall be adjusted to allow the developer taking over development responsibility to perform it by its own resources where the capacity of the state-appointed agency is limited or inadequate to ensure rapid and quality development of the project.

RECOMMENDATIONS

- To follow recommendations outlined in other Chapters - Development of an Updated Ukraine Energy Strategy (with due consideration of available technologies as described in cl. 4.3 hereof), Harmonization of Subordinate Plans, Legislation, Programs and development frameworks
- Elaborate a one-stop-shop for Ukraine: To elaborate a one stop shop as recommended in Clause 4.5 hereof.
- Establishment of the insurance mechanisms: the of efficiency of Law of Ukraine "On financial mechanism for promoting export activities" regarding insuring investments in Ukraine against military risks (draft law No. 9015 dated 14 February 2023) will be directly linked to availability of funds for such insurances which shall be involved from IFIs, international donors and other sources. The government can implement comprehensive policy reforms that include subsidies, risk guarantees, and regulatory support, tailored to mitigate the specific risks associated with various sectors.
- Reliable Payment Systems for RE Electricity Generators. It's essential to establish reliable and prompt payment mechanisms from offtakes to RE existing and future electricity generators – these mechanisms may be supervised by international referees
- Expedient settling of the existing debts and mal-performance issues. Settling debt issues, imbalances and limitations imposed on developers. Lifting bureaucratic limiting by establishment of one-stop-shops and transparent development, construction and operation manuals will provide a very clear signal to investors willing to contribute in Ukraine's "building back better"
- AI technologies in balancing and forecasting. Ukraine is often proclaiming digitalization as one of the main drivers of Economy restoration.
- Active Support for Prosumers: Encouraging the concept of "prosumers" – consumers who also produce electricity – is crucial. This approach not only reduces the load on the grid but also promotes local energy generation and consumption. Policies and incentives such as feed-in tariffs, net metering, and subsidies for installing renewable energy systems can stimulate prosumer participation.
- Grid Reinforcement and Decentralization: Moving from a centralized system with large generation capacities to a distributed generation model is key. This involves reinforcing the grid infrastructure to support the integration of renewable energy sources from areas most suitable for RE generation to areas with high consumption. Investment in smart grid technologies, which allow for better integration and management of distributed energy resources, is essential. This shift will enable a more resilient and flexible energy system, capable of accommodating diverse renewable energy sources
- Demand-Side Management and Harmonizing Supply and Demand: Effective demand-side management is necessary to align variable RE electricity supply with demand. This requires a combination of significant price incentives (varying by factors of 10 or more depending on RE availability