LONG-TERM LOW-EMISSION DEVELOPMENT STRATEGY OF UKRAINE UNTIL 2050

Approved by the Cabinet of Ministers of Ukraine (by the Order No. 561-r dated 10 June 2026)

Contents

Figures

Tables

Abbreviation

NPP	Nuclear Power Plant
GDP	gross domestic product
RES	renewable energy sources
WPP	wind power plant
IDPs	internally displaced person
GW	gigawatt
HPPs	hydroelectric power plant
SAEE	State Agency on Energy Efficiency and Energy Saving
SSSU	State Statistics Service of Ukraine
R&D	research and development
LT-LEDS	Long-Term Low Emissions Development Strategy
SES	State Emergency Service
ESCO	energy service company
ESU	Energy Strategy of Ukraine to 2050
EBRD	European Bank for Reconstruction and Development
EGD	European Green Deal
EIB	European Investment Bank
EU	European Union
HCO	housing association
LULUCF	land use, land-use change, and forestry
kW	kilowatt
CMU	the Cabinet of Ministers of Ukraine
KSE	Kyiv School of Economics
IBRD	International Bank for Reconstruction and Development
MW	megawatt
IMF	International Monetary Fund
MENR	Ministry of Ecology and Natural Resources
MinEconomy	Ministry of Economy, Environment and Agriculture
MinEnergo	Ministry of Energy
MDCT	Ministry of Community and Territorial Development
MinDigital	Ministry of Digital Transformation
SMR	small modular reactors (nuclear)
MES	Ministry of Education and Science of Ukraine
ILO	International Labour Organisation
SMEs	small and medium-sized enterprises
MFO	international financial institutions
NASU	National Academy of Sciences of Ukraine
NATO	North Atlantic Treaty Organisation
NBU	National Bank of Ukraine
NDC	nationally determined contribution (under the Paris Agreement)

RTD	research, development, and engineering
The NEFCO	Nordic Environment Finance Corporation
NSSMC	National Securities and Stock Market Commission
NREAP	National Renewable Energy Action Plan
NECP	National Energy and Climate Plan
NRFU	National Research Foundation of Ukraine
o.e.	oil equivalent
IPS of Ukraine	United Energy System of Ukraine
United Nations	United Nations
TSO	transmission system operator
DSO	distribution system operator
HW	household waste
VAT	value-added tax
GHG	greenhouse gases
PSO	public service obligation scheme
UN FCCC	United Nations Framework Convention on Climate Change
SPP	solar power plant
ETS	emissions trading scheme
TPP	thermal power plant
CHP	Combined heat and power plant
BESS	battery energy storage system
WHR	waste heat recovery
CA	central authorities
BMWK	Federal Ministry for Economic Affairs and Climate Action of Germany (German: Bundesministerium für Wirtschaft und Klimaschutz)
CBAM	carbon border adjustment mechanism
CCS	carbon capture and storage
CCUS	carbon capture, storage and use
COP	Conference of the Parties
DAC	direct air capture
ESG	environmental, social, governance
EuGB	European green bond standard
GBP	Green Bond Principles
GIZ	German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH)
GSC	guaranteed savings contract
KfW	Kreditanstalt für Wiederaufbau (Credit Institute for Reconstruction), Germany
PPA	power purchase agreement
PPCA	Powering Past Coal Alliance
NZE	net-zero emissions

SAF	sustainable aviation fuel
STEM	Science, Technology, Engineering and Mathematics
TEN-T	Trans-European Transport Network
UNIDO	United Nations Industrial Development Organisation
USAID	United States U.S. for International Development
WAM	with additional measures
WEM	with existing measures
ZEB	zero-emission buildings

1. LT-LEDS DEVELOPMENT PROCESS

1.1. EXECUTIVE SUMMARY

Recognising the need for an effective and consistent response to the urgent threat of climate change, Ukraine's state climate policy is being shaped with due regard to international commitments and an irreversible course toward European integration. Ukraine is a Party to the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Paris Agreement, which obliges participating countries to develop and implement long-term low-emission development strategies (LT-LEDS) aligned with the objective of holding the increase in global average temperature well below 2°C. At the national level, the key legislative act that has established a long-term vision for the country's development is the Law of Ukraine "On the Main Principles of State Climate Policy". This law sets an ambitious target of achieving climate neutrality by 2050, fully consistent with the objectives of the European Green Deal.

To achieve the long-term objectives of state climate policy, this LT-LEDS defines medium-term targets up to 2035, as well as priority policy directions for attaining them. The purpose of the LT-LEDS is to reduce climate-related risks to Ukraine's socio-economic development. The LT-LEDS integrates policies and measures aimed at adapting the population and the economy to the adverse impacts of climate change, as well as measures to prevent anthropogenic impacts on global climate-forming conditions and factors.

Taking into account Ukraine's Second Nationally Determined Contribution under the Paris Agreement for the period up to 2035 and based on modelling results, **the medium-term target of state climate policy is defined as a reduction of anthropogenic greenhouse gas (GHG) emissions, taking removals into account, by more than 65% across all sectors of the economy by 2035 compared to 1990 emission levels.**

At the same time, Ukraine confirms its readiness, following the restoration of its territorial integrity within internationally recognised borders and on the basis of verified information, to review and refine its medium-term targets in order to align them with an updated pathway toward climate neutrality and the principles of a just transition.

Pathway to Carbon Neutrality: Development Scenarios

This Strategy reaffirms the national commitment to achieving climate neutrality by 2050. Under the ambitious scenario, this implies that GHG emissions will be almost entirely reduced, while any remaining emissions will be offset through carbon removals by natural ecosystems.

The Strategy considers three main scenarios that model different pathways for Ukraine's economic development:

Scenario with Existing Measures (WEM): This baseline scenario reflects emission dynamics in the absence of new climate policies after 2025. Taking into account the decline in economic activity due to the war, emissions in 2050 may amount to 285.4 million tonnes of CO_2 equivalent, or 31.1% of the 1990 level.

Scenario with Additional Measures (WAM): This scenario includes the implementation of already existing plans, such as the modernisation of heat supply systems and improvements in energy efficiency, and additionally envisages the implementation of planned but not yet adopted measures. Under this scenario, emissions could be reduced to 92.0 million tonnes of CO_2 equivalent by 2050, or 10.0% of the 1990 level.

Net-Zero Emissions Scenario (NZE): This scenario enables the achievement of climate neutrality, taking into account removals from the land use and forestry sector, which are projected to increase to 30 million tonnes per year. Deep decarbonisation of the economy will require transformative technological and structural changes.

Policy and Measures for Climate Change Adaptation

Climate change adaptation is an integral component of Ukraine's state climate policy, aimed at reducing vulnerability and increasing the resilience of economic sectors and ecosystems. Ukraine is already implementing the National Strategy for Environmental Security and Climate Change Adaptation, which provides for a range of measures, including:

- Water resource management — implementation of efficient water resource management systems, including the modernisation of irrigation infrastructure, construction of small reservoirs and deployment of technologies that reduce water losses. These measures are critical for preventing droughts and floods, which are becoming more frequent due to climate change;
- Climate-resilient agriculture — development of climate-smart agriculture, including the introduction of drought-resistant crop varieties, improvement of agricultural practices and modern irrigation systems that reduce dependence on precipitation;
- Infrastructure protection — modernisation of infrastructure, particularly transport and energy infrastructure, to ensure resilience to extreme weather events such as strong winds, floods, and heavy snowfall;
- Early warning systems — enhancement of meteorological forecasting and early warning systems for hazardous weather events in order to minimise losses and protect human life.

Development of Renewable Energy Sources

The development of renewable energy sources (RES) is a key driver of decarbonisation in the energy sector. National policy documents already set ambitious targets aimed at significantly increasing the role of RES in Ukraine's energy mix. Under favourable conditions, the share of renewable energy in electricity and heat generation could reach up to 80% by 2050.

Policy and measures include:

- Development of an efficient market environment — creation of favourable conditions for investment in renewable energy, including the improvement of support mechanisms such as auctions and simplification of permitting procedures;
- Grid integration — development of energy storage technologies and smart grids to enable the integration of large volumes of renewable capacity into the energy system while maintaining

stability. This also includes the construction of new pumped storage power plants and the deployment of modern energy management systems;

- Decentralisation — stimulation of small-scale distributed renewable generation, particularly at the level of households and small business entities, contributing to enhanced energy resilience;
- Development of bioenergy — promotion of bioenergy, including biogas and biofuel production, to replace conventional fuels in heat supply and final energy consumption.

Energy Efficiency Policy

Energy efficiency is one of the most effective tools for reducing greenhouse gas (GHG) emissions and strengthening energy independence. Strategic objectives regarding energy efficiency are defined in the National Energy Efficiency Action Plan until 2030 and the Long-Term Building Renovation Strategy, while the key policy is set out in the framework Law of Ukraine "On Energy Efficiency" and a number of related regulatory acts. Priority areas of action include:

- Thermal modernisation — priority is given to deep thermal renovation of the entire residential and commercial building stock, including wall insulation, replacement of windows and doors and modernisation of heating and ventilation systems;
- Standards and regulations — introduction of strict energy efficiency standards for new construction and household appliances, contributing to reduced energy consumption;
- Energy management — implementation of energy management systems in manufacturing and in public sector institutions;
- Improving energy efficiency in industry — mandatory energy audits and implementation of energy management systems, as well as the introduction of energy efficiency obligation schemes.

The realisation of energy efficiency potential will be supported by the expansion of financial support instruments and incentives. These include revision of the carbon tax rate and administration principles, ensuring the effective operation of state decarbonisation funds, expansion of green bond instruments and the introduction of mechanisms for issuing carbon certificates and carbon credits. The primary role of the state in this process is to initiate significant financial flows towards the most in-demand decarbonisation areas and to support their scaling through private and international official sources by strengthening institutional frameworks.

Sectoral Policy and Measures

Energy Sector: This Strategy envisages a comprehensive transformation of the energy sector. The key priority is a complete phase-out of fossil fuels and a transition to RES. This includes not only the construction of new solar and wind power plants, but also the integration of energy storage systems to ensure grid stability. In addition, the introduction of smart grids is planned, enabling efficient management of distributed generation. For industrial facilities with high GHG emissions, such as combined heat and power plants and metallurgical enterprises, the Strategy provides for the

implementation of carbon capture, storage and utilization technologies, as well as the production of "green" hydrogen, which will enable the decarbonisation of heavy industry.

Industry: The decarbonisation of the industrial sector is one of the most challenging yet critically important objectives. This Strategy provides for a transition to low-carbon and energy-efficient technologies in energy-intensive industries (metallurgy, chemical industry, mechanical engineering), modernisation of equipment, and the use of alternative fuels such as hydrogen and biomethane. To stimulate technological transformation, the Strategy provides for the creation of targeted financial instruments, including state programmes, grants, concessional loans for investments in decarbonisation. In addition, the Strategy emphasises the importance of supporting innovation and research and development, which will enable the development and deployment of new environmentally friendly technologies.

Buildings Sector: In addition to deep thermal modernisation of the entire residential and commercial building stock, the LT-LEDS provides for stricter building codes and energy efficiency standards for new construction. The introduction of mandatory energy performance certification of buildings is planned, which will allow for monitoring and incentivising improvements in performance. Another important component is the development of smart home systems and the installation of intelligent meters, enabling consumers to manage their energy consumption more efficiently.

Transport: The transport sector has significant decarbonisation potential. The primary vector is transport electrification, including the expansion of fast-charging infrastructure for electric vehicles, incentives for electric vehicle purchases and the complete transition of public transport to electric and low-carbon vehicles. For freight transport, the Strategy provides for legislative incentives for the use of biofuels, as well as the development of rail transport as the most environmentally friendly option for intercity and interregional transportation.

Waste Management Sector: This sector is a significant source of methane emissions. The implementation of EU waste management legislation is a key measure. The introduction of separate waste collection will increase recycling and reuse rates. In addition, the Strategy provides for the modernisation of landfills to prevent methane generation, as well as the development of biogas plants that enable the conversion of organic waste into energy.

Agriculture: In agriculture, the policy focuses on reducing methane and nitrous oxide emissions. Key implementation areas include the adoption of innovative technologies in livestock farming (e.g. manure management) and crop production (organic production, which allows for reducing the use of fertilizers). Another important focus of the Strategy is sustainable land management, which will enhance its carbon sequestration capacity.

Land Use, Land-Use Change and Forestry (LULUCF): This sector is the only one capable of providing net carbon removals. The main objective of public policy in this sector should be to increase forest cover through afforestation and sustainable forest management. Additional measures to increase removal may include establishing orchards, berry plantations, and vineyards, as well as agroforestry (combining agricultural and forestry land use), specifically shelterbelt afforestation. Under the climate neutrality scenario, removals could increase to 30 million tonnes of CO_2-equivalent by 2050 from the current level of approximately 25 million tonnes of CO_2-equivalent, through the creation of new forests (around 1 million hectares), new shelterbelts (up to 50 thousand hectares), and continued incentives for orchard establishment (23 thousand hectares). Realising this potential will require strengthening state policy in the restoration of degraded forest ecosystems, the creation of new

protective forest belts and fruit orchards. In particular, it envisages the development of mechanisms to provide incentives for the establishment of such plantations under conditions where the legal regime and designated use of land plots remain unresolved (change of land use, options for long-term leases, or private ownership of forests and shelterbelts), through both public and private funding. Special attention will be paid to preserving naturally regenerated forests on long-unused lands as an additional, low-effort measure to increase forest cover. This will require the development of mechanisms for obtaining consent from landowners where natural regeneration has occurred.

In addition, further measures to reduce greenhouse gas emissions include expanding the application of organic fertilisers and rationalising cultivation and drainage practices on organic soils. Priority actions for the use of organic soils in agriculture should include: inventorying organic soils and wetlands; rewetting areas, especially those no longer used for agriculture; avoiding drainage of new agricultural lands; and converting arable organic soils to permanent grassland or forest cover, which slows CO_2 emissions.

Financing Mechanisms

The implementation of this Strategy requires substantial investment. Under the With Existing Measures (WEM) scenario, total investment needs amount to EUR 588 billion, while under the With Additional Measures (WAM) scenario and the Climate Neutrality scenario, investment requirements increase significantly, reaching up to EUR 1 trillion. The state budget is unable to cover the majority of these costs; therefore, the primary sources of financing should be international mechanisms and private capital, while the role of the state will be to create a favourable institutional environment and to de-risk investments. At the same time, expanding fiscal space remains a relevant task and will require reform of the carbon tax and the introduction of an emissions trading system.

At the same time, the current situation can be viewed as a unique opportunity to mobilise financial resources for decarbonisation.

Sources of financing for the Strategy include:

- International Financial Institutions (IFIs): loans and grants from IFIs such as the World Bank and the EBRD will constitute a key source of funding;
- Green finance: attracting investment through the issuance of green bonds and other financial instruments that support decarbonisation of economic sectors;
- Private investment: stimulation of private investment through state guarantees, preferential lending programmes;
- State budget: financing of critically important projects from the state budget;
- Paris Agreement mechanisms: utilisation of cooperation mechanisms provided for under Article 6 of the Paris Agreement to implement emission reduction projects.

Economic Impacts

According to model-based economic assessments of the impacts of implementing the LT-LEDS, effective mobilisation of investment capital and rational redistribution of budget revenues from carbon-related charges will generate a significant positive effect on GDP during the first ten years of the Strategy's implementation, amounting to approximately 2.1%.

Research and Innovation

The development of science and innovation is a key driving force of decarbonisation policy. Unlocking national scientific and technological potential will involve:

- providing state support for research and development in low-carbon technologies, energy efficiency and carbon capture technologies;
- creating platforms for cooperation between research institutions, government and business to facilitate the commercialisation of innovations;
- participation of domestic researchers in international research projects and experience-exchange programmes.

Socio-Economic Impacts and Just Transition

The transition to a low-carbon economy will have significant macroeconomic effects. It is expected to reshape the structure of the economy and triGHGer the emergence of new high-tech, low-carbon industries. At the same time, it poses risks for traditional sectors, particularly the coal industry.

In addition, decarbonisation policies may create challenges for coal-dependent and mono-industrial regions whose economies rely on fossil fuels. Adhering to the principles of a just transition will require the implementation of programmes that help workers in such regions or sectors to retrain and find new jobs, ensuring a smooth and socially protected transition.

Human Capital and Labour Market

The shift to a low-carbon economy will require substantial changes in the labour market. Demand is expected to grow for specialists in renewable energy, energy efficiency, green construction and biotechnology. It is essential to develop training and reskilling programmes for workers whose occupations may disappear, as well as to integrate climate education at all levels of the education system.

Gender Equality

Ensuring equal opportunities for women and men in emerging “green” sectors is crucial for a successful and inclusive transition. Upholding the principles of gender equality will require conducting gender analyses of climate policies to ensure they do not create disparities, as well as guaranteeing equal access to education, training, and employment opportunities in new sectors of the economy.

1.2. LEGAL AND POLICY (INSTITUTIONAL) FRAMEWORK

Legal principles

Ukraine has a well-developed legal framework that governs the formulation and implementation of the state's climate policy and ensures low-carbon development.

International legal acts, particularly those related to European integration, play a significant role in Ukraine's climate policy. Ukraine is a Party to the ***United Nations Framework Convention on Climate Change*** (ratified on 29 October 1996) (hereinafter referred to as the UNFCCC), the ***Kyoto Protocol to the United Nations Framework Convention on Climate Change*** (ratified on 4 February 2004) (hereinafter referred to as the Kyoto Protocol), and the ***Paris Agreement*** (ratified on 14 July 2016). Ukraine is a party to ***the Montreal Protocol*** on Substances that Deplete the Ozone Layer and has initiated the ratification procedure for the Kigali Amendment thereto.

Ukraine is a member state of the Energy Community and transposes its legislation which, pursuant to the decision of the Energy Community Ministerial Council D/2021/14/MC-EnC, includes Regulation (EU) No 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action. The EU legislation has a considerable influence on Ukraine's national climate policy due to the legislative approximation process under the Association Agreement between Ukraine, on one side, and the European Union, the European Atomic Energy Community, and their Member States, on the other side (hereinafter referred to as the Association Agreement).

The primary legislative acts in the field of state climate policy in Ukraine include:

The Law of Ukraine "On the Main Principles of State Climate Policy," adopted by the Verkhovna Rada of Ukraine on 8 October 2024, establishes the goals of the state climate policy, its principles, as well as the system of legal, institutional, and economic mechanisms created and functioning in Ukraine to achieve climate policy goals. The Law establishes an ambitious long-term objective of Ukraine's state climate policy: achieving climate neutrality by 2050, increasing resilience and reducing risks to public health, ensuring low-carbon and sustainable development, as well as strengthening Ukraine's environmental, food, and energy security. The document also sets an interim target to reduce greenhouse gas (GHG) emissions in Ukraine by 65% by 2030 compared to 1990 levels. It defines a system of state planning documents on climate policy, the key ones being the LT-LEDS and the Climate Change Adaptation Strategy, which assesses risks, outlines priorities and measures and specifies financing and monitoring mechanisms for its implementation. In addition, the Law establishes requirements for the preparation of GHG emission reduction plans and climate change adaptation strategies at the local level. It establishes a national system for tracking and assessing progress in state climate policy, forecasting climate change impacts, and implementing scientific support mechanisms, intergovernmental coordination, and public participation in shaping and implementing state climate policy.

The Law of Ukraine "On the Principles of Monitoring, Reporting, and Verification of Greenhouse Gas Emissions", adopted on 12 December 2019, defines the legal and organisational principles for the monitoring, reporting, and verification of GHG emissions from the plants located within the territory of Ukraine whose activities involve GHG emissions.

The Law of Ukraine "On Regulation of Economic Activity with Ozone-Depleting Substances and Fluorinated Greenhouse Gases" adopted on 12 December 2019, establishes the legal principles for

regulating operations with ozone-depleting substances and fluorinated GHG, as well as with goods and equipment that contain or utilise them.

The Law of Ukraine "On Energy Efficiency" establishes the legal and organisational principles for promoting energy efficiency measures. In particular, the law introduces a national energy efficiency goal, which is set out in the National Action Plan for Energy Efficiency and the National Energy and Climate Plan.

The Law of Ukraine "On Energy Efficiency of Buildings" adopted on 22 June 2017, defines the legal, socio-economic, and organisational framework for energy efficiency of buildings, aims at reducing energy consumption in buildings, and implements provisions of EU and Energy Community legislation in this area.

Law of Ukraine "On the Introduction of New Investment Opportunities, Guaranteeing the Rights and Legitimate Interests of Business Entities for the Implementation of Large-Scale Energy Modernisation" adopted on 9 April 2015 establishes the legal and economic framework for implementing energy service contracts to increase the energy efficiency of state- and municipally-owned facilities.

Law of Ukraine "On Combined Production of Heat and Electric Energy (Cogeneration) and the Use of Waste Energy Potential" adopted on 5 April 2005 defines the legal framework and main principles of state policy on cogeneration and introduces mechanisms to stimulate the development of cogeneration.

Law of Ukraine "On Certain Issues of the Use of Vehicles Equipped with Electric Motors and on Amendments to Certain Laws of Ukraine to Overcome Fuel Dependence and Develop Electric Charging Infrastructure and Electric Vehicles" adopted on 24 February 2023 introduces terminology in electric transport, aims to create conditions for the widespread use of electric vehicles and the development of charging infrastructure, and ensures the implementation of EU directives in this area.

Law of Ukraine "On Alternative Fuels" adopted on 14 January 2000 establishes the legal framework and main principles of state policy on alternative fuels, sets a mandatory share of biofuel use in the transport sector, introduces sustainability criteria for liquid biofuels (bio-components) and biogas intended for transport, and aims to implement EU legislation.

The Law of Ukraine "On Alternative Energy Sources" adopted on 20 February 2003 defines the principles of using alternative energy sources and aims to facilitate their expanded use.

Law of Ukraine "On Waste Management" adopted on 20 June 2022 defines the basic principles, objectives and foundations of state policy on waste prevention and management, and aims to implement EU legislation in this area.

The aforementioned laws of Ukraine, together with by-laws adopted pursuant to and for the purpose of their implementation, constitute the legal framework for the formulation and implementation of the state climate policy in Ukraine.

Strategic documents play a significant role in defining the objectives, pathways, and tools for achieving the goals of the state climate policy. The principal cross-sectoral strategic documents in the field of state climate policy in Ukraine:

- The Plan of Ukraine approved by Resolution of the Cabinet of Ministers of Ukraine No. 244-p of 18 March 2024;

- The Strategy for the Development and Implementation of the State Policy on Climate Change until 2035 approved by Resolution of the Cabinet of Ministers of Ukraine No. 483-p of 30 May 2024;
- The National Energy and Climate Plan until 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 587-p of 25 June 2024;
- The Second Nationally Determined Contribution of Ukraine to the Paris Agreement approved by Resolution of the Cabinet of Ministers of Ukraine No. 1172-p of 29 October 2025;
- The Environmental Security and Climate Change Adaptation Strategy until 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1363-p of 20 October 2021;
- The Action Plan for the Implementation of Ukraine's Climate Policy as Part of its Participation in the Global Methane Emissions Reduction Initiative Global Methane Pledge, approved by Resolution of the Cabinet of Ministers of Ukraine No. 607-p of 7 July 2023.
- The Action Plan on the Establishment of the National Greenhouse Gas Emissions Trading System No. 146-p of 21 February 2025.

Sectoral strategic documents in the economic sectors and state policies covered by the LT-LEDS include:

- The National Economic Strategy until 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 179 of 3 March 2021;
- The Energy Strategy of Ukraine until 2050 approved by Resolution of the Cabinet of Ministers No. 373-p of 21 April 2023;
- The National Energy Efficiency Action Plan until 2030 approved by Resolution of the Cabinet of Ministers No. 1803-p of 29 December 2021;
- the Long-Term Strategy for the Thermal Modernisation of Buildings for the Period until 2050 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1228-r dated 29 December 2023 (Official Gazette of Ukraine, 13.02.2024, No. 13, p. 100, Article 843);
- The Concept of the State Targeted Economic Programme for the Energy Modernisation of Heat-Generating Enterprises in State or Municipal Ownership for the Period up to 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1093-p of 28 November 2023;
- The State Targeted Economic Programme for the Energy Modernisation of Water Supply and Sewerage Enterprises in State or Municipal Ownership for the Period up to 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1133-p of 15 November 2024;
- The National Renewable Energy Action Plan for the Period up to 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 761-p of 13 August 2024;
- The National Plan for the Reduction of Emissions from Large Combustion Plants approved by Resolution of the Cabinet of Ministers of Ukraine No. 796-p of 8 November 2017;
- The Strategy for the Development of Distributed Generation for the Period up to 2035 approved by Resolution of the Cabinet of Ministers of Ukraine No. 713 of 18 July 2024;

- The Strategy for the Development of Agriculture and Rural Areas in Ukraine for the Period up to 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1163-p of 15 November 2024;
- The National Transport Strategy of Ukraine for the Period up to 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1550 of 27 December 2024;
- The Strategy for the Innovation Activity Development until 2030, approved by Resolution of the Cabinet of Ministers of Ukraine No. 526-p of 10 July 2019;
- The National Waste Management Plan until 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1353-p of 27 December 2024;
- The State Forest Management Strategy of Ukraine until 2035 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1777-p of 29 December 2021;
- The Concept of the Nationwide Targeted Programme for Land Use and Protection approved by Resolution of the Cabinet of Ministers of Ukraine No. 70-p of 19 January 2022;
- The Concept of the State Targeted Programme for the Just Transition of Coal Regions in Ukraine for the Period up to 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1024 of 22 September 2021;
- The Concept for the Implementation of Smart Grids in Ukraine until 2035 approved by Resolution of the Cabinet of Ministers of Ukraine No. 908 of 14 October 2022.

Political (Institutional) Foundations

The institutional foundations of state climate policy, aimed at ensuring low emissions development at the national level in Ukraine, include:

The Verkhovna Rada of Ukraine, which establishes the principles of state climate policy, including the long-term goals of state climate policy, and exercises parliamentary oversight over the implementation of state climate policy.

The Cabinet of Ministers of Ukraine directs and coordinates central executive authorities in the development and implementation of cross-sectoral climate policy and assesses whether regulatory acts comply with the goals of state climate policy as established by the LT-LEDS.

The Ministry of Economy, Environment and Agriculture (Ministry of Economy), in accordance with Resolution of the Cabinet of Ministers of Ukraine No. 903 of 21 July 2025, assumed the functions of the Ministry of Environmental Protection and Natural Resources of Ukraine and the Ministry of Agrarian Policy and Food, which were abolished under the aforementioned Cabinet Resolution. According to paragraph 37 of item 1 of Clause 3 of the Regulations on the Ministry of Economy, Environment and Agriculture approved by Resolution of the Cabinet of Ministers of Ukraine No. 903 of 21 July 2025, one of the tasks of the Ministry of Economy is to ensure the formation and implementation of climate policy. It should be noted, however, that under Clause 4 of Article 8 of the Law of Ukraine ‘‘On the Main Principles of State Climate Policy ’’, the Cabinet of Ministers of Ukraine shall designate a central executive authority responsible for developing Ukraine’s LT-LEDS and for assessing and monitoring its implementation, as these powers are not included in the Regulations on the Ministry of Economy. The Ministry of Economy is also responsible for forming and implementing state policy in economic and social development, industrial policy, conservation, reproduction and sustainable use of biological and landscape diversity, agrarian policy, agricultural policy and food

security policy. Furthermore, the Ministry of Economy ensures the inventory of anthropogenic GHGs by sources and absorption by sinks at the national level, as well as the preparation of the national registry of anthropogenic GHG emissions and absorptions.

The *Ministry for Communities and Territories Development of Ukraine* (MCTD) is the central executive authority responsible for developing and implementing state policy in the field of transport, regional policy, construction, technical regulation in construction, and household waste management.

The Ministry of Energy of Ukraine (ME) is the central executive authority in Ukraine responsible for developing and implementing state policy in the fields of electric power, nuclear, coal, peat extraction, oil, gas, and oil refining sectors. The ME develops and ensures the implementation of the Energy Strategy of Ukraine, along with other executive authorities.

The Ministry of Social Policy, Family and Unity of Ukraine (Ministry of Social Policy) is the central executive authority responsible for forming and implementing state policy on social protection.

The Ministry of Education and Science of Ukraine (MES) is responsible for formulating and implementing state policy on education and science, scientific and technological activities, innovation in these areas and technology transfer. A key component of the MES's activities is the development and implementation of the policy aimed at building high-quality human capital to support the development of an efficient, innovative and competitive economy and to ensure high standards of quality of life.

The State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEE) is a central executive authority responsible for implementing state policy on energy efficiency in Ukraine. One of the SAEE's primary tasks is to enhance energy efficiency across economic sectors and increase the share of alternative fuels in Ukraine's energy balance.

The State Emergency Service of Ukraine, as the central executive authority implementing state policy in the field of hydrometeorological activities, provides information support on climate change issues.

The State Employment Service of Ukraine is a centralised system of public institutions whose activities are aimed at implementing state policy on employment and labour migration, as well as social protection against unemployment.

To ensure the coordination of executive authorities' actions regarding the implementation of state policy in the field of climate change and ozone layer protection, and to fulfil Ukraine's obligations under international climate change and ozone layer protection treaties, *the Interdepartmental Commission on Climate Change and Ozone Layer Protection has been set up.* This Commission is an advisory body that coordinates the activities of central executive authorities in the fields of climate change and ozone layer protection.

At the regional and local levels, state climate policy management in Ukraine is carried out *by the Council of Ministers of the Autonomous Republic of Crimea, local state administrations, and local governments*. These authorities ensure the implementation of state policy in the fields of economy and state policy covered by the LT-LEDS at the regional and local levels, including develop and ensure the implementation of local plans to reduce anthropogenic GHG emissions and increase GHG removals by sinks, as well as local climate change adaptation strategies.

1.3. PUBLIC CONSULTATIONS

During 2024, more than 20 national and international experts were involved in the preparation of the Strategy. The work was coordinated by the State Institution "Institute for Economics and Forecasting of the National Academy of Sciences of Ukraine", with the support of the United Nations Development Programme (UNDP) under the global Climate Promise initiative.

The key elements of the updated Strategy were presented for the first time at the international level at the Ukrainian Pavilion during the UN Climate Change Conference (COP29) in Baku, Azerbaijan, at a high-level event on 18 November 2024[1]. During the presentation, Kurt Vandenberghe, Director-General of the European Commission's Directorate-General for Climate Action (DG CLIMA), positively assessed Ukraine's continued implementation of progressive environmental reforms despite Russia's aggression and highlighted the ambitious nature of the updated Strategy[2].

The national presentation of the results of modeling decarbonisation pathways and achieving climate neutrality of Ukraine's economy, which constitute the core elements of the updated Strategy, took place during the forum "Ukraine at COP29: Achievements, Challenges and Prospects" on 11 December 2024[3]. The event included a discussion of the Strategy with the participation of representatives of government, business, civil society organisations and international partners.

At the beginning of January 2025, UNDP in Ukraine submitted the first draft text of the updated Low-Carbon Development Strategy for review to the Ministry of Environmental Protection and Natural Resources of Ukraine. On 14 January 2025, the draft text was discussed at a meeting involving the authors and experts of the Ministry.

On 16 January 2025, an online training titled "Gender Issues in Climate Policy" was conducted for 60 civil servants from ministries and central executive authorities. The training included a presentation and discussion on the integration of a gender-responsive approach in the development of the Strategy[4].

On 6 February 2025, a roundtable discussion was held with the participation of the authors of the updated Strategy, experts from the Ministry of Environmental Protection and Natural Resources, and invited climate policy specialists, including representatives of the Ministry's Reform Support Team, the Ukrainian Hydrometeorological Institute, the National Greenhouse Gas Emissions Inventory Center, the Ukrainian Climate Office, and civil society organisations, in particular NGO "Ecoaction". As a result of the discussion, an updated draft text was prepared, incorporating the experts' recommendations.

At the end of February 2025, the English-language version of the updated draft Strategy was submitted for peer review to international experts. The review team included 5 leading experts from the UNDP Climate Hub. On 7 April 2025, UNDP in Ukraine received comments and proposals on the draft Strategy text from international experts and forwarded them for processing.

Between 14 and 18 April 2025, the content of the updated Strategy was discussed with international experts as part of preparations for the bilateral meeting between Ukraine and the European

[1] COP29: Ukraine Presented Key Elements of the Updated Long-Term Low-Carbon Development Strategy to 2050 https://mepr.gov.ua/onovlena-klimatychna-strategiya-ukrayiny-yak-my-dosyagnemo-nulovyh-vykydiv/
[2] COP29: Presentation of Ukraine's Long-Term Low-Carbon Development Strategy (LT-LEDS) https://www.youtube.com/watch?v=dt1GJtZhbNQ
[3] Updated Climate Strategy of Ukraine: How We Will Achieve Net-Zero Emissions https://mepr.gov.ua/onovlena-klimatychna-strategiya-ukrayiny-yak-my-dosyagnemo-nulovyh-vykydiv/
[4] Online Training: "Gender Issues in Climate Policy" https://www.youtube.com/watch?v=bH_LAqtQXA4

Commission under Negotiation Chapter 27 on Environment and Climate Change.[5] The updated draft of the Strategy was also discussed during a bilateral session between Ukraine and the European Commission held as part of the screening of compliance of Ukrainian legislation with EU law, which took place in Brussels, Belgium, on 16-20 June 2025[6]. The Ukrainian delegation further discussed the key elements of the draft Strategy with experts at the 62nd session of the Subsidiary Body for Implementation (SB62) of the UN Framework Convention on Climate Change, held in Bonn, Germany, from 16 to 26 June 2025. UNDP in Ukraine provided support in organising and facilitating Ukraine's participation in the negotiation simulations and the bilateral Ukraine–EU session under Chapter 27, as well as in the SB62 conference.

Following the results of 10 months of public consultations with international and national experts and civil society, the team of authors prepared a revised third draft of the text.

At the beginning of September 2025, UNDP in Ukraine submitted the text of the updated Long-Term Low Emission Development Strategy of Ukraine to 2050 to the newly established Ministry of Economy, Environment and Agriculture for approval by the Government of Ukraine and subsequent submission to the Secretariat of the UN Framework Convention on Climate Change, in fulfilment of Ukraine's international obligations under the Paris Agreement.

[5] Completion of the First Round of Simulation Sessions in Preparation for the Bilateral Meeting with the European Commission under Negotiation Chapter 27 https://mepr.gov.ua/zavershuyetsya-pershyj-raund-imitatsijnyh-sesij-u-mezhah-pidgotovky-do-dvostoronnoyi-zustrichi-z-yevrokomisiyeyu-po-peregovornomu-rozdilu-27/

[6] Ukraine Launches Bilateral Meeting with the EU on Environment, Climate and Civil Protection as Part of the Official Screening of National Legislation https://mepr.gov.ua/ukrayina-rozpochala-dvostoronnyu-zustrich-z-yes-u-sferi-dovkillya-klimatu-ta-tsyvilnogo-zahystu-u-mezhah-ofitsijnogo-skryningu-natsionalnogo-zakonodavstva/

1.4. INTERNATIONAL AND NATIONAL CONTEXT

Climate change poses serious risks to Ukraine, affecting various aspects of life and the economy. The key climate-related risks are briefly outlined below.

Temperature increase. Over the past 60 years, Ukraine's climate has changed significantly, particularly since the 1980s, when warming started accelerating. Currently, temperatures are increasing by 0.4–0.6 °C per decade, exceeding the European average and several times the global rate.[7] Over the past 30 years, Ukraine's average annual temperature has risen by 1.5 °C.[8]

European reports also indicate overall continental warming. From the 1950s to the 1980s, temperature changes were minor or showed slight cooling, but significant warming began thereafter. In 2023, the average temperature in Europe exceeded the 1991–2020 baseline by 1.02–1.12 °C, making it the second warmest year on record after 2020. The three warmest years on record have occurred since 2020.[9]

According to Copernicus data, 2023 recorded an unprecedented number of days with "extreme heat stress." Rising temperatures are accompanied by more frequent and intense heatwaves, posing serious health risks, namely: heatstroke, cardiovascular diseases, and other conditions, particularly for vulnerable groups such as the elderly and children. Climate change also contributes to the spread of infectious diseases like malaria and leishmaniasis, posing further public health risks.

Changes in precipitation and water distribution. Precipitation patterns in Ukraine are becoming increasingly irregular, with alternating wet and dry years depending on the region. While total annual precipitation has not changed significantly, it is increasing in autumn and decreasing in summer, leading to more frequent droughts, especially in the south and southeast. Over the past decade, droughts that previously occurred once every 100 years now affect up to 30% of the country and recur every 2–3 years.[10] Between 2000 and 2010, Ukraine experienced five major droughts (2003, 2007, 2008, 2009, 2010), covering up to 80% of grain-producing areas.[11]

Ukraine has one of the lowest levels of freshwater availability in Europe. Warm, low-snow winters hinder groundwater replenishment, while unstable snow cover and reduced meltwater threaten the drying of small rivers, particularly in mountainous areas. Climate change is also altering seasonal runoff distribution: winter runoff is increasing, while spring runoff is decreasing. Depending on temperature rise scenarios, river runoff in the south could decline by 30–50% by 2050, while in the

[7] Pillai,Madhavi M.; Golub,Elena Strukova; Lokshin,Michael M.; Rakovych,Oksana; Ha,Thanh Phuong. (2021). Ukraine — Building Climate Resilience in Agriculture and Forestry (English). Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/893671643276478711/Ukraine-Building-Climate-Resilience-in-Agriculture-and-Forestry

[8] Wilson, L., New, S., Daron, J., Golding, N. (2021). Climate Change Impacts for Ukraine. Met Office. https://mepr.gov.ua/wp-content/uploads/2023/07/2_Vplyv-zminy-klimatu-v-Ukrayini.pdf

[9] Copernicus Climate Change Service. (2023). European State of the Climate 2023. https://climate.copernicus.eu/sites/default/files/custom-uploads/ESOTC%202023/Summary_ESOTC2023.pdf

[10] United Nations Environment Programme (UNEP) DTU Partnership. (2019). Technology needs assessment for climate change adaptation: Ukraine. https://tech-action.unepccc.org/wp-content/uploads/sites/2/2019/09/final-ukraine-tna adaptation-report.pdf

[11] Walz, Y., and others (2018). Understanding and reducing agricultural drought risk: Examples from South Africa and Ukraine, Policy Report No.3. Bonn: United Nations University – Institute for Environment and Human Security (UNU-EHS).

north, it may increase by 15–25%[12]. More frequent droughts and floods increase the vulnerability of agriculture, energy, transport, and social sectors, which depend critically on water resources.

Extreme weather events and natural disasters. Ukraine is increasingly experiencing more frequent extreme weather events such as hail, squalls, and tornadoes in areas where they were previously rare, occurring once every 50–100 years. Other adverse phenomena include sudden pressure changes leading to unstable weather with large temperature fluctuations over short periods, as well as an increase in natural disasters such as floods, hurricanes, storms, prolonged heavy rainfall, and flash flooding, particularly in Ciscarpathia and Transcarpathia.

Biodiversity loss. Climate change, exacerbated by habitat fragmentation, is affecting natural ecosystems, particularly forests and wetlands. This may lead to biodiversity loss and shifts in species' habitats or potential extinction of some species. A 1° C rise in average annual temperature causes isotherms — imaginary lines of equal temperature — to shift approximately 160 km northward (toward the poles) or 160 m upward (in mountainous areas).[13] This means that plant and animal species capable of adapting to these changes will migrate accordingly, either northward toward the poles or to higher altitudes in accordance with the new climate conditions. Direct economic losses from biodiversity loss include reduced agricultural yields, loss of forest resources, and declining fish stocks.

