

National Academy of Sciences of Ukraine Institute of Engineering Thermophysics

Municipal energy of Ukraine: current state and trend of post-war development

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VI International Scientific-Technical Conference ACTUAL PROBLEMS OF RENEWABLE EN CONSTRUCTION AND ENVIRONMENTAL ENGINEERING

Kyiv, Kielce – 2022

Part 1

Post-war Development of Energy Industry of Ukraine

Energy of Ukraine:

- difficult situation
- uncertain expectations
- probable recovery and development scenarios

Ukraine Recovery Plan



Ukraine Recovery Vision:

Strong European Ukraine is a magnet for international investments. Ukraine's Recovery is aimed to accelerate sustainable economic growth. The plan identifies a list of National programs to achieve key results. The plan is designed for 10 years - from 2023 to 2032.

Its implementation will take place in two stages. The first stage will last three years (2023-2025), in which it is planned to implement most of projects - 580. Over these three years, it is planned to use more than \$350 billion. The second stage will contain fewer projects, but will require more funding - more than \$400 billion.

At the same time, the plan predicts that the Ukrainian economy will grow by 7% annually for 10 years.

The most expensive projects are the restoration and modernization of housing and infrastructure in the regions, which will require \$150-250 billion, as well as the expansion and integration of logistics with the EU, which will cost \$120-150 billion.

Need for Energy Independence and Green Deal reaches \$130 billion.

ALL 10 YEARS

📶 Number of projects	850
🖌 GDP impact	>7%
🔯 Funding	>750 bn USD
Economic Complexity	TOP-25 countries

👮 Human Capital Index 🛛 TOP-25 countries

2023-2025

Index

Ĺ	Number of projects	580
6 <mark>8</mark> 9	Funding	>350 bn USD
u	Economic Complexity Index	TOP-40 countries



Ukraine Recovery Plan. https://recovery.gov.ua/en



📶 Number of projects	270
💷 Funding	>400 bn USD
Economic Complexity Index	TOP-25 countries
👮 Human Capital Index	TOP-25 countries

Human Capital Index TOP-40 countries

NATIONAL PROGRAMS

Recovery prerequisites: Strengthening institutional capacity

<0,1 bn USD 620

Energy independence and Green Deal

130 bn USD 8

Logistics debottleneck and integration with EU 120 - 160 bn USD 680

Develop Culture and Sport systems

20 bn USD s

Upgrade HealthCare system

5 bn USD 680

Recovery prerequisites: Digital government s

<0,1 bn USD

Ukraine Recovery Plan. https://recovery.gov.ua/en

Strengthen defense					
and	security	in			
6 <mark>8</mark> 0	50 bn USD	8 2			

Ensure competitive

access to funding

75 bn USD

Recovery and

modernization of

social infrastructure

35 bn USD

625

680

rive for FU tegration

<1bn USD

Boost business environment 620 5 bn USD

Recovery and upgrade of housing and regions infrastructure 150 - 250 bn USD 620

Secure targeted and effective social policy 7 bn USD SS

Re-build clean and safe environment 20 bn USD 625

Secure macrofinancial stability

689 60 - 80 bn USD

Improve Education system

6<mark>8</mark>0 5 bn USD

Grow value adding sectors of economy 50 bn USD 680

Projects of national programs

Energy independence and Green Deal

- Build 1.5–2 GW peaker and 0.7–1 GW of storage
- Build smart grids
- Re-build damaged energy objects, including Kremenchuk, Chernihiv, Okhtyrka CHPs)
- Oil pipeline Brody-Adamova Zastava
- Securing gas supplies/storage for EU and Ukraine (e.g., extension of Świnoujście/Gdansk LNG and/or interconnect or import from Turkey/Italy/Germany)
- Increasing nuclear capacity (prolongation, higher utilization of existing capacities, and 2 GW new units at KhmelnytskyiNPP)
- Localize RES equipment production (towers, transformers, cables, electrolyzers, Li batteries)
- Localizing nuclear value chain (uranium mining, plant for fuel production, waste storage)
- Modernize gas transmission and distribution networks
- Natural gas stock replenishment
- Develop unconventional gas fields
- Oil, oil products emergency stock for 30+ days
- Expanding oil refining capacity post-war
- Test and develop H2 transport infrastructure
- Build out ~15 GW electrolyzer capacities
- Build out of 3.5 GW hydro and pumped hydro capacities
- Build 30+ GW RES for H2 production
- Expanding interconnectors with ENTSO-E to ~7 GW (multiple projects)
- Developing biofuels (bioethanol, biodiesel, biomethane, biomass) production from agroproduce, residues and waste
- Increase gas production from existing fields
- Expanding oil products interconnectors with EU refineries and ports