Impacts on the coastal zone of the Black and Azov Seas. Over the past 60 years, the Black Sea level has risen by 15 cm. The Black Sea is currently rising at a rate of 0.25 cm per year[14]. The Azov Sea level is increasing more slowly, at a rate of 1.5–0.69 mm per year.[15] Sea level rise is driven by global factors,such as warming and glacier melting, and regional factors, such as water exchange processes between seas, changes in precipitation and river runoff, wind-induced surges, and modern vertical crustal movements. According to the latest modelling, under a high GHG emission scenario (Representative Concentration Pathway (RCP) 8.5), the Black Sea level could be 0.82 metres higher by 2100 than at present. Wind-induced surges and storms could further raise the Black and Azov Sea levels by nearly 1 metre.[16] This could have serious consequences for coastal areas, including flooding, coastal erosion, and soil salinisation.

Ukraine was among the first countries to ratify the Paris Agreement, which entered into force on 4 November 2016. The Paris Agreement enhances the implementation of the United Nations Framework Convention on Climate Change and aims to strengthen the global response to the threat of climate change in the context of sustainable development and efforts to eradicate poverty. This includes: limiting the increase in the global average temperature to well below 2°C and putting effort

[12] The National Academy of Agrarian Sciences of Ukraine (2020). Information and analytical report on the state of the country's water resources and the features of agricultural production under climate change conditions http://naas.gov.ua/upload/iblock/78a/Інформаційна%20довідка%204.05.2020-конвертирован.pdf

[13] Hetem, R. S. et al. (2014) 'Responses of large mammals to climate change', Temperature, 1(2), pp. 115–127. doi: 10.4161/temp.29651.

[14] Climate changes and dynamics of the coasts of Ukraine / Y.N. Horiachkin, V.A. Ivanov // Rep. of the National Academy of Sciences of Ukraine. — 2008. — No. 10. — P. 118-122. — Sources: 6 titles — Rus. http://dspace.nbuv.gov.ua/xmlui/bitstream/handle/123456789/6102/21-Horiachkin.pdf?sequence=1

[15] The Third, Fourth and Fifth National Communications of Ukraine on climate change issues, prepared to implement Articles 4 and 12 of the UN Framework Convention on Climate Change and Article 7 of the Kyoto Protocol. 2009, Kyiv, 367 p., p. 223.

[16] Water is coming. Sea level rise in Ukraine due to climate change (full report on the results of the study) / O.H. Holubtsov, A.P. Biatov, O.Y. Seliverstov, S.S. Sadohurska; https://mepr.gov.ua/wp-content/uploads/2023/07/6_Pidvyshhennya-rivnya-morya-v-Ukrayini-vnaslidok-zminy-klimatu.pdf

to limit the temperature rise to 1.5°C above pre-industrial levels; enhancing adaptive capacity to the adverse effects of climate change, as well as promoting climate resilience and low-emission development in a manner that does not threaten food security; aligning financial flows with low-emission and climate-resilient development[17].

The Paris Agreement stipulates that Parties must prepare, communicate, and update their Nationally Determined Contributions (NDCs) every five years to address global climate change. Ukraine's[18] first NDC set a national obligation to limit GHG emissions in 2030 to no more than 60% of the 1990 emission levels. In 2016, Ukraine's GHG emissions amounted to 348.8 million tonnes of CO_2-equivalent (including LULUCF)[19], representing 38% of the 1990 emission levels. Thus, the national aim of the first NDC allowed for some potential growth in emissions following the liberation of territories and the recovery of the economy.

The updated Nationally Determined Contribution (NDC), approved by the Cabinet of Ministers on 30 July 2021, has significantly strengthened Ukraine's national commitments to reducing greenhouse gas (GHG) emissions by 2030 – by 65% compared to 1990 levels. The same target is reflected in Ministerial Council Decision 2022/02/MC-En of the Energy Community[20]. Given that Ukraine's emissions in 1990 amounted to 916.5 million tonnes of CO_2 equivalent (including LULUCF)[21], achieving the updated NDC target would require a reduction in emissions to 320 million tonnes of CO_2 equivalent by 2030. In 2021, GHG emissions accounted for 328.1 million tonnes of CO_2 equivalent (including the LULUCF sector), which is 64% less than 1990 levels but 6% more than in 2020. As a result of the full-scale aGHGression of the Russian Federation against Ukraine and the associated decline in economic activity, as well as the destruction of energy and industrial facilities, GHG emissions in 2022 decreased to 223.5 million tonnes of CO_2 equivalent (including the LULUCF sector), which is 75.6% below the 1990 emission level.

In November 2021, during the UNFCCC Conference of the Parties in Glasgow, Ukraine joined the Global Methane Pledge, an initiative aimed at enhancing global action and strengthening support for existing international efforts to reduce methane emissions. Participating countries have committed to implementing voluntary measures to contribute to the collective goal of reducing global methane emissions by at least 30% from 2020 levels by 2030. This will help avoid a global temperature increase of 0.2 °C by 2050 while also delivering co-benefits such as improved public health and increased agricultural productivity.[22] In July 2023, the government approved a plan comprising 23 measures designed to reduce methane emissions by 30% by 2030 relative to 2020 levels, supporting the implementation of its climate policy within the framework of the Global Methane Pledge. In 2021, methane emissions amounted to 82.6 million tonnes of CO_2 equivalent (approximately one-fourth of total GHG emissions).

At the UNFCCC Conference of the Parties in Glasgow, Ukraine also joined the Powering Past Coal Alliance, a coalition of national and subnational governments, businesses, and organisations working towards the transition from coal-fired power generation without carbon capture, utilisation and

[17] The Paris Agreement. https://zakon.rada.gov.ua/laws/show/995_l61#Text

[18] https://unfccc.int/sites/default/files/NDC/2022-06/Ukraine%20First%20NDC.pdf

[19] https://unfccc.int/sites/default/files/resource/Ukraine_NIR_2024.pdf

[20] Decision of the Ministerial Council of the Energy Community No 2022/02/MC-EnC. https://www.energy-community.org/dam/jcr:421f0dca-1b16-4bb5-af86-067bc35fe073/Decision_02-2022-MC_CEP_2030targets_15122022.pdf

[21] According to the National Greenhouse Gas Inventory for 1990–2022, https://unfccc.int/sites/default/files/resource/Ukraine_NIR_2024.pdf

[22] Global Methane Pledge. https://www.globalmethanepledge.org/#about

storage (CCUS) to clean energy sources. Ukraine has committed to phasing out coal-fired power generation by 2035. This commitment is reaffirmed in the Energy Strategy of Ukraine until 2050, which states that coal-fired power generation will be progressively reduced until its complete decommissioning in 2035. However, the feasibility of fulfilling this commitment will depend on the condition of Ukraine's energy system following the cessation of hostilities and the availability of financial resources for its recovery.

Since 1988, Ukraine has been a Party to the Montreal Protocol, implementing national policies regulating commercial activities involving ozone-depleting substances and fluorinated GHGs. The relevant Law of Ukraine and other regulatory legal acts have been adopted in this field, and a Unified State Register of Controlled Substance Operators (ozone-depleting substances and fluorinated GHGs) has been established. Furthermore, the ratification of the Kigali Amendment to the Montreal Protocol on Substances That Deplete the Ozone Layer, which mandates the phasedown of fluorinated GHGs with high climate impact, is anticipated in 2026. This will be done in conjunction with the preparation of a Strategy for Reducing Emissions of Ozone-Depleting Substances and Fluorinated GHGs.

This Low Emission Development Strategy of Ukraine until 2050 has been developed and [approved] in fulfilment of Ukraine's commitments under the Paris Agreement, the Operational Plan for the Implementation of the Climate Change Policy Strategy for 2024–2026, and the Law of Ukraine "On the Main Principles of State Climate Policy". Under this law, the Cabinet of Ministers of Ukraine is responsible for approving the LT-LEDS to ensure strategic planning and the achievement of long-term state climate policy goals until 2050. The first LT-LEDS was developed in 2018. The present Strategy is expected to be approved in 2025 and, based on monitoring and evaluation results, may be reviewed every five years.

Additionally, Ukraine is taking consistent steps towards European integration and adaptation of its national legislation, climate policy, and energy policy to the EU acquis. For instance, Ukraine has been a Contracting Party to the Energy Community of South-Eastern Europe since 1 February 2011. According to the 2024[23] Implementation Report on Ukraine's obligations under the Energy Community Treaty, Ukraine's implementation of the Energy Community acquis received one of the highest ratings (54%) among Energy Community member states from November 2023 to October 2024. In particular, progress in decarbonising the energy sector was assessed at 67%, while progress in environmental protection was rated at 52%.

In 2014, Ukraine signed the Association Agreement with the EU, including the Deep and Comprehensive Free Trade Area. By doing so, it committed to carrying out systemic socio-economic reforms and aligning a vast body of national legislation with EU standards. According to the Ukrainian government's assessment as of 2024,[24] overall progress in implementing the Association Agreement reached 81%, with progress in the energy sector at 78%, in energy efficiency and housing and utilities also at 83%, and in environmental protection and civil security at 83%.

On the fifth day after the full-scale invasion by the Russian Federation – on 28 February 2022 – Ukraine submitted its application for EU membership. In June 2022, a decision was made to grant

[23] Energy Community Secretariat. Annual Implementation Report 2024 . https://www.energy-community.org/implementation/report.html

[24] Cabinet of Ministers of Ukraine. Report on the Implementation of the Association Agreement between Ukraine and the European Union for 2024. https://www.kmu.gov.ua/diyalnist/yevropejska-integraciya/vikonannya-ugodi-pro-asociaciyu/zviti-pro-vikonannya-ugodi-pro-asociaciyu

Ukraine candidate status, and on 14 December 2023, EU leaders approved the start of accession negotiations with Ukraine.

In the 2024[25] Enlargement Package report, the European Commission noted that Ukraine's climate legislation was not yet fully harmonised with the EU acquis, though some progress had been made over the past year. In particular, in October 2024, Ukraine adopted the Framework Law "On the Main Principles of State Climate Policy", aligning the country's long-term GHG emissions reduction target with the EU goal of achieving climate neutrality by 2050. Additionally, in June 2024, the National Energy and Climate Plan until 2030 was adopted. Certain progress was also made in developing a national GHG emissions trading system. For instance, in November 2023, amendments to the Cabinet of Ministers' resolutions were adopted, partially implementing Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of GHG emissions.

On 1 October 2023, the European Union launched the transitional phase of the Carbon Border Adjustment Mechanism (CBAM), designed to establish a fair price on GHG emissions generated during the production of imported carbon-intensive goods. CBAM aims to prevent so-called "carbon leakage" – the relocation of carbon-intensive production from the EU to countries with weaker climate policies and lower carbon pricing or the replacement of EU goods with more carbon-intensive imports. It is also expected to encourage emission reductions in non-EU countries' industries[26]. CBAM is also expected to stimulate the reduction of GHG emissions in industries outside the EU.

During the initial phase, which will last until the end of 2025, importers must report, without financial obligations, the volume of imported CBAM-covered goods, direct and indirect GHG emissions, and CO_2 payments already paid in the country of production. Starting from 1 January 2026, CBAM will become fully operational, requiring importers of carbon-intensive goods, such as cement, iron and steel, aluminium, fertilisers, electricity and hydrogen, to purchase CBAM certificates at a price equivalent to the average weekly auction price of EU ETS allowances. In this respect, payments already made for carbon emissions in the country of origin will be deducted.

Ukraine's economy is highly dependent on access to the EU market since more than half of its exports are currently directed to the EU countries. Of these, 15–17% are potentially subject to CBAM regulation[27]. According to estimates by the Kyiv School of Economics (KSE)[28], the annual losses for Ukrainian businesses due to CBAM implementation will amount to approximately €396 million from 2026 till 2030, leading to an annual GDP decline of 0.08% by 2030.

Despite the Russian Federation's full-scale invasion in 2022, Ukraine is consistently taking steps to strengthen its climate policy and increase the price of carbon emissions. In particular, the country plans to reform its carbon tax and introduce a domestic emissions trading system (which will operate in a pilot phase from 2026 and be fully implemented from 2029). In the long term, this system may be integrated into the EU ETS. Thus, over time, Ukraine's carbon pricing policy will be fully aligned with that of the EU. However, the convergence of Ukraine's carbon price with that of the EU ETS cannot

[25] European Commission. Ukraine 2024 Report. https://neighbourhood-enlargement.ec.europa.eu/document/download/1924a044-b30f-48a2-99c1-50edeac14da1_en?filename=Ukraine%20Report%202024.pdf

[26] European Commission. Carbon Border Adjustment Mechanism. https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

[27] GMK Center. How the European SWAM could weaken Ukraine's economy. https://gmk.center/wp-content/uploads/2024/10/CBAM24-research_10-2024_ukr.pdf

[28] Kyiv School of Economics. Research of the impact on the economy of Ukraine from the introduction of CBAM by the European Union. https://kse.ua/wp-content/uploads/2021/12/ENG_20211115-KSE_CBAM_for-publication.pdf

occur in the near future, given the devastating impact of the full-scale war on the economy and household incomes and the need to mobilise all available resources for post-war recovery. In fact, the full-scale invasion of Ukraine by the Russian Federation can be classified as "an unforeseeable, exceptional, and unprovoked event outside the control of one or more third countries subject to the CBAM, and that event has destructive consequences on the economic and industrial infrastructure of such country or countries concerned" under Article 30(7) of Regulation (EU) 2023/956[29]. This may serve as grounds for postponing and/or mitigating the application of the CBAM to Ukrainian exporters. However, this issue requires resolution through negotiations with the EU.

Synchronising Ukraine's energy and climate policies with those of the EU also creates additional economic opportunities, particularly in terms of the potential export of renewable gases to the EU. Thus, in February 2023, a Memorandum of Understanding was signed between Ukraine and the European Union on a strategic partnership in the fields of biomethane, hydrogen and other synthetic gases. Two years later, in early February 2025, Ukraine began exporting biomethane to the EU via pipeline transport. Furthermore, the EU's REPowerEU Strategy provides for the import of up to 10 million tonnes of renewable hydrogen by 2030, with Ukraine mentioned as a potential strategic partner in this regard[30]. The Green Hydrogen Initiative 2x40 GW in 2030 considers the possibility of constructing electrolysers in Ukraine with a total capacity of 8 GW by 2030 to produce renewable hydrogen for export to the EU[31].

At the same time, the full-scale invasion by the Russian Federation has had devastating consequences not only for Ukraine's economy as a whole but also for its energy sector and environment. This presents additional challenges for planning and achieving sustainable low-emissions development in the medium and long term. For instance, continuous Russian attacks on Ukraine's energy system have led to disruptions in electricity and gas supply and have complicated the operation of district heating systems.

From the start of the full-scale invasion until May 2024, over 18 GW of power-generating capacity fell under occupation, including the Zaporizhzhia Nuclear Power Plant, the largest in Europe. In addition, the Zmiivska and Trypilska TPPs, as well as the Kakhovka HPP, were destroyed. Private thermal power plants, including the Ladyzhynska, Burshtynska, Dobrotvirska, Kurakhivska, Kryvorizka, and Prydniprovska TPPs, also suffered critical damage. Furthermore, around half of Ukraine's high-voltage power transmission substations sustained damage.[32] The impact of the full-scale invasion on the renewable energy sector is outlined in Section 2.2 of the Strategy.

According to the Fourth Rapid Damage and Needs Assessment (RDNA4)[33], in nearly three years of the full-scale invasion of the Russian Federation, the energy sector suffered direct damages (destruction of power generation facilities, high-voltage transmission lines, oil and gas infrastructure, etc.) and indirect financial losses (lost revenues and costs for debris removal and dismantling works) totaling

[29] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32023R0956

[30] European Commission. EU external energy engagement in a changing world. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=JOIN%3A2022%3A23%3AFIN&qid=1653033264976

[31] Ad van Wijk, Jorgo Chatzimarkakis. Green Hydrogen for a European Green Deal. A 2x40 GW Initiative. https://www.waterstofnet.eu/_asset/_public/WIC/Hydrogen-Europe_2x40-GW-Green-H2-Initative-Paper-1.pdf

[32] Kyiv School of Economics Assessment of direct and indirect losses to Ukraine's energy sector as a result of a full-scale Russian invasion. https://kse.ua/wp-content/uploads/2024/06/KSE_Vpliv-vii--ni-na-energetiku_UA-1.pdf

[33] World Bank. Ukraine - Fourth Rapid Damage and Needs Assessment (RDNA4) : February 2022 - December 2024. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099022025114040022

approximately USD 93 billion . At the same time, the cost of reconstruction of the destroyed facilities according to the "Build Back Better" principle is estimated at around USD 68 billion .

As of June 2025, the environmental damage caused by the Russian Federation's full-scale war against Ukraine[34] reached nearly EUR 108 billion, with over 9,000 cases of environmental destruction recorded. As of July 2024, the Prosecutor General's Office reported that specialised environmental prosecutors were investigating 209 criminal cases related to 367 episodes of war crimes against the environment resulting from the armed aggression of the Russian Federation.[35] At the same time, 14 of these cases have been preliminarily classified as ecocide (Article 441 of the Criminal Code of Ukraine).[36]

Combat operations and wildfires have destroyed 3 million hectares of forests, reducing their capacity to absorb GHGs by 1.7 million tonnes[37]. According to experts from the War-Related GHG Emissions Accounting Initiative, over the three years of Russia's full-scale war[38] against Ukraine, greenhouse gas emissions increased to 230 million tonnes of CO_2 equivalent, with the largest share attributable to military activities, landscape fires and the reconstruction of destroyed buildings and infrastructure. This volume of additional GHG emissions (caused by the military aggression of the Russian Federation) is comparable to the annual emissions of Austria, Hungary, the Czech Republic and Slovakia combined or to the annual emissions from 120 million fossil-fuel-powered cars. In monetary terms, the cost of climate damage has reached US$ 42 billion.

[34] Svitlana Hrynchuk: Environmental damages from the war have already reached EUR 108 billion. https://mepr.gov.ua/svitlana-grynchuk-zbytky-dovkillyu-vid-vijny-vzhe-syagayut-108-mlrd-yevro-vidnovlennya-ye-pytannyam-ne-lyshe-natsionalnoyi-bezpeky-ale-j-bezpeky-vsogo-kontynentu/

[35] Ecoaction. War and environmental damage: can Russia be held accountable? https://ecoaction.org.ua/vijna-ta-shkoda-dlia-dovkillia-prytiahnuty-rosiu.html

[36] Interfax-Ukraine. Ukraine has preliminarily classified 14 criminal proceedings regarding damage to nature due to the Russian war as ecocide.https://interfax.com.ua/news/general/1026087.html

[37] Ministry of Ecology and Natural Resources of Ukraine. At COP29, Ukraine outlined the scale of damage to nature during the 1,000 days of war. https://mepr.gov.ua/71-mlrd-dolariv-zbytkiv-ta-180-mln-tonn-vykydiv-na-sor29-ukrayina-nazvala-masshtab-shkody-pryrodi-za-1000-dniv-vijny/

[38] Ecoaction. Climate damage caused by russian war in Ukraine in three years. https://en.ecoaction.org.ua/climate-damage-3-years-numbers.html

2. PATHWAY TO CLIMATE NEUTRALITY BY 2050

2.1. OVERALL REDUCTION OF GHG EMISSIONS AND INCREASE IN CARBON SINK ABSORPTION

In accordance with Article 15(6) of Regulation (EU) 2018/1999, as well as Part One of Article 10 of the Law of Ukraine "On the Basic Principles of State Climate Policy of Ukraine", the national energy and climate plan (NECP) must be consistent with the long-term low-carbon development strategy. The main provisions of the LT-LEDS must be taken into account when developing operational policies and decisions regarding the level, scope, and type of necessary transformations. The 2050 outlook should serve as the foundation for measures up to 2030, acting as a clear imperative in operational decision-making.

The NECP for the period up to 2030 was approved by the Ukrainian Cabinet of Ministers in June 2024, so it was considered in preparing Ukraine's LT-LEDS for the period up to 2050. In particular, the LT-LEDS includes the same but updated NECP scenarios:

1. Scenario with existing measures (WEM, with existing measures):

- *policies and measures* that have been implemented, regarding which national legislation exists, or one or more voluntary agreements have been concluded, or financial resources have been allocated, or human resources mobilised;
- policies and measures that have been adopted, for which an official government decision has been made, and there is a clear commitment to their implementation;
- serves as a baseline for comparison with the following two scenarios.

2. Scenario with Additional Measures (WAM, With Additional Measures): a scenario that considers planned measures currently under discussion and with a realistic likelihood of adoption and implementation after the submission of this document.
3. Net-Zero Emissions Scenario (NZE): was specifically developed for the LT-LEDS to identify priorities and effective pathways to achieve one of the long-term goals of state climate policy – achieving climate neutrality for Ukraine by 2050 in accordance with the Law of Ukraine "On the Basic Principles of State Climate Policy" and pursuant to the requirements of Regulation (EU) 2018/1999.

The quantitative results of modeling under the NZE scenario do not establish operational sectoral targets – the relevant targets and measures to ensure the achievement of medium-term goals of the state climate policy are defined in the National Energy and Climate Plan.

A range of models and tools were used to model the three LT-LEDS scenarios, including:

- TIMES-Ukraine — an energy system model for the Energy and Industrial Processes and Product Use (IPPU) sectors (Appendix 2);
- A model for the Waste sector (Appendix 3);
- Excel-based tools for the Agriculture (Appendix 4) and LULUCF sectors (Appendix 5);
- UGEM — a general equilibrium model for assessing the economic impacts of climate policies.

For visualisation and joint analysis of the results of emissions modelling and scenario projections, the https://vedaonline.cloud/SignIn.aspxVEDA Online platform was used.

2.1.1. Greenhouse Gas Emission Reduction and Absorption Forecast till 2050

The results of GHG emission dynamics modelling for Ukraine until 2050 are presented in Figure 2.1.

As shown in Figure 2.1, the existing and additional measures (NECP) are insufficient to achieve climate neutrality (net-zero GHG emissions).

Implementing additional measures (WAM scenario) by 2030 is assessed as sufficient to align with the climate neutrality scenario. However, further measures and policies must be developed to ensure a more substantial reduction in GHG emissions beyond 2030.

Modelled scenarios indicate that GHG emission reductions by 2030, compared to 1990 levels, could be significant. Total GHG emissions in 2030 may amount to 18.1–26.6% of the 1990 level. Depending on the scenario, Ukraine's GHG emission level may be between 15.0% and 29.5% of the 1990 level by 2035. GHG emissions must not exceed 10% of the 1990 level by 2040 to achieve climate neutrality (NZE scenario), and net-zero emissions must be achieved by 2050.

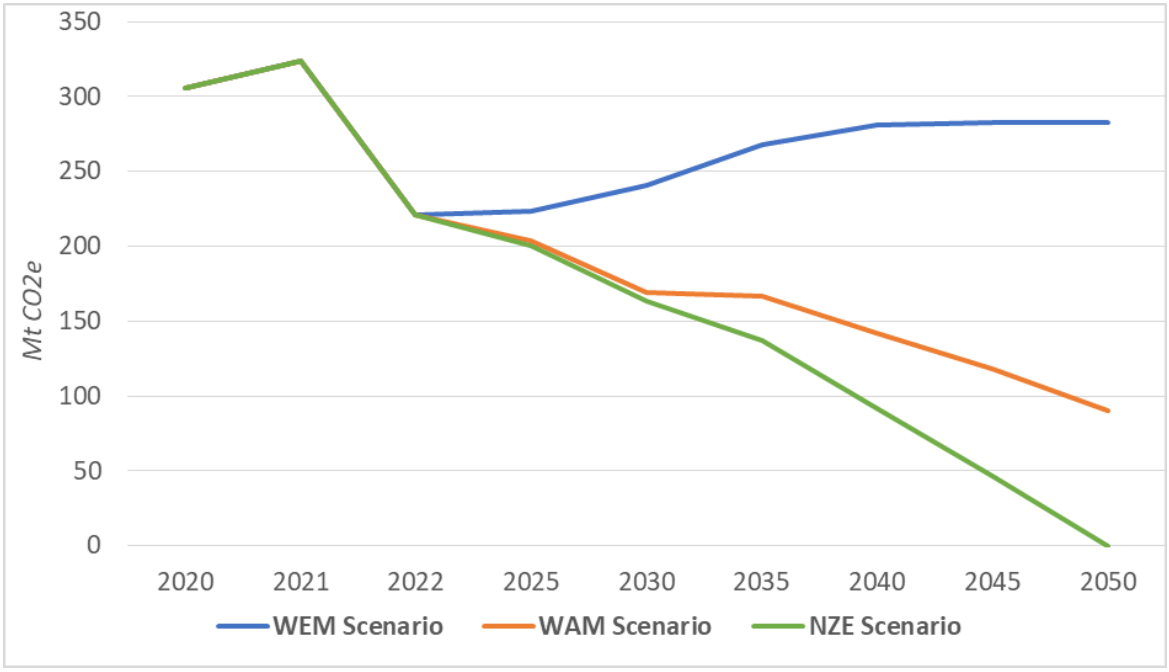

Fig. 2.1. GHG emission scenarios in LT-LEDS under three scenarios: WEM, WAM and NZE

Table 2.1 Dynamics of greenhouse gas emissions by IPCC sector

WEM scenario													
IPCC sectors	**1990**	**2000**	**2010**	**2020**	**2021**	**2022**	**2023**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Energy and IPPU	857.8	388.9	369.2	271.1	275.7	192.0	185.1	196.2	198.2	219.4	230.0	233.4	237.6
Agriculture	89.6	36.8	31.5	37.7	41.7	32.5	33.0	32.7	37.5	41.4	43.1	44.3	45.4
LULUCF	-47.9	-33.4	-21.0	-15.5	-5.4	-15.7	-11.2	-7.8	-6.5	-4.6	-2.7	-5.0	-8.7
Waste	17.0	15.9	16.5	16.4	16.1	14.8	14.8	14.4	14.6	14.4	13.6	12.5	11.1
TOTAL	**916.5**	**408.2**	**396.2**	**309.7**	**328.1**	**223.6**	**221.7**	**235.5**	**243.8**	**270.6**	**283.9**	**285.2**	**285.4**
Compared to 1990		***-55.5%***	***-56.8%***	***-66.2%***	***-64.2%***	***-75.6%***	***-75.8***	***-74.3%***	***-73.4%***	***-70.5%***	***-69.0%***	***-68.9%***	***-68.9%***
Share of 1990 level	***100.0%***	***44.5%***	***43.2%***	***33.8%***	***35.8%***	***24.4%***	***24.2***	***25.7%***	***26.6%***	***29.5%***	***31.0%***	***31,1%***	***31,1%***
WAM scenario													
IPCC sectors	**1990**	**2000**	**2010**	**2020**	**2021**	**2022**	**2023**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Energy and IPPU	857.8	388.9	369.2	271.1	275.7	192.0	185.1	179.5	133.7	127.3	100.9	79.8	56.6
Agriculture	89.6	36.8	31.5	37.7	41.7	32.5	33.0	32.5	36.3	40.6	42.4	43.4	44.2
LULUCF	-47.9	-33.4	-21.0	-15.5	-5.4	-15.7	-11.2	-10.7	-11.6	-10.9	-10.3	-13.6	-18.1
Waste	17.0	15.9	16.5	16.4	16.1	14.8	14.8	13.9	13.0	11.8	11.0	10.2	9.3
TOTAL	**916.5**	**408.2**	**396.2**	**309.7**	**328.1**	**223.6**	**221.7**	**214.9**	**171.5**	**168.8**	**144.0**	**119.7**	**92.0**
Compared to 1990		***-55.5%***	***-56.8%***	***-66.2%***	***-64.2%***	***-75.6%***	***-75.8***	***-76.6%***	***-81.3%***	***-81.6%***	***-84.3%***	***-86.9%***	***-90.0%***
Share of 1990 level	***100.0%***	***44.5%***	***43.2%***	***33.8%***	***35.8%***	***24.4%***	***24.2***	***23.4%***	***18.7%***	***18.4%***	***15.7%***	***13.1%***	***10.0%***
NZE scenario													
IPCC sectors	**1990**	**2000**	**2010**	**2020**	**2021**	**2022**	**2023**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Energy and IPPU	857.8	388.9	369.2	271.1	275.7	192.0	185.1	178.6	133.7	105.0	60.0	20.0	-20.2
Agriculture	89.6	36.8	31.5	37.7	41.7	32.5	33.0	32.4	35.9	39.6	41.2	41.8	42.3
LULUCF	-47.9	-33.4	-21.0	-15.5	-5.4	-15.7	-11.2	-13.3	-16.0	-16.4	-16.8	-20.8	-25.9
Waste	17.0	15.9	16.5	16.4	16.1	14.8	14.8	13.9	11.9	9.6	7.3	5.0	2.8
TOTAL	**916.5**	**408.2**	**396.2**	**309.7**	**328.1**	**223.6**	**221.7**	**211.6**	**165.5**	**137.8**	**91.7**	**46.0**	**-1.0**
Compared to 1990		***-55.5%***	***-56.8%***	***-66.2%***	***-64.2%***	***-75.6%***	***-75.8***	***-76.9%***	***-81.9%***	***-85.0%***	***-90.0%***	***-95.0%***	***-100.1%***
Share of 1990 level	***100.0%***	***44.5%***	***43.2%***	***33.8%***	***35.8%***	***24.4%***	***24.2***	***23.1%***	***18.1%***	***15.0%***	***10.0%***	***5.0%***	***0.1%***

2.1.2. National Target for 2030, Future Prospects, and Indicative Interim Targets for 2040 and 2050

The Law of Ukraine "On the Main Principles of State Climate Policy" establishes the long-term goal of Ukraine's climate policy to achieve climate neutrality by 2050 and also sets an intermediate target of reducing GHG emissions in Ukraine by 65% by 2030 compared to the 1990 level.

According to Article 4 of the Law of Ukraine "On the Main Principles of State Climate Policy", the LT-LEDS defines the medium-term targets and their indicators. Taking into account Ukraine's Second Nationally Determined Contribution under the Paris Agreement for the period up to 2035 and based on the updated modelling results, the medium-term **target of state climate policy is defined as a reduction of anthropogenic greenhouse gas (GHG) emissions, taking removals into account, by more than 65% across all sectors of the economy by 2035 compared to 1990 emission levels.**

This medium-term target serves as a benchmark for Ukraine's climate policy in planning, budgeting, monitoring and evaluation and applies to GHG emissions accounted for on a territorial basis within the national system of anthropogenic GHG emissions and removals by sinks.

In light of the full-scale invasion and ongoing armed aggression of the Russian Federation against Ukraine, the defined medium-term target does not yet fully establish a trajectory consistent with achieving NZE by 2050, according to the modeling conducted.

Nevertheless, Ukraine confirms its readiness, after restoring territorial integrity within internationally recognised borders and based on verified information, to review and refine the medium-term targets to align them with the updated NZE trajectory and the principles of a just transition (see Section 5 "Implementation and Updating of the Strategy", Subsection 5.2 "Monitoring and Evaluation of Implementation"). Achieving full alignment will also require further engagement of international financial support from partners, given the limitations of domestic resources.

2.1.3. Adaptation Policies and Measures

State Policy on Climate Change Adaptation

Ukraine is developing its climate change adaptation policy in line with international commitments and the recommendations of the European Commission. Thus the long-term objectives of climate policy defined in the *Law of Ukraine "On the Main Principles of State Climate Policy in Ukraine"* (No. 3991-IX of 8 October 2024), include enhancing resilience and reducing risks to public health, ensuring low-carbon and sustainable development, as well as Ukraine's environmental, food and energy security. The law sets out the requirements for the Climate Change Adaptation Strategy, which assesses risks, identifies priorities and measures, and establishes mechanisms for financing and monitoring its implementation. The Strategy is developed for a ten-year period and reviewed every five years.

At this stage, the operational action plan for 2024–2026 *under the Strategy for the Formation and Implementation of State Policy on Climate Change until 2035* approved by the Cabinet of Ministers of Ukraine (Order No. 483-р of 30 May 2024), includes the development of methodological guidelines for integrating the climate component into state planning documents. It also provides for risk and vulnerability assessments in sectors such as population, agriculture, forestry, biodiversity, water resources, energy, fisheries, coastal areas, settlements and tourism. Additionally, proposals for adaptation programme documents for various sectors are to be developed and submitted to the

Cabinet of Ministers of Ukraine. Regional and local adaptation strategies and the integration of adaptation measures into regional development strategies are also to be developed.

Order of the Ministry of Environmental Protection and Natural Resources of Ukraine No. 1382 of 31 October 2024 "*On the Approval of Methodological Guidelines for Considering the Climate Component in State Planning Documents and During Strategic Environmental Assessment and Environmental Impact Assessment*" provides for the integration of climate aspects into planning documents and assessment procedures. This allows for taking into account potential climate-related risks, assessing their impact on the environment and human health, and ensuring the development of measures aimed at increasing the resilience of territories and economic sectors to climate challenges.

The Environmental Security and Climate Change Adaptation Strategy for the period up to 2030 (Cabinet of Ministers of Ukraine Resolutions No. 1363-p of 20 October 2021 and No. 96-p of 7 February 2025) aims to strengthen the adaptive capacity and resilience of social, economic and ecological systems to climate change, as well as to create organisational prerequisites and provide scientific and methodological support for the development of sectoral climate adaptation action plans and the implementation of adaptation measures. As part of the Strategy, Methodological Recommendations for Risk and Vulnerability Assessment of Socio-Economic Sectors and Natural Components to Climate Change were developed (approved by Resolution of the MENR No. 386 of 3 June 2023). These recommendations provide tools for assessing climate change impacts on various economic sectors and natural resources, enabling the development of measures to enhance resilience and adaptation. Furthermore, as part of the operational plan for implementing the Strategy for 2025–2027, the development of climate adaptation plans is envisaged in the areas of water resources management, biodiversity conservation, forestry, energy, health care, agriculture and soils, transport and infrastructure, and tourism. The plan also includes conducting a national forest inventory, integrating climate change considerations into strategic planning — in particular, adapting the energy sector to 2050 — and taking climate aspects into account in the Tourism and Resort Development Strategy up to 2030.

An important aspect of climate governance is engaging the public and stakeholders in the policy development process, conducting consultations, and providing training to integrate climate adaptation issues into socio-economic development and post-war recovery plans.

Adaptation Measures in Vulnerable Sectors

The following adaptation measures are proposed for each of the social and economic sectors identified in the *Environmental Security and Climate Change* Adaptation Strategy until 2030 as vulnerable to climate change's impacts.

Biodiversity adaptation measures include a wide range of actions aimed at preserving biodiversity, slowing species loss, establishing seed banks for long-term genetic stability, and assessing and monitoring ecosystem services. An important task is the implementation of measures to control and combat invasive species that pose a threat to local ecosystems.

Water Resources adaptation measures should ensure effective water resource management under changing climate conditions. This includes measures to mitigate excessive rainfall and flooding and water resources management during droughts ("water surplus" and "water scarcity" scenarios). In flood-prone areas, integrated spatial planning, early warning systems, and enhanced institutional capacity are essential. Innovative irrigation technologies, water collection and conservation systems,

and nature-based solutions that help ensure sustainable water supply should be implemented to address issues caused by water shortages.

Energy adaptation measures should be based on a detailed assessment of climate change impacts on energy production, transportation, and distribution. Attention should also be paid to technological processes where water resources are used without direct consumption or transformation of water, in particular for cooling power plants. Infrastructure modernisation is essential with respect to socio-economic development trends. The transition to RES, a key element in climate change mitigation, also has significant adaptation potential. These sources require far less water than traditional fuels.

Public Health adaptation measures should include a wide range of measures for the physical adaptation of buildings and public spaces to higher temperatures, particularly through nature-based solutions. Furthermore, it is important to enhance institutions' capacity to respond promptly to natural disasters and provide citizens with information on potential health threats, particularly those related to extreme temperatures and invasive species. Addressing energy poverty and ensuring access to necessary resources for comfortable living conditions year-round is also essential.

Forestry adaptation measures provide for expanding forested areas and focusing on creating climate-resilient forest ecosystems. One key area is improving the forest fire prevention system and developing innovative methods for early detection and combating fires of various types. Controlling invasive species that cause damage to forest resources is another priority.

Coastal Areas adaptation measures should be based on an integrated approach to land use planning and infrastructure development, taking into account projected sea level rise. Nature-based solutions should be implemented to protect coastal zones, along with protective structures where necessary to prevent flooding. Cooperation with the Water Resources sector is crucial, particularly in cases of excess water accumulation.

Adaptation measures in the "*Fisheries*" sector must take into account the impact of climate change on aquatic ecosystems, which can affect fisheries productivity, including changes in water temperature, oxygen levels, and the chemical composition of aquatic environments. Key adaptation measures should include monitoring and forecasting climate changes in aquatic ecosystems to assess their impact on fish populations and stocks, evaluating species' adaptive potential, developing aquaculture to reduce reliance on natural ecosystems, and protecting aquatic environments through nature-based solutions.

Agriculture and Soil adaptation measures cover several key areas. Key measures in crop production include adapting cultivated crops to changes in climatic zones by developing frost — and heat-resistant varieties, as well as crops resistant to pests and diseases. Given potential water shortages, crop production is closely linked to effective water resource management. In livestock farming, the priorities are breeding heat-resistant animal breeds and implementing technologies that reduce GHG emissions, such as the use of silica gels to reduce methane emissions. Maintaining soil fertility requires modern land management practices and economic incentives for farmers to preserve and restore soil quality.

Territorial Communities' *adaptation measures* aim to ensure resilience to adverse weather conditions and natural disasters and prepare infrastructure for "water scarcity" and "water surplus" scenarios. Since territorial communities directly experience the impacts of climate change, this sector is crucial for the country's overall adaptive capacity. Territory development planning must

consider climate change forecasts and align with adaptation strategies in other sectors, such as Water Resources, transport, and Infrastructure.

Transport and *Infrastructure* is one of the key sectors in implementing adaptation activities in the context of climate change. Main adaptation measures in this sector should enhance resilience to extreme temperatures, natural disasters, and adverse weather conditions. This includes ensuring the readiness of transport systems for potential disruptions caused by climate change, as well as ensuring the accessibility of transport infrastructure for vulnerable groups of the population and people with disabilities. Transport infrastructure planning must take into account long-term climate change forecasts and their potential impact on specific regions. This may require modernising existing infrastructure, changing building codes, and using innovative construction solutions, including those already applied in countries with hot climates. Another important aspect is the greening of areas to maximise water retention and mitigate the impact of extreme weather conditions. Nature-based solutions should become a core component of adaptation strategies in this sector.

Tourism adaptation measures should integrate climate change forecasts into long-term industry planning. This should influence investment decisions and encourage the diversification of tourism services. In the context of climate change adaptation, it is important to reduce tourism services' dependence on natural phenomena and weather conditions (e.g., the availability of snow) and focus more on offerings that provide indoor or controlled environment-based recreation.

Measures to reduce emissions should be closely integrated with adaptation policies to achieve mutual benefits and enhance resource efficiency. This integrated approach is particularly important given that mitigation initiatives often attract more funding due to higher economic returns. Therefore, aligning emission reduction and adaptation measures allows multiple objectives to be achieved simultaneously[39].

Nature-based solutions (NbS) are a key tool for simultaneously advancing adaptation and mitigation goals. Activities such as reforestation, wetland conservation, agroforestry (combining agricultural and forestry land use), and river basin management promote carbon dioxide sequestration and increase the resilience of ecosystems and communities to climate risks[40]. For example, forest restoration helps reduce flood risks, improve water quality, preserve biodiversity and serves as an effective means of carbon capture. Implementing NbS in urban environments helps reduce the urban heat island effect, improve air quality, lower energy consumption for heating and cooling, and enhance overall living comfort[41].

Enhancing the climate resilience of critical infrastructure — transport, energy, and housing — is a priority for adaptation. Given the increasing vulnerability of infrastructure to extreme weather events such as floods, heatwaves, and storms, it is necessary to implement both "grey" (engineering) and "green" (nature-based) solutions. In the energy sector, it is important to promote the

[39] EU's New Climate Adaptation Strategy: https://rac.org.ua/wp-content/uploads/EGDcards/Final_0000_23_Adaptation%20strategy_card_2021_ua.pdf

[40] Climate challenges and adaptation pathways through the lens of water, forest and agricultural sectors (results of the online meeting): https://mepr.gov.ua/wp-content/uploads/2022/08/Rezultaty-napratsyuvan-pershoyi-chastyny-polilogu-1.pdf

[41] Mikhieienko, V. M. (2024) Use of Nature-Based Solutions in Urban Ecosystems. Scientific Journal of DonNABA, (2), 33. https://donnaba.edu.ua/journal/wp-content/uploads/2024/06/58-67.pdf

development of decentralised and renewable energy sources, the modernisation of energy grids, and the deployment of energy-efficient technologies.

In the transport sector, it is necessary to increase the resilience of roads, bridges and railways to extreme weather conditions, as well as to develop electric transport and cycling infrastructure. NbS can include green plantings along transport corridors, which help reduce air pollution, lower noise levels, provide shade (e.g., at public transport stops), and create ecological barriers to protect adjacent areas[42]. Implementing sustainable drainage systems based on bioengineering approaches is essential for managing stormwater and meltwater runoff and reducing the risk of flooding[43]. Green spaces should be integrated into urban transport infrastructure, including bike and pedestrian corridors. The use of green roofs on transport facilities can enhance user comfort and positively influence the urban microclimate[44].

Cities and towns in Ukraine are increasingly facing overheating, air pollution, a shortage of green spaces, and insufficiently effective drainage systems that cannot cope with heavy rainfall. NbS in urban environments can include green roofs and walls, parks, restoration of small rivers, and the creation of urban green spaces and corridors. These measures can significantly improve the microclimate, air quality, and overall livability. In the residential sector, priorities should include thermal modernisation, green roofs, rainwater harvesting systems and adaptive urban planning practices.

Achieving climate resilience requires the systemic integration of adaptation and emission reduction policies at all governance levels — from national to local. This includes developing strategies that account for regional and sectoral characteristics, conducting demographic analyses, investing in human capital, integrating NbS into urban and rural planning, and mobilising investments in sustainable infrastructure. Strengthening the integration of adaptation and emission reduction measures, scaling up the use of NbS, and enhancing the resilience of critical infrastructure are necessary to ensure an effective and timely response to climate challenges in Ukraine.

In summary, post-war reconstruction must consider climate challenges, particularly in the context of rebuilding infrastructure. Climate change adaptation should be a key element of reconstruction and development. To achieve this, it is necessary to: To do this, it is necessary to:

- Refine the draft Strategy for the Formation and Implementation of State Policy in Ecosystem Services Management for the period up to 2030, which defines the concept of ecosystem services and provides for the development of methodological recommendations for their consideration in the process of state planning and forecasting, as well as to ensure their integration into adaptation measures. In particular, ecosystem services such as water purification, microclimate regulation, plant pollination, soil fertilisation by microorganisms, biodiversity and forest preservation should be considered in developing adaptation strategies. Information on ecosystem services can be used to raise public awareness and engage local communities in adaptation activities, contributing to effective implementation and increased resilience;

[42] UNDP. Nature-Based Solutions for Cities in Legislation, Strategies, Policies and Action Plans at the National, Regional and Local Levels in Ukraine: https://www.undp.org/sites/g/files/zskgke326/files/migration/ua/nbs-legal-report-ua.pdf
[43] UNDP. Nature-Based Solutions for Cities in Legislation, Strategies, Policies and Action Plans at the National, Regional and Local Levels in Ukraine: https://www.undp.org/sites/g/files/zskgke326/files/migration/ua/nbs-legal-report-ua.pdf
[44] UNDP. Nature-Based Solutions for Your City: https://www.undp.org/sites/g/files/zskgke326/files/migration/ua/Leaflet-NBS-for-your-city.pdf

- (Approve and) systematically integrate the list of nature-based solutions into the planning, implementation and evaluation of adaptation strategies and programs. Examples include wetland and forest restoration, the creation of green infrastructure in cities, coastal protection and sustainable agricultural development.
- Expand access to climate data by providing more and better information on climate risks and losses, and by creating a professional knowledge platform on adaptation. This will help make informed decisions and plan adaptation measures (e.g., the EU Climate Adapt online platform);
- Develop and approve adaptation targets, which will enable effective monitoring of the success of adaptation measures;
- support the growing role of local communities as key players in implementing adaptation measures. This includes developing a support system for local communities in the design and implementation of adaptation measures;
- Integrate the concept of climate resilience into fiscal policy by regularly assessing the financial resources required to implement adaptation measures across different regions and sectors. This is an important tool for attracting international financing and conducting cost–benefit analyses, which will help identify climate policy priorities and ensure efficient use of resources.
- Improve physical infrastructure and expand human capacity in the field of meteorological observations, in particular by training a larger number of professional meteorologists to meet the needs of various economic sectors and to provide high-quality climate services.

2.2. RENEWABLE ENERGY SOURCES

2.2.1. RES in the Forecast Energy Balance

Under the NZE scenario, which incorporates all planned policies and measures alongside achieving net-zero emissions by 2050, electricity generation will be fully decarbonised by 2040 and will be primarily based on RES — wind and solar power, supported by CHPP and cogeneration units operating on biomass and biomethane with carbon capture and storage (CCS). This ensures negative greenhouse gas emissions, flexibility, and inertia for the electric power system. Electricity production will reach 558 billion kWh by 2050, with the share of RES potentially reaching 82% (Fig. 2.2).

In the WAM scenario, all planned policies and measures are also included; however, instead of a mandatory net-zero emissions target by 2050, a carbon price is applied based on assumptions adopted in line with NECP. Under these conditions, electricity demand grows less rapidly, reaching 359 billion kWh by 2050, with RES accounting for 71%. At the same time, full decarbonisation of electricity generation will also be achieved by 2040. Electricity production from biomethane in 2050 is lower — 11 billion kWh, compared to 43.5 billion kWh under the NZE scenario.

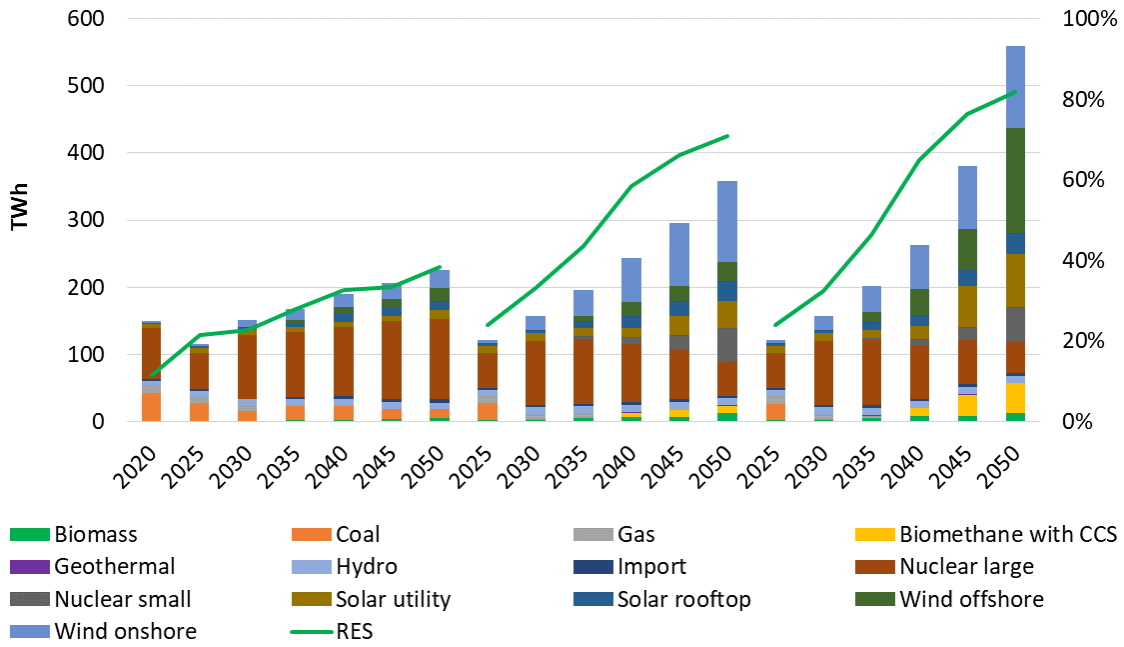

Fig. 2.2 (a). Electricity Generation by Type and RES Share Across Scenarios

The WEM scenario reflects only the development of existing policies and measures. Therefore, electricity demand increases only moderately compared to other scenarios, rising by 50% from 2020 levels to reach 225 billion kWh by 2050. Biomethane is not used for electricity generation.

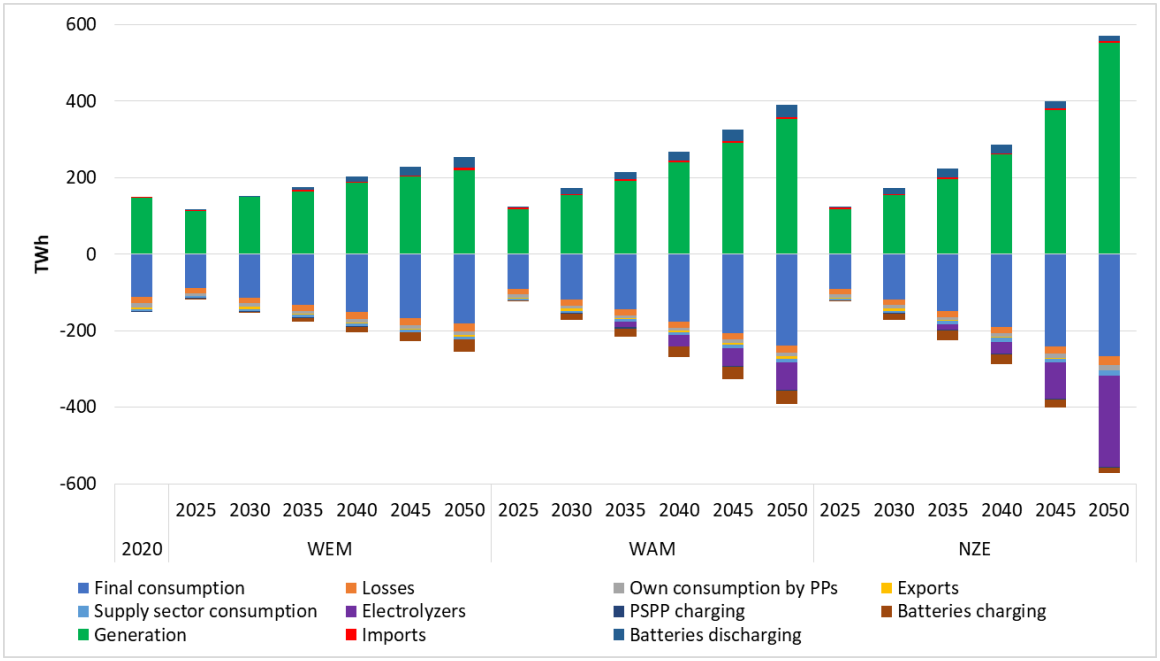

Fig. 2.2 (b). Balance of Electricity Production and Consumption by Scenarios

Figure 2.2 (b) shows the balance of electricity production and consumption by main consumption sectors. The volumes consumed by electrolyzers for the production of hydrogen and its derivatives are notable, especially in the NZE scenario.

The increase in installed generation capacity from RES (SPP and WPP) to 172 GW requires the deployment of approximately 17 GW of battery energy storage systems (BESS) by 2050 under the NZE scenario (Fig. 2.3). Although the total capacity of SPPs and WPPs is lower under the WAM scenario — 106 GW, the need for BESS is even higher — 18.2 GW. Under the WEM scenario, 35 GW of SPPs and WPPs and 14.4 GW of battery storage are planned to be built.

The capacity of nuclear power plants, including small modular reactors (SMRs), in such a structure of the Integrated Power System (IPS of Ukraine) under the NZE scenario may be economically viable at a level of up to 12.8 GW. Their share in electricity generation would make up 17% by 2050. The WAM scenario presents a similar picture — 13 GW of nuclear capacity, but its share increases to 28%. Under the WEM scenario, NPP capacity could reach 15 GW, which would maintain the share of nuclear generation at the current level of 53%.

The dynamics of heat production are presented in Fig. 2.4. While the WEM scenario forecasts an increase in heat production, peaking in 2045, the NZE and WAM scenarios demonstrate the potential for reducing heat production by 2050 due to planned large-scale thermal modernisation of buildings.

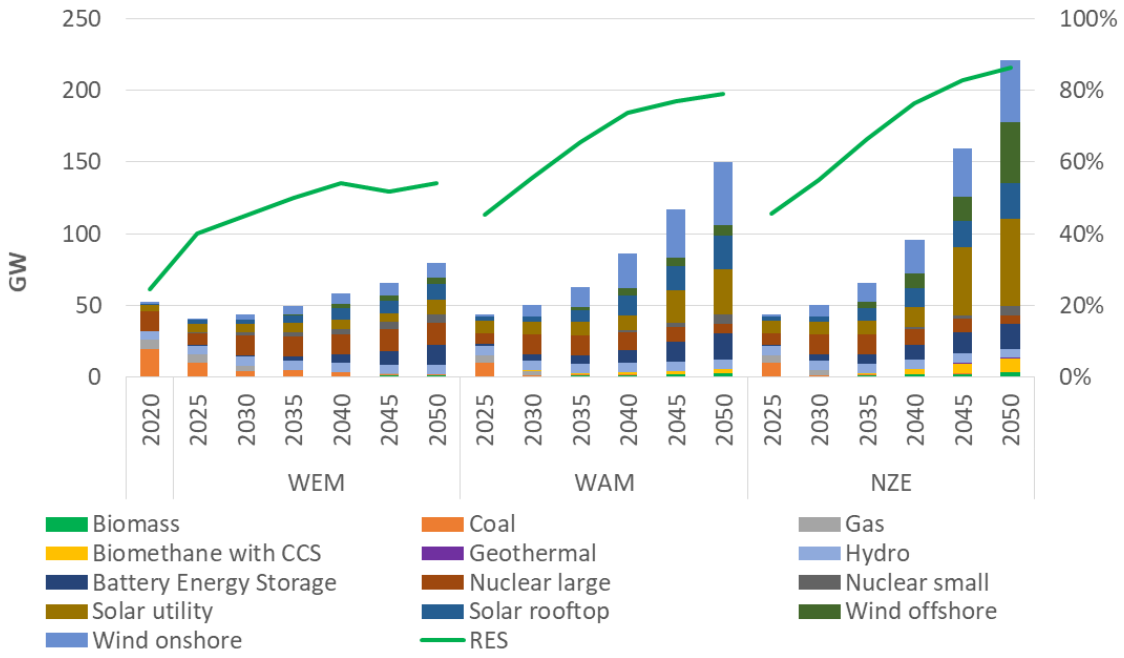

Fig. 2.3. Installed Capacity of IPSU by Generation Type and the Share of RES Capacity by Scenario

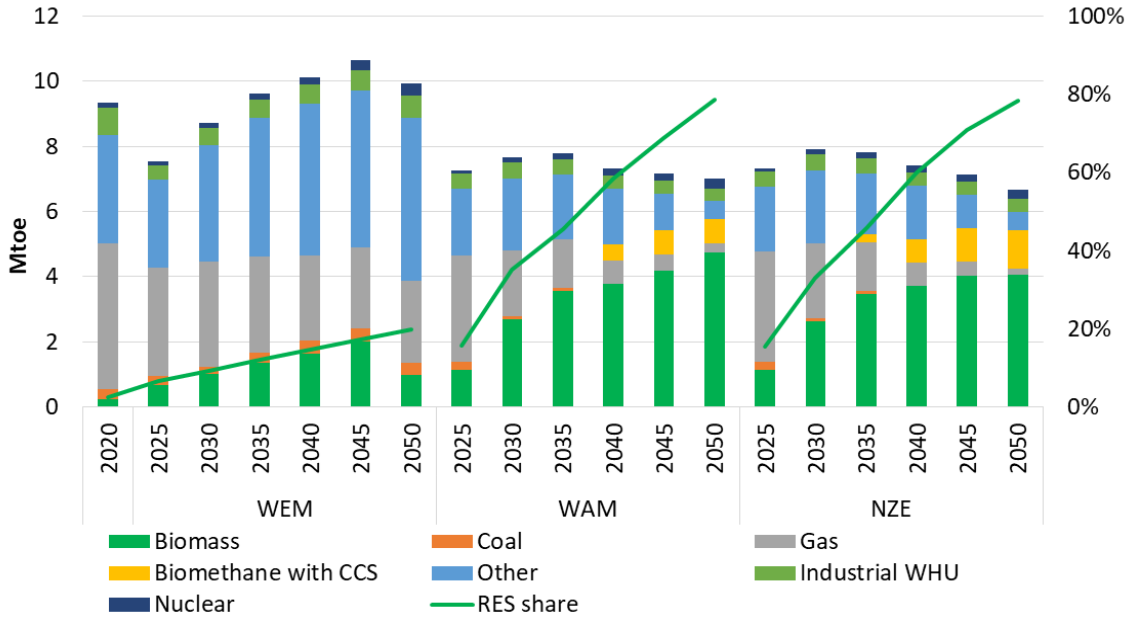

Fig. 2.4. Heat Generation by Type and RES Share Across Scenarios

In the heat generation structure under the NZE and WAM scenarios, biomass use increases significantly, rising from 223 thousand TOE in 2020 to 4,059 thousand TOE and 4,755 thousand TOE by 2050, respectively. The higher biomass consumption for heat in WAM is likely due to lower demand for it in this scenario for biomethane synthesis.

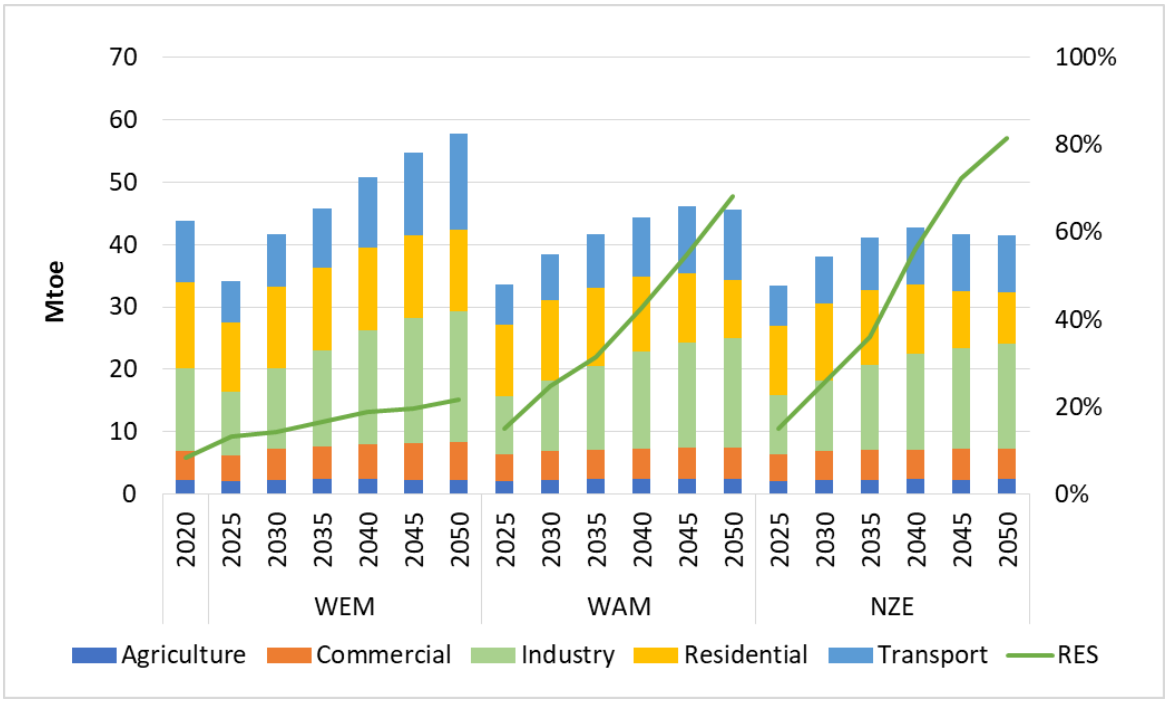

Fig. 2.5. Final Energy Consumption by Sector and the Share of RES across Scenarios

Coal is also completely phased out by 2040 in both target scenarios, aligning with the projected objective. Natural gas and other fossil energy sources are sharply reduced, reflecting increased energy independence. The share of RES rises substantially, from 2% in 2020 to 79% by 2050 in both

scenarios. Waste heat recovery (WHR) in industry decreases due to a shift to more efficient processes.

All scenarios project an increase in final energy consumption. However, WEM shows higher growth rates, while WAM sees stabilisation of final energy consumption by 2050, and in NZE, after peaking in 2040, final consumption slightly declines. This indicates improved efficiency in the energy transformation sector in both target scenarios and reduced energy intensity of the economy (Fig. 2.5). The primary sector driving consumption growth is industry, while household energy consumption declines the most. Transport consumption grows only slightly in the target scenarios, while the service and agricultural sectors remain nearly unchanged. By 2050, the share of RES in final consumption may reach 82% in NZE, 68% under the WAM, and only 22% under the WEM scenario.

2.2.2. Policy and Measures

General Overview

Since 2009, the RES sector has grown rapidly, primarily due to the stimulating "green" tariff. In 2009, the installed capacity of power generation facilities operating under the "green" tariff was approximately 126 MW, with electricity supply reaching 51.8 million kW·h[45].

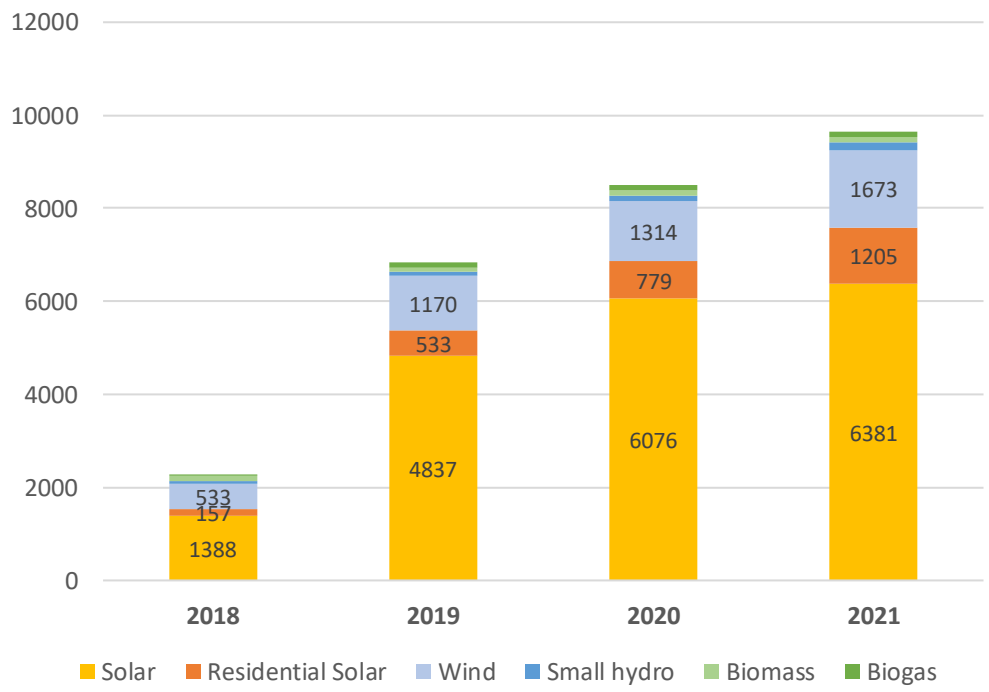

Fig. 2.6. Installed Capacity of RES Facilities Operating Under the "Green" Tariff, *MW*

Source: UWEA Public Union, NERC, 2021.[46]

[45] 2014 Annual NERC Report, https://www.nerc.gov.ua/data/filearch/Catalog3/Richnyi_zvit_2014.pdf

[46] Ukraine's Renewable Energy Sector Before, During and After the War. Andriy Konechenkov / Razumkov Centre. https://razumkov.org.ua/statti/sektor-vidnovlyuvanoyi-energetyky-ukrayiny-do-pid-chas-ta-pislya-viyny

By the end of 2021, the installed capacity of RES facilities, including household SPPs but excluding facilities located in territories occupied before 24 February 2022, reached 9,656 MW (see Fig. 2.6), generating 11.4 billion kW·h[47] of electricity.

Russia's full-scale aggression has led to significant losses in RES capacity due to destruction and occupation of territories. According to the National Renewable Energy Action Plan (NREAP) until 2030, approximately 25% of RES capacity is in the occupied territory. Notably, wind power has suffered the most, with 75% (1.25 GW) of its capacity located in the occupied areas of Kherson and Zaporizhzhia regions. Regarding SPPs, about 14% (0.6 GW) is currently in the occupied territories.

In 2023, the share of RES in electricity generation reached 10% (including large HPPs — 20.3%). Despite the war, new RES facilities continue to be built. In 2022–2023, new RES facilities (SPPs, WPPs, biomass TPPs, biogas plants, small HPPs, as well as household SPPs) with a total capacity of 662 MW were commissioned[48].

Strategic goals

National RES sector goals are set out in several strategic documents. For instance, one of the indicators for achieving the goals of the National Economic Strategy is attaining a 25% share of RES in electricity generation by 2030. A sectoral goal for the RES development in the heat energy sector is defined in the Concept for Implementing State Policy in the Heat Supply Sector. The Concept envisions increasing the share of alternative energy sources (RES and secondary energy resources) in heat generation to 40% by 2035. One of the expected outcomes of the National Transport Strategy of Ukraine up to 2030 is to increase, by 2030, the share of alternative and renewable fuels and electricity used across all modes of transport and transport infrastructure facilities to 50%.

At the same time, as part of the development of the National Energy and Climate Plan (NECP) until 2030 and the National Renewable Energy Action Plan (NREAP) until 2030, a detailed assessment of national indicative RES targets by energy source and sector has been conducted. The NECP and NREAP set the share of energy generated from RES in the gross final consumption structure to at least 27% by 2030. Table 2.2 presents the indicative trajectories for increasing the share of RES in heating and cooling systems, electricity generation and the transport sector by 2030.

Table 2.2. National Indicative Targets for Renewable Energy Development, % of Gross Final Energy Consumption by 2030

Areas of RES Energy Use	2020	2025	2026	2027	2028	2029	2030
Heating and cooling	9.3	20.8	23.2	24.6	26.7	28.6	32.5
Electricity	10.7	20.9	23.9	27.8	30.5	31.1	29.4
Transport	2.5	4.9	7.3	10.1	12.7	15.9	17.2
Gross final energy consumption	**8.4**	**17.3**	**19.5**	**21.6**	**23.7**	**25.3**	**27.1**

Key RES policies and measures in the electricity sector

According to the NREP, in 2020, the share of renewable energy in the gross final consumption of the electricity sector was 10.7% (1,332 thousand TOE), with a projected increase to 29.4% (3,365

[47] Bulletin to the 2021 annual NERC report.https://www.nerc.gov.ua/storage/app/sites/1/Docs/Byuleten_do_richnogo_zvitu/byuleten_do_richnogo_zvitu_nkrekp-2021.pdf

[48] National Renewable Energy Action Plan until 2030. https://zakon.rada.gov.ua/laws/show/761-2024-%D1%80#Text

thousand TOE) by 2030. Electricity generation from wind power plants and bioenergy facilities is expected to increase more than fivefold by 2030, to 17.5 TW·h and 3.9 TW·h, respectively. Meanwhile, electricity production from SPPs will grow from approximately 6 TW h·in 2020 to 13.5 TWh in 2030.

Since 2009, the "green" tariff has been the primary incentive for increasing electricity generation from renewable sources. However, the financial instability of the "green" tariff model and the persistent shortage of funds for payments to producers of "green" electricity, as well as the limited capacity of Ukraine's Unified Energy System to integrate renewable energy facilities, have driven the search for alternative models to develop the RES sector in Ukraine.

In 2019, Law of Ukraine No. 2712-VIII introduced an auction-based quota allocation mechanism for large-scale renewable energy plants to enhance competition in the RES market. Under the law, participation in auctions is mandatory for WPPs with an installed capacity exceeding 5 MW and SPPs exceeding 1 MW, while smaller producers can participate voluntarily. In the following years, regulatory frameworks for the auction mechanism were developed.

In August 2024, the government approved the renewable energy support quota for 2024 (11 MW for SPPs, 88 MW for WPPs, and 11 MW for other RES). Pilot auctions were held in October–November; however, their effectiveness proved to be low. Out of the available quota of 110 MW, only 0.9 MW was allocated for support to a hydropower project, while auctions for allocating quotas for solar (PV) and wind power plants did not take place due to a lack of interest from businesses.

At the end of November 2024, the government set the RES support quota for 2025 at 330 MW and also defined indicative forecast annual support quotas for 2026–2029, with a planned increase from 340 MW to 400 MW, respectively.

On 30 June 2023, the Verkhovna Rada of Ukraine adopted Law No. 3220-IX, "On Amendments to Some Laws of Ukraine Regarding the Recovery and Green Transformation of Ukraine's Energy System," which introduced new or improved existing market-based instruments to support the development of the RES sector, including:

- The rights and obligations of the new market participant, the "active consumer", have been defined, and a self-generation mechanism (the Net Billing model) has been introduced. This model supports active consumers by encouraging their own electricity consumption. It involves a settlement system for the value of electricity supplied to the grid by generating installations of such consumers and the value of the electricity they withdraw from the grid, considering the cost of electricity transmission and/or distribution services. Household and non-household consumers have the right to install generation capacities within their contractual capacity (for households, no more than 30 kW; for non-households, no more than 50 kW);
- The rights and obligations of a new market participant — the "aggregator" — have been defined, and an aggregation mechanism has been introduced. This mechanism serves as a tool to combine the electrical installations of consumers, distributed generation producers, and energy storage system owners for their joint participation in the electricity market. This model ensures the development of the demand-side management segment by providing balancing and ancillary services through the collective modification of electricity consumption or generation volumes by a group of facilities in response to market signals. Participation in such mechanisms is accessible to both industrial and residential consumers,

allowing small participants who lack sufficient capacity to enter the market independently to integrate into the power system, generate income from their flexibility, and stimulate the deployment of smart grids;

- instead of fixed payments under the "green" tariff, a market premium mechanism (the feed-in premium model) has been introduced for existing producers under the "green" tariff, and a contract for the difference model has been introduced for future auction winners. Thus, renewable energy producers have become full participants in the market, are able to sell electricity independently, and are entitled to receive a supplement from the guaranteed buyer — the difference between the "green" tariff or auction price and the calculated market price;
- a number of regulatory barriers have been removed to facilitate the operation of the direct contract segment (both physical and virtual) for the buying and selling of electricity between producers and end energy consumers (corporate PPAs);
- A mechanism for issuing, using, and terminating the validity of guarantees of origin for electricity produced from RES has been introduced, and a legislative foundation has been established for the functioning of a renewable energy guarantee of origin register, which was launched by the regulator in August 2024.

Based on the analysis of the pilot "green" auctions in April 2025, the draft Law of Ukraine "On Amendments to Certain Laws of Ukraine Regarding the Improvement of Competitive Conditions for the Production of Electricity from Alternative Energy Sources" (No. 13219 dated 28 April 2025) was developed and adopted in the first reading. This draft Law aims to improve the conditions and increase the efficiency of auctions for the allocation of support quotas for electricity production from RES, in particular by extending the support period based on auction results from 2029 to 2034, defining the procedure for the circulation and redemption of guarantees of origin within 12 months after energy production, clarifying financial guarantees and project implementation timelines, defining requirements for energy storage systems, and other provisions.

Active consumers (prosumers) will play a key role in the further development of the RES sector. Thanks to the "green" tariff model, the number of household SPPs has increased nearly tenfold over the past five years, reaching 1,493 MW (about 17.3% of all RES objects). However, the "green" tariff incentivised the maximum export of expensive electricity to the grid, rather than using it for personal consumption. In contrast, the self-generation mechanism (the new Net Billing model) encourages the consumption of self-produced electricity. At the same time, households can benefit from state support and receive an interest-free loan for the purchase and installation of photovoltaic modules and/or wind installations with capacities from 1 kW to 10 kW, hybrid inverters capable of operating both autonomously and synchronised with the external grid, and energy storage systems with a capacity of 1 kW·h per 1 kW of installed generation capacity.

In May 2024, the Energy Efficiency Fund launched the GreenDIM programme, under which homeowners associations (HA) and housing construction cooperatives (HCC) can receive a 70% reimbursement of the cost of equipment and materials (heat pumps for heating and hot water supply, and SPPs). By the end of 2024, only UAH 18.11 million[49] had been disbursed under this

[49] The Energy Efficiency Fund has summed up the results of programme implementation in 2024. https://kbu.org.ua/news/fond-enerhoefektyvnosti-pidviv-pidsumky-realizatsii-prohram-u-2024-rotsi?utm_source=chatgpt.com

program, and as of March 2025, the acceptance of applications for participation in the programme was suspended due to a lack of funds.

State and municipal-owned facilities, including medical and educational institutions, can implement projects to install SPPs and energy storage systems (BESS) under energy service contracts in accordance with the provisions of the Ukrainian Law on Energy Efficiency. The strategy for developing distributed generation until 2035 includes measures to require the mandatory installation of renewable energy facilities and energy storage systems in public and administrative buildings during 2024–2026.

In the context of ongoing Russian missile and drone attacks on Ukraine's energy system, which have caused electricity supply interruptions, more and more private companies are implementing projects to provide autonomous power supply based on RES and BESS. Additionally, preferential loans under the state Affordable Loans 5–7–9% programme are available for entrepreneurs who operate RES installations (without applying the "green" tariff and the market premium mechanism), BESS, as well as construct and install biogas generation systems.

RES in the Heating Sector

In 2020, RES accounted for 9.3% (2,869 TOE) of the gross final consumption in the heating and cooling sector. The further growth of RES in this sector, both in the medium term (until 2030) and in the long term (until 2050), is primarily associated with the development of bioenergy, particularly through the use of woody biomass (wood chips, wood waste, firewood), agricultural residues (straw, sunflower husks), energy crops, and biomethane.

To stimulate the production of heat energy from RES, in 2017, an incentive tariff was introduced for heat energy generated from alternative sources at 90% of the prevailing tariff for heat energy produced from natural gas (or, in its absence, at the level of the average weighted tariff for heat energy from gas in the respective regions)[50]. However, this mechanism has proven insufficiently effective due to the volatility of natural gas prices and the establishment of a tariff below the production cost. Consequently, legislative amendments are currently under consideration to improve the existing mechanism and grant heat energy producers using alternative energy sources the right to choose an alternative tariff calculation method, namely, on general principles in accordance with approved methodologies. This would ensure full coverage of all economically justified costs incurred by enterprises in the course of their activities.

The National Energy and Climate Plan (NECP) provides for the introduction of a unified electronic trading system for solid biofuel to address issues in the biofuel market, such as price instability and unreliable supply, and to encourage investment in the sector. A legislative package aimed at creating the legal framework for establishing and operating a solid [5152]biofuel exchange has been registered in the Verkhovna Rada (Reg. No. 8052 of 19 September 2022; Reg. No. 8053 of 19 September 2022).

[50] Law of Ukraine No. 1959-VIII of March 21, 2017, "On Amendments to the Law of Ukraine 'On Heat Supply' Regarding the Stimulation of Thermal Energy Production from Alternative Energy Sources. https://zakon.rada.gov.ua/laws/show/1959-19#Text

[51] Draft Law on Amendments to Certain Legislative Acts of Ukraine Regarding the Development of Electronic Trade in Alternative Fuels, No. 8052 of 19 September 2022 https://itd.rada.gov.ua/billInfo/Bills/Card/40449

Furthermore, the NECP and the NREAP plan to develop the energy crop cultivation sector, which represents a promising renewable source of heat generation. As of early 2024, only 6.5 thousand hectares of low-productivity land were utilised for energy crops, whereas over 500 thousand hectares in Ukraine require conservation. Cultivating energy crops on these lands, with an average yield of 11.5 million tonnes per year, would allow the substitution of up to 2.7 billion cubic metres of gas annually. To establish the legislative framework for utilising degraded and low-productivity agricultural land for energy crop cultivation, a package of draft laws[53][54] has been submitted to the Verkhovna Rada. These draft laws propose introducing the term "energy crops" into the legislative framework and regulating land lease arrangements for energy crop cultivation.

The NREAP also provides for the introduction of a mechanism for issuing guarantees of origin for heat energy produced from RES, in accordance with the requirements of RED III.

RES in the Transport Sector

As of 2020, the gross final consumption of energy from RES in the transport sector amounted to 95 thousand tonnes of oil equivalent (2.5%), with 54% provided by bioethanol and the remainder by electricity generated from RES. The NREAP envisages a sharp increase in the share of RES in the transport sector, reaching 17.2% (1,138 TOE) by 2030. This target is expected to be achieved through further electrification of the transport sector and a gradual increase in the use of liquid biofuels and, to a lesser extent, biomethane.

Regarding electrification, the electric vehicle market has grown more than tenfold since 2018 (from 7,439 units[55] in 2018 to 85,881 units in 2023[56]), largely due to tax incentives introduced in 2018 to encourage the import and use of electric vehicles. Additionally, in 2022–2023, further measures were adopted, including incentives to stimulate domestic production of electric vehicles, requirements for the approval of local programmes for the development of charging infrastructure, provisions for parking spaces for electric transport, mandates for the installation of charging infrastructure in new residential buildings, and gradual replacement targets for municipal transport with low-carbon alternatives (see Section 2.4.4.2. for details).

To promote the use of liquid biofuels in the transport sector, the Verkhovna Rada adopted the Law of Ukraine No. 3769-IX, "On Amendments to Some Laws of Ukraine Regarding the Mandatory Use of Liquid Biofuels (Biocomponents) in the Transport Sector" of 4 June 2024. This law establishes the regulatory framework for the development, circulation, and use of liquid biofuels in the transport sector, sets a mandatory share of liquid biofuels (quotas) in the total annual sales of petrol (5% by volume) from 1 May 2025, and introduces sustainability criteria for liquid biofuels (biocomponents) and biogas intended for transport use.

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[52] Draft Law on Amendments to the Code of Ukraine on Administrative Offenses Concerning Liability for Violations in the Sphere of Electronic Trade in Alternative Fuels, No. 8053 of 19 September 2022 https://itd.rada.gov.ua/billinfo/Bills/Card/40450

[53] Draft Law on Amendments to Certain Legislative Acts of Ukraine to Promote the Development of the Energy Crop Growing Sector, No. 5227 of 12 March 2021 http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?pf3511=71384

[54] Draft Law on Amendments to Article 288 of the Tax Code of Ukraine Regarding Rent Payments for Land Plots Used for Growing Energy Crops, No. 5228 of 12 March 2021 http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?pf3511=71385

[55] texty.org.ua. How many, where, and what kind of electric vehicles are there in Ukraine?https://texty.org.ua/fragments/85448/Skilky_de_ta_jakyh_jelekromobiliv_v_Ukrajini-85448/

[56] The VRU Committee on Energy, Housing and Communal Services. Report on the results of the study on the effectiveness of the application of the Law of Ukraine "On Some Issues of the Use of Vehicles…" No. 2956-IX of 24 February 2023,https://kompek.rada.gov.ua/uploads/documents/31243.pdf

Furthermore, projects related to the production of bioethanol (for use as a fuel component), biogas, and biomethane (including liquefied or compressed forms) have been included in the scope of investment projects with significant investments, which may qualify for state support[57].

Renewable Gas Production Sector

In the long term, by 2050, the Ukrainian government anticipates a gradual increase in the production, domestic consumption, and export of renewable gases (produced using RES), particularly biomethane and green hydrogen.