Ukraine Recovery Plan. https://recovery.gov.ua/en

As of July 2022, according to [1, 2], about 4% of generating capacities were destroyed during hostilities, another 35% of capacities are located in the occupied territories [2]. In particular, the Zaporizhzhia Nuclear Power Plant periodically operates in very difficult conditions and is under constant pressure from the Russian occupiers, including its mining, constant shelling, and nuclear-political blackmail. In general, about 50% of thermal electricity generation, 30% of solar generation and more than 90% of wind generation have been destroyed or are in the occupied territories. Gas production decreased by 10-12% during the full-scale military invasion. The main oil refineries were stopped (own production provided about 30% of oil products) causing logistical difficulties with oil products supply. As of mid-June 2022, the direct damage caused to the infrastructure of the Ukrainian energy industry and the oil and gas sector, according to preliminary estimations, counts nearly 47 billion UAH. (1.7 billion USD). The total indirect losses of the power sector since the beginning of the war are estimated at 341.8 billion UAH. In the sector of gas production, transit and distribution, the damage estimations reached 61 billion UAH. For the sector of oil production and oil refining – 66 billion UAH.

As of August 10, 2022, 300 Ukraine's communal thermal power facilities were damaged or destroyed due to the Russian Federation war, 158 of them have been already restored [3]. Among these facilities are 10 CHPP, three of which have been restored. From October 10 to 20, more than 400 energy facilities in 16 regions of Ukraine were damaged as a result of Russian invaders shelling, 10% of which are in critical condition.

During the period from October 10 to November 10, 2022, a third of the existing energy infrastructure was destroyed or damaged, including large CHPP, main networks, and powerful boiler houses. This caused interruptions in water, electricity and heat supply.

As of June 14, 2022, 12900 apartment buildings (~13.5 million m²), 107707 private houses (~1.9 million m²) were destroyed/damaged [4]. Damaged and destroyed: more than 1000 institutions of general secondary education and more than 600 institutions of preschool education; more than 700 healthcare facilities; 255 cultural objects were damaged and 295 were destroyed; 41 social welfare institutions were damaged and 30 were destroyed.

According to the Office of the United Nations High Commissioner for Refugees, 11.4 million Ukrainians left their homes only in the first month and a half after the start of the hot phase of the war. As of June 7, 2022, 4816923 refugees from Ukraine were registered in Europe alone, and a total of 5.5 million people left the country. According to the assessment of the UN International Organization for Migration, another 7.7 million citizens of Ukraine are considered internally displaced persons, that is, they remained in the country, but had to leave their own homes [4].

[2] National Council for the Recovery of Ukraine from the War. Working group "Energy security". July 2022. https://www.kmu.gov.ua/storage/app/sites/1/recoveryrada/ua/energy-security.pdf [3] Preparation for the heating period under martial law. USAID seminar materials, August 12, 2022.

^[1] National Council for the Recovery of Ukraine from the War. Working group "Audit of losses incurred as a result of the war". July 2022. <u>https://www.kmu.gov.ua/storage/app/sites/1/recoveryrada/ua/audit-of-war-damage.pdf</u>

^[4] National Council for the Recovery of Ukraine from the War. Draft of the Post-War Recovery and Development Plan for Ukraine. Working group "Construction, urban planning, modernization of cities and regions of Ukraine". July 2022. https://www.kmu.gov.ua/storage/app/sites/1/recoveryrada/ua/construction-urbanplanning-modernization-of-cities-and-regions.pdf

Distribution of operating capacity of power generation facilities, MW



Forecast energy balance for 2032 according to the recovery plan of Ukraine and indicators of the New Energy Strategy by 2035

№	e Energy resource	Primary energy suppl equivalent	New energy strategy by 2035, million tons of oil equivalent and (%)				
		2019	2032	2030	2035		
1	Nuclear energy	21,8 (27%)	30,2 (35,7%)	27	24 (25,0%)		
2	Renewable Energy Sources, incl. hvdropower	1,0 (1%)	4,7 (5,5%)	7,5	13 (13,5%)		
3	Renewable Energy Sources for H_2 production	-	8,6 (10,1%)	-	-		
4	Energy coal	14,8 (18%) including imports, 2,9	1,9 (2,2%)	13	12 (12,5%)		
5	Natural gas	25,8 (32%) including imports, 9,5	21,7 (25,6%) including exports, 3,4	28	29 (30,2%)		
6	Oil	13,4 (17%) including imports, 10,9	9,1 (10,7%) including imports, 5,9	7,5	7 (7,3%)		
7	Biofuel	4,2 (5%)	8,5 (10,0%)	8	11 (11,5%)		
	Total		84,7 (99,8%)	91	96,0 (100%)		
	GDP of Ukraine, billion international \$	588,4 (2021)	1157,5	606,7	738,5		
	Energy Efficiency - GDP/Total Primary Energy Supply, billion international \$ \$/tons of oil equivalent	6323 (2020)	13666	6667	7693		
	Energy Intensity - Total Primary Energy Supply/GDP, tons of oil equivalent/1000\$	0,16 (2020)	0,07	0,15	0,13		
	Export of electricity	0,3	1,7				
	Export of H ₂	-	∼1,5 million tons	-	10		



Several EU countries are extending the life of coal-fired power plants that are slated for closure, reopening closed plants, or raising limits on the operating hours of coal-fired power plants to reduce gas consumption. This will increase coal-fired power generation in the second half of 2022 and lead to an annual increase in thermal coal demand of approximately 33 million tonnes for the full year. In July, the German government created a "gas replacement reserve" with a total capacity of 10.6 GW. It includes 1.9 GW of lignite and 4.3 GW of hard coal already in reserve, and 2.6 GW of hard coal scheduled to be decommissioned in 2022 and 2023. Overall, we expect coal consumption in the EU to grow by 7% year-on-year to 476 Mt in 2022.

But despite the general thoroughness, the energy block of the recovery plan is burdened with certain shortcomings, namely:

• the problems and ways to solve them for the communal (municipal) energy sector of Ukraine are rather poorly presented, in particular regarding the operation of boiler houses;

- no energy-efficient cogeneration, highly efficient heat supply;
- the problems of providing energy resources to the individual household sector of the country are insufficiently covered;
- the problems of energy efficiency improvement are not sufficiently reflected;
- the aspect of the use of heat pump technologies is presented in a tendentious manner;
- the hidden role of using local fuels;

• the role of the use of information technologies (digitalization, intellectualization, use of start-systems), especially in heat energy, is practically not reflected.

KEY DEVELOPMENT CATALYST PROJECTS

- Expansion of interconnectors with ENTSO-E up to ~6 GW
- Increase in nuclear power (2 new units at the Khmelnytskyi NPP, safety and prolongation, load increase)
- Development of 30 GW of wind and solar energy
- Development of ~3.5 GW of hydro- and hydro-storage power plants
- Development of ~15 GW of electrolyzers and H2-infrastructure
- Natural gas: increase in production from existing fields, development of unconventional gas fields
- HUB of natural gas in the EU: replenishment of the strategic reserve and provision of connection with the LNG reserves of the EU / Turkey
- Modernization of the gas transportation network

• Development of the production of biofuels (bioethanol, biodiesel, biogas/biomethane)

• Post-war expansion of oil refining capacities (reconstruction of the Kremenchug Refinery and construction 1 new refinery, Brody-Adamova Zastava pipeline

Priority initiatives:

□ introduce a complete ban on Russian energy resources, ensure that sufficient energy reserves are stored and diversify energy supply;

develop renewable energy sources to ensure the transition to clean energy;

□ rebuild infrastructure that reflects the economic needs of the economy and citizens, and ensure that this infrastructure is capable of transporting new energy resources;

• modernize multi-apartment and private buildings in accordance with the principles of energy efficiency;

□ develop an additional 30 GW of RES and implement the construction of 2 new units at the Khmelnytskyi NPP, which will ensure the decarbonization of the energy sector and reduce air pollution, produce hydrogen and export it to the EU in order to strengthen Europe's energy sustainability and reduce dependence on Russia;

□ develop energy independence from critical resources and produce new energy resources that replace traditional fossil fuels;

□ significantly increase the survivability of energy infrastructure facilities.

How do people survive?

Planned electricity blackouts in a high-rise building where one of the authors lives, Kyiv, November 07-13, 2022

	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Monday							×	×	×	×						×	×	×	×					
Tuesday	×	×	×	×						×	×	×	×						×	×	×	×		
Wednesday				×	×	×	×						×	×	×	×						×	×	×
Thursday	×						×	×	×	×						×	×	×	×					
Friday	×	×	×	×						×	×	×	×						×	×	×	×		
Saturday				×	×	×	×						×	×	×	×						×	×	×
Sunday	×						×	×	×	×						×	×	×	×					

Accommodation: Internet (router) from a serious provider on a car battery; cold water and sewerage work as usual, electricity is on the schedule; hot water is available thanks to the regular electric tank-accumulator; cooking is discrete in time, in principle you can adapt; lighting – local or spot from a LED lamp with a battery or from a vintage kerosene lamp.

Part 2 LOSSES AND PAYMENT THE PRICE OF THE WORLD FOR THE WAR

The GDP cost of the war for the global economy



The Economic Costs of the Russia-Ukraine Conflict. 02 March, 2022 https://www-niesr-ac-uk.translate.goog/publications/economic-costs-russia-ukraine-conflict?type=policypapers& x tr sl=en& x tr tl=ru& x tr hl=ru& x tr pto=sc

To date, the most popular model is NiGEM (Global Econometric Model of the National Institute for Economic and Social Research of Great Britain). At the moment, the model uses neo-Keynesian long-term equilibrium equations, which does not interfere with the flexibility of the system, which can change depending on historical data and helps to build quarterly forecasts for more than 60 countries, divided into regional blocs, for more than 500 indicators.

Model forecasts are also published for various other OECD countries. The model is used by the UK Treasury, the IMF, the Bank of England, the OECD and the European Central Bank.

The inflation cost of the war



https://www-niesr-ac-uk.translate.goog/publications/economic-costs-russia-ukraine-conflict?type=policypapers& x tr_sl=en& x tr_tl=ru& x tr_hl=ru& x tr_pto=sc



Summary

OECD Economic Outlook, Interim Report September 2022: Paying the Price of War https://www.oecd-ilibrary.org/sites/ae8c39ec-en/index.html?itemId=/content/publication/ae8c39ec-en/

• The global economy has been hit by Russia's invasion of Ukraine. Global economic growth stalled in the second quarter of 2022, and indicators in many economies now point to an extended period of subdued growth.

- The war has pushed up energy and food prices substantially, aggravating inflationary pressures at a time when the cost of living was already rising rapidly around the world.
- Global growth is projected to slow from 3% in 2022 to 2¼ per cent in 2023, well below the pace foreseen prior to the war. In 2023, real global incomes could be around USD 2.8 trillion lower than expected a year ago (a shortfall of just over 2% of GDP in PPP terms).
- Annual GDP growth is projected to slow sharply to ½ per cent in the United States in 2023, and ¼ per cent in the euro area, with risks of output declines in several European economies during the winter months. Growth in China is projected to drop to 3.2% this year, amidst COVID-19 shutdowns and property market weakness, but policy support could help growth recover in 2023.
- Inflation has become broad-based in many economies. Tighter monetary policy and easing supply bottlenecks should moderate inflation pressures next year, but elevated energy prices and higher labour costs are likely to slow the pace of decline.
- Headline inflation is projected to ease from 8.2% in 2022 to 6½ per cent in 2023 in the G20 economies, and decline from 6.2% in the G20 advanced economies this year to 4% in 2023.

• Significant uncertainty surrounds the projections. More severe fuel shortages, especially for gas, could reduce growth in Europe by a further 1¼ percentage points in 2023, with global growth lowered by ½ percentage point, and raise European inflation by over 1½ percentage points.

The cost of gas and electricity for the last time



OECD Economic Outlook, Interim Report September 2022: Paying the Price of War

https://www.oecd-ilibrary.org/sites/ae8c39ec-en/index.html?itemId=/content/publication/ae8c39ec-en



End-use electricity prices for households in selected countries from Q3 2019 to Q2 2022



Publication of the IEA database on energy prices and taxes for OECD countries (third quarter 2022)

The price of oil for the last year



Change in real GDP, year to previous year, %

	2021	2022 Interim EO projections	2023 Interim EO projections
World	5.8	3.0	2.2
G201	6.2	2.8	2.2
Australia	4.9	4.1	2.0
Canada	4.5	3.4	1.5
Euro area	5.2	3.1	0.3
Germany	2.6	1.2	-0.7
France	6.8	2.6	0.6
Italy	6.6	3.4	0.4
Spain ²	5.5	4.4	1.5
Japan	1.7	1.6	1.4
Korea	4.1	2.8	2.2
Mexico	4.8	2.1	1.5
Türkiye	11.0	5.4	3.0
United Kingdom	7.4	3.4	0.0
United States	5.7	1.5	0.5
Argentina	10.4	3.6	0.4
Brazil	4.9	2.5	0.8
China	8.1	3.2	4.7
India ³	8.7	6.9	5.7
Indonesia	3.7	5.0	4.8
Russia	4.7	-5.5	-4.5
Saudi Arabia	3.4	9.9	6.0
South Africa	4.9	1.7	1.1

	2021	2022 Interim EO projections	2023 Interim EO projections
G201	3.8	8.2	6.6
Australia	2.8	6.1	4.4
Canada	3.4	6.9	4.5
Euro area	2.6	8.1	6.2
Germany	3.2	8.4	7.5
France	2.1	5.9	5.8
Italy	1.9	7.8	4.7
Spain ²	3.0	9.1	5.0
Japan	-0.2	2.2	2.0
Korea	2.5	5.2	3.9
Mexico	5.7	7.9	4.9
Türkiye	19.6	71.0	40.8
United Kingdom	2.6	8.8	5.9
United States	3.9	6.2	3.4
Argentina	50.9	92.0	83.0
Brazil	8.3	10.8	6.6
China	0.8	2.2	3.1
Indiaª	5.5	6.7	5.9
Indonesia	1.6	4.1	3.9
Russia	6.7	13.9	6.8
Saudi Arabia	3.1	2.5	₂₄ 3.2
South Africa	4.6	6.7	5.9

General inflation, %

High prices are pushing economy-wide energy expenditures up significantly this year

Energy expenditures, in per cent of GDP, total economy, selected OECD countries



Global growth is significantly weaker than expected prior to the war in Ukraine

World GDP growth, per cent



Source: OECD Economic Outlook 110 database; and OECD Interim Economic Outlook 112 database.

Due to Russia's war against Ukraine, the world will lose \$2.8 trillion - OECD

Demand reductions are required to avoid excessively low EU gas storage levels

Scenarios for European gas storage levels, per cent of available storage

Projections for EU and United Kingdom, based on 2017-2021 gas consumption: "No change" average consumption; "Cold winter" maximum consumption; "-10% change" 90% of average consumption. Source: OECD Economic Outlook, Interim Report September 2022

An enforced reduction in gas usage could hit some European sectors significantly

Per cent reduction in total energy supply

Natural gas demand and supply in Central and Eastern European countries, 2021

https://www.iea.org/data-and-statistics/charts/natural-gas-demand-and-supply-in-central-and-eastern-european-countries-2021

Liquified natural gas import capacity in Central and Eastern Europe, 2022-2026

Distribution of gas storage capacity in Central and Eastern Europe, 2022

COUNCIL REGULATION (EU) 2022/1369 of 5 August 2022 on coordinated demand-reduction measures for gas

Several countries are now implementing "use it or lose it" rules across the EU to free up gas storage capacity for new entrants.

Part 3 Conclusions

It is very unfortunate that all future plans must be implemented in the extreme conditions of war:

- The unprecedentedly aggressive and poisonous global information war of the Russian Federation
- Russia's energy war with the world, first of all with Europe, incl. Ukraine
- Wild for the civilized world of the XXI century military aggression against Ukraine and the genocide of the civilian population of Ukraine, the destruction of infrastructure, incl. energy and buildings
- For the civilized world of the 21st century: wild military aggression against Ukraine and the genocide of the civilian population of Ukraine, the destruction of infrastructure, incl. energy and buildings

We really want to think that Ukraine and the civilized world will win THANK YOU FOR ATTENTION basok@ittf.kiev.ua; borys.basok@gmail.com