According to the NREAP estimates, Ukraine has the potential to produce up to 21.8 billion cubic metres (18.7 million TOE) of biogas/biomethane annually. On the domestic market, biomethane is considered a promising substitute for natural gas in conventional power generation facilities, including TPPs, CHPPs, and cogeneration units. In the transport sector, biomethane can replace conventional motor fuels. Furthermore, Ukraine possesses substantial potential and the necessary infrastructure for exporting biomethane to the EU.

As of early 2025, a regulatory framework has already been established to support the development of the biomethane market in Ukraine. In particular, producers of biogas or other gases from alternative sources have already gained legal access to gas transmission and distribution networks, gas storage facilities, and LNG terminals, provided they comply with technical standards and safety requirements. Additionally, the DSTU EN 16723-1:2023 standard has been adopted for biomethane use in transport and for injection into the natural gas grid[58]; the legislative foundation has also been laid for the creation and operation of a biomethane registry, the issuance and circulation of guarantees of origin, and customs clearance procedures for biomethane.

In October 2024, biomethane was fed into Ukraine's gas transmission system for the first time, and by early February 2025[59], its export to the EU had begun.

Hydrogen production via electrolysis using electricity generated from renewable sources (primarily wind and solar power) is an emerging and promising direction for the renewable energy sector. The demand for renewable hydrogen is expected to gradually rise due to the need for decarbonisation in industry and transport, as well as the necessity of addressing energy system balancing challenges, particularly seasonal fluctuations in demand. According to the Institute of Renewable Energy of the National Academy of Sciences of Ukraine, the potential annual production of green hydrogen using electricity generated from wind and solar power plants amounts to 44.96 million tons.[60]

In May 2024, the Ministry of Energy published a draft Hydrogen Strategy of Ukraine until 2050[61], which aims to define the key principles for developing the hydrogen sector. The draft strategy envisages creating detailed sectoral plans for hydrogen technology integration by 2026 and implementing pilot projects for renewable hydrogen production by 2035.

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[57] Under the Law of Ukraine "On State Support for Investment Projects with Significant Investments in Ukraine".

[58] DSTU EN 16723-1:2023 regarding biomethane for use in transport and biomethane for injection into the natural gas network, adopted by the order of the state enterprise "Ukrainian Research and Training Center for Standardization, Certification and Quality Problems" dated 3 April 2023, No. 55

[59] IA Interfax-Ukraine. VITAGRO launched the first Ukrainian biomethane in the GTS of Ukraine with a daily volume of 6 thousand cubic meters. https://interfax.com.ua/news/greendeal/1017563.html

[60] Hydrogen Strategy of Ukraine (Draft). Institute of Renewable Energy of the National Academy of Sciences of Ukraine, 2022. https://www.ive.org.ua/wp-content/uploads/Проєкт-ВС-України.-Презентація.-2022-pdf.pdf

[61] Ministry of Energy. Announcement of the publication of the draft Hydrogen Strategy of Ukraine until 2050 and the report on its strategic environmental assessment. https://www.mev.gov.ua/proyekt-normatyvno-pravovoho-aktu/povidomlennya-pro-oprylyudnennya-proyektu-vodnevoyi-stratehiyi

2.3. ENERGY EFFICIENCY

2.3.1. Energy efficiency potential

Figure 2.7 shows the change in total primary energy supply by fuel type in Ukraine from 2020 to 2050 under different scenarios. In all scenarios, there is a reduction in coal use. Under the WEM scenario, coal consumption will decrease slightly and gradually by 2050, except for the drop between 2020 and 2050. Under the WAM and NZE scenarios, coal use will nearly disappear by 2050. In WAM, this is linked to the significant increase in carbon taxation, while in NZE, it is due to stricter GHG emission limits.

Natural gas remains an important energy source under the WEM scenario, with an increase in consumption until 2050. In WAM, gas consumption decreases due to the implementation of more efficient technologies and the shift to alternatives. In NZE, natural gas consumption decreases more sharply, leaving only minimal volumes in 2050.

Oil products see a decline in both target scenarios, but this reduction is most significant in NZE, where their use is minimised after 2045 due to the electrification of transport and the transition to other carbon-neutral fuels.

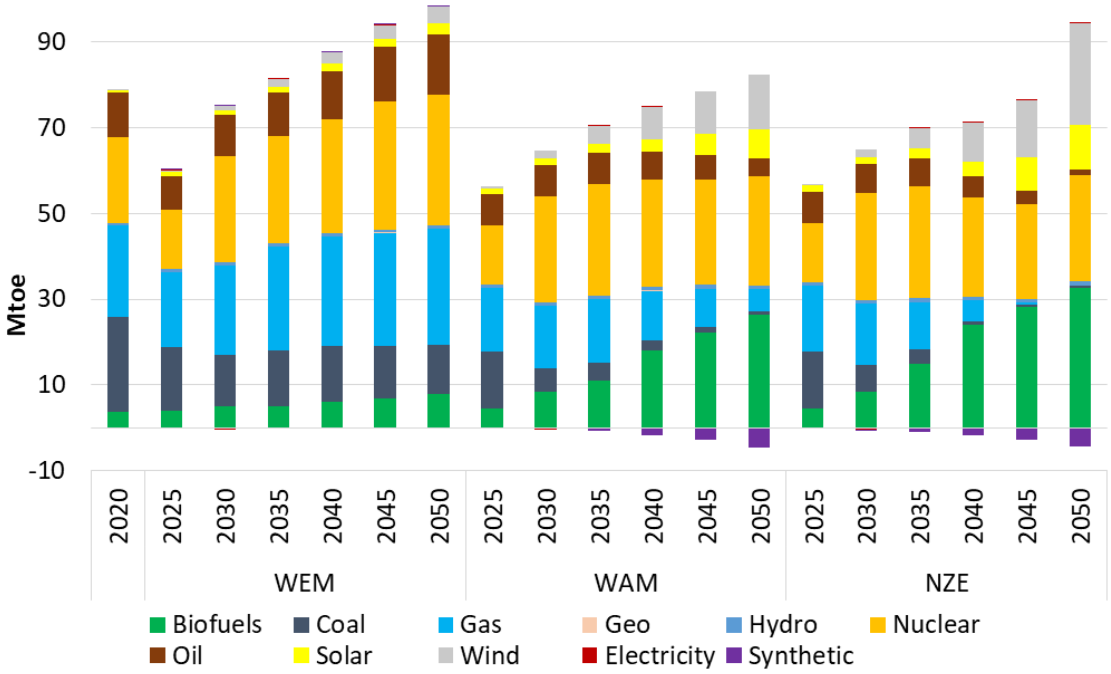


Fig. 2.7. Primary energy consumption by fuel type across scenarios

Wind energy sees growth in all scenarios, with a particularly strong increase by 2050 in the NZE scenario, making it one of the key energy sources. Solar energy also shows growth, especially in NZE. Hydropower consumption remains nearly unchanged across all scenarios. Under the WAM and NZE scenarios, biofuels are growing significantly. They provide a climate-neutral alternative to fossil fuels. Biofuels can be used in combustion facilities and for biomethane synthesis, while CO_2 captured from these installations can generate negative emissions via CCS or CCUS.

Hydrogen export, as foreseen in the energy strategy, can be seen in the target scenarios.

Nuclear energy maintains its share in all scenarios, continuing to play a significant role in primary energy consumption. Electricity imports and exports are nearly even, making their impact on the diagram negligible.

To sum up, the WEM scenario shows continued reliance on traditional energy sources, with slight shifts towards RES. The WAM scenario reflects a significant move towards more carbon-neutral energy sources, as well as overall consumption reductions due to improved efficiency and a decrease in fossil fuel share. The NZE scenario sees comprehensive decarbonisation. Coal, natural gas, and oil products will nearly disappear by 2050. Renewable energy sources, including synthetic fuels and nuclear energy, play a key role in this process.

Figure 2.8 illustrates the projected dynamics of final energy consumption in Ukraine under the WEM, WAM, and NZE scenarios, divided by fuel type, from 2020 to 2050. Economic recovery and the reintegration of temporarily occupied territories drive the increase in final energy consumption across all sectors.

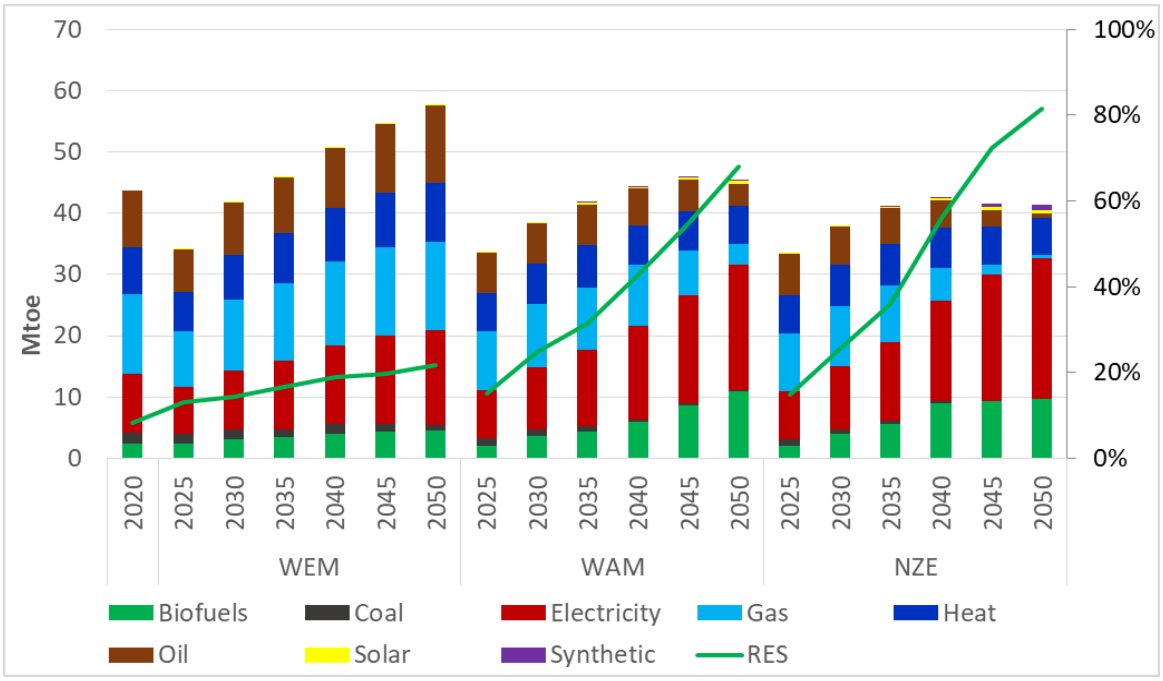


Fig. 2.8. Final Energy Consumption by Fuel Type and the Share of RES across Scenarios

Overall, the dynamics of final energy consumption are similar to that of primary energy consumption. However, in the NZE scenario, there is no sharp peak in consumption in 2050, and in the target scenarios, final energy consumption stabilises after 2040, indicating improved energy transformation and consumption efficiency. In all scenarios, particularly in the target ones, the share of electricity increases. There is also substantial growth in the direct consumption of bioenergy resources, notably biomethane. Due to carbon pricing reforms and the significant rise in CO_2 costs, biomethane could become an economically viable fuel in industry by around 2030 and in other sectors between 2040 and 2050. However, direct final consumption of hydrogen is expected to be minimal without specific support measures.

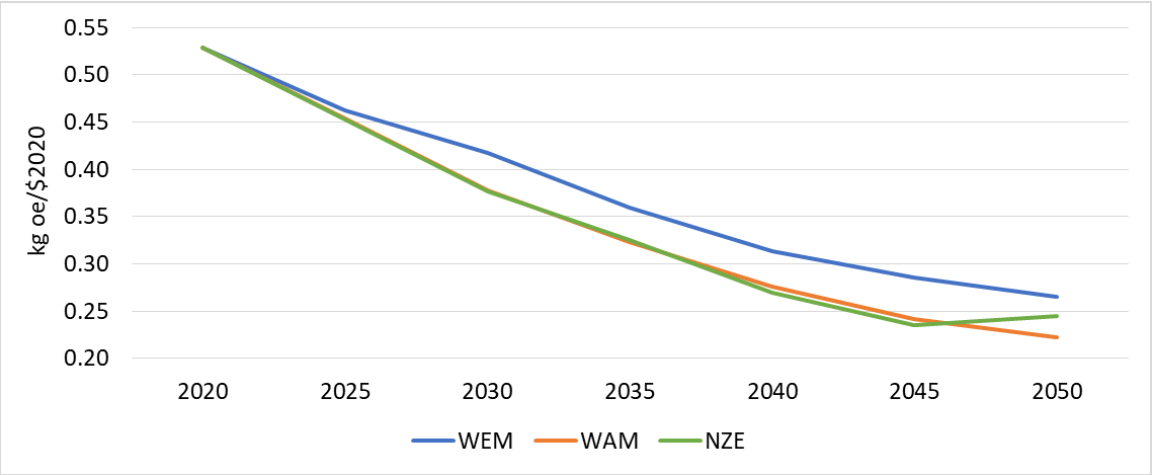


Fig. 2.9. Energy Intensity of GDP across Scenarios

Under the target scenarios, RES will significantly increase their share of final energy consumption. This is especially true in NZE, where they are projected to account for over 80% of total consumption by 2050, becoming the dominant energy source. The efficiency gains in energy transformation and consumption are further confirmed by the projected energy intensity of GDP until 2050 (Fig. 2.9), which is calculated based on the total primary energy supply. However, in the NZE scenario, a reversal occurs due to a significantly higher domestic demand for biomass and the absence of its exports. As a result, the total primary energy supply in 2050 will be higher in the NZE scenario than in the WAM scenario.

2.3.2. Policy and Measures

General Overview

As of 2020, the country's final energy consumption amounted to 47.8 million TOE (excluding the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol, and parts of the temporarily occupied territories in Donetsk and Luhansk Oblasts). Final energy consumption declined significantly (by 12.4%) in 2014 due to several factors, including the occupation of Crimea and major industrial areas in Donetsk and Luhansk Oblasts, the economic downturn, energy supply constraints, and rising energy prices. In 2016 and 2018, final energy consumption increased due to structural factors such as economic recovery and the normalisation of energy supply to consumers. Such growth in final energy consumption also contributed to an increase in primary energy consumption during those years. As of 2020, primary energy consumption in Ukraine was 82.7 million TOE.

In 2020, the largest share of final energy consumption was attributed to industry (33.4%). The second largest energy-consuming sector was the residential sector, which amounted to 28.5%. The transport sector accounted for 16.8% of total consumption, while services made up 10.2%, non-energy use 7.7%, and agriculture, forestry, and fisheries 3.5%.

Official state statistics for final energy consumption from 2021 to 2024 are currently unavailable.

Russia's full-scale invasion of Ukraine has had a devastating impact on both energy production and key energy-consuming sectors. More than 18 GW of power generation capacity was occupied, including Zaporizhzhia NPP — the largest in Europe — which generated 44% of Ukraine's nuclear

power. As of May 2024, the Kakhovka HPP, as well as the Zmiivska and Trypilska TPPs, had been completely destroyed. Private thermal power plants, including the Ladyzhynska, Burshtynska, Dobrotvirska, Kurakhivska, Kryvorizka and Prydniprovska TPPs, sustained critical damage (over 80%). Around half of Ukraine's high-voltage transmission substations were damaged[62].

The full-scale invasion also led to a 30–35% decrease in energy consumption compared to 2021. Damage to Energy Consumption Sectors:

- Buildings: As of January 2024, due to the hostilities of the Russian Federation, over 50% of the residential stock had been damaged or destroyed. Around 250,000 residential buildings were affected, including 222,600 private homes, 27,000 apartment buildings, and 530 dormitories. Non-residential buildings also suffered severe damage: at least 1,284 healthcare facilities had been damaged or destroyed, at least 380 educational infrastructure facilities had been destroyed, 3,429 had been damaged, and 160 social welfare facilities had been damaged or destroyed.
- Industry: as of the beginning of 2024, the assets of at least 426 large and medium-sized enterprises, as well as tens of thousands of small businesses, have been damaged or destroyed.
- Transport: as of January 2024, direct damages caused to legal entities of all organizational and legal forms, particularly regarding destroyed transport, were estimated at 0.83 billion dollars. (destroyed trolleybuses, trams, and buses), amounted to $0.83 billion. Direct losses in private passenger vehicles totalled $1.9 billion, with 212,000 cars destroyed. Additionally, 1,629 units of firefighting equipment worth US$89 million were lost [63].

Strategic goals

Pursuant to Decision 2022/02/MC-EnC of the Ministerial Council of the Energy Community, primary energy consumption in Ukraine in 2030 shall not exceed 91,468 thousand TOE, while final energy consumption shall not exceed 50,446 thousand TOE. At the same time, considering the consequences of the full-scale invasion of the Russian Federation of Ukraine, its impact on the economy as a whole and the energy sector in particular, and demographic changes, the indicative values of primary and final energy consumption were updated in the framework of preparing the NECP. According to the NEPC, Ukraine's primary energy consumption in 2030 must not exceed 72,224 thousand TOE, while its final energy consumption must not exceed 42,168 thousand TOE.

Table 2.3 presents the trajectory for achieving the indicative national energy efficiency target by 2030 in absolute values of primary and final energy consumption.

Table 2.3. Indicators of primary and final energy consumption, thousand TOE.

Power consumption evaluation	2020	2025	2030	2040	2050
Total primary energy consumption	79,172	58,683	72,224	75,942	75,985
Total final energy consumption	45,239	34,786	42,168	46,234	48,671

[62] Assessment of Direct Damage and Indirect Losses to Ukraine's Energy Sector as a Result of Russia's Full-Scale Invasion as of May 2024. https://kse.ua/wp-content/uploads/2024/06/KSE_Vpliv-vii--ni-na-energetiku_UA-1.pdf

[63] Report on Direct Infrastructure Damages from Destruction Due to Russia's Military aggression Against Ukraine as of Early 2024 https://kse.ua/wp-content/uploads/2024/04/01.01.24_Damages_Report.pdf

Additionally, in accordance with the requirements of the Law of Ukraine "On Energy Efficiency", the NECP sets the following sub-targets:

- the total volume of energy savings in final energy consumption to be achieved from 2021 to 2030 must be at least 17,300.36 thousand TOE;
- the volume of energy savings to be achieved through the implementation of energy efficiency measures in state authorities' buildings is set at 21.4 TOE per year and 192.4 TOE by 2029.

In addition, the National Economic Strategy for the period until 2030, approved by Order of the Cabinet of Ministers of Ukraine No. 179 of 3 March 2021 (Official Bulletin of Ukraine, 2021, No. 22, Article 1015) (hereinafter referred to as the NES), establishes a sectoral target of reducing the energy intensity of the extractive industry by 30% by 2030.

Cross-sectoral principle "Energy Efficiency First"

At present, the Government's efforts are largely focused on ensuring a sufficient supply of energy to the economy through supply-side measures. At the same time, given the large-scale destruction of energy facilities, structural changes in the economy, the relocation of enterprises, and the displacement of at least 4.6 million people, the "Energy Efficiency First" principle should be one of the key principles of state policy. According to the applicable law, this principle means prioritising energy efficiency measures that reduce energy demand in the development of regulatory legal acts, strategic state policy documents, and decisions on financing measures for the development of Ukraine's integrated power system, gas infrastructure, or district heating facilities, where energy efficiency measures are more economically feasible than investments in energy production infrastructure. Compliance with this principle is currently designated by [64]state and local government authorities when making decisions on strategic and energy planning, financing, and investment[65]. Meanwhile, adherence to this principle should be encouraged among all stakeholders when making significant investment decisions , not only in the energy sector but also in other sectors of the economy, including transport and finance.

Enhancing Energy Efficiency in the Energy Sector

According to the Strategy for the Development of Distributed Generation until 2035 approved by Resolution of the Cabinet of Ministers of Ukraine No. 713 of 18 July 2024 (Official Bulletin of Ukraine, 2024, No. 73, Article 4366), by the end of 2026, the Government plans to construct and/or deploy new distributed generation facilities for electricity and achieve up to 4 GW of additional generating capacity. Further, the Strategy prioritises the use of electrical installations that ensure guaranteed delivery of available capacity, in particular, cogeneration plants.

Under the NEPC, measures to support the construction of high-efficiency cogeneration plants will continue as part of energy efficiency policy. Currently, provisions are in place for the qualification of such plants, issuance of guarantees of origin for electricity produced by high-efficiency cogeneration plants, simplification of licensing and grid connection conditions, and streamlining of tariff-setting procedures for heat energy produced by cogeneration plants with a thermal capacity of up to 4.3

[64] Cabinet of Ministers of Ukraine, Ministry for Development of Communities and Territories, Ministry of Energy, Ministry of Economy, Environment and Agriculture, National Energy and Utilities Regulatory Commission, State Agency on Energy Efficiency and Energy Saving

[65] Article 3 of the Law of Ukraine "On Energy Efficiency".

Gcal/h. To further develop this type of generation, central executive authorities will define target indicators for using cogeneration in district heating systems and establish regulatory, economic, and technical conditions for third-party access to district heating networks. Additionally, further policy alternatives for stimulating the construction of new high-efficiency cogeneration capacities will be analysed.

Modernisation of networks will play a crucial role in improving energy efficiency in the energy sector. As of 2023, technical losses in the electricity transmission system amounted to 2.5%, while losses in distribution networks were 10.99% against a normative loss level of 12.93%[66]. Currently, most electricity distribution system operators are subject to incentive-based tariff regulation. This regulation aims to ensure investments in the modernisation and development of electrical grids and achieve target indicators for the quality and reliability of electricity supply by determining the necessary operator revenue for the proper performance of electricity distribution activities.

At the same time, as regards natural gas distribution, normative and production-technological losses/consumption of natural gas for gas distribution system operators are set by the National Commission for State Regulation of Energy and Public Utilities for each operator individually. The median volume of natural gas losses set for gas distribution system operators for 2025 is 26,995 thousand cubic metres. Currently, incentive-based tariff regulation applies to the Gas Transmission System Operator of Ukraine but does not extend to gas distribution system operators. Pursuant to the Law of Ukraine, "On the Specifics of Regulating Relations in the Natural Gas Market and the District Heating Sector during Martial Law and the Subsequent Restoration of Their Functioning", a moratorium is in place during martial law in Ukraine and for six months after the month in which martial law is lifted or revoked, prohibiting increases in tariffs for natural gas distribution services for household consumers.

Ukraine plans to ensure a comprehensive approach to the planning, construction, management, and modernisation of energy networks, taking into account the economic and energy efficiency of the system to achieve maximum efficiency in energy and resource use. The transmission system operator, electricity distribution system operator, gas transmission system operator, and gas distribution system operator will assess the energy efficiency potential of their respective systems every five years. Identified measures will be gradually implemented as part of the investment programmes of the respective operators.

In the electric power sector, network development will be carried out, taking into account the Concept for the Implementation of "Smart Grids" in Ukraine until 2035, approved by Resolution of the Cabinet of Ministers of Ukraine No. 908 of 14 October 2022 (Official Bulletin of Ukraine 2022, No. 84, Article 5201). "Smart grid" technologies and consumption management will be actively developed, and their implementation will be facilitated by the gradual liberalisation of energy markets through the removal of administrative regulatory instruments and the increasing variability of energy sources.

Conditions will also be ensured to cover part of the electricity demand through demand response measures. These measures include the cessation of electricity demand as an ancillary service, demand shifts (reduction or increase) as a balancing market service, and ensuring optimal load

[66]Report on the Results of the Activities of the NERC for 2023.
https://www.nerc.gov.ua/storage/app/sites/1/Docs/Byuleten_do_richnogo_zvitu/broshura_do_richnogo_zvitu_nkrekp-2023.pdf

shedding. The ESU provides for the implementation of pilot projects and the creation of a demand management programme for household consumers by 2032. As part of the respective programme, a set of regulatory and technical measures will be introduced, including the state procurement and controlled sale at preferential prices to household consumers of energy storage units of standardised minimum capacity (one per private house/apartment), "smart sockets" and smart meters. Differentiated pricing based on time-of-use tariffs will also be applied to household consumers. This will allow for a shift in energy consumption to off-peak hours.

Currently, certain measures are already in place in Ukraine to encourage household consumers to manage their demand. For household electricity consumers with time-based electricity meters, calculations are carried out at a fixed electricity price using the following coefficients (at the consumer's choice):

- under two-zone time differentiation: 0.5 of the fixed price during the nighttime minimum load hours of the power system (from 23:00 to 07:00) and the full fixed price during the rest of the day;
- under three-zone time differentiation: 1.5 of the fixed price during peak load hours of the power system (from 08:00 to 11:00 and from 20:00 to 22:00); the full fixed price during the semi-peak period (from 07:00 to 08:00, from 11:00 to 20:00, and from 22:00 to 23:00); and 0.4 of the fixed price during the nighttime minimum load hours of the power system (from 23:00 to 07:00).

As of early 2023, 2.9 million smart meters with remote reading and control had been installed among household consumers in Ukraine. The average level of smart meter coverage among household consumers is 21%[67].

Furthermore, legislative amendments are being introduced to enhance the regulatory framework governing demand-side management by industrial consumers. Specifically, Law of Ukraine No. 3220-IX "On Amendments to Certain Laws of Ukraine on the Restoration and Green Transformation of the Energy System of Ukraine" recommends that consumers install energy storage facilities and hybrid-type generating units to enable their participation in demand-side management, as well as to ensure the uninterrupted power supply of their facilities. In accordance with the Procedure for Conducting Tenders for the Construction of Generating Capacity and the Implementation of Demand-Side Management Measures[68], Transmission System Operators (TSOs) determine the necessity of procuring demand-side management measures based on the generating capacity adequacy assessment report. Tenders are conducted in line with the principles of transparency and non-discrimination, establishing the parameters of impact on the electrical load profile, the minimum and maximum volumes of additional capacity, as well as specific technical characteristics of the industrial enterprises' equipment engaged in the execution of such measures.

As part of the implementation of the Electricity Integration Package provisions, industrial consumers, including those offering demand response through aggregation, are granted equal rights with producers to participate in all market segments of the electricity market. TSOs and Distribution

[67] Energy map. Level of smart electricity meter deployment in Ukraine. https://map.ua-energy.org/uk/resources/b676f89a-188b-4179-8d56-1b984a2e477f/

[68] The Procedure for Conducting Tenders for the Construction of Generating Capacity and the Implementation of Demand-Side Management Measures, approved by Resolution of the Cabinet of Ministers of Ukraine No. 677 dated 10 July 2019. https://zakon.rada.gov.ua/laws/show/677-2019-%D0%BF/ed20200818#Text

System Operators (DSOs), when procuring ancillary services, are obliged to engage aggregators performing demand-side management on a non-discriminatory basis. This enables industrial enterprises to integrate their own flexibility into the market-based power system balancing mechanisms, thereby generating revenue from adjusting their energy consumption in accordance with the technical capabilities and requirements of the grid. When planning the development of distribution systems, DSOs must assess the medium-term and long-term demand for flexibility services, considering demand response and the deployment of energy storage facilities as a priority alternative to the expansion or reconstruction of grid infrastructure. Such an approach will incentivize industrial consumers to adopt smart solutions and energy management systems, enabling the substitution of capital expenditure on the construction of new lines and substations with energy efficiency and operational load management measures.

Enhancing Energy Efficiency in the Industry Sector

To improve energy consumption efficiency, the Law of Ukraine "On Energy Efficiency" has introduced the requirement for mandatory energy audits or the implementation of energy management systems for designated business entities. Business entities with an average annual energy consumption volume of 100,000 MWh per year and above are required to undergo an energy audit every four years. The first energy audits must be completed by mid-November 2025. Alternatively, such business entities may implement energy or environmental management systems, which must be certified in accordance with harmonised international and regional standards. In addition, energy management systems must be implemented by legal entities, irrespective of their legal structure in accordance with the procedure approved by the Cabinet of Ministers of Ukraine. Ukraine will align its legislative requirements for conducting energy audits and implementing energy management systems with Directive (EU) 2023/1791 as part of the European integration process.

The government also plans measures to improve energy efficiency among small and medium-sized enterprises. A programme to finance energy audits and provide subsidies for improving energy efficiency of micro-enterprises and small enterprises is planned to be launched in 2026. Additionally, a preferential financing programme for SMEs will be introduced by the end of 2027, in accordance with the criteria of EU Regulation 2020/852 on establishing the framework for sustainable investment (the Taxonomy Regulation).

The introduction of an energy efficiency obligation scheme will also contribute to improving industrial sector energy efficiency. This policy tool may be introduced by the Cabinet of Ministers of Ukraine if the target for annual energy consumption reduction is not met. In such a case, obligated parties (electricity and natural gas suppliers) will be required to implement or finance energy efficiency measures at the level of end consumers. Subsidiary legislation regulating the functioning of the energy efficiency obligation scheme must establish a mandatory share of energy savings for energy-poor households while allowing obligated parties the flexibility to implement part of the measures not only in the residential sector but also in industry and services.

Business entities may seek support from the State Fund for Decarbonisation and Energy-Efficient Transformation to finance the implementation of energy efficiency measures. The Fund commenced operations in 2024 amid the full-scale invasion of Ukraine by the Russian Federation. The sources of funding for this Fund include revenues from the environmental tax on CO2 emissions from stationary pollution sources, state borrowings for investment projects in energy efficiency, increased use of RES

and alternative fuels, carbon emission reduction, and potential other income. Thus, sustainable funding sources are designated for measures such as:

- government-targeted programmes in energy efficiency, increased use of RES and alternative fuels, and CO_2 emission reductions;
- financing compensation, reimbursement, and cost reductions for individuals and legal entities regarding credit and leasing obligations under agreements made for implementing energy efficiency measures, energy service contracts, increased use of RES and alternative fuels, and CO_2 emission reductions;
- servicing debt obligations from borrowings obtained by the state for implementing investment projects in energy efficiency, increased use of RES and alternative fuels, and CO_2 emission reductions.

Industrial enterprises receiving preferential financing from the Fund must ensure a reduction in production energy intensity by at least 15%.

Measures such as replacing technologies in industrial production (e.g., green steel, green ammonia) and investing in innovation (R&D), fostering technologies aimed at reducing GHG emissions and pollutants from industry, are priority investment areas for Ukraine's reconstruction and recovery, according to the Ukraine Plan, approved by Resolution of the Cabinet of Ministers of Ukraine No. 244 of 18 March 2024 (Official Bulletin of Ukraine, 2024, No. 32, Article 2035).

In the industrial sector, the principles of energy efficiency and the circular economy are closely interconnected. A comprehensive approach that combines improving the efficiency of primary material and resource use with transitioning to secondary, recycled resources will enable industrial enterprises to significantly reduce energy consumption and GHG emissions at all stages of the production process. The government's adoption of the Strategy for Implementing Circular Economy Principles in 2026 will lay the foundation for policies and measures to modernise Ukraine's economy and enhance its resource and energy efficiency. The Strategy will be implemented gradually, and key product value chains will be considered a priority. However, introducing circular economy principles presents significant challenges, including the need for substantial investment in innovative technologies, acceleration of technological modernisation in enterprises, and development of new business models.

Setting Requirements for Energy-Consuming Products

Ukrainian legislation already covers energy efficiency and certain aspects of circularity for energy-consuming products. In 2018, Ukraine transposed Directive 2009/125/EC, which established a framework for setting ecodesign requirements for energy-related products, into its legislation. Requirements for ecodesign and energy labelling of certain groups of energy-consuming products have also been defined. In particular, 28 technical regulations establish ecodesign requirements for specific groups of energy-consuming products, and 15 technical regulations on energy labelling. Meanwhile, additional efforts are needed to ensure compliance with the adopted regulations through effective market surveillance. It is necessary to strengthen the capacity of the State Service on Food Safety and Consumer Protection to identify energy-using products that do not comply with ecodesign requirements. This includes enhancing the material and technical base of labouratories and conducting relevant training. Legislative updates are also necessary to enable inspections of goods introduced to the market via online trading platforms.

Moreover, maintaining the competitiveness of Ukrainian industry and mitigating economic stress from regulatory changes require actively informing economic operators about the transition process, broad implementation of training programmes and financial incentives for modernising production facilities that manufacture energy-consuming products. Effective implementation of technical regulations can create new export sectors for Ukraine's economy and compensate for the loss of traditional markets adhering to post-Soviet standards.

Energy Efficiency in Public Authorities and Local Government Bodies

State authorities and legal entities, irrespective of their legal structure, are obliged to implement energy management systems. In local government bodies, the implementation of such systems is carried out on a voluntary basis by the decision of the respective council. Along with that, a mandatory condition for receiving state support (assistance) for the implementation of energy-efficient measures by local government bodies is the presence of a decision on the implementation of an energy management system within these bodies. To fully exploit the potential of such management systems, the Government will enhance the qualifications of energy managers in public authorities and local government bodies, provide financing for measures that ensure the exemplary role of central executive bodies, and finance energy efficiency measures in communities.

All local government bodies must develop and adopt local energy plans. The aim of local energy plans is to assist in achieving national energy efficiency goals, the development of RES, the use of waste heat energy, the application of high-efficiency cogeneration, the reduction of GHG emissions, and the decarbonisation of energy consumption in territorial communities and regions by 2050, with consideration of the "Energy Efficiency First" principle. Local government bodies must define the sustainable energy development objectives (e.g., improving energy efficiency, and developing RES) in these plans. Local energy plans cover the following sectors: public buildings, residential buildings, heating supply, water supply and sewage, waste management, street lighting, and public transport. Such plans will serve as a guide for local government bodies in attracting funding for identified priority projects. Some communities in Ukraine already have experience in developing such plans thanks to their participation in the Covenant of Mayors. Currently, Ukraine has 217 active signatories of the Covenant, and 198 Sustainable Energy Action Plans have been approved.

In order to attract funding for the implementation of energy efficiency measures at state and municipal property objects, actions will be taken to continue improving the regulation of energy service contracts. The use of this type of contract was legislated in 2015, and as of the end of 2024, 712 ESCO contracts had been concluded with a total value of UAH 2.6 billion. After the Russian Federation's full-scale invasion of Ukraine, access to credit funds decreased, the cost of equipment and materials increased, and the risks of doing business generally rose, which significantly reduced the dynamics of concluding energy service contracts in Ukraine. As a result, the government simplified and relaxed the procedures for concluding energy service contracts during the period of martial law in Ukraine and for 90 days following its termination or cancellation. In addition, business entities providing energy services to improve the energy efficiency of state- and municipally-owned facilities can access concessional financing under the government programme "Affordable Loans 5-7-9" as well as preferential financial support instruments offered by the Decarbonisation and Energy Efficiency Transformation Fund. Only the Guaranteed Savings Contract (GSC) model of energy service contracts, which is not optimal for comprehensive projects, currently operates in Ukraine. Therefore, the Government will implement measures to expand the existing energy service mechanism models.

Improving Energy Efficiency in Other Sectors

Buildings play an important role in reducing final energy consumption, and section 2.4.3 outlines measures and policies to improve their efficiency.

The policies that will contribute to improving efficiency in the transport sector are described in section 2.4.4 hereof.

2.4. SECTOR MEASURES

2.4.1. Energy sector

2.4.1.1. GHG Emission Forecast

Under the WEM scenario, which does not foresee additional measures beyond those currently in place, economic growth will lead to a gradual increase in GHG emissions by 2050, although the 2020 level will not be exceeded (Fig. 2.10), and the NDC commitments will be met.

At the same time, modelling shows that under the conditions of rapid post-war economic recovery in Ukraine, in line with the "build back better" principle, the implementation of energy efficiency measures, an increase in the share of RES, and other planned initiatives for decarbonisation and modernisation of energy technologies, including the reform of the carbon tax on carbon dioxide emissions and an increase in its rate for all sectors—it is possible not only to prevent an increase in GHG emissions within the Energy and Industrial Processes and Product Use (IPPU) sectors under target scenarios, but also to achieve net-zero emissions by 2050. Therefore, the implementation of additional measures under the WAM scenario will significantly reduce greenhouse gas emissions in the Energy and Industrial Processes and Product Use sectors by 2050, leaving only about 6.6% of the 1990 emission level, or 56 million tonnes of CO_2-equivalent. However, this reduction will be insufficient to meet Ukraine's long-term climate commitments.

In contrast, the NZE scenario opens the prospect of achieving net-zero GHG emissions through negative CO_2 emissions in the electricity and heat generation sector from 2040. This is possible thanks to the application of bioenergy technologies in combination with carbon capture and storage CCS (CCUS) and DAC technologies.

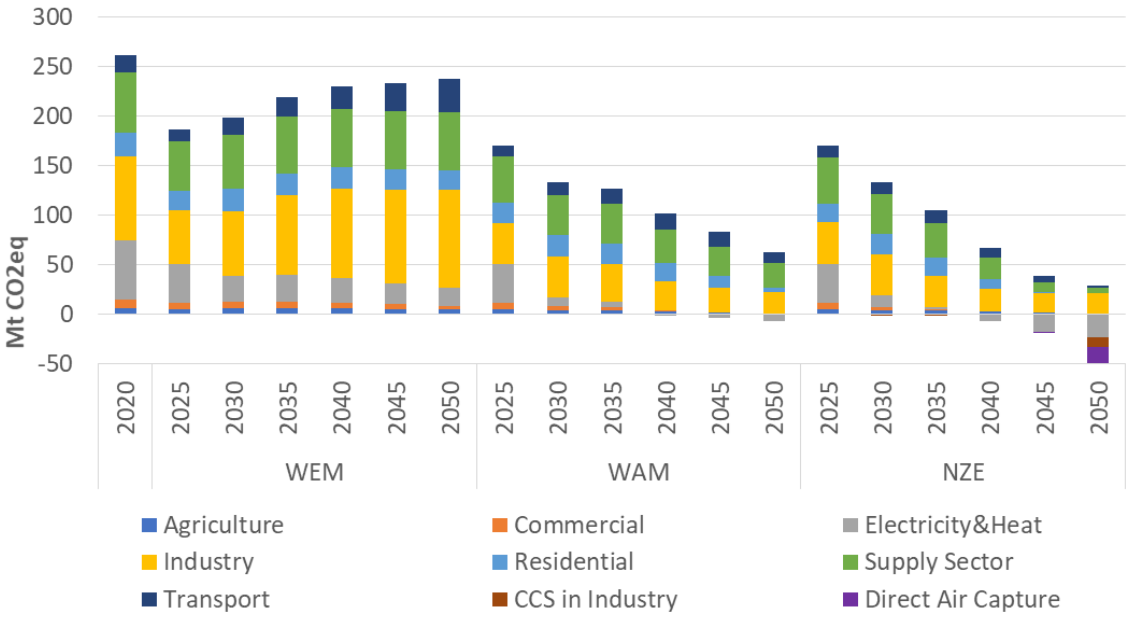


Fig. 2.10. GHG emissions in the Energy and Industrial Processes and Product Use sectors by economic sectors across scenarios.

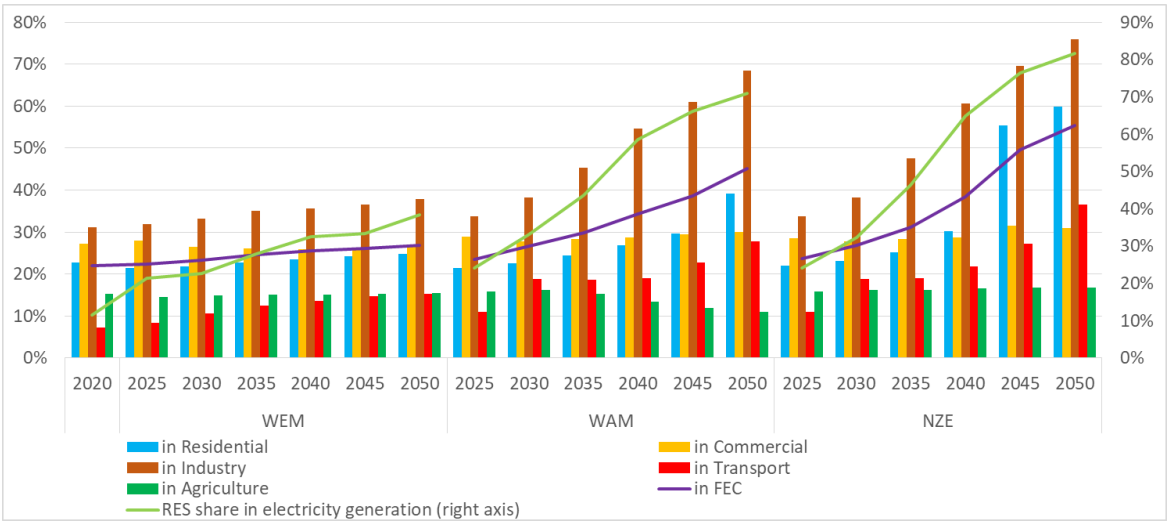


Fig. 2.11. Share of electricity in final energy consumption by economic sectors and share of RES in electricity generation under different scenarios

Figure 2.11 illustrates the change in the share of electricity in final energy consumption by economic sectors and overall, according to the scenarios. Overall, there is a clear correlation between the growth of the share of RES and the overall electrification of the economy, although the pace varies across different periods. Final consumption sectors also demonstrate varying rates of electrification growth. In the agriculture sector under the WAM scenario, the share of electricity in final energy consumption even decreases in favor of biofuels. Under the NZE scenario, the highest share of RES in electricity generation is achieved, which correspondingly ensures the highest level of electrification.

2.4.1.2. Overview of Policies, Plans, and Measures

Even before Russia's full-scale aggression against Ukraine began, it was evident that the strategic prioritisation of environmental issues and the achievement of carbon neutrality by EU countries in the foreseeable future would impact both the energy sector and Ukraine's overall economy, regardless of the actual level of political and economic integration, involvement, or neglect of decarbonisation processes. At the same time, the actual level of such integration and regulatory and structural convergence will determine the opportunities to strengthen the advantages and minimise the risks to the functioning of the energy sector and energy resource markets under the objective conditions of global transformations. In particular, the effectiveness of adapting the domestic energy sector and energy resource markets to structural changes in the energy balance caused by Ukraine's main trading partners' transitioning to a carbon-neutral economy policy will be determined by the presence and degree of formation of prerequisites such as institutional maturity, structural optimisation, infrastructure readiness, and the economic potential of agents in existing and new segments of the energy market. Under these conditions, the issue of a managed structural-institutional transformation of energy markets becomes strategic for Ukraine's economy and, therefore, requires a systematic, methodological scientific-expert analysis.

At the same time, under the conditions of the ongoing hot phase of hostilities, implementing the full EU "institutional franchise" regarding energy and climate policy in line with the regional vision, goals, and priorities of sectoral development effectively becomes a single option. The energy sector of Ukraine has become one of the primary targets of enemy attacks, and the scale of destruction and losses in the energy sector is unprecedented as of now, as no economy in the world has experienced the total physical destruction of two-thirds of its production capacities, as well as a significant portion of transportation capacities and the raw material base. At the same time, these considerations suggest that energy will play a key role in the post-war recovery and reconstruction of Ukraine's economy. Thus, the choice of energy policy during the reconstruction phase could significantly influence the achievement of long-term social, economic, and climate goals. In addition to restoring basic industry infrastructure and forming new fuel supply chains, Ukraine must enter the post-war period with a clear understanding of at least medium-term perspectives and priorities for the development of the energy sector. Clearly, Ukraine will need to adjust its energy model in accordance with European principles and goals (including taking into account the status of a candidate for EU membership), while simultaneously restoring infrastructure and optimising investments, adhering to the "build back better" principle.

Despite the anticipated economic consequences of the war and the scale of post-war recovery measures, the Ukrainian government has repeatedly reaffirmed its goals regarding compliance with the global climate change agenda and its respective intentions to implement sectoral reforms in the context of the European Green Deal. Achieving a carbon-neutral economy will require the formation of an appropriate regulatory policy that ensures the transition to the use of low-carbon and new synthetic fuels, creating conditions to stimulate demand and supply for such fuel, centrally coordinating significant investments in production, making corresponding infrastructure changes and transforming the market environment.

Moreover, not only is the transformation of the energy system necessary, but also the restructuring of infrastructure provision, attracting significant investment in technological updates in the end-use sectors, and changing the rules of organisation in energy and related markets. A separate analysis is needed on the mechanisms of regulation during the transition to a low-carbon economy, which

would ensure competitiveness between traditional and low-carbon fuels. It is also necessary to assess the volume of investments in the formation of new generation sources and the cost of transformations in the energy and other sectors of the economy within the "green transition".

The Russo-Ukrainian war has become a significant obstacle to Ukraine's progress towards climate neutrality. However, it could also create opportunities for rebuilding Ukraine's energy sector using the latest "green" energy technologies and facilitate Ukraine's active involvement in the European Green Deal. With the beginning of the post-war recovery and reconstruction phase, the Ukrainian government will prioritise measures in accordance with European security and climate priorities while also facilitating the rapid recovery of the economy.

Strategic directions of the state energy policy will be as follows:

- diversification of gas supply sources and integration with the European gas market: completion of reforms in the gas sector and acceleration of the integration of the domestic natural gas market with the European market; optimisation of transport infrastructure to create conditions for importing LNG, considering the significant reduction (cessation) of Russian gas transit to Europe; redesign of the gas distribution system taking into account forecasted natural gas consumption levels and access to networks for alternative low-carbon gases; optimisation of investments in gas electricity and heat generation based on careful model calculations, taking into account energy security requirements and climate goals; development of hydrogen production capacities;
- integration with the EU electricity market and improving operational efficiency of the electricity sector: further integration and regulatory convergence of the domestic electricity market with the European one; in particular, the gradual replacement of the scheme of special obligations (SSO) for state-owned enterprises and the system transmission operator (STO) with more progressive targeted support programmes for vulnerable consumer categories; restructuring of outdated and damaged infrastructure in the electricity sector using modern efficient technologies; reduction of physical and regulatory barriers to external electricity trade; prevention of cyberattack risks;
- improving energy efficiency and electrification in end-use sectors: implementation of the provisions of the Law of Ukraine "On Energy Efficiency"; implementation of programmes for the reconstruction of residential and public buildings; restoration of destroyed centralised heating infrastructure in accordance with modern sustainable heating standards; "green" reconstruction of the industrial sector; achieving European fuel standards; restoration and further electrification of public transport, encouraging behavioural changes to abandon private transport in favour of public transport to reduce fuel demand; promoting the spread of electric vehicles in both private and public transport; improving the transport and logistics network considering energy efficiency criteria;
- decarbonisation of the electricity sector and further development of renewable energy generation: achieving decarbonisation goals in electricity generation will require a significant expansion of solar and wind generation capacities; assessment of the actual potential of offshore (located on the sea shelf) wind energy, and preparation of a regulatory framework for its construction in the long term; evaluation of its potential for green hydrogen production; supporting the introduction of large-scale energy storage systems for frequency support and regulation (based on highly manoeuvrable pumped storage plants and battery

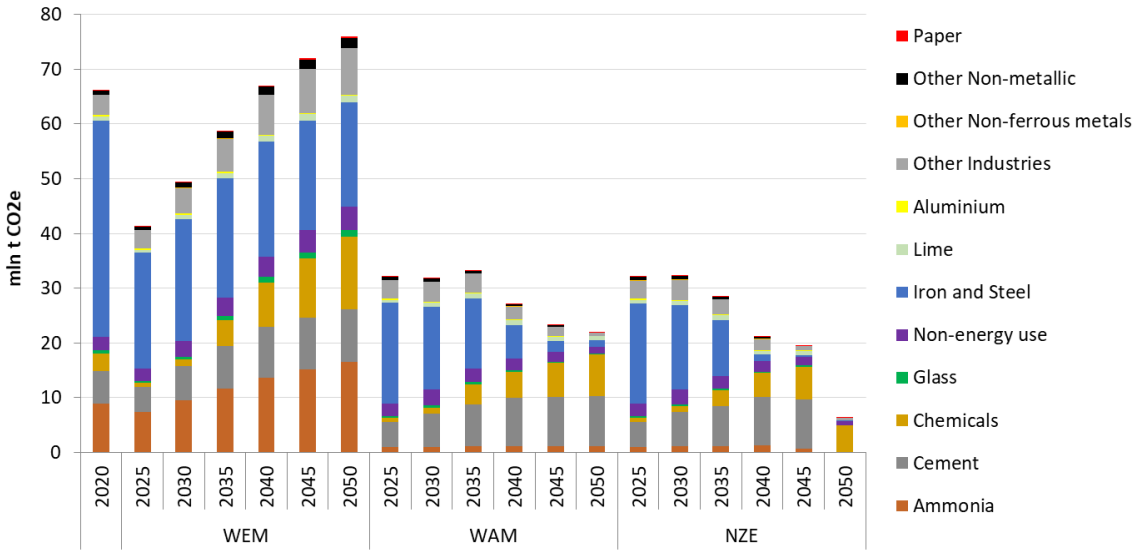
storage) and ensuring the integration of large volumes of variable RES generation; supporting the development of distributed RES generation to reduce energy consumption; reconsidering the role of nuclear energy and the need for future investments;

- the gradual phase-out of coal and the development of the extraction of critical minerals required for the production of low-carbon technologies.

2.4.2. Industry

2.4.2.1. Forecast of Energy Consumption and GHG Emissions

The forecast volumes and structure of industrial GHG emissions from fuel combustion and industrial processes differ drastically between the baseline WEM and target scenarios (Fig. 2.12). In particular, under the WAM scenario, emissions from ammonia production are significantly reduced to 1.1 million tonnes of CO_2 due to the implementation of more efficient technological chains and the use of CCS (CCUS) in hydrogen production. In the NZE scenario, there is almost complete elimination of emissions in ammonia production, reducing them to 15 thousand tonnes of CO_2 by 2050 after transitioning to electrolysis-based green hydrogen. Emissions in the metallurgy industry also decline over time due to the transition to electric steel production. However, some sectors, such as the chemical industry (excluding ammonia production), see an increase in emissions over time in all scenarios due to methane and carbon dioxide emissions from technological processes in the growing industry. While carbon dioxide emissions are almost entirely captured under the NZE scenario thanks to carbon capture installations, methane emissions require other mitigation strategies. Increased GHG emissions in cement production are also due to industry growth and chemical processes, but thanks to the implementation of CCS technologies, these emissions can be avoided by 90–95% (Fig. 2.12). GHG emissions from the energy component disappear after 2045 as energy use in this sector is decarbonised.



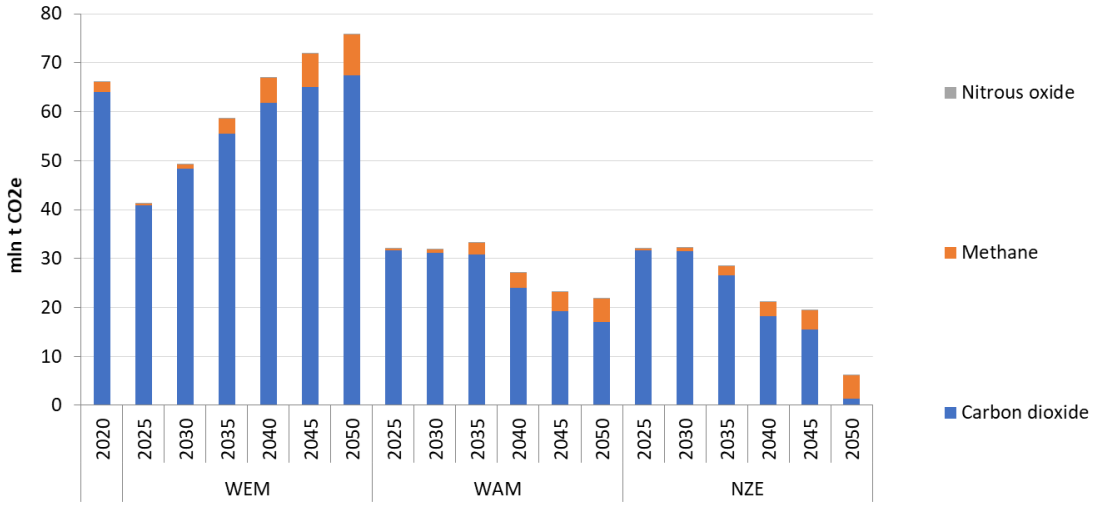


Fig. 2.12. GHG emissions in industry by scenario by sector (a) and by type of gas (b)

Fig. 2.13 illustrates a threefold increase in industrial electricity consumption and a twentyfold increase in biomass and biomethane consumption, which, alongside the growing share of decarbonised electricity and heat and the implementation of CCS (CCUS), ensures a reduction in GHG emissions.

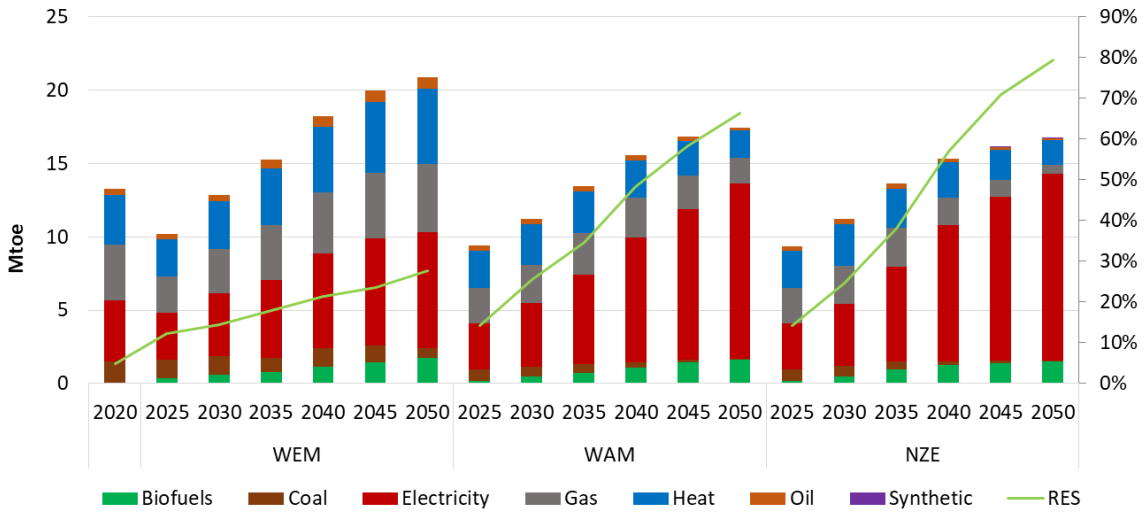


Fig. 2.13. Final Energy Consumption in the Industry by Sector and the Share of RES across Scenarios

2.4.2.2. Overview of Policies, Plans, and Measures

General Overview

As of 2021, the industrial sector accounted for approximately one-quarter of the GDP, comprised 41,926 active enterprises[69], and provided 2.3 million jobs[70]. Due to the loss of production facilities in occupied territories and the destruction of industrial capacities in areas adjacent to the frontline, in 2022, the industrial sector's production volume declined by 37.5% year on year, accounting for 7.6% of the overall GDP contraction[71].

The full-scale invasion by the Russian Federation has caused colossal destruction to Ukraine's industry. According to the Fourth Rapid Damage and Needs Assessment (RDNA4)[72], over nearly three years of the full-scale war (as of 31 December 2024), the value of direct damage to industrial and commercial facilities reached USD 17.5 billion, which represents approximately 10% of the total direct damage. Notably, around 84% of this damage resulted from the destruction or damage of industrial facilities. More than USD 4 billion in damages was incurred as a result of the destruction of two metallurgical plants in Donetsk Oblast: The Azovstal plant and the Illich Iron and Steel Works in Mariupol. The industrial sector suffered the greatest damage in Donetsk, Kharkiv, Kyiv, Zaporizhzhia and Mykolaiv Oblasts, where hostilities have taken place or are still ongoing and where industrial production capacities are concentrated. Furthermore, the total losses, including increased operational costs and loss of revenue (assessed over 52 months until 30 June 2026), amount to approximately USD 142.3 billion and approximately USD 71.6 billion for the trade sector.

According to the results of a survey conducted in 2024[73], the most common impacts of the war on businesses include disrupted access to domestic and international markets, limited compliance with international standards, reduced access to finance, interruptions in the supply of key resources, insufficient demand, shortages of labour and skills, as well as increased uncertainty. Approximately one in nine to ten enterprises ceased operations between 2021 and 2022. Overall, the impact of the war on private businesses varies depending on the sector of the economy, location, market presence and company size. Enterprises located in the main areas of active hostilities in the east and south of the country have been affected the most. At the same time, those businesses that continued operating adapted their business strategies. As of mid-2024, companies were operating on average at 49% of their production capacity. Following a sharp decline in investment (–76%) after the invasion of the Russian Federation, investments increased by 31% in the first half of 2024.

According to estimates, the cost of full recovery and reconstruction of the industrial and trade sectors by 2035 amounts to USD 64.4 billion, with approximately one third of this amount required for rebuilding infrastructure and assets according to the "build back better" principle.

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[69] State Statistics Service. Ukraine in Figures — 2021. Statistical Handbook. https://www.ukrstat.gov.ua/druk/publicat/kat_u/2022/zb/08/zb_Ukraine%20in%20figures_21u.pdf

[70] State Statistics Service. Ukraine's Labour Force — 2021. Statistical Handbook. https://www.ukrstat.gov.ua/druk/publicat/kat_u/2022/zb/07/zb_RS_2021.pdf

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[72] World Bank. Ukraine - Fourth Rapid Damage and Needs Assessment (RDNA4) : February 2022 - December 2024. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099022025114040022

[73] World Bank, Ukraine: Firms through the War 2.0, 2024, https://documents1.worldbank.org/curated/en/099061924125589588/pdf/P177312124626806b1aa081021aad774db2.pdf

Strategic goals

The National Economic Strategy until 2030[74] states that climate neutrality must be achieved for the economy as a whole by 2060. The Law of Ukraine "On the Main Principles of Climate Policy" sets an even more ambitious national target — achieving climate neutrality by 2050. At the same time, sector-specific decarbonisation targets for the industrial sector are currently absent from national legislation. As demonstrated by the modeling results presented in the previous section, even under implementation of the most ambitious NZE scenario, it will not be possible to fully eliminate GHG emissions in the industrial sector by 2050 using technologies available today. The challenge is primarily driven by increasing methane emissions from technological processes in the chemical industry. If significant technological breakthroughs do not occur in the coming decades, achieving climate neutrality by 2050 will require compensating residual GHG emissions in the industrial sector through the deployment of carbon capture and storage (CCS) (CCUS) and enhanced GHG absorption in other sectors.

Policies and Measures

In the short term (2024–2030), measures should be implemented to maximise the potential for improving energy efficiency in the industrial sector[75], electrifying industrial processes, and increasing the use of RES while introducing circular economy approaches. In the longer term (2031–2050), hydrogen and other low-carbon technologies are expected to become significantly cheaper, facilitating the achievement of carbon neutrality in industry.

Ukraine has already undertaken or plans to undertake a series of measures in these areas. In particular, to incentivise energy efficiency improvements at large enterprises, the Law of Ukraine "On Energy Efficiency" introduces requirements for mandatory and regular energy audits or the implementation of energy management systems for enterprises with an average annual energy consumption of 100,000 MWh to incentivise energy efficiency improvements at large enterprises. MWh This law also provides for the potential introduction of an energy efficiency obligation scheme, which could serve as an additional instrument for enhancing energy efficiency in industry.

As of January 2024, the Decarbonisation and Energy Efficiency Transformation Fund was launched as a separate budgetary programme within the special fund of the State Budget. It provides preferential loans for financing energy efficiency and RES expansion projects, in particular, for enterprises (see section 3.1.2 for more details).

The Strategy for the Recovery, Sustainable Development, and Digital Transformation of Small and Medium-Sized Enterprises until 2027 includes measures to facilitate the "green transition" at the SME level. Thus, a state programme for conducting professional energy audits and providing support for improving SME energy efficiency will be introduced in 2026. In 2027, a preferential loan programme is planned for SMEs that meet the criteria of the EU Green Taxonomy or a corresponding national taxonomy if adopted. This includes projects related to distributed generation and/or energy storage and electricity produced using low-carbon technologies.

The National Energy and Climate Plan includes additional measures to support SME decarbonisation and overall environmental sustainability, such as the establishment of eco-industrial parks to provide

[74] National Economic Strategy of Ukraine until 2030. Approved by Resolution of the Cabinet of Ministers of Ukraine No. 179 of 3 March 2021. https://zakon.rada.gov.ua/laws/show/179-2021-%D0%BF#Text

[75] Policies and measures to improve energy efficiency in the industrial sector are discussed in more detail in section 2.3.2.

SMEs with access to technologies, best practices, and financing, as well as the development of financial products such as leasing, refinancing of existing loans, and grant programmes for SMEs, which will operate effectively subject to the simplification and digitalisation of all procedures and the reduction of decision-making timeframes.

Additionally, international organisations' programmes aimed at supporting energy efficiency improvements in the industrial sector operate in Ukraine. In 2020, the United Nations Industrial Development Organisation (UNIDO), in cooperation with the joint-stock bank Ukrgasbank, established a Credit Guarantee Fund as a special financial mechanism within the UNIDO/GEF Project "Introduction of Energy Management System Standard in Ukrainian Industry". The Fund was created to improve financing conditions for industrial enterprises, particularly those in chemical production, building materials manufacturing, metallurgy, food and processing industry, manufacturing, export-oriented companies, and ESCOs working with industry. The Fund provides an opportunity to obtain UNIDO and GEF guarantees (including via a Citibank cross-guarantee) for the securitisation of loans to enable companies to implement energy efficiency projects, such as: 1) the implementation and certification of an energy management system (in accordance with ISO 50001) to reduce energy consumption by 20–25%;the implementation of energy consumption optimisation measures, such as the modernisation of compressed air systems, ventilation/air conditioning systems, and pumping systems[76]. The Fund's capital is USD 1.5 million, but its increase to USD 40 mln [77].

Since 2022, the "Add Energy to Your Business" programme has been operational, aimed at supporting the financing of energy-efficient investments for small and medium-sized enterprises. The programme is funded by a loan (EUR 7 million) and a grant provided by the German Government (via the German Development Bank KfW) to the Business Development Fund, with additional financial support from the European Union. Under this programme, enterprises can receive preferential loans (up to EUR 500,000 EUR in UAH equivalent) for the procurement of, inter alia, uninterruptible power supplies, energy-efficient technologies, or RES-based technologies[78].

The transition to low-carbon technologies is another promising area for decarbonising the industrial sector. The Ukraine Plan references technologies such as "green" metallurgy and "green" ammonia as priority investments for rebuilding and recovery in 2024–2027, based on the "build back better" principle. The plan also states that one of the key reform areas in the processing industry for the period 2024–2027 is the development of a coordinated Action Plan for recovery, modernisation, and the transition to "green" metallurgy.

The Energy Strategy of Ukraine (ESU) until 2050 highlights the strategically significant role of hydrogen technologies and biomethane in replacing fossil fuels in industry. The use of low-carbon[79] hydrogen in carbon-intensive and export-oriented industrial sectors, such as steel production, will help maintain Ukrainian manufacturers' competitiveness in the European market, especially given

[76] The Credit Guarantee Fund established by UNIDO together with Ukrgasbank will continue its operations until the end of 2025. https://www.ukrgasbank.com/press_center/news/13641-

[77] Ukrinform. UNIDO expects to increase its Credit Guarantee Fund to USD 40 million. https://www.ukrinform.ua/rubric-economy/3821998-unido-rozrahovue-na-zbilsenna-svogo-fondu-garantuvanna-kreditiv-do-40-miljoniv.html

[78] BDF. Add Energy to Your Business Program. https://bdf.gov.ua/programs/prohrama-doday-enerhiyi-tvoyemu-biznesu/

[79] Under the draft Hydrogen Strategy of Ukraine until 2050, "low-carbon hydrogen is fossil fuel-based hydrogen with carbon capture and electricity-based hydrogen with significantly reduced GHG emissions over the entire life cycle compared to existing hydrogen production".

the implementation of CBAM. The draft Hydrogen Strategy until 2050[80] outlines the prospects for using low-carbon hydrogen to decarbonise industries such as metallurgy, cement production, ammonia, ammonium nitrate, and methanol.

The introduction of circular economy practices will facilitate deeper decarbonisation of the industrial sector by reducing greenhouse gas (GHG) emissions at various stages of the product life cycle. The promotion of the circular economy development is provided for by a range of strategic documents in Ukraine. For instance, the National Economic Strategy until 2030 includes measures to implement circular economy principles, such as simplifying scrap metal transaction procedures and creating transparent and competitive secondary raw material markets. Ukraine's plan stipulates that the Ministry of Economy must develop and approve the Strategy and Action Plan for the Circular Economy by the first quarter of 2026 to align regulatory acts for key industries and consumers with the EU Circular Economy Action Plan. The Strategy will identify potential opportunities for transition to the economy of priority sectors and value chains, including textiles, plastics, batteries, electronics, metals, and minerals.

In the ESU, carbon capture, utilisation, and storage (CCUS) technologies are identified as a critical tool for mitigating residual GHG emissions in power generation and industrial production, and for achieving total climate neutrality. Preliminary estimates of the cumulative CO_2 capture requirements in Ukraine up to 2050 amount to tens of millions of tonnes. The realisation of such a large-scale potential will require a profound adaptation of the existing oil and gas infrastructure, specifically the gas transmission system and underground gas storage facilities, for the transport and long-term geological storage of carbon. The utilisation of depleted fields and available UGS capacities is considered a strategic advantage for Ukraine, which will enable it not only to mitigate its domestic carbon footprint but also to integrate into the future pan-European CCUS infrastructure.

The development of this sector is characterised by exceptionally high capital and research intensity, necessitating the mobilisation of significant investment resources and the execution of fundamental R&D activities. The first strategic step in this direction is a comprehensive study of the CCUS infrastructure development potential in Ukraine, scheduled for 2025–2028. This study aims to identify new business opportunities, assess the technical condition of existing assets, and incorporate EU forecasts regarding future carbon storage capacity requirements. The lengthy implementation timeline of such projects and their technological complexity necessitate the immediate initiation of a legal framework formulation, which will establish a robust foundation for the decarbonisation of the energy and industrial sectors in the medium term.

An overview of existing and prospective financing instruments for decarbonisation, in particular in industry, is presented in sections 3.1.2 and 3.1.3.

2.4.3. Building sector

2.4.3.1. Forecast of Energy Consumption and GHG Emissions

GHG emissions in the building sector are presented separately for residential buildings (Fig. 2.14) and the service sector (Fig. 2.15) by fuel use category. As shown in the figures, most emissions from

[80] Ministry of Energy. Announcement of the publication of the draft Hydrogen Strategy of Ukraine until 2050 and the report on its strategic environmental assessment. https://www.mev.gov.ua/proyekt-normatyvno-pravovoho-aktu/povidomlennya-pro-oprylyudnennya-proyektu-vodnevoyi-stratehiyi

residential buildings and a significant share from the service sector stem from meeting the demand for heating spaces. Thanks to the implementation of goals of the basic scenario of the building thermal modernisation strategy and the introduction of advanced energy-efficient technologies, such as heat pumps, emissions from heating have the potential to be reduced by 23 times in residential buildings and by 3.6 times in the service sector under the NZE scenario.

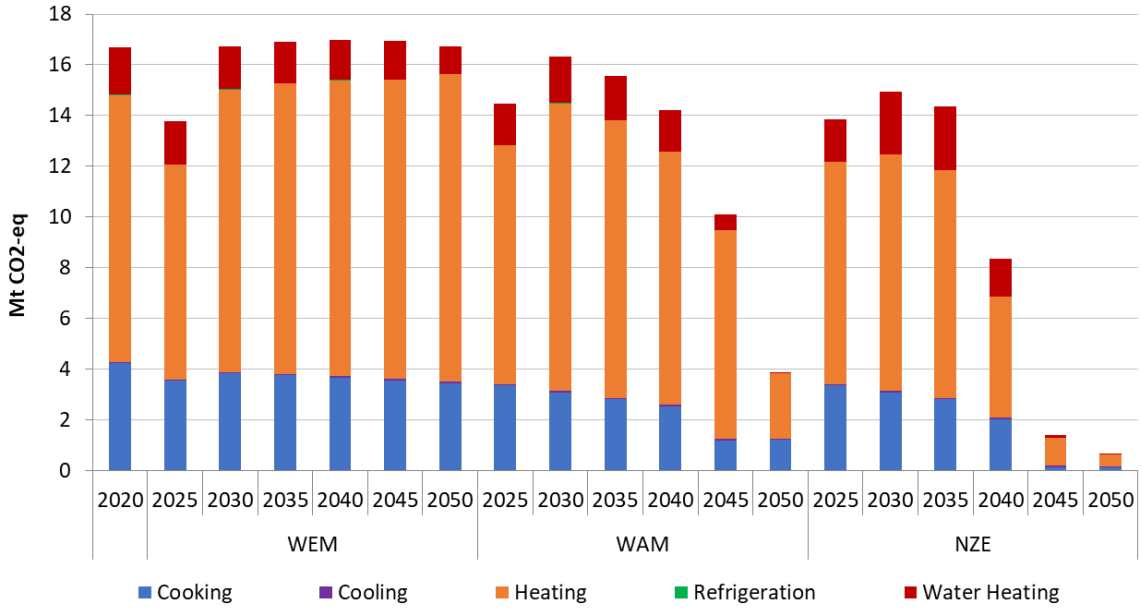

Fig. 2.14. GHG emissions in residential buildings by fuel use across scenarios

Cooking and water heating are second and third among the largest sources of GHG emissions in residential buildings, respectively. By electrifying these demands and substituting natural gas with biomethane, emissions from the corresponding processes will also be reduced. In the service sector, the most carbon-intensive category is currently the aggregate demand for other needs, but the use of biofuels and increased reliance on municipal heating will minimise emissions in all scenarios.

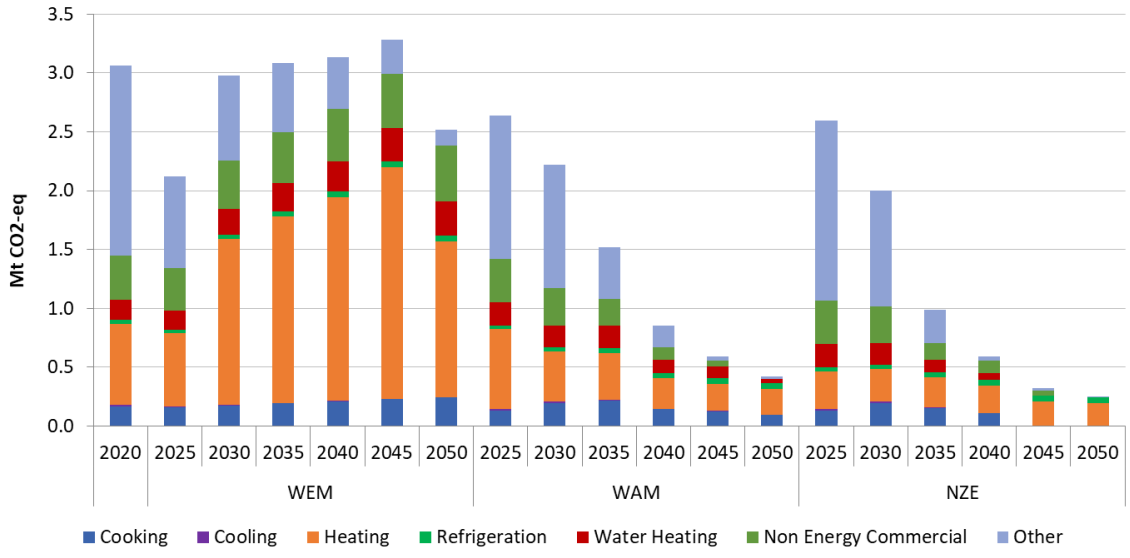

Fig. 2.15. GHG emissions in service sector buildings by fuel use across scenarios

2.4.3.2. Overview of Policies, Plans, and Measures

General Overview

As of 2021, the total floor area of residential premises in Ukraine amounted to 1,079.5 million m2, while the number of buildings reached 9,154,372 units, of which 181,191 units were multi-apartment buildings. A significant portion (65%) of the housing stock was built between 1945 and 1980, while only 9% of buildings were constructed after 1991. The low energy efficiency of the ageing housing stock makes the sector one of the largest energy consumers in Ukraine, second only to industry in final energy consumption. Buildings account for about 40% of final energy consumption, with residential buildings responsible for 31.7%.

Russia's full-scale invasion has caused severe damage to the housing sector. According to the Rapid Damage and Needs Assessment resulting from the large-scale invasion of the Russian Federation (hereinafter — RDNA3), more than 10% of the total housing stock has been damaged or destroyed, affecting approximately 2 million households, As of 31 December 2023, the total cost of damages in the housing sector was estimated at USD 55.9 billion, of which USD 17.4 billion was attributable to direct losses. Post-war reconstruction will not fully restore the housing stock to pre-2021 levels. Local authorities are currently developing comprehensive recovery programmes that outline main spatial, urban planning, and socio-economic priorities for regional and municipal recovery policies. These programmes include assessing the technical feasibility and economic viability of restoring damaged buildings through reconstruction, renovation, major or current repairs, or entirely new construction. As of June 2024, 200 territorial communities had initiated such programmes.

Under the Long-Term Building Thermal Modernisation Strategy until 2050, Ukraine had 255,344 public buildings with a combined floor area of 320.2 million m^2. These included 12,983 preschool facilities, 16,143 schools, 2,442 healthcare facilities and 223,776 other public buildings.

According to RDNA3 data, between February 2022 and 31 December 2023, 13% of educational infrastructure was damaged or destroyed due to the war, resulting in an estimated loss of USD 5.6 billion (Table 8). These 13% include damage to 3,583 educational institutions, 394 of which were destroyed. While most of the damage affected schools (1,888 institutions), higher education institutions and research facilities experienced the highest damage rates, with 21% and 31% of total facilities affected, respectively. 12.5% of all healthcare facilities sustained partial or complete damage. Total sector losses are estimated at USD 17.8 billion .

Strategic goals

The Long-Term Strategy for Building Thermal Modernisation until 2050 defines the main objectives of state policy in the building sector. This Strategy envisages the decarbonisation of the national building stock by 2050. In modelling the expected outcomes of the Strategy's implementation, two basic development scenarios were adopted, concerning the potential extent of thermal modernisation in the building stock and its level:

- basic scenario: a low level of thermal modernisation deployment, which will cover approximately 10% of buildings (and 17% of the building stock area) by 2030;
- ambitious scenario: a high level of thermal modernisation deployment, which could cover about 35–40% of the building stock area by 2030.

When developing the NECP, the Government established indicative targets for primary and final energy consumption, taking into account the basic scenario of the Long-Term Strategy for Building

Thermal Modernisation until 2050. The government also considered the dynamics of the Russian Federation's attacks, the high level of risk, which significantly reduces the attractiveness of investments in the sector's thermal modernisation, and the limitations of state and local budgets in the context of a large-scale invasion. This LT-LEDS is also based on the basic scenario of building thermal modernisation until 2030 and achieving decarbonisation of the national building stock by 2050.

Key Measures and Policies

The path to decarbonising the building sector will include continuing and expanding the measures outlined in the NECP, particularly the thermal modernisation of the existing residential stock, the gradual introduction of mandatory compliance with nearly zero-energy building requirements (NZEB) and, subsequently, zero-emission building requirements (ZEB), the transformation of the district heating sector, and the decarbonisation of individual and autonomous heating systems.

Currently, the foundation of the state policy in the field of energy efficiency for buildings is the Law of Ukraine "On Energy Efficiency of Buildings," which transposes most provisions of Directive 2010/31/EU on the energy performance of buildings. According to this law, minimum energy efficiency requirements for buildings have been established, energy certification for buildings has been introduced, and a National Plan to increase the number of nearly zero-energy buildings has been approved. The Energy Efficiency Fund operates in Ukraine and provides partial reimbursement for the cost of thermal modernisation of buildings.

Current financial instruments for implementing building thermal modernisation are directed at building co-owners, regardless of their level of access to energy services necessary to ensure a decent standard of living and health. However, the Long-Term Strategy for Building Thermal Modernisation until 2050 identifies overcoming energy poverty as one of its goals. The Strategy highlights that, alongside the existing system of housing subsidies that performs a social function, systematic investment support (public co-financing) for the thermal modernisation of residential buildings must be introduced.

In April 2024, the European Union adopted the updated Directive (EU) 2024/1275 on the energy performance of buildings (hereinafter — Directive 2024/1275). As part of the European integration process, Ukraine is transposing the provisions of Directive 2024/1275. In accordance with this Directive, the Government will develop a National Building Thermal Modernisation Plan, which will outline the paths to decarbonising the building stock and removing key barriers to thermal modernisation, such as insufficient funding, the need to upskill workers, and raising awareness among building owners about the benefits of implementing energy-efficient measures. The National Building Thermal Modernisation Plan is expected to be developed based on data from the National Database of Energy and Operational Characteristics of Buildings in Ukraine, the initial data collection period for the database will last through 2025–2026.

Directive 2024/1275 also establishes the standard for zero-emission buildings (ZEB). In the EU, all new buildings must comply with this standard by 1 January 2028 for public buildings and by 1 January 2030 for all other new buildings, with certain exceptions. At the same time, the Long-Term Strategy for Building Thermal Modernisation until 2050 already anticipates the transition to constructing new buildings in compliance with the ZEB standard by 2040.

Ukraine must also establish requirements for the readiness to install solar power stations on new buildings. Ukraine is already taking initial steps towards implementing decentralised generation in

multi-apartment buildings. Specifically, the Energy Efficiency Fund has adopted the GreenDIM programme, which provides partial reimbursement for the installation of hybrid solar power stations on multi-apartment buildings. Co-owners of multi-apartment buildings can also get preferential loans for financing solar power stations under the state programme "Affordable Loans 5–7–9." In the future, Ukraine will be required to establish an obligation to install such stations where technically and economically feasible in accordance with Directive (EU) 2024/1275.

An important element in achieving the decarbonisation of the building sector is ensuring the transformation of existing district heating systems to those that meet the definition of efficient heating systems. Synchronising building thermal modernisation processes with the renewal of heating systems in settlements will contribute to optimising costs for decarbonising the heat supply sector. At present, efficient heating systems are those that use a minimum of 50% RE, 50% waste heat, 75% heat generated through cogeneration, or 50% of a combination of such energy and heat. Meanwhile, the updated Directive (EU) 2023/1791 on energy efficiency establishes a gradual tightening of such requirements. By 2050, heating systems in EU countries must use exclusively renewable energy, exclusively waste heat, or a combination of RE and waste heat. Ukraine's Euro-integration ambitions require the country to upgrade its heating systems to these standards. Most projects for modernising heat supply sources should be carried out between 2030 and 2050. By 2030, Ukraine plans to increase the share of heat produced using RES to 33%.

Ensuring the development and adoption of heating supply schemes by local authorities, which will include relevant projects for modernising heat generation enterprises and reconstructing heating supply networks, is an essential prerequisite for transforming the municipal heating sector. The draft State Target Economic Programme for the Energy Modernisation of Heat Supply Enterprises, owned by the state or municipalities until 2030, envisages the adoption of 100 heating schemes in settlements with a population of over 20,000.

Approximately 30% of households have access to centralised heating, while the remaining households rely on autonomous or individual heating systems. For such households, the government plans to gradually reduce the use of fossil fuels in building energy supply by shifting to municipal heating and electricity and supporting the use of RES and/or installations with low or zero GHG emissions. In particular, the following steps are planned:

- a ban on the installation of new gas and coal boilers during new construction and reconstruction of buildings by 2028;
- a phased ban on the use of gas and coal boilers:
    - by 2030 — for public buildings;
    - by 2035 — for multi-apartment residential buildings;
    - by 2040 — for buildings of all categories.

Ukraine also has significant potential for using heat pumps for heating purposes. Policies are already in place to lay the foundations for encouraging the use of this solution. According to the Law of Ukraine "On Alternative Energy Sources," aerothermal, hydrothermal, or geothermal heat energy obtained through heat pumps should be considered extracted from RES, provided that the final energy output significantly exceeds the primary energy consumption needed to operate the heat pumps. At the same time, scaling up the use of heat pumps requires the phased introduction of mandatory compliance with the requirements for nearly zero-energy buildings. Financial incentives

for partially reimbursing the cost of heat pumps also need expanding. Currently, for homeowners' associations of apartment buildings, partial reimbursement is available under the Greendim Programme of the Energy Efficiency Fund. However, this reimbursement is only available only to co-owners who have already carried out the thermal modernisation of their building.

In addition to the national-level policy and measures, local authorities' initiatives and active actions to mitigate the effects of climate change play an extremely important role in achieving the decarbonisation goals for buildings and heating. In accordance with current law, all local government bodies must develop and adopt local energy plans. The aim of local energy plans is to assist in achieving national energy efficiency goals, the development of RES, the use of waste heat energy, the application of high-efficiency cogeneration, the reduction of GHG emissions, and the decarbonisation of energy consumption in territorial communities and regions by 2050, with consideration of the "Energy Efficiency First" principle. Local government bodies must define the sustainable energy development objectives (e.g., improving energy efficiency, and developing RES) in these plans. Local energy plans cover, in particular, sectors such as public buildings, residential buildings and district heating.

2.4.4. Transport

2.4.4.1. Forecast of Energy Consumption and GHG Emissions

In Ukraine, the transport sector accounted for 41% of all atmospheric emissions and 29% of CO_2 emissions in 2021. This represented a significant increase compared to 2020, both in relative and absolute terms (in 2020, transport was responsible for 17% of CO2 emissions). Despite the relatively low level of motorisation in Ukraine (239 passenger cars per 1,000 people as of 2023, compared to 574 in the EU[81]), emissions from domestic road transport are considerable due to the outdated national vehicle fleet. The average age of vehicles in Ukraine increases every year: as of 2023, the average age was 23.2 years, compared to 11.8 years in the EU. This trend has not yet been reduced. In 2023, 40% of new car registrations were for vehicles over 10 years old, and their share of the total vehicle fleet was 85.8%. Due to Ukraine's economic situation, the used car market dominates the new car market by a factor of 3.8. Despite challenges with the electricity supply, the number of electric vehicles in Ukraine continues to grow (with an increase of over 37,000 in 2023, or one in every six registrations)[82].

The average distance for freight transportation by land in 2021 was 400 km. Due to the full-scale war, freight transport decreased significantly. Thus, air transport saw a 100% reduction, maritime transport dropped by 85%, railway transport decreased by 48%, and road transport by 22%[83].

Target scenarios show the potential for significant emission reductions in the transport sector by 2050 (Fig. 2.16), especially in the NZE scenario, where in 2050, the only considerable emitter remains road freight transport. Although the emissions will have decreased by three times from 2020 levels through the use of biofuels and electrification with hydrogen, it will still consume around 600,000 tonnes of oil products.

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[81] ACEA. Vehicles on European roads. 2024. https://www.acea.auto/publication/report-vehicles-on-european-roads/

[82] Federation of the Automotive Industry. Review No. 87. https://fra.org.ua/uploads/media/file/0001/08/bd2e5ecdfc4ddb23c88a0464b80a89db29a0269e.pdf

[83] State Statistics Service. Freight transport volumes by mode of transport. https://ukrstat.gov.ua/operativ/operativ2018/tr/opv/arh_opv_u.htm

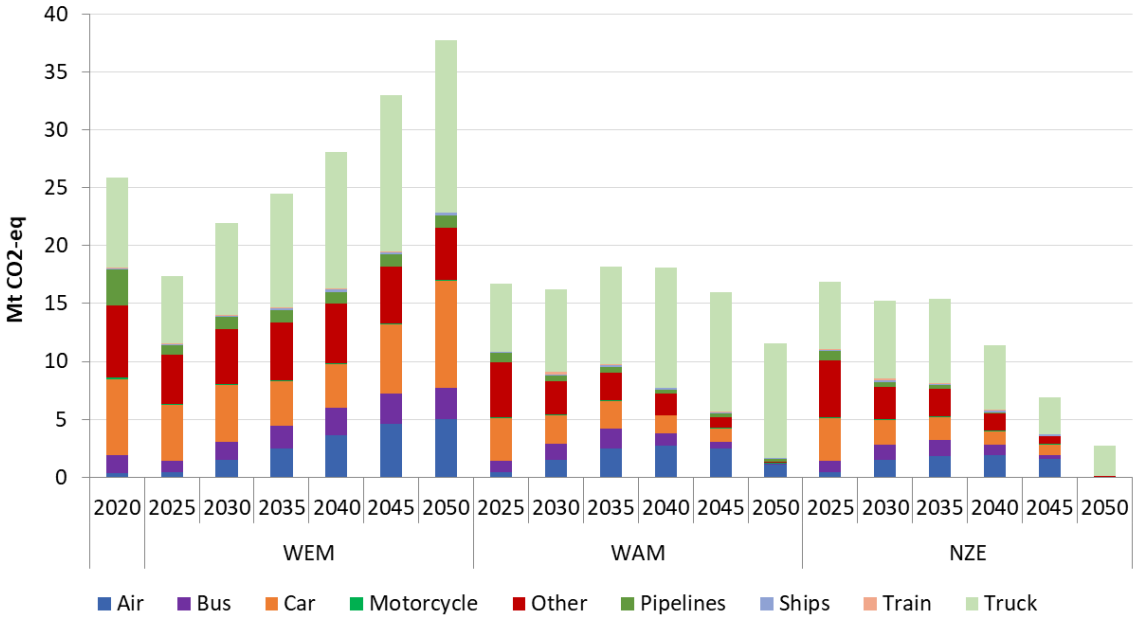


Fig. 2.16. GHG Emissions in the Transport Sector by Mode of Transport across Scenarios

Despite the growth in transport volumes and the corresponding demand for motor fuel, it is possible to achieve decoupling after 2035 through the utilisation of sustainable biofuels, direct electrification, and hydrogen, whilst the share of RES in the sector under the NZE scenario reaches nearly 90% (Fig. 2.17).

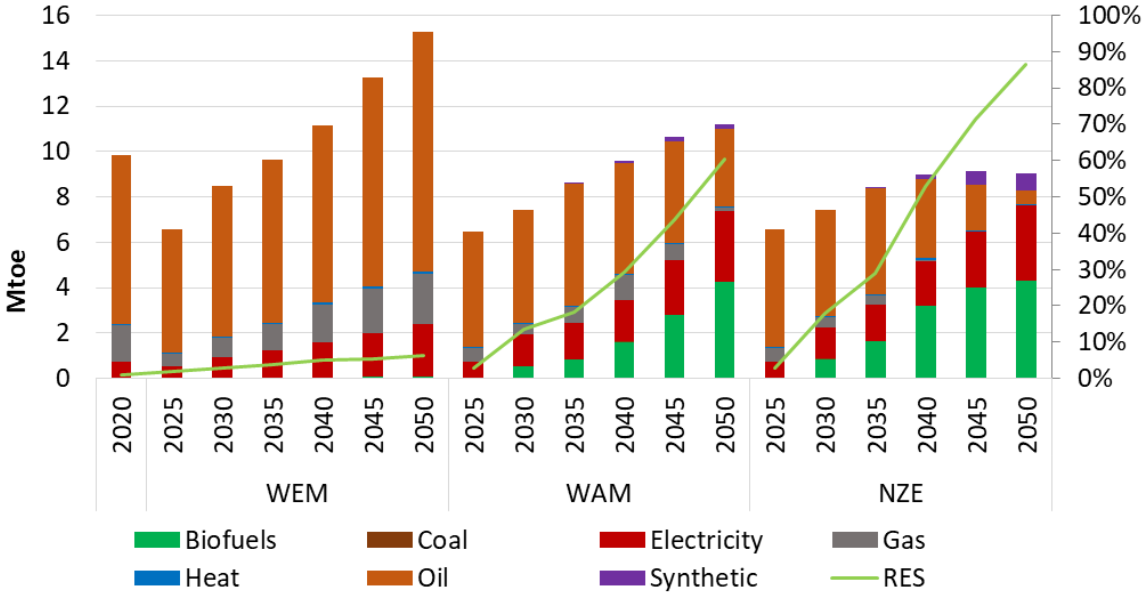


Fig. 2.17. Final Energy Consumption in the Transport Sector by Fuel Type under the Scenarios

2.4.4.2. Overview of Policies, Plans, and Measures

The decarbonisation of the transport sector is one of the country's priority tasks in the context of post-war recovery and socio-economic development. Reduction of GHG emissions in the transport sector may be achieved through the following measures:

- electrification of transport using low-carbon energy sources as fuel;
- use of liquid motor biofuels, compressed or liquefied natural gas methane, and biomethane;
- renewal of the vehicle fleet and rolling stock;
- behavioural changes (increased use of public transport, reduction in transport demand, use of human muscle power (active mobility), and shared mobility services).

Strategic goals

The decarbonisation of the transport sector is a cross-cutting task in a number of existing programme documents. Thus, the National Transport Strategy of Ukraine until 2030[84] envisions increasing the share of alternative and renewable fuels and electricity across all types of transport and transport infrastructure facilities to 50% by 2030. It also provides for a 30% reduction in specific fuel consumption per unit of transport work by 2030.

The Energy Strategy of Ukraine up to 2050 foresees an increase in electricity consumption in the transport sector to 11% by 2032 due to transport electrification. The share of electric transport is expected to reach 15% by 2032.

The achievement of these targets is outlined in the National Energy and Climate Plan until 2030[85]. One of the strategic objectives is to achieve a share of RES in gross final energy consumption of at least 27% by 2030. The National Renewable Energy Action Plan until 2030[86] sets a target of 17.2% renewable energy consumption in transport by 2030.

To ensure the use of motor biofuels (bioethanol) in transport, the Law of Ukraine "On Amendments to Certain Laws of Ukraine Regarding the Mandatory Use of Liquid Biofuels (Biocomponents) in the Transport Sector" has been adopted[87].

To facilitate transport electrification in Ukraine, a wide range of documents has been adopted to encourage the production, acquisition, and use of electric vehicles, the development of charging infrastructure, and the decarbonisation of municipal public transport.

The Tax and Customs Codes of Ukraine provide for incentives to encourage the use of passenger electric vehicles. In particular, the import of electric vehicles is exempt from customs duties, and operations related to their importation into Ukraine are exempt from VAT until 2026 (as are vehicles with internal combustion engines that run exclusively on compressed natural gas methane, liquefied

[84] The National Transport Strategy of Ukraine until 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 1550 of 27 December 2024.

[85] The National Energy and Climate Plan until 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 587-p of 25 June 2024 https://zakon.rada.gov.ua/laws/show/587-2024-p#Text

[86] The National Action Plan for Renewable Energy until 2030 approved by Resolution of the Cabinet of Ministers of Ukraine No. 761-p. of 13 August 2024 https://www.kmu.gov.ua/npas/pro-zatverdzhennia-natsionalnoho-planu-dii-z-vidnovliuvanoi-enerhetyky-na-p-a761

[87] Law of Ukraine "On Amendments to Certain Laws of Ukraine Regarding the Mandatory Use of Liquid Biofuels (Bio-components) in the Transport Sector" https://zakon.rada.gov.ua/laws/show/3769-20#Text

natural gas methane, or biogas)[88]. From 2026, the standard tax regime will be reinstated. An excise tax of 1 euro per 1 kWh of battery capacity is levied on electric vehicles. Since July 2022, passenger electric vehicles have been exempt from the mandatory state pension insurance contribution upon first registration[89]. Until 2031, goods used to produce vehicles equipped exclusively with electric motors are exempt from import duties (under the Customs Code of Ukraine) and VAT (under the Tax Code of Ukraine). Until the end of 2035, enterprises engaged exclusively in the production of electric motors, lithium-ion and lithium-polymer batteries, charging devices for electric vehicles, and electric vehicles themselves are exempt from profit tax. At the same time, the retained funds must be allocated to research, development, and engineering in the field of electric transport, the creation or modernisation of material and technical infrastructure, the expansion of production volumes, and the implementation of advanced technologies.

Current legislation has expanded the list of vehicles equipped with electric motors, enacted the Law of Ukraine "On Urban Electric Transport"[90], and introduced requirements for the development of electric charging infrastructure programmes[91], the provision of parking spaces for electric transport[92], and the inclusion of electric charging infrastructure in new residential developments.

It is stipulated that, on urban bus routes in cities with a population exceeding 250,000, the share of electric buses and/or buses operating exclusively on methane (compressed or liquefied), biogas, or hydrogen fuel cells must be at least 25% by 1 January 2030 and 50% by 1 January 2033. Starting from 2036, only electric buses or buses powered by methane, biogas, or hydrogen fuel cells will be permitted on urban public transport routes in district and regional cities. Local government authorities may revise these quotas (by no more than 50%) and deadlines (by no more than two years). Starting in 2028, progressive restrictions on the procurement of internal combustion engine buses for public transport needs will also be introduced.

Measures and Policies

The objective of transforming the transport sector by 2050 should be the maximum possible decarbonisation of transport (excluding pipelines), which would benefit both people and the environment. It is necessary to establish target indicators for reducing CO_2 emissions in the transport sector by 2050.

Electrification of transport can take place in several directions. For instance, in railway transport, the electrification of currently non-electrified sections should continue. Night passenger rail transport will remain in demand and continue to be significant. Ukraine's railway network should become fully integrated into European routes and transport corridors. Ukrainian logistics routes should be part of the Trans-European Transport Network (TEN-T), which includes 3,300 km of railway track with a standard gauge of 1,435 mm.

[88] Tax Code of Ukraine. https://zakon.rada.gov.ua/laws/show/2755-17#Text

[89] Law of Ukraine "On Amendments to the Tax Code of Ukraine and Other Legislative Acts of Ukraine Regarding the Revision of Certain Tax Benefits" https://zakon.rada.gov.ua/laws/show/2325-20#Text

[90] Law of Ukraine on Urban Electric Transport. https://zakon.rada.gov.ua/laws/show/1914-15#Text

[91] Law of Ukraine on Certain Issues of the Use of Vehicles Equipped with Electric Motors and on Amendments to Certain Laws of Ukraine to Overcome Fuel Dependence and Develop Electric Charging Infrastructure and Electric Vehicles https://zakon.rada.gov.ua/laws/show/2956-20#Text

[92] State Building Codes approved by Order of the Ministry of Development of Communities and Territories No. 366 of 30 December 2021 https://e-construction.gov.ua/laws_detail/2845786368808847244?doc_type=2

The share of electric vehicles should continue to grow, increasing the demand for electricity. This necessitates increasing the share of RE in the electricity balance, as well as expanding charging infrastructure, relevant research, and new technological solutions. Network load will increase; however, as the share of electric transport rises, the charging profile will become clearer, allowing the network to gradually adapt. Electric vehicles themselves will be able to provide additional services (demand response services) and enhance grid flexibility.

Urban electric bus routes should be developed in public transport, and the procurement of ICE vehicles should be significantly reduced. Starting in 2036, the purchase of ICE public transport vehicles should cease (except for ICE buses operating exclusively on compressed natural gas methane, liquefied natural gas methane, biogas, or hydrogen fuel cells). Connectivity between cities, towns, and villages should improve, including through the use of low-carbon fuels. To enable the use of biomethane in road transport, appropriate legislation must be developed. The use of liquid motor biofuels, compressed or liquefied natural gas methane, and biomethane is promising, particularly in the medium term, given the challenges in electricity production and supply caused by the Russo-Ukrainian war and the large number of ICE vehicles in Ukraine. The uptake of motor biofuels (in particular ethanol) is supported by the mandatory requirement to blend a biological component into fuels starting from June 2025.

Given the war and its impact on human capital, passenger transport and infrastructure must facilitate barrier-free' movement for people with disabilities and low-mobility groups.

Freight transport electrification is necessary, including the use of hydrogen fuel cell vehicles. Long-distance freight delivery (over 300 km) should rely less on road transport (contrary to current trends) and more on rail and water transport. Last-mile delivery should also use electric and hydrogen-powered transport, which enables nighttime deliveries that reduce congestion and noise pollution — an issue particularly relevant for urban areas.

The role of freight and passenger transport by inland waterways should increase (ensuring navigable depths in the context of climate change), and transport vehicles should utilise low-carbon energy sources.Ukraine must have convenient air connections with the rest of the world. The aviation fleet should adopt low-carbon energy sources, primarily alternative fuels (sustainable aviation fuel, SAF), whose research and implementation are actively progressing in many countries.

Behavioural changes should be a cornerstone of low-carbon development. Urban and intercity public transport (as opposed to private vehicles) should become the primary means of travel, and public transport must be made convenient, reliable, and the most accessible option. Active mobility (use of human muscle power) should be used for short distances. Settlements should provide a broad range of options for both individual vehicle ownership and rental. Shared mobility and vehicle-sharing services should also be developed. Avoiding unnecessary trips will help partially reduce transport demand.

2.4.5. Waste Management Sector

2.4.5.1. General Information on Waste Management in Ukraine

Ukraine faces a critical situation regarding the generation, accumulation, storage, processing, recovery and disposal of waste, which continues to pose growing environmental threats. Despite the declared priority of the waste issue, the development of the relevant legal and regulatory

framework, and the implementation of various targeted programs at both national and local levels, the increase and accumulation of waste have not been halted[93].

According to the Ministry of Reconstruction, in 2022 over 7 million t of household waste (HW) were generated in Ukrainian settlements. This waste was disposed of in 5,700 landfills and waste disposal sites covering a total area of nearly 8,000 ha. These statistics account only for populations provided with HW collection services and do not include territories temporarily out of the control of the Government. The coverage of HW collection services in Ukraine amounts to approximately 80% of the population. In 2022, about 9.9 % of collected HW was processed or disposed of: 1.66 % was incinerated, and 8.24 % was sent to scrap collection points and recycling lines. Overall, over the past 30 years, the share of HW landfilling in the country has remained around 90–95%.

The situation with wastewater sludge processing in Ukraine, compared to other countries, is extremely poor. Currently, over 5 billion t of sludge are accumulated in sludge fields, of which only 3–5 % is treated. According to the State Statistics Service, municipal utility enterprises discharge on average about 3,400 million m³ of wastewater per year, generating 17 million m³ (0.5 %) of wastewater sludge, equivalent to approximately 0.7 million t of dry matter. The low treatment rate of wastewater sludge in Ukraine is mainly due to imperfect legislation and outdated treatment plant equipment.

As a result of inadequate waste management, the share of the Waste sector in Ukraine's total GHG emissions increased from 1.8% in 1990 to 6.1% in 2022[94]. The Waste sector is the only sector where GHG emissions reductions by 2022 were less than 50 % compared to the 1990 baseline. Moreover, this reduction amounted to a mere 13.8%: from 17.0 million tonnes of CO_2 eq in 1990 to 14.6 million tonnes of CO_2 eq in 2022, as illustrated in Fig. 2.18 below.

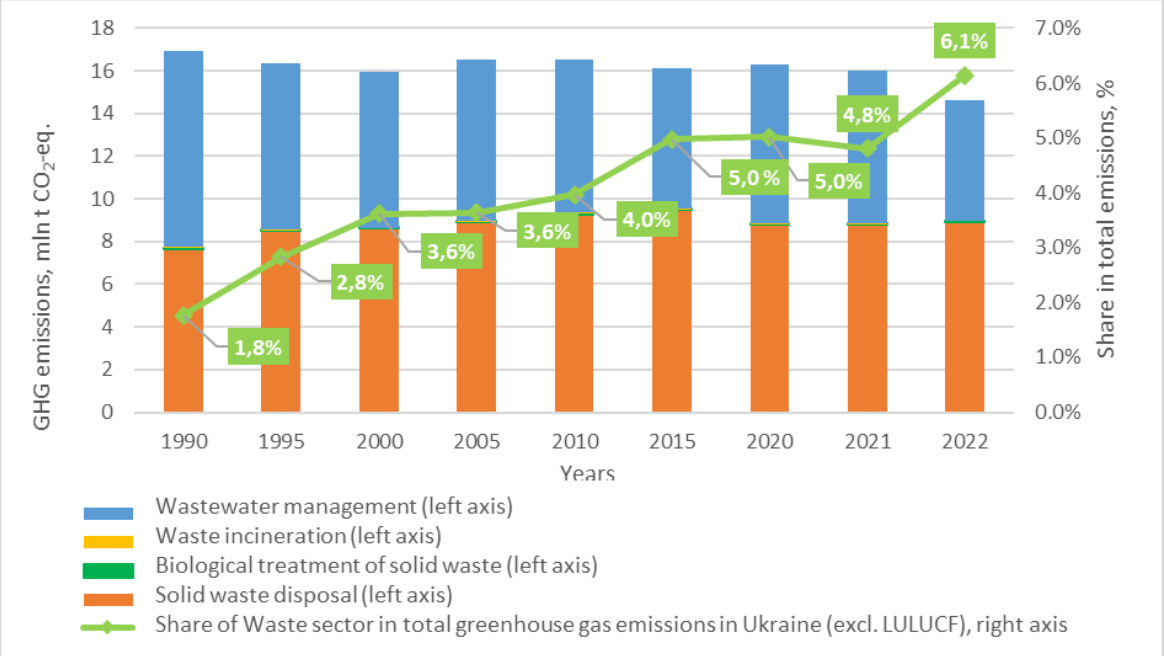


Fig. 2.18. GHG Emissions in the Waste Sector from 1990 to 2020

[93] The National Waste Management Plan of Ukraine until 2033 (approved on 27 December 2025) is available at: https://zakon.rada.gov.ua/laws/show/1353-2024-%D1%80#Text

[94] This data is recorded in the National Cadastre of Anthropogenic Emissions from Sources and Absorption by Greenhouse Gas Sinks, covering GHG emissions in Ukraine from 1990 to 2022. Available at: https://unfccc.int/documents/645143

The largest source of emissions in the Waste sector is landfills and HW disposal sites, accounting for 61.0% of total sector emissions in 2022. The second-largest source is wastewater treatment and discharge processes, contributing 38.7%. Other emission sources, such as biological treatment and waste incineration, are negligible, collectively not exceeding 0.3%.

2.4.5.2. Prospective GHG Emissions Trajectory

The WEM scenario assumes the continuation of long-term trends in the transformation of Ukraine's waste management sector, accompanied by a slow and gradual reduction of HW landfilling to 70% by 2030 and 30% by 2050. This scenario also assumes that Ukraine will achieve its Sustainable Development Goals by 2030, including reductions in untreated wastewater, increases in per capita food consumption efficiency and reductions in water use per unit of GDP.

Under the WEM scenario, GHG emissions in the Waste sector are projected to decrease to 14.6 million tonnes of CO_2 eq by 2030 (14% below the 1990 level) and to 11.1 million tonnes of CO_2 eq by 2050 (34% below the 1990 level).

The WAM scenario assumes strict compliance with the 2022 Law "On Waste Management"[95]. It is based on the assumption that the National Waste Management Plan of Ukraine until 2033[96] and its Action Plan will be implemented fully and on time[97]. Under this scenario, the share of HW landfilling is projected to decrease to 30% by 2033 and 20% by 2050.

Under the WAM scenario, GHG emissions in the Waste sector are projected to decrease to 13.0 million tonnes of CO_2 eq by 2030 (23% below the 1990 level) and to 9.3 million tonnes of CO_2 eq by 2050 (45% below the 1990 level).

The NZE scenario envisages the implementation of a circular economy and the development of modern wastewater management infrastructure in Ukraine by 2050.

Under the NZE scenario, GHG emissions in the Waste sector are projected to decrease to 11.9 million tonnes of CO_2 eq by 2030 (30% below the 1990 level) and to 2.8 million tonnes of CO_2 eq by 2050 (83% below the 1990 level).

Projected GHG emissions in the Waste sector under the LT-LEDS scenarios are presented in Table 2.4 and illustrated in absolute and relative terms in Figure 2.19.

[95] Law of Ukraine On Waste Management | No. 2320-IX of 20 June 2022

[96] https://zakon.rada.gov.ua/laws/file/text/123/f542151n26.pdf

[97] https://zakon.rada.gov.ua/laws/file/text/123/f542151n27.pdf

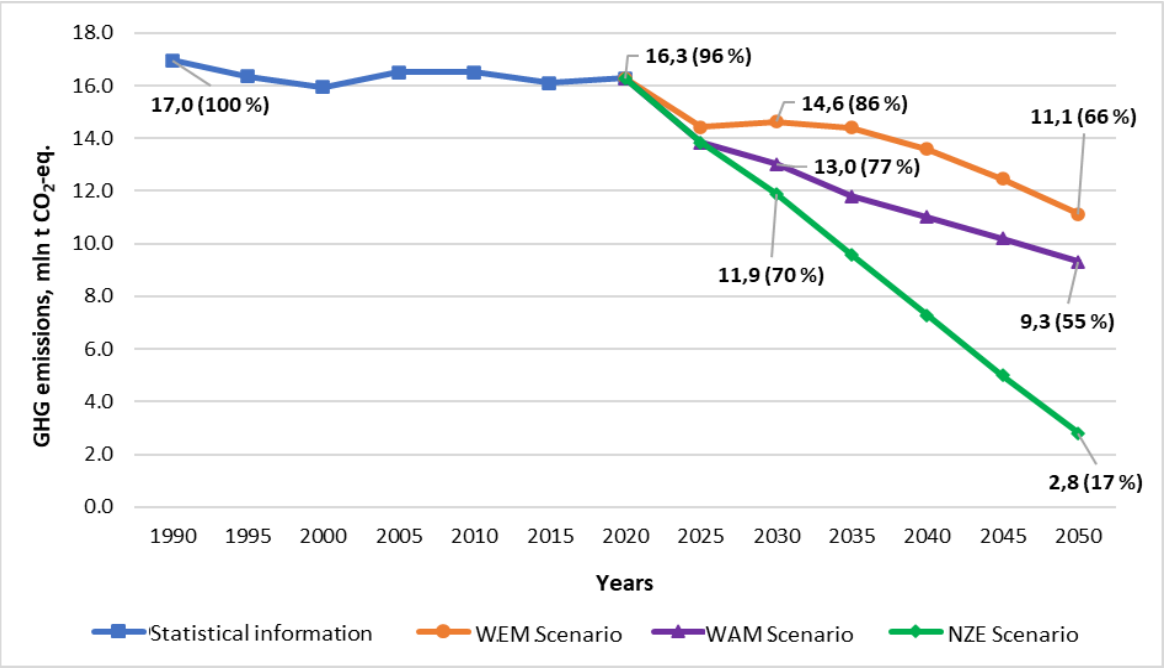


Fig. 2.19. Projected GHG emissions in the Waste sector until 2050

Table 2.4. Projected GHG emissions in the Waste sector by category until 2050 (thousand tonnes of CO_2 eq)

	1990	2020	2021	2022	2025	2030	2035	2040	2045	2050
HW Landfilling, thousand tonnes of CO_2 eq										
WEM	7661	8816	8803	8926	8725	8647	8522	7924	7074	6081
WAM					8099	6906	5819	5280	4802	4361
NZE					8099	6906	5557	4309	3138	2101
Biological treatment of solid waste, thousand tonnes of CO_2 eq										
WEM	35	7	17	24	57	67	109	148	189	229
WAM					106	210	214	202	185	142
NZE					106	210	212	190	153	59
Waste incineration, thousand tonnes of CO_2 eq										
WEM	34	9	12	10	8	11	13	14	15	16
WAM					8	11	13	14	15	16
NZE					8	11	13	14	15	16
Wastewater treatment and discharge, thousand tonnes of CO_2 eq										
WEM	9225	7457	7177	5662	5638	5902	5762	5513	5189	4793
WAM					5638	5902	5762	5513	5189	4793
NZE					5638	4777	3801	2761	1697	624
Total Waste sector, thousand tonnes of CO_2 eq										
WEM	16955	16289	16010	14622	14428	14627	14406	13599	12466	11119
WAM					13851	13029	11807	11009	10191	9312
NZE					13851	11904	9582	7273	5003	2800

Detailed descriptions of the scenarios and modeling methodology, as well as the investment volumes required to implement the LT-LEDS scenarios in the Waste sector, are provided in Appendix 3.

2.4.5.3. Overview of the Policy, Plans and Measures

General Overview

The [98]first municipal waste management strategy in Ukraine and its implementation plan[99] were adopted in 2017 and 2019, respectively. These documents outlined ambitious goals and specific steps to achieve them, supported by detailed economic calculations from international financial experts. One key target in the National Waste Management Strategy of Ukraine until 2030 was to reduce the municipal waste landfill rate from 95% in 2016 to 30% by 2030. However, due to the lack of a modern legislative framework for waste management at the time, as well as the absence of enforcement mechanisms and accountability for failing to implement approved policies and measures, these documents were only partially executed.

Moreover, Russia's full-scale military aggression against Ukraine in early 2022 had a severe negative impact on the country's ability to carry out effective reforms in the waste management sector. According to the report Ukraine: Rapid Damage and Needs Assessment, as of 2023, 5% of waste collection vehicles, 17% of biogas plants, and 9% of sorting lines had been destroyed or damaged. Direct losses in the waste management sector amounted to USD 95.36.

To widely implement modern waste management practices in Ukraine and align its national legislation with EU laws, a modern, ambitious law — Law of Ukraine No. 2320-IX "On Waste Management," dated 20 June 2022 — was adopted on 20 June 2022[100]. This law aims to implement the provisions of EU directives, including Directive 2008/98/EC on waste, certain provisions of Directive 1999/31/EC on landfill waste, the waste incineration provisions of Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control), and directives on specific waste streams covered by extended producer responsibility. It also aims to implement the Basel Convention on transboundary waste movement and other European regulations.

The new law is a framework law, so its core provisions are regulated by by-laws and sectoral laws, many of which are still being developed or are in draft form. Pursuant to the Law of Ukraine "On Waste Management," on 27 December 2024, the Cabinet of Ministers of Ukraine approved the National Waste Management Plan of Ukraine until 2033[101] and the Action Plan for the Implementation of the National Waste Management Plan of Ukraine for 2025–2033[102].

Strategic goals

The Law of Ukraine "On Waste Management" establishes that the main objectives of state policy on waste prevention and management are:

- Protect human health and the environment from the adverse impacts of waste;
- Implement waste management measures without posing a threat to human health or causing environmental harm beyond established standards for harmful physical impacts;
- Observe the waste management hierarchy;

[98] National Waste Management Strategy of Ukraine until 2030. Approved by Order of the Cabinet of Ministers of Ukraine No. 820-p of 08 November 2017 https://zakon.rada.gov.ua/laws/show/820-2017-%D1%80#Text

[99] National Waste Management Plan until 2030. Approved by Order of the Cabinet of Ministers of Ukraine No. 117-p of 20 February 2019 https://zakon.rada.gov.ua/laws/show/117-2019-%D1%80#Text

[100] Law of Ukraine No. 2320-IX of 20 June 2022 "On Waste Management". https://zakon.rada.gov.ua/laws/show/2320-20/ed20240629

[101] https://zakon.rada.gov.ua/laws/file/text/123/f542151n26.pdf

[102] https://zakon.rada.gov.ua/laws/file/text/123/f542151n27.pdf

- Introduce extended producer responsibility.

The key principles of state policy include prevention, the "polluter pays" principle, territorial proximity, and the creation of a competitive environment in the waste management sector.

The target indicator for HW management in Ukraine is defined in the National Waste Management Plan of Ukraine until 2033. This target is to reduce the total amount of HW sent to landfills to at least 30% by 2033, in line with EU legislation on reducing landfill disposal. Unfortunately, wastewater management in Ukraine receives very little attention, and effective mechanisms for reducing greenhouse gas emissions from wastewater management have not been developed.

Policy and Measures

To achieve the target of reducing HW disposal from the current level of about 90% to 30% by 2033, it is necessary to rapidly implement effective legislative mechanisms, modern waste management methods and technologies, and to develop the corresponding infrastructure.

Considering that the primary source of greenhouse gas emissions from waste management is the biodegradation of organic HW components such as food waste, paper and cardboard, garden and park waste, and personal hygiene products, the following measures are required for effective GHG emission reduction in the waste sector:

- Achieve the following levels of preparation for reuse and recycling of HW: by 2025 — at least 10% of total HW mass; by 2030 — at least 20%; by 2035 — at least 25%; by 2040 — at least 35%.
- Increase population coverage by waste management services to at least 85% by 2033.
- Implement source-separated HW collection systems in settlements, with annual population coverage growth of 10% starting from the second year of local waste management plans.
- Introduce composting of green waste from public parks and gardens for all settlements with populations over 100,000.
- Establish a nationwide network of regional landfills for HW disposal, which is estimated to require approximately 150 modern HW landfills, all equipped with effective landfill gas collection and utilisation systems.

These targets can be achieved through:

- Setting target indicators for reducing HW disposal at landfills and reducing the disposal of biodegradable HW;
- Implementing technical requirements for the production and use of waste-derived fuel (RDF/SRF);
- Upgrading the material and technical base for mixed HW collection and for source-separated HW not subject to extended producer responsibility;
- Establishing transfer stations for mixed household waste;
- Creating centers or mobile points for source-separated collection and preparation for reuse of HW not covered by extended producer responsibility systems;
- Conducting site surveys to determine locations for regional landfills or regional HW treatment facilities based on pre-defined optimal "coverage areas" or clusters;

- Installing scales and weighing devices for HW accounting at waste treatment facilities;
- Constructing HW treatment facilities, including mechanical-biological treatment for material recovery, composting, thermal treatment, and anaerobic treatment for biogas production;
- Installing sorting lines at landfills for non-hazardous waste to separate biodegradable waste and creating composting areas to reduce landfill disposal of biowaste;
- Phased closure of HW disposal sites (landfills and dumps) that do not comply with legislation, following the commissioning of new landfills;
- Establishing facilities for pre-treatment of biodegradable HW fractions at mechanical-biological treatment complexes or regional landfill sites;
- Creating effective wastewater sludge management systems and infrastructure for sludge treatment through the construction of new and expansion of existing treatment facilities.

Full and timely implementation of the National Waste Management Plan of Ukraine until 2033 and its Action Plan will allow the transition towards a circular economy in Ukraine. At the same time, these efforts alone will be insufficient to achieve significant GHG emission reductions in the Waste sector, even in the long term.

Substantial reduction of GHG emissions in the Waste sector by 2050 is possible only through a full transition of Ukraine's economy to a circular state. This is entirely feasible, as several countries already today have either virtually no landfilling of HW (Switzerland) or landfill rates not exceeding 1–2% (Belgium, Sweden, Denmark, Germany, Netherlands). An overview of HW management practices in European countries as of 2022 is provided in Appendix 3.

The NZE scenario envisages a full transition to a circular economy in Ukraine and is based on the broad implementation of the following technologies by 2050:

- Aerobic biological treatment (composting) of food and garden/park waste, and mechanical-biological treatment of waste with biogas and energy production (anaerobic decomposition of organic HW components) — up to 24% of total generated HW;
- Reuse and recycling of HW components (metals, glass, paper, plastics) — up to 47% of total generated HW;
- Mechanical-biological treatment for production of alternative fuels: SRF for the cement industry; RDF for centralised heating and/or electricity generation; Incineration of residual HW for centralised heating and/or electricity; Gasification/pyrolysis of HW for large energy-generating plants — up to 28% of total generated HW;
- Biological stabilisation of waste;
- Methane capture at landfills and dumps for energy production — up to 54% of total landfill methane generated in the country;
- Closure of old landfills and waste dumps and construction of flare installations (incineration, biocover, passive ventilation, etc.) for utilisation of up to 6% of total landfill methane generated in the country;
- Anaerobic treatment of wastewater sludge.

2.4.6. Land use, land-use change, and forestry

Agriculture is naturally closely related to the environment and, therefore, is highly dependent on climate change. On the one hand, it causes significant GHG emissions and is a source of these changes. Measures to reduce GHG emissions from agricultural activities can substantially mitigate climate change. However, the main condition for their implementation is sustainable agricultural production, the demand for which is constantly growing.

A unique feature of agricultural activity is its close connection with biological processes, including crop cultivation and livestock rearing. Thus, reducing GHG emissions to "zero" in this sector of human activity is impossible.

On the path to European integration, it is important to define priority directions, objectives, and effective ways to create favourable conditions for developing a competitive, resilient, and diversified agricultural sector. This sector will, in turn, ensure long-term food security for Europe and the world, protect the environment — including biodiversity — mitigate climate change impacts, and strengthen the socio-economic structure of rural areas. These and other related issues have laid the foundation of Ukraine's Strategy for Agricultural and Rural Development until 2030.

2.4.6.1. Agricultural Activities

The agro-industrial sector is an important part of the economy, consisting of two closely linked branches: livestock and crop production. Despite the overall trend of decreasing GHG emissions from agriculture, agriculture's contribution to total emissions gradually increased between 1990 and 2022 (Fig. 2.20).

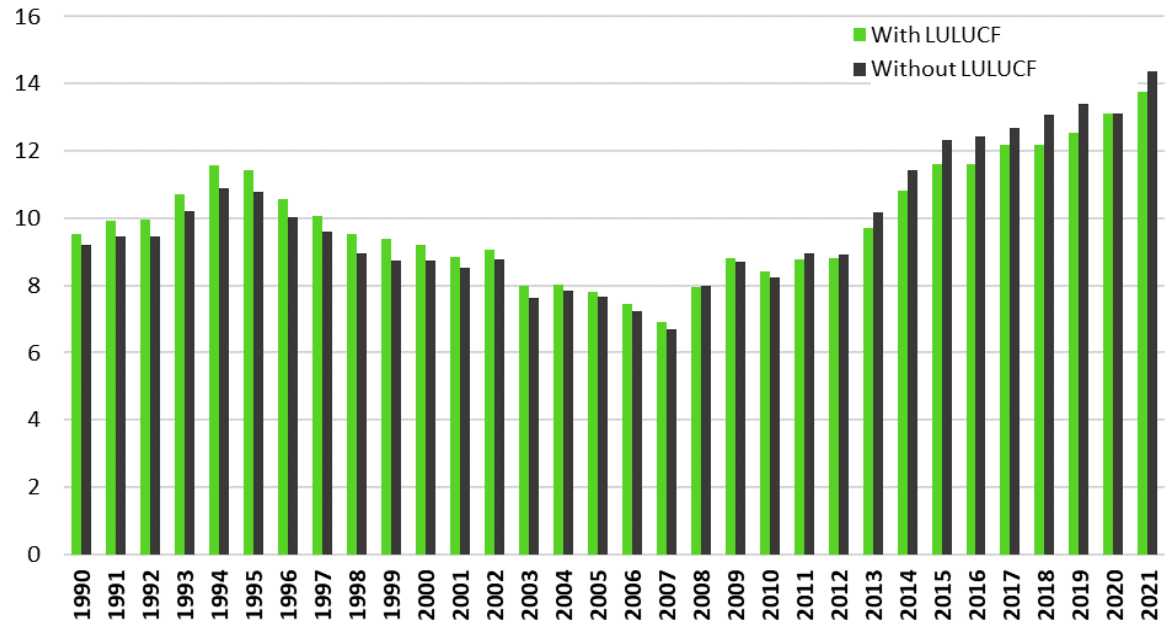


Fig. 2.20. Contribution of agricultural activities to GHG emissions in Ukraine, %

The key factors influencing the dynamics of GHG emissions in livestock farming are the number of agricultural animals and the manure management system, which collects, transports, stores, and uses manure.

The crop production sector, in turn, is more complexly structured; it has consistently developed and provided a significant share of exports. Thus, it is characterised by a greater number of key factors:

application of organic fertilisers	— the amount of organic fertilisers applied to arable soils;
application of organic fertilisers from livestock grazing	— the amount of manure that remains on the grazing fields of farm livestock;
Nitrogen input with crop residues	— the amount of nitrogen in plant residues (and thus the volume of residues) left on fields after harvest and ploughed into the soil;
cultivation of organic soils	— the area of organic soils allocated for crop production;
mineralisation or immobilisation of N related to organic matter movement in the soil	— the amount of N lost as a result of land use (tillage, fertiliser application, ploughing in of crop residues, etc.);
N volatilisation	— the amount of N introduced into the soil from various sources;
N leaching	— the amount of N introduced into the soil from various sources;
rice cultivation	— the area of agricultural land used for rice production and the amount of organic fertilisers applied;
urea application	— the amount of urea applied to arable soils;
soil liming	— the amount of liming materials applied.

The transition from a centrally planned to a market economy led to a decline in agricultural activity and a shift in the structure of the agro-industrial sector. A significant reduction in methane emissions has been observed, clearly reflected in changes in the distribution of GHG shares (Fig. 2.21).

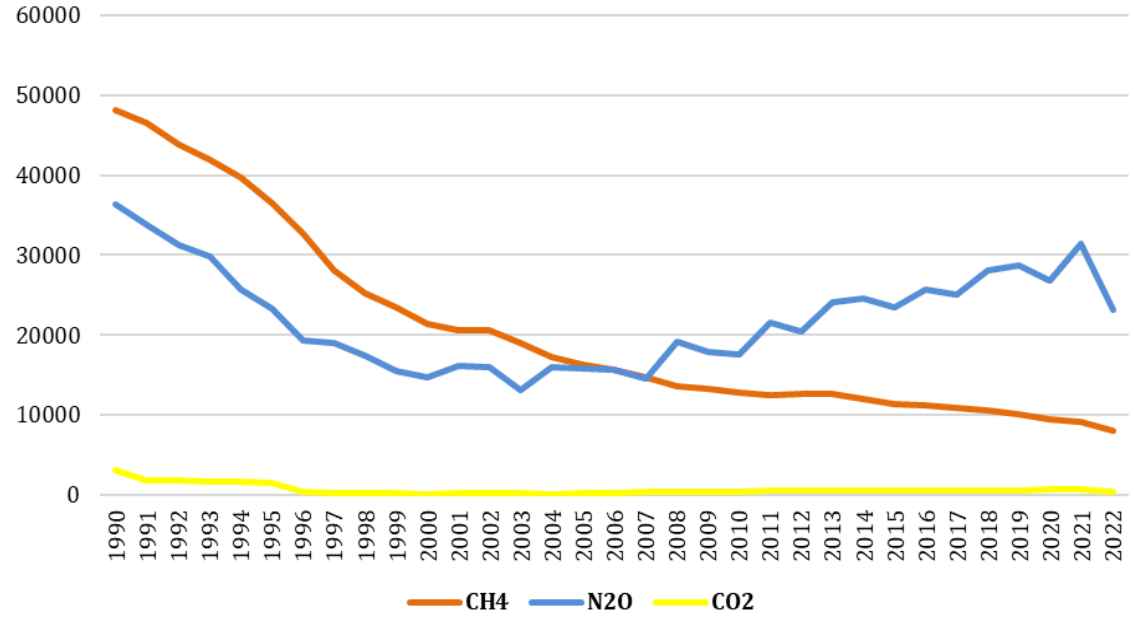


Fig. 2.21. Emissions of specific GHG types from agricultural activities, thousand tonnes of CO_2-eq

Source: Greenhouse gas emissions assessment from the draft National Inventory of Anthropogenic Emissions from Sources and Removals by Sinks of Greenhouse Gases in Ukraine for 1990–2022.

The recovery and stabilisation of crop production coupled with the significant decline of the livestock sector due to a sharp reduction in agricultural animal numbers (particularly cattle) have resulted in the Agricultural Soils category becoming the primary GHG emitter (Fig. 2.22).

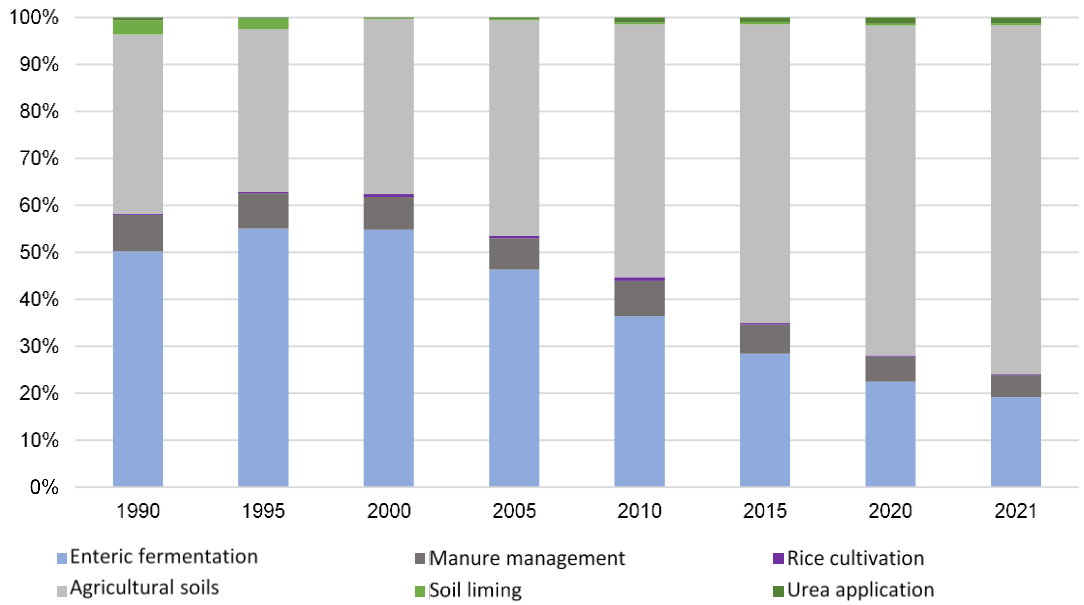


Fig. 2.22. Change in GHG composition in emissions from agricultural activities, %

The escalation of hostilities after 24 February 2022 led to a significant reduction in agricultural production. There was a decline in the livestock population, a change in the ratio of manure management systems, a decrease in the volume of applied mineral and organic fertilisers, a reduction in the land area occupied by field crops (both sown and harvested areas), and a decline in gross crop yields, and consequently, in productivity, etc.

Such changes led to a reduction in GHG emissions in 2022 by nearly 23% compared to the previous year (Figure 2.23), or down to 64% compared to the base year of 1990. The determination of forecasted GHG emissions from agricultural activities in 2030–2040–2050 will depend on numerous conditions, primarily the cessation of hostilities (both the current active conflict and the potential future confrontations with periodic escalations); the restoration of agricultural activities (reconstruction of destroyed/damaged livestock farms; demining of pastures, meadows, arable and other lands; restoration/replenishment of the mechanised component of agricultural activities, etc.); the recovery of population numbers and resettlement (migration from abroad; return to pre-war/pre-hostilities places of residence; settlement of temporarily displaced persons in new places of residence; natural population growth, etc.); the quality of demographic policy; the level of domestic demand for agricultural activities; the export potential of agricultural activities; and the national strategy for post-war recovery and development of agriculture.

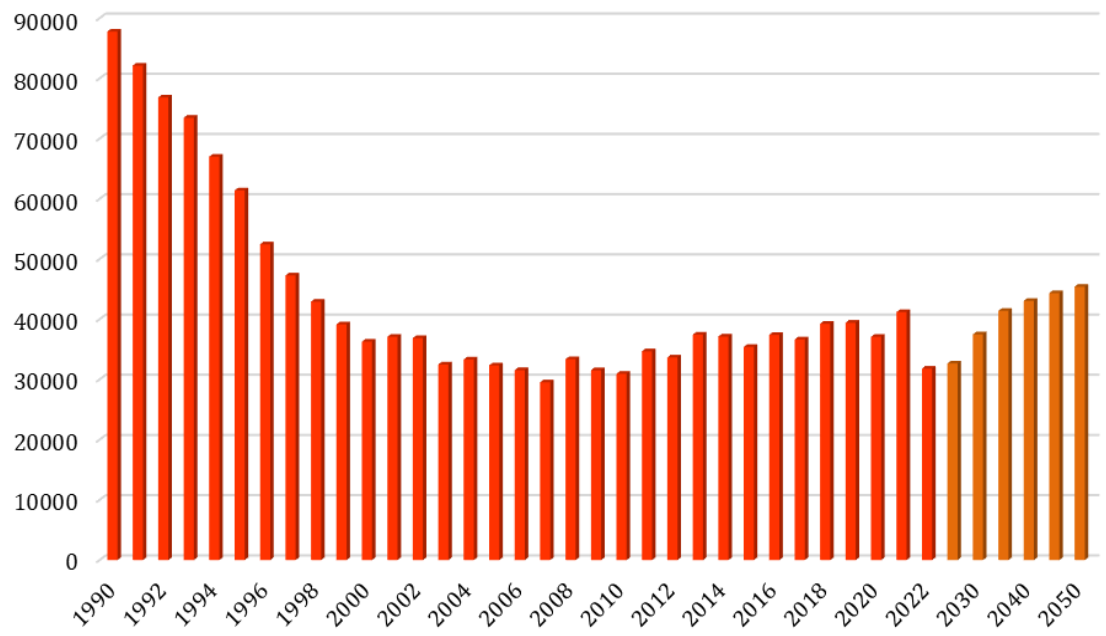


Fig. 2.23. Forecasted GHG emissions from agricultural activities, thousand tonnes of CO_2-eq

Assuming a rapid post-war recovery to pre-war growth rates and the preservation of the agro-industrial sector's development trajectory, it can reasonably be expected that GHG emissions will also increase, but will not exceed 52% of the baseline year's emission level.

Options for emission reduction

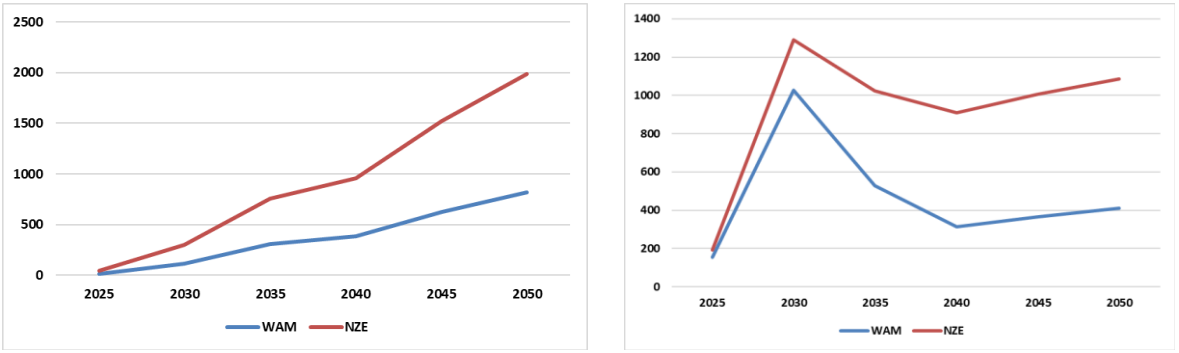
The baseline scenario for agro-industrial complex development (WEM scenario), based on the current (limited) level of implementation of current legislation, which entails a significant delay between policy formulation, its adoption, and implementation, will ensure a relatively slight increase in GHG emissions. Compared to the base year 1990, forecasted GHG emissions in 2030, 2040 and 2050 under this scenario will amount to 42.7%, 49.1% and 51.7%, respectively (Table 2.5).

Table 2.5. Dynamics of GHG emissions in the agro-industrial sector by scenarios, mln tonnes of CO_2-eq

Scenarios for the agro-industrial sector development	1990	2022	2025	2030	2035	2040	2045	2050
WEM Scenario	87.77	31.80	32.65	37.48	41.38	43.05	44.34	45.40
WAM Scenario	87.77	31.80	32.48	36.34	40.55	42.35	43.35	44.17
NZE Scenario	87.77	31.80	32.41	35.90	39.60	41.19	41.81	42.33

The implementation of measures for climate-oriented agricultural functioning may determine the reduction of GHG emissions, the scale of which depends on the scenario for implementing planned measures.

Thus, in the livestock sector, the most promising approach is the reduction of GHG emissions from changes in livestock manure management practices and from enteric fermentation in cattle, which can be achieved through the introduction of protein-concentrated feed into feeding rations. Depending on the scale of implementation of these measures, emission reductions of 17 to 45 thousand t CO_2-eq in 2025 and up to 818 to 1985 thousand t CO_2-eq in 2050 can be achieved (Fig. 2.24-a).



a) livestock farming b) crop production

Fig. 2.24. Effectiveness of climate-oriented agro-industrial sector development strategies, thousand t CO2-eq

In the crop production sector, three measures should be considered: the development of organic production, the use of nitrogen fertilisers with slow or controlled release of active substances, and the use of information and telecommunication technologies in crop production, as outlined in the Agricultural and Rural Development Strategy of Ukraine until 2030. Their implementation may lead to GHG emission reductions from 154 to 194 thousand t CO_2-eq in 2025 to 410 and 1085 thousand t CO_2-eq in 2050 (Fig. 2.24-b).

The differences in the timing of peak efficiency for these strategies are due to various key factors, such as global trends, market demands, technological development, etc.

Policy for Agricultural Development

Under the Agricultural and Rural Development Strategy of Ukraine, developed considering the need for changes in state policy implementation in the agricultural sector, measures will be taken to address several issues, including the deterioration of food security levels, low competitiveness, biodiversity loss, increased negative impact on ecosystems, low effectiveness of environmental conservation measures, and landscape preservation, etc.

To develop climate-oriented agriculture, qualitative and quantitative development of livestock farming, organic crop production, bioenergy, etc., is envisaged.

Feed additives in the feeding system of agricultural animals. The use of protein-concentrated feeds (bypass products) containing protein protected from ruminal degradation, which remains undigested after passing through the rumen and is well-digested in the stomach and intestines, reduces the intensity of rumen microflora activity in ruminants, prevents the development of acidosis, and leads to a reduction in methane emissions. These bypass products can constitute a significant portion of a balanced diet for cattle. Laboratory studies have shown that incorporating up to 20% bypass products in the concentrate feed of cattle diets contributes to more than a 10% reduction in

methane emissions. Bypass products are in the development stage, and further research will enhance their efficiency and expand their application.

Improvement of manure management practices. The decomposition of farm livestock manure leads to GHG emissions. It is manure management that is the key factor which can help regulate emission intensity. The main limiting factor for implementing an environmentally safe system is the structure of the enterprise, the number of animals kept, etc. Therefore, despite significant potential, this measure cannot be applied to all livestock enterprises. The most promising option for implementing this measure is using animal manure for biogas production.

Organic crop production. The development of organic agriculture is one of the priority areas for the medium-term "green transformation" of agriculture. Organic crop production is a well-established practice and can play an important role in climate change adaptation. This type of farming is based on the exclusion of chemical substances (primarily those contributing to GHG emissions) from crop cultivation technology. From this perspective, it is considered a low-carbon agricultural system. Ukraine has significant potential for organic agriculture but requires substantial financial support.

Use of information and telecommunication technologies in crop production. This measure aims to optimise the use of agrotechnologies in crop production, primarily by reducing GHG emissions from excessive irrigation and fertiliser application. Information and telecommunication technologies, such as drones and satellite imagery, facilitate the development and refinement of soil maps and the assessment of crop conditions. These technologies help identify specific fields or field sections that require additional fertilisation, thereby also reducing fuel and fertiliser consumption. This measure also has additional benefits in reducing GHG emissions due to decreased use of machinery for irrigation and fertiliser application, etc.

Use of nitrogen fertilisers with slow or controlled release of active substances. Mineral nitrogen fertilisers contain nitrogen in compounds that decompose easily, releasing it. Therefore, they are characterised by significant losses of active substances through leaching or volatilisation. To compensate for these losses, increased fertiliser rates and multiple applications are practised. New forms of mineral fertilisers with slow or controlled nitrogen release are capable of meeting the need for fewer applications at lower rates. The abovementioned fertiliser savings will also have an additional positive effect on reducing GHG emissions by lowering the demand for their production.

2.4.6.2. Forestry

Current State

According to Ukraine's annual GHG inventory, forests are net absorbers of GHGs, absorbing 24–41 million tonnes of CO_2-eq per year. On the one hand, this trend is determined by the variability of carbon losses from biomass due to natural (extreme weather events) or anthropogenic causes (logging). On the other hand, this trend is also influenced by the process of afforestation on lands previously used for other purposes (e.g., former arable land or pastures).

The increasing demand for biomass is driving more intensive use of woody biomass. In particular, whereas in the early 1990s, around 12 million cubic metres of timber were harvested annually, by 2021, this volume had risen to nearly 18 million cubic metres. Moreover, hostilities and the heightened need for timber for fortifications, as well as for rebuilding destroyed buildings and

infrastructure, will further increase demand, which in turn will lead to an overall reduction in the volume of GHG removal by forests (see Fig. 2.25 and 2.26).

Another factor contributing to increased GHG emissions from forests is timber loss due to forest stand damage caused by fires, pests, diseases, and other adverse events (Fig. 2.26). Despite strengthened forest protection measures, which have somewhat reduced the areas affected by adverse events in 2017–2021 (except for wildfires in 2020), the affected areas are still almost twice as large as in the early 1990s.

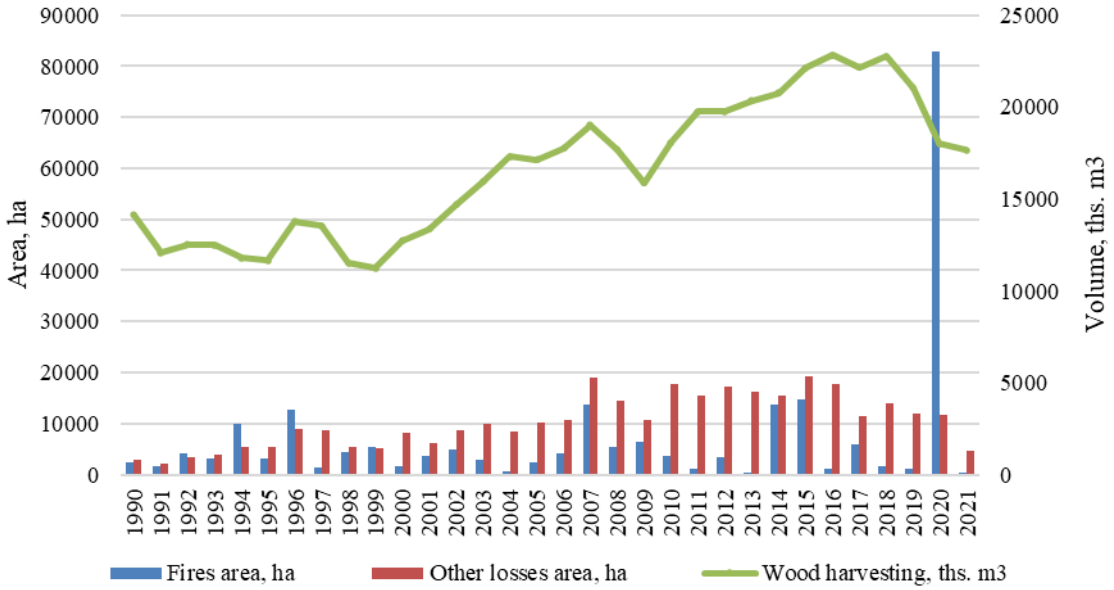


Fig. 2.25. Timber harvesting volumes and forest areas damaged by adverse events

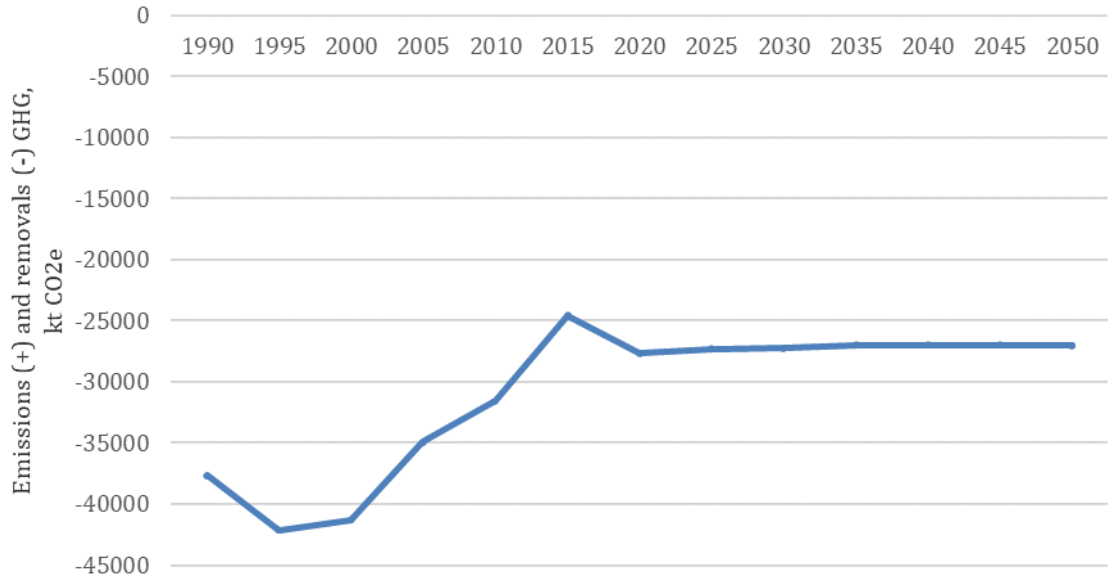


Fig. 2.26. GHG removal by forests under the baseline scenario

At present, Ukraine has adopted the State Forest Management Strategy of Ukraine until 2035, as well as the Operational Action Plan for its implementation for 2025–2027[103]. The Strategy sets out a range of strategic objectives in the areas of effective forest governance, environmental sustainability, the contribution of forests to economic development, recreation, open society, research and education.

The Strategy defines qualitative targets and quantitative indicators including, inter alia: increasing the national forest cover to at least 18%; raising the level of GHG absorption by forests to 75.6 million tonnes of CO_2-eq; increasing the total growing stock of Ukraine's forests to no less than 2.5 billion cubic meters.

In addition, the objective of increasing forest area was included in the State Environmental Policy Strategy of Ukraine until 2030[104], which sets a target to raise forest cover to 17.5% by 2030. However, given the lack of effective implementation instruments, particularly financial mechanisms, this target has remained largely declarative.

The absence of clearly defined implementation tools does not imply a complete lack of activities related to afforestation or the protection of forests from damage caused by fires, pests and diseases. For example, in 2017–2021, afforestation was carried out on an area of 1.7–3.2 thousand hectares. However, these efforts are of purely economic significance at the local level and lack nationwide coherence or a significant impact on GHG removal levels. Under this afforestation trajectory, forest cover could reach 16.1 % by 2050.

Emission Reduction Options and Measures to Achieve Them

The primary factor considered when developing forecasts for potential forest carbon sequestration scenarios is forest area. In particular, the key measure is afforestation on lands previously not covered by tree vegetation.

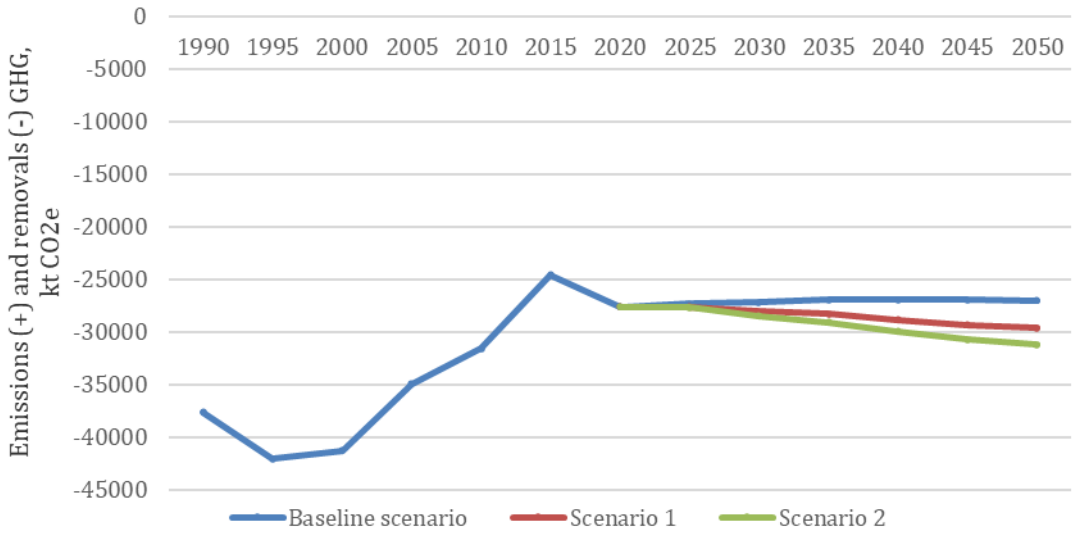


Fig. 2.27. Forecasted GHG removal volumes by forests across scenarios

[103] Resolution of the Cabinet of Ministers of Ukraine No. 1356-r dated 28 November 2025 "On the Approval of the Operational Action Plan for the 2025–2027 Implementation of the State Forest Management Strategy of Ukraine until 2035" https://zakon.rada.gov.ua/laws/show/1356-2025-%D1%80#Text

[104] Law of Ukraine No. 2697-VIII of 28 February 2019 "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine Until 2030," https://zakon.rada.gov.ua/laws/show/2697-19#Text

Under different afforestation scenarios, removal levels of up to 27 million tonnes of CO_2-eq per year can be achieved (Fig. 2.27). Forecasting did not assume significant changes in timber harvesting volumes or losses due to adverse events in the future. This is partly due to the lack of more specific quantitative targets on this issue in strategic documents, as well as the balance between the ecological, social and economic roles of forests that will be maintained in future forest planning and management.

Afforestation. Expanding forested areas is the simplest yet one of the most effective ways to increase removal in this category. Historically, since 1990, afforestation has always been present, but it peaked in 2005–2015, when a state programme for planting new forests was in effect (see Fig. 2.28).

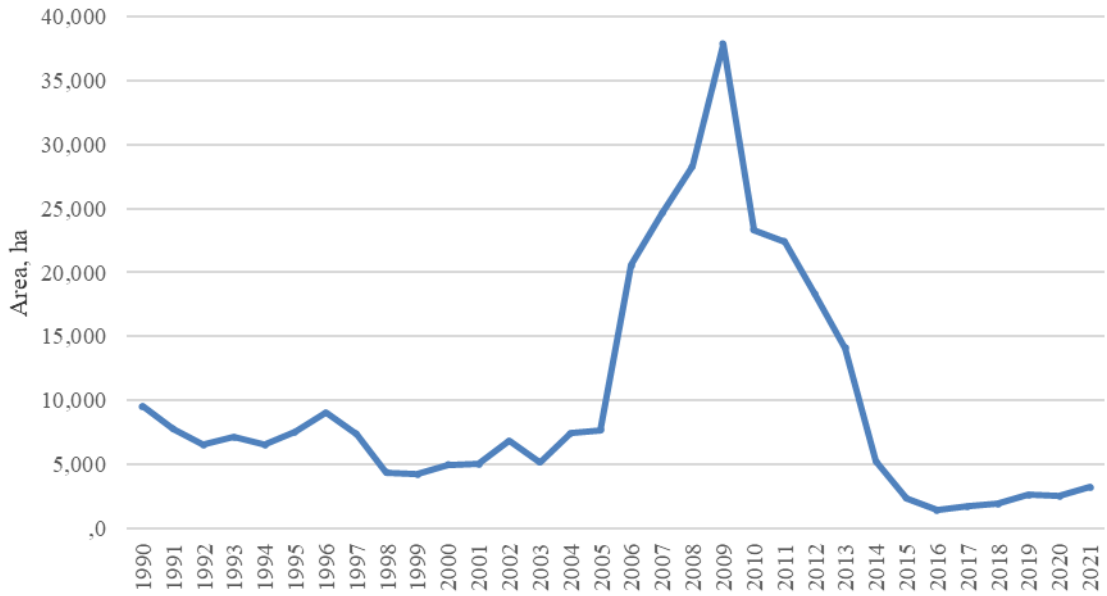


Fig. 2.28. Afforestation area, ha

Considering that forested land in Ukraine covers about 10.4 million hectares, of which approximately 9.7 million hectares are covered, the afforestation rates of 2015–2021 will not allow for a substantial increase in removal in this category. However, under the most favourable conditions for afforestation (as in 2009, for example), Ukraine could gain 1 million hectares of new forests by 2050.

The relative success of the state programme in 2005–2015 was due to government funding for all afforestation activities. At the same time, several obstacles were identified that should be taken into account in the future. In particular:

- the availability of free land areas not subject to other types of land use when planning afforestation in different regions;
- the willingness of communities to allocate land for forests when other alternative uses are available, including the preservation of naturally regenerated areas;
- the lack of motivation from funding sources apart from the state one.

Given the significant land degradation caused by military operations and the heavy presence of land mines in certain regions of Ukraine, it is expected that, in the medium term, a large area of land may become unsuitable for agriculture. Consequently, afforestation on these lands could serve as an alternative.

Special attention should be given to lands where forests have naturally regenerated. Often, such areas have long remained unused for their primary purpose (most commonly, agricultural use). Considering possible alternative land uses and the restrictions imposed by forestry legislation, owners of such plots often do not wish to preserve naturally regenerated forests. Therefore, mechanisms should be developed to encourage the preservation of these naturally regenerated areas, for example through financial compensation, allocation of alternative land plots in other locations, securing land ownership, or granting forest plots into private ownership.

For forecasting potential afforestation scenarios, experience and data from previous years were used, with particular attention to the duration of the "Forests of Ukraine 2002–2015" state program. For scenarios 1 and 2, the average and maximum afforestation areas achieved in the past were used. This approach allows a significant approximation to the strategic afforestation goals set out in strategic planning documents. Climate-smart forestry. Traditional forestry in Ukraine is focused on maximising the yield of high-value tree species common in Ukraine (pine, oak, ash, walnut, spruce, and others). Other types of forest use (e.g., gathering berries, mushrooms, and firewood) also exist but are not widely practised. Key assumptions and indicators underpinning the forestry forecast are presented in Table 2.6.

The philosophy behind maximising revenue from timber harvesting centres on the trunks of the most valuable tree species. However, carbon is stored in all forest components, including those with no significant commercial use (understory, litter, deadwood, small branches, needles, and leaves). Due to existing forestry practices, this carbon is often lost (e.g., through the burning).

Table 2.6. Forecast assumptions for forestry development

Indicator		1990	2000	2010	2020	2025	2030	2035	2040	2045	2050
Area covered by forest vegetation, '000 ha	BAU	8,815	9,414	9,517	9,472	9,624	9,636	9,648	9,660	9,672	9,684
	S1					9,645	9,764	9,882	10,001	10,119	10,238
	S2					9,659	9,848	10,038	10,227	10,416	10,605
Annual afforestation area, thousand hectares	BAU	9.55	5.00	23.32	2.54	2.4	2.4	2.4	2.4	2.4	2.4
	S1					23.7	23.7	23.7	23.7	23.7	23.7
	S2					37.84	37.84	37.84	37.84	37.84	37.84
Total timber harvesting volume, thousand m^3	BAU, S1, S2	14127	12735	18064	17989	20360	20360	20360	20360	20360	20360
Forest cover, %	BAU	14.6	15.6	15.8	15.9	15.9	16	16	16	16	16
	S1					16	16.2	16.4	16.6	16.8	17
	S2					16	16.3	16.6	16.9	17.3	17.6
Net balance of greenhouse gas removals and emissions by forests, thousand tonnes of CO_2e	BAU	-37652	-41268	-31571	-27649	-27311	-27212	-26960	-26959	-26987	-27017
	S1					-27635	-28058	-28326	-28846	-29344	-29640
	S2					-27705	-28473	-29086	-29951	-30761	-31234

Another aspect of climate-oriented forestry is protecting carbon stocks from losses due to natural disasters (fires, pest outbreaks, and diseases). In recent years, the area affected by these events has increased significantly, along with the volume of timber. This is, not least, due to inadequately predicted climatic conditions and insufficient consideration or research of tree species characteristics.

Priorities for climate-oriented forestry must include:

1. Preserving carbon stocks in biomass that is not used commercially;
2. Protecting forests from adverse natural events and minimising biomass losses caused by them;
3. Taking into account current and future climate changes when designing measures and managing forestry.

Given the growing demand for timber in the future, it is unlikely that the total harvested timber volume in the forests will decrease. However, with extensive afforestation, the intensity of use per hectare will be lower, enabling the achievement of strategic sustainable forest management goals.

2.4.6.3. Arable land

Current status

Crop production has traditionally been highly developed in Ukraine, facilitated by climatic and, particularly, soil conditions. Crop production also has significant export potential, and market demand for exports has dictated the development of agriculture in Ukraine.

Since 1990, the structure of crop production has changed. Traditionally, the most commonly grown crops are cereals, especially wheat and maize. In recent years, strong demand has led to a significant increase in the cultivation of oilseed crops (maize, soybeans, rapeseed), driven by the use of these crops as biofuel feedstocks (Fig. 2.29).

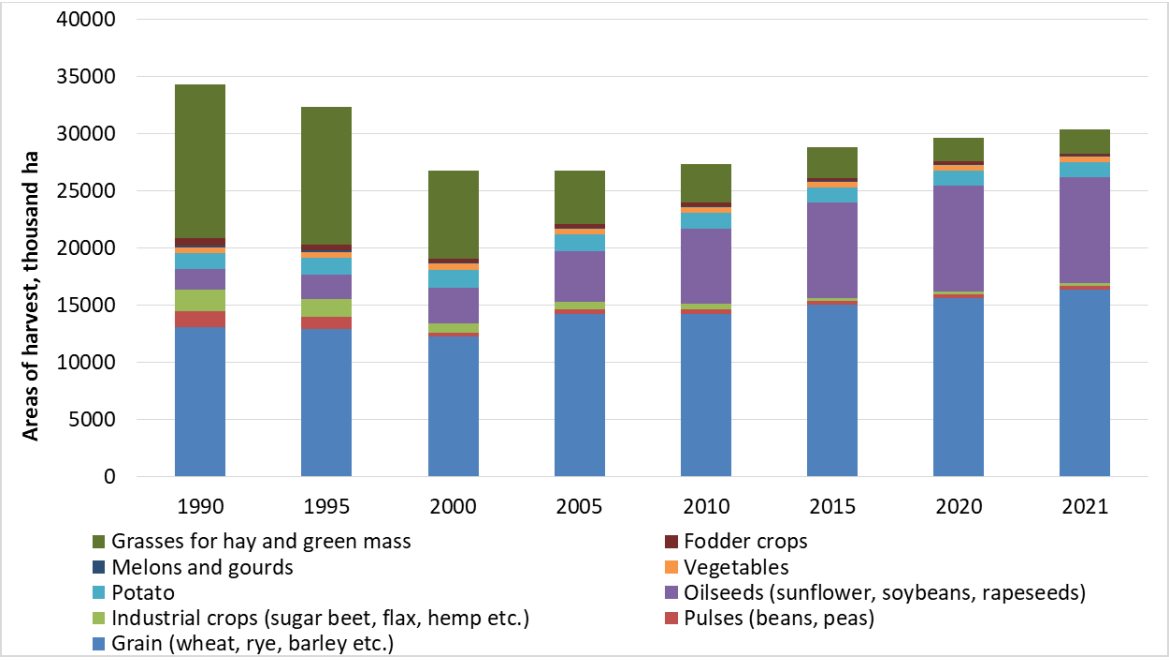


Fig. 2.29. Structure of Agricultural Crop Cultivation

This cultivation structure, along with the reduction in total fertiliser application due to a decrease in livestock numbers (cattle and pigs), has led to a significant increase in emissions from this activity. Specifically, in the 1990s, greenhouse gas absorption reached up to 20 million tonnes of CO_2-eq, whereas in recent years, emissions have risen to 30 million tonnes of CO_2--eq.

Currently, 57.5% of Ukraine's agricultural soils are affected by erosion, and these processes continue. According to the National Target Programme on Land Use and Protection[105], transforming degraded lands through grassland establishment, afforestation or renaturalisation can help expand areas under protected natural reserves and increase forest-covered lands. Ukrainian legislation provides a procedure for land conservation, but so far there are only isolated examples of removing small plots from agricultural use, including withdrawing arable land to restore steppe phytocenoses. Therefore, simplifying and further promoting land conservation is a necessary measure.

A draft Strategy for the Development of Agriculture and Rural Areas in Ukraine until 2030 has been developed to establish goals for agricultural development in Ukraine, including crop production. Certain elements from the draft strategy have been incorporated into the modelling of projected emissions and removals of GHG (Fig. 2.30).

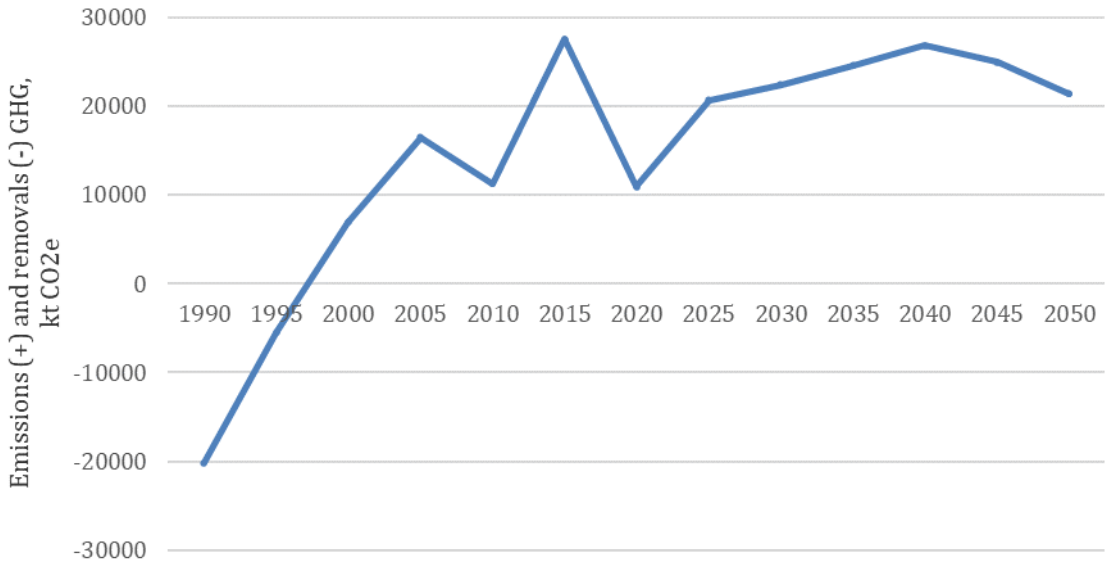


Fig. 2.30. GHG Emissions and Removals from Arable Land Under the Baseline Scenario

The baseline scenario includes the continuation of the state programme supporting horticulture, berry farming, and viticulture, eWork. In particular, state funding for the creation of fruit and berry orchards, as well as vineyards, has led to the creation of around 900 ha of plantations annually.

However, current strategic documents lack information regarding policy plans for agroforestry (combining agricultural and forestry land use). Specifically, this policy could encompass a wide range of possible implementations. Ukraine has considerable experience with one of these methods — protective forest strips. The uncertainty of state policy regarding protective forest strips has led to a reduction in their area and a lack of motivation for their establishment.

[105] Concept of the Nationwide Targeted Programme for Land Use and Protection approved by Order of the Cabinet of Ministers of Ukraine No. 70-p of 19 January 2022. https://zakon.rada.gov.ua/laws/show/70-2022-%D1%80#Text

Projected Emission Reduction Options and Measures to Achieve Them

As experience from previous years shows, arable land can even act as a sink for GHG (as in the 1990s). The active development of crop production and economic incentives for growing specific types of crops has led to higher yields, while nitrogen input into the soil, along with fertilisers, has not kept pace.

The modelling of potential GHG emission reductions from arable soils is based on managing soil nitrogen and improving fertiliser efficiency. As a result, GHG emissions could be reduced by more than half compared to the baseline scenario (Fig.2.31).

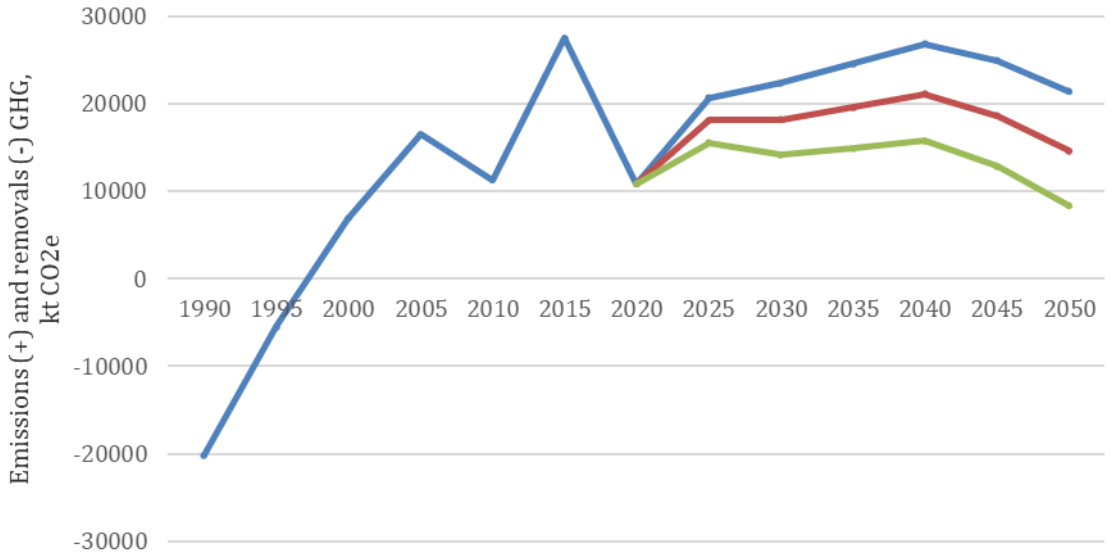


Fig. 2.31. Projected GHG emissions and removals from arable land across scenarios

Additionally, an extra factor in reducing GHG emissions is increasing removal through the creation of perennial woody plantations in the form of protective forest strips and fruit orchards.

Shelterbelt afforestation and agroforestry (combining agricultural and forestry land use). Field-protective forestation in Ukraine has a long history. Planting trees between fields was an experiment conducted in Poltava Oblast as early as the beginning of the 19th century. After World War II, forest belts were actively created in the forest-steppe and steppe regions.

After Ukraine's independence, attention to forest belts waned. However, with the increasing global focus on combating climate change, attention has once again turned to protective forest belts, particularly as a method of agroforestry.

In general, agroforestry is an alternative method of increasing forested areas without fully abandoning high-productivity agriculture. Moreover, under certain conditions, agroforestry does not reduce crop yields due to its positive impact on field microclimates. Furthermore, agroforestry serves as an adaptation measure to climate change, as it can improve microclimatic conditions in fields.

Accumulated scientific knowledge and practical experience make agroforestry in Ukraine highly promising. It also contributes to increased GHG absorption. According to various estimates, forest belt areas should be created over 120,000–150,000 hectares, potentially providing GHG absorption of up to 0.5 million tonnes of CO_2-equivalent.

Taking into account certain challenges in the development of shelterbelt afforestation, particularly with regard to land allocation and financing of these activities, the projections are based on the assumption of the annual establishment of 1 thousand hectares and 2 thousand hectares of shelterbelts for Scenarios 1 and 2, respectively. Accordingly, under Scenario 2, an additional 52 thousand hectares of new shelterbelts may be established by 2050.

Increased nitrogen input in soils. The cultivation of oilseed crops increases the demand for key nutrients (nitrogen, phosphorus, potassium) in the soil. From the perspective of GHG emissions, nitrogen application is particularly significant.

Sources of additional nitrogen in soils include plant residues, organic and mineral fertilisers, and compost. The amount of plant residues left on fields depends directly on whether there is an alternative use for them. For instance, using plant residues (straw) for bioenergy reduces the need for nitrogen input in the soil, requiring compensation from other sources.

The application of organic fertilisers directly depends on the amount of organic matter generated in livestock farming; thus, the direction of livestock development will also impact crop production. Furthermore, the use of animal manure for bioenergy requires further research into the impact of methane tanks on organic fertilisers and GHG emissions from soils.

Not very common fertiliser type in Ukraine, compost, could become an additional nitrogen source. Composting could involve food industry waste, household organic waste, livestock waste, plant organic matter, and others. Mineral fertilisers will remain one of the most common sources of nitrogen input in soils.

Measures for additional nitrogen input in soils must adhere to the following principles:

- consistency — carbon emission reductions must not lead to higher direct and indirect N_2O emissions from agricultural soils;
- efficiency — increased nitrogen input must be focused on the lands and areas of fields that require it;
- synchronisation — measures in other sectors should be considered in agriculture when they relate to agricultural products and materials.

Cultivation/drainage of organic soils. Ukraine has nearly 0.5 million hectares of agricultural land that can be classified as organic (peat) soils, and drainage continues in these areas. These soils are characterised by a high organic carbon content, which is actively lost under drainage conditions. This leads to a loss of soil fertility. Due to the use of drained organic soils for agriculture (crop production, livestock grazing, and haymaking), approximately 2.3 million tonnes of CO_2 are emitted annually, with an additional 1.6 million tonnes of CO_2-eq emitted in the form of direct N_2O emissions (2021 data).

Numerous studies show that the drainage and use of organic soils for crop production quickly depletes them. Consequently, the economic benefits of cultivating organic soils also diminish rapidly. Moreover, often being swampy or excessively wet, these areas play an exceptionally important role in providing fresh water to regions, serve as habitats for many plant and animal species, and, most importantly, conserve carbon, preventing it from being released into the atmosphere as CO_2.

For the purposes of the projections, an assumption was made regarding the conversion of 45 thousand hectares and 90 thousand hectares of organic soils used for agricultural crop production

into grassland and pastureland under Scenarios 1 and 2, respectively. As a result, emissions can be reduced by 0.8 million tonnes of CO_2-eq and 1.6 million tonnes of CO_2-eq under Scenarios 1 and 2, respectively.

Priorities for the use of organic soils in agriculture should be:

1. Rewetting of areas, particularly those no longer used for agriculture;
2. Avoiding drainage of new areas for agricultural use;
3. Conversion of arable organic soils into areas with permanent grass or tree cover, which slows CO_2 emissions.
4. Prevention of the cultivation of carbon-rich ecosystems, in particular steppes and peatlands.

3. FUNDING

3.1. ASSESSMENT OF REQUIRED INVESTMENTS

3.1.1. Current State Overview

The volume of required investments depends significantly on the chosen scenario for achieving carbon neutrality: within the framework of already implemented measures, with additional measures, or through an accelerated transition to net-zero emissions. According to these scenarios, implementing decarbonisation measures in key sectors (energy, industry, waste) in Ukraine will require investments ranging from EUR 0.6 to EUR 1.0 trillion from 2024 to 2050 to achieve zero carbon emissions (Table 3.1.). This sum exceeds Ukraine's 2023 GDP by 3.3–5.6 times[106].

Table 3.1. The amount of investment required to implement the LT-LEDS goals in the areas of energy, industrial processes and the waste sector

	2024–2027	2028–2032	2033–2037	2038–2042	2043–2047	2048–2050	Total
WEM scenario* — amount, billion EUR	25,233	67,260	89,489	140,425	170,450	94,741	587,598
Share of total investment amount, %	4.3%	11.4%	15.2%	23.9%	29.0%	16.1%	100.0%
WAM scenario* — amount, billion EUR	35,775	119,666	123,110	179,637	205,417	130,737	794,343
Share of total investment amount, %	4.5%	15.1%	15.5%	22.6%	25.9%	16.5%	100.0%
NZE scenario* — amount, billion EUR	36,480	119,025	160,553	199,926	290,577	195,541	1,002,103
Share of total investment amount, %	3.6%	11.9%	16.0%	20.0%	29.0%	19.5%	100.0%

** WEM — the scenario with existing measures, same as in the NECP*
WAM — the scenario with additional measures, same as in the NECP
NZE — Net-zero emissions scenario

The sectors requiring the most investment will be those related to energy production, supply and transportation. On average, 37.4% of the investment needs will be directed toward these sectors during the strategy's implementation. Another 32.9% of investments will be needed for transport modernisation; 18.2% for the household sector. At the same time, the need for investment also has a temporal differentiation (Fig. 3.1).

[106] This aligns with IFC calculations, which suggest that Ukraine will need USD 73 billion in green financing between 2021 and 2030. NSSMC Recommendations on green bonds. URL: https://www.nssmc.gov.ua/wp-content/uploads/2021/11/211122_green_bonds_ifc_2.pdf

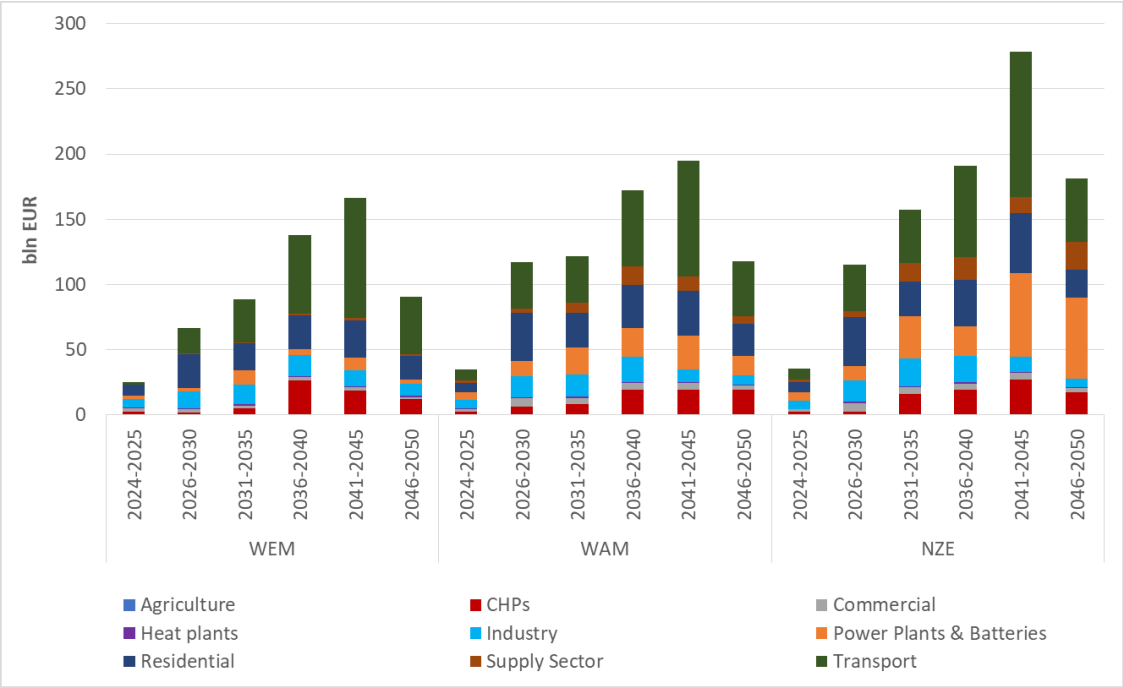


Fig. 3.1. Investment needs by sector for 2025–2050 under different scenarios, EUR billion

Thus, the share of investments in agriculture, services, water heating, and industrial production will gradually decrease over time. Meanwhile, investments in power stations, energy storage systems, households, and transport will continue to require significant amounts of money. The transition to net-zero emissions will increase the need for investment in power stations and renewable energy sources (RES). This structure of investment needs accordingly determines the dynamic target segmentation of credit-investment products in the green finance market. According to the defined structure, it is advisable to launch a large-scale credit programme for household sector decarbonisation starting in 2026, implement extensive financing instruments for transport projects during 2026–2045, and focus on the power generation and UES sectors in 2040–2050.

At the same time, it is worth noting that the level of green financial instrument usage in Ukraine does not meet the needs of implementing the LT-LEDS goals and fails to keep pace with the EU level. The main intermediaries in the financial services market — banks — only sporadically issue loans for green transition goals in general and only indirectly for decarbonisation goals. The exact volumes of green loans issued by banks or carbon credits issued in Ukraine are unknown, as the statistics for verified green instruments are currently unavailable. It is worth noting, however, that the number of bank energy-efficiency programs increased in 2024, thanks to international financing.

As of the end of 2024, only two large green bond issues have been made in Ukraine[107]. At the same time, expert estimates suggest that the potential of the green finance market in Ukraine is USD 73 billion by 2030. Of these, almost half — USD 36 billion — represents the potential of the green bond market.[108]

[107] In particular, DTEK raised EUR 325 million for 5 years with a yield of 8.5% on the Irish Stock Exchange, and NEC Ukrenergo raised USD 825 million for 5 years at a coupon rate of 6.875% on the London Stock Exchange. In 2025, the rate increased to 8.5% as one of the options for green bondholders. (https://www.eximb.com/eng/bank/press/no vyny-banku/news-list/ukreximbank-became-a_co-manager-of-the-debut-issuance-of_eurobonds-of-nec-ukrenergo.html).

[108] https://www.kmu.gov.ua/news/uryad-shvaliv-koncepciyu-zaprovadzhennya-ta-rozvitku-rinku-zelenih-obligacij-v-ukrayini

The largest volumes of funding for decarbonisation measures come through international programmes involving international financial organisations[109] This source is expected to continue to dominate in the coming years[110]. The above creates the need for special measures to resolve issues in the financial sector. The goal is to use both domestic and foreign capital to achieve the LT-LEDS goals, with a focus on attracting foreign capital.

Key challenges in financing the LT-LEDS goals in Ukraine include:

- weakness of financial markets, especially the securities market, a limited range of instruments;
- high country risk, which increases the cost of financial instruments and limits the interest of private foreign investors;
- the continuation of hostilities and the unconditional priority of military funding, which creates the risk of redirecting funds allocated for decarbonisation programmes and continues to create adverse conditions for attracting and supporting private and international investments;
- gaps in the legal and regulatory framework and institutional structure, caused by the novelty of the issues, which slow down the expansion of green financing, particularly regarding the proper institutional arrangements for the use of green bonds, carbon credits, certificates, and the like.
- insufficient attractiveness of domestic capital markets and the lack of material interest from domestic investors in green projects;
- low awareness among enterprises, local authorities, financial organisations, and potential investors about the benefits provided by low-carbon, climate-oriented, and ecological programmes.

3.1.2. Existing Financial Instruments for Decarbonisation

Over the past three years, despite the war, Ukraine has made significant progress in employing specialised financial instruments to accelerate decarbonisation processes. At present, these instruments include:

Carbon tax. Introduced in Ukraine in 2011 and revised upwards in 2022. At a rate of UAH 30 per tonne of CO_2, revenues from the CO_2 emissions tax remain relatively stable, contributing UAH 1.7–2.0 billion annually to the budget[111]. However, in its current form, this tax is among the lowest in the

[109] In 2023, under the participation of international organisations, projects in Ukraine were financed with a total value of EUR 4.4 billion. In 2024, only 18 projects, amounting to over EUR 4.2 billion, were implemented in the energy sector with the participation of international financial organisations, and 14 projects, worth over EUR 4.2 billion, were implemented in the transport sector. A significant portion of these will result in reducedCO_2 emissions.

[110] In early 2024, the European Council supported a revision of the EU budget, which includes EUR 50 billion for macro-financial support to Ukraine under the Ukraine Facility programme in 2024–2027. The programme envisages the allocation of EUR 38.27 billion to the Ukrainian state budget to strengthen macro-financial stability and EUR 6.97 billion through a special investment instrument to cover investor risks in priority sectors via the EBRD, EIB, and other international institutions.[17] The implementation of projects within this instrument is expected to attract an additional EUR 30 billion in investment.

[111] According to OpenBudget, revenues in 2023 are UAH 1.95 billion; as of August 2024, they are UAH 1.48 billion. The revenue plan for 2025 is UAH 1.75 billion, and for 2026 — UAH 1.87 billion.

world and is 73 times lower than the EU average (EUR 49.2).[112] Besides, it does not provide full coverage of CO_2 emissions, encompassing only up to 32% of CO_2[113] emissions (in the ferrous metallurgy sector, the share of non-taxed emissions reaches up to 60%; emissions from transport and agricultural production are not subject to taxation). Increasing the tax to the average European level would mobilise up to UAH 65 billion (approximately EUR 1.45 billion at the current exchange rate) annually. Expanding the tax base to include a broader range of CO_2 emission sources would allow this sum to increase two- to threefold.

State Fund for Decarbonisation and Energy-Efficient Transformation. Established within the special fund of the State Budget in May 2023. The sources of revenue for this fund include state budget revenues (from the environmental tax and state borrowings, as well as other sources). In 2024, UAH 759 million was allocated to this Fund. The Fund's instruments are aimed at compensating interest on loans and leasing agreements through the Decarbonisation Fund of Ukraine.

JSC Decarbonisation Fund of Ukraine. Established in 2012, its statutory capital was regulated by the Order of the Cabinet of Ministers of Ukraine, dated 21 June 2024, providing for funding from the special fund of the State Fund for Decarbonisation and Energy-Efficient Transformation. On 26 August 2024, the Decarbonisation Fund of Ukraine obtained a financial institution licence from the NBU. In addition to funds from the State Fund for Decarbonisation and Energy-Efficient Transformation, its financial sources may include state borrowings and international investor contributions. The objectives of the Fund include: financing state-targeted programmes, implementing financial and credit mechanisms in the field of energy efficiency, increasing the use of RES and alternative fuels, reducing carbon emissions, and providing production and scientific-technical services. Local government bodies, municipal associations, utility companies, and Ukrainian enterprises may participate in the Fund's programmes. The Fund's instruments include interest rate compensation on loans and leasing agreements provided by state-owned commercial banks financing energy efficiency projects, direct preferential lending for designated projects, and cost reduction for financial leasing and factoring. As of September 2024, the Fund had accumulated UAH 379 million in revenues from CO_2 tax payments and had begun reviewing applications.

Green bonds. Under the EU's Green Deal, this debt instrument plays a key role in mobilising investments for green transition objectives, including decarbonisation. In Ukraine, the Law of Ukraine "On Capital Markets and Organised Commodity Markets," which came into force in July 2021, recognises green bonds as a distinct category of securities and establishes rules for market participants. The Concept for the Introduction and Development of the Green Bonds Market (approved in February 2022) is specifically aimed at addressing the issue of reducing the national economy's energy intensity. The NSSMC has also approved an annex to the Corporate Governance Code and issued recommendations regarding the implementation or financing of environmental projects through the issuance of green bonds. The expansion of the green bonds market in Ukraine is constrained by the underdeveloped capital market and long-term financing institutions (private pension funds, life insurance companies, institutional investors); a lack of investor awareness regarding the benefits of green bonds; high transaction costs associated with compliance with green

[112] World Bank. 2024. State and Trends of Carbon Pricing 2024. Washington, DC: World Bank. DOI: 10.1596/978-1-4648-2127-1. License: Creative Commons Attribution CC BY 3.0 IGO

[113] State and Trends of Carbon Pricing Dashboard. World Bank. URL: https://carbonpricingdashboard.worldbank.org/compliance/coverage

bond requirements; a limited number of institutional green investors (particularly at the local level); and difficulties for international investors in entering local markets;

Emissions trading scheme. The ETS is intended to become one of the key instruments of Ukraine's national climate policy aimed at limiting the overall level of emissions and creating economic incentives for their reduction. Since 2018, Ukraine has declared its intention to implement an ETS as part of fulfilling its commitments under European climate integration and harmonisation with the EU (EU Emissions Trading System). The ETS is designed to complement or partially replace the carbon tax as a mechanism for paying for GHG emissions, as it allows emissions to be controlled through a market-based mechanism. As of 2025, Ukraine has already implemented a system for monitoring, reporting, and verifying GHG emissions, which requires operators of installations subject to state regulation to submit and verify reports. It is expected that, following the completion of regulatory preparation in 2026, the system will enter the phase of full operation.

Voluntary carbon credits (certificates). Ukraine is gradually developing a segment of the voluntary carbon market, within which projects aimed at reducing or absorbing GHG emissions are implemented, particularly in agriculture and land use. Such projects can generate carbon credits (certificates) that are used for voluntary emissions compensation and the implementation of business climate and ESG strategies. As of 2025, foreign fintech companies already operate in Ukraine. These companies facilitate the development of carbon farming by enabling agricultural producers to obtain carbon certificates for implementing regenerative practices. The average price of carbon certificates in Ukraine is USD 25-50 per 1 t CO_2[114]. These carbon certificates are verified according to international standards and sold on international voluntary carbon markets, creating additional income sources for farmers and promoting sustainable agricultural development in Ukraine. Mechanisms for issuing these instruments within Ukraine are expected to be implemented. At the same time, voluntary carbon credits are non-fiscal and non-regulatory in nature, do not create mandatory obligations for participants, and therefore can only indirectly influence the achievement of climate policy objectives.

Special programmes of international organisations and funds. Programmes run by international organisations such as the EIB, IBRD, EBRD, NEFCO, KfW, USAID, etc., which finance grants, loans, and leasing services for green energy transition initiatives in Ukraine, play a crucial role. A significant part of these programmes is specifically directed at decarbonisation measures in energy production, industrial sectors, transport, and agriculture. In cooperation with IFIs, special institutions are being

[114] One such company is Agreena, Denmark, which operates in 19 European countries and implements the AgreenaCarbon programme. Within the framework of this programme, the company issues carbon certificates following the adoption of regenerative agricultural methods in place of traditional practices. Agreena sells these carbon certificates on the international voluntary carbon credit market (an estimated market price is EUR 20–30 per certificate or per 1 tCO2). The company retains 15% of the certificate's value as a fee for its verification and issuance. (https://agreena.com/uk-ua/fermeram/) Additionally, Raiffeisen Bank has entered into agreements with Agreena within the framework of the carbon programme and offers the bank's agricultural clients who adopt regenerative farming practices the opportunity to obtain carbon certificates generated by Agreena. https://raiffeisen.ua/news/raiffeisen-bank-uklav-ugodi-z-agreena-u-sferi-vuglecevo-programi-2034. Another company operating in Ukraine is Heavy Finance, Lithuania, which is implementing the international consortium programme Carbon Credit Ukraine with the support of the European Investment Fund (EIF) in 2022–2024. The company also verifies carbon certificates in accordance with Verra's Verified Carbon Standard methodology by measuring soil carbon content in laboratories and using satellite data. The value of such certificates is estimated at EUR 50 per certificate per 1 tCO2 (for carbon removal). Participants in the programme — agricultural producers who apply regenerative farming methods — receive these certificates. (https://carboncreditukraine.com/)

established to facilitate green financing.[115] Another important focus area of international organisations is financing decarbonisation measures at the municipal level.[116] The volume of programmes involving international organisations may be expected to continue to grow in the coming years.

3.1.3. State Support Measures for Financing the Decarbonisation Process.

General Approach.

Financing of planned decarbonisation measures, particularly under the net-zero emissions scenario, requires approximately EUR 38 billion in capital investments annually. During 2021–2024, less than 5% of this amount was allocated in Ukraine from various sources for decarbonisation purposes. Analysis by international financial institutions (World Bank, IFC, EIB) shows that the state budget alone is insufficient to cover most of the financing needs for decarbonisation. Therefore, the primary financing channels should be external mechanisms and private investors. Based on theoretical analyses and approaches used in other countries, the approximate distribution of funding sources could be: 10–20% from the state budget, 20–30% from the domestic capital market and 50–70% from international mechanisms.

According to the "cascade" logic of the World Bank, the role of the state will primarily consist of creating a favorable institutional environment, developing decarbonisation financing instruments, joining international financing mechanisms, using limited budgetary resources to de-risk private investments. At the same time, given the large financing needs, it is critically important to expand fiscal space for state and local expenditures, including through the establishment of a fair CO_2 price, which should involve carbon tax reform and the implementation of an emissions trading system.

Increasing the State's Financial Resources. This includes mechanisms such as a carbon tax, the issuance of green bonds, the release of specialised infrastructure and municipal bonds, and restructuring public debt with the obligation to invest in decarbonisation measures.

Carbon tax. To enhance the potential of the carbon tax, it is advisable to reform it as soon as possible, aligning it with EU levels and expanding the tax base (covering more CO2 emitters). Simultaneously, the possibility of transitioning the tax base from actual emissions to the amount of fuel extracted or consumed multiplied by a CO_2 generation coefficient will be analysed. Reforming the carbon tax is consistent with measures planned under the National Revenue Strategy to 2030 and Ukraine's commitments to the IMF regarding the development of a comprehensive post-war package for carbon emissions taxation.

Use of Debt Instruments. To finance national and regional decarbonisation projects, the Government and local authorities will consider attracting targeted funds to finance projects by issuing green bonds, as well as targeted municipal and infrastructure bonds. To do this, measures to stimulate

[115] For instance, on 30 June 2020, UNIDO and Ukrgasbank established the Credit Guarantee Fund in the amount of USD 1.5 million, by agreement. The Fund functions as a special financial mechanism within the framework of the UNIDO/GEF Project Implementation of the Energy Management System Standard in Ukrainian Industry, supported by national stakeholders and cross-guarantees from Citibank Europe PLC. The Fund is intended to facilitate access to capital for industrial enterprises to: implement and certify an energy management system (under ISO 50001), as well as to implement measures aimed at optimising energy consumption.

[116] Thus, in 2024 EIB entered into a grant agreement with Kyiv on the decarbonisation of energy supply and consumption. The City Climate Finance Gap Fund — a fund aimed at enhancing the capacity of cities to utilise low-carbon potential — is already reviewing financing applications submitted by the cities of Lviv, Vinnytsia, Korosten, and Poltava.

green public (local) procurement will include setting clear green criteria for public tenders and auctions and prioritising state funding for projects that meet low-carbon benchmarks (Regulation 2019/2088/EU178) and comply with environmental objectives.

Mobilising Additional Financing by State-Owned Banks. Given that state-owned banks in Ukraine account for over 50% of the banking services market, it is advisable to use their potential to redistribute capital in favour of decarbonisation. For this state-owned banks may increase the volume of credit and investment support for decarbonisation projects in line with priorities as set by the Government (within the framework of the LT-LEDS) by issuing green bonds and introducing specialised long-term deposits.

Allocation of Public Funds for Decarbonisation Purposes. The primary focus of state-accumulated resources for financing decarbonisation measures should be increasing their market attractiveness by reducing costs, expanding access, and improving profitability. Accordingly, financing programmes will prioritise the following:

Reducing the cost of decarbonisation financial instruments through compensation for part of their cost (interest rate). This will enhance profitability and investor interest in carbon financial instruments for both investors and intermediaries.

Provision of public (and mobilisation of international) guarantees This is expected to reduce the risk associated with such instruments, lower collateral requirements and diversify financing areas.

Compensating (reimbursing) part of the cost of acquired energy-efficient equipment and technology. This is expected to improve access to low-carbon solutions for businesses and individuals, stimulating market decarbonisation mechanisms.

Refinancing of banks and financial companies by large private and state-owned banks, using decarbonisation financial instruments as collateral. This measure is expected to lower the market cost of such instruments and diversify their applications. It will be aligned with the prudential policy of the National Bank to maximise effectiveness.

State grants are planned to be used limitedly and only to finance decarbonisation measures in non-profitable sectors (in particular, RDE).

Retail carbon loans, leasing, and factoring provided by private and state financial institutions. The Government will facilitate the expansion of these instruments, but direct state spending on them will be limited to a narrow range of specialised institutions (state-owned banks, JSC Decarbonisation Fund of Ukraine).

Development of Institutional Structure. Measures for institutional support in the carbon finance market should primarily involve implementing best practices and policies and adapting the institutional structure of the financial services market to new needs.

Information Support. Access to climate information for accurate risk assessment and monitoring is a key element in developing a green finance system. The green project taxonomy should clearly define, based on international approaches, the relevant "environmental" performance indicators of enterprises, such as increased energy efficiency and conservation and reduced CO_2. emissions. A lack of adequate information lowers transparency and accountability, which are essential for effectively developing policies to stimulate green finance within the LT-LEDS. Such an information system should include a harmonised green taxonomy catalogue containing criteria for most sectors

and activities, allowing classification as "low-carbon," "transitional" or "enabling". It should also include quantitative indicators for decision-making and harmonised standards for non-financial reporting and disclosure of other sensitive information.[117] The policy to stimulate green investment will be complemented by measures to improve the overall business environment and investment climate and to integrate ESG criteria into business processes.

Creating a National Emissions Trading System (ETS) will include:

- developing the relevant legislation, monitoring, and accounting infrastructure, as well as creating a trading platform for allowances;
- establishing the national GHG emissions trading system (planned for 2026);
- implementing procedures for the issuance and circulation of carbon certificates (planned for 2025);
- supporting national carbon certificate issuers and developing the carbon credit market.

Development of Domestic Capital Markets. It is advisable to develop a roadmap for establishing a capital market in Ukraine, outlining investment needs, promising investment directions, and barriers to capital mobilisation. The Government and the NSSMC can also promote the issuance and circulation of green bonds, carbon credits and certificates in domestic capital markets. In line with EU approaches, green bonds will serve as one of the primary green financing instruments in Ukraine. In this regard, the following requires activation:

- the process of developing a national green taxonomy aligned with the European green taxonomy;
- regulation of the market of independent appraisers and verifiers of green bonds, who confirm the "greenness" of projects, implementation of the activities of external verifiers;
- implementing rules and incentives for using green bonds that comply with international standards;
- creating a registry of nationally significant projects eligible for sovereign green bond issuance;
- raising awareness among market participants regarding the green bond market;
- preparing and implementing pilot projects for green bond issuance by various categories of issuers;
- engaging international development banks in investing in green bonds;
- creating favourable conditions for attracting financing to the market (state-targeted programmes, promotion in external capital markets).

Development of a support programme for municipal authorities to expand their access to financing for decarbonisation measures and projects, which would facilitate access to private financing for cities and territorial communities. One of the promising mechanisms may be financing in partnership between cities that seek to finance similar investment projects. A joint issuance of green,

[117] Kashiwase, K., Kutlukaya, M., Li, M., Refayet, E., Seneviratne, D., Sy, M., & Yang, R. (2024). Unlocking Climate Finance in Asia-Pacific. IMF Departmental papers. https://www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2024/01/29/Unlocking-Climate-Finance-in-Asia-Pacific-Transitioning-to-a-Sustainable-Future-541458

infrastructure, and social bonds by municipal authorities under state guarantees for financing similar climate projects will open prospects for obtaining funds on more favourable terms.

Expansion and improvement of the institutional structure. The activities of the JSC Decarbonisation Fund should be expanded to include additional sources of financial resource accumulation, apart from the carbon tax. An organisation will be designated to take on the functions of coordinating green projects, ensuring cooperation between regulators, investors, and initiators of green projects, and assuming responsibility for raising awareness and providing training for interested businesses, local authorities, financial organisations, and potential investors.[118]

Financing of technical assistance programmes. To activate the decarbonisation process, one of the promising directions of technical assistance, which the Government may finance, is the development and implementation of educational materials, consultancy services, and information platforms for the technical support of the decarbonisation process. To enhance investment attractiveness, it is reasonable to introduce international standards, including in the fields of green construction, green transport, energy efficiency of buildings and residential premises, and environmental management.

Facilitating the expansion of international mechanisms. The activation of cooperation with IFIs and involvement in international decarbonisation and energy efficiency funds is a critically important element for the success of the decarbonisation process. The components of this process will include:

Government involvement in relations with international funds and IFIs offering financing for decarbonisation measures. Implementation of public-private and international partnership programmes. Attraction of investments through various joint channels involving the state, IFIs, corporate projects, banking and non-banking financial institutions. In particular, efforts should be made to secure accessible financing for industrial pollution reform in accordance with Directive 2010/75/EU, which provides for the introduction of the best available techniques and methods in various economic sectors.

Harmonisation of national regulatory, institutional and legal frameworks, implementation of standards and taxonomy for green financing, considering international developments for climate adaptation and low-carbon development, in particular in accordance with the EU Green Bond Standard Regulation EuGB. Domestic legislation should be harmonised in particular, according to the following provisions: alignment of legislation with the Green Bond Principles (GBP); compliance of a green project with environmental objectives; the list of environmental objectives of EU green bonds and the extent to which the issuer's strategy aligns with these objectives, as well as the reasons for issuing green bonds; alignment of reporting with the EU Green Bond Standards; definition of the concept and functions of a qualified verifier.

3.1.4. Risks of implementing the LT-LEDS in the financial sector

- the prolonged continuation of hostilities, which will maintain unfavourable conditions for attracting and supporting private and international investments for the implementation of low-emission development technologies. The inability to implement financial resource mobilisation measures through budgetary and tax mechanisms due to continued hostilities;

[118] An example of such an organisation could be the Credit Guarantee Fund, established by UNIDO together with Ukrgasbank, provided that its powers and functions are expanded.

- gaps in regulatory and institutional frameworks, given the novelty of the legislative and regulatory base, which may slow down the spread of green financing, particularly in completing the proper institutional arrangement for the use of green bonds, carbon credits, etc.;
- insufficient attractiveness of domestic capital markets and the lack of material interest from domestic investors in green projects;
- low awareness among enterprises, local authorities, financial organisations and potential investors about the benefits provided by low-emission, climate-oriented, and ecological programmes.

At the same time, it is anticipated that the challenges and potential negative effects of implementing the LT-LEDS on the activities of financial intermediaries will be mitigated by initiatives from regulators and state authorities aimed at developing the institutional capacity of the financial sector to support decarbonisation policy measures. In particular, it can be expected that:

- a transparent plan for implementing legislation related to LT-LEDS and new regulatory requirements for financial intermediaries will help the financial sector plan its own adaptation measures;
- the involvement of financial regulators and state authorities in the full process of implementing and reviewing LT-LEDS, assessing its impacts, developing sustainable finance taxonomy, and labeling climate budgets will enable prompt responses to critical challenges and obstacles in the financial sector;
- adequate information support, including the dissemination of systems for tracking financial flows and investment needs of decarbonisation projects, informing investors of the long-term vision of objectives and financing priorities, and publishing risk and cost assessments in economic sectors, will facilitate sound decision-making and create new opportunities for investors;
- the implementation of EU best practices to enhance the financial sector's readiness for low-carbon development, including corporate sustainability reporting systems in financial services and ESG disclosure, will help financial intermediaries and investors adequately assess and manage the risk levels of their assets;
- the development of capital market and banking infrastructure (development institutions, guarantees, verification, etc.) will contribute to reducing financing risks for decarbonisation projects and attracting private investors, including foreign ones;
- state policies facilitating financial institutions' access to international green and climate finance funds and projects will expand the resource base and reduce the cost of capital;
- the implementation of financial literacy policies (e.g., the National Financial Literacy Development Strategy until 2030) will improve awareness of green finance opportunities.

The implementation of these measures will not only help limit certain negative impacts of decarbonisation policies but also open new opportunities for investors and create the conditions for a more resilient financial sector, adapted to climate challenges, within the national economy.

3.2. POLICIES AND MEASURES IN THE FIELD OF RESEARCH, DEVELOPMENT, AND INNOVATION

According to the European Innovation Scoreboard 2024, Ukraine belongs to the "Emerging Innovators" group. At the same time, its Innovation Index stands at 32.4% of the EU average[119], which is one of the lowest levels among the countries for which the index is calculated.

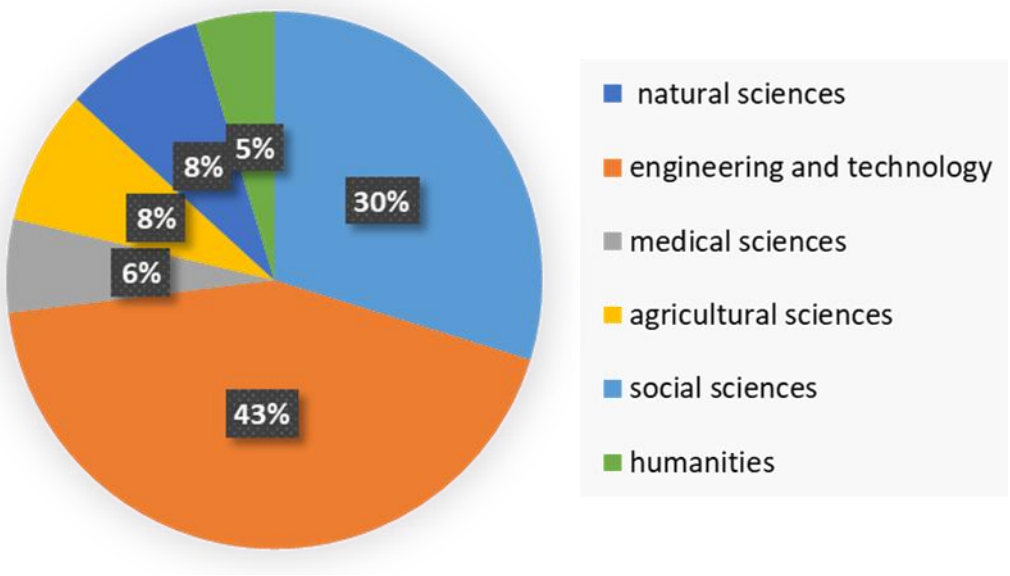


Fig. 3.2. Sectoral structure of employees engaged in R&D, 2024

Source: State Statistics Service of Ukraine.

A key indicator of scientific development, the R&D intensity of the GDP, has not exceeded 0.4% since 2021, and in 2024 it amounted to 0.37%. On average, during 2018–2023, about EUR 570 million per year was spent on R&D, of which EUR 250 million came from the state budget. In 2024, total funding increased to EUR 650 million. The number of employees involved in scientific research and development in 2024 was almost 64,000. However, the current level of funding limits the development of science and its impact on the economy. Most of the human resources (over 70%) are concentrated in technical and natural sciences, which are crucial for the development of new low-carbon technologies and for providing scientific support for their implementation.

State policy in the field of science and innovation is shaped by the following key Ukrainian laws:

- The Law of Ukraine "On Scientific and Scientific-Technical Activities";
- The Law of Ukraine "On Innovation Activity";
- The Law of Ukraine "On Priority Branches of Science and Technology Development"[120];
- The Law of Ukraine "On Priority Directions of Innovation Activity in Ukraine"[121]

[119] https://projects.research-and-innovation.ec.europa.eu/en/statistics/performance-indicators/european-innovation-scoreboard/eis-2024#/eis/countries/UA?country_scope=all
[120] https://zakon.rada.gov.ua/laws/show/2623-14#Text
[121] https://zakon.rada.gov.ua/laws/show/3715-17#Text

The last two laws define the priority directions for the development of science, technology and innovation (Table 3.2).

Table 3.2. Strategic Priorities for Science and Innovation Development

Scientific and Scientific-Technical Activities	Innovation Activity
national security and defence;	technological modernisation and development of national security and defence sectors;
fundamental scientific research on key issues of the development of scientific-technical, socio-economic, socio-political, and human potential to ensure Ukraine's global competitiveness and sustainable development of the society and the state;	mastering new high-tech transport systems, rocket and space industry, aviation and shipbuilding, armaments, and military equipment;
new substances and materials.	mastering new materials production technologies, their processing and joining, creation of a nanomaterials and nanotechnology industry;
rational use of natural resources;	technological modernisation and development of the agro-industrial complex;
life sciences, new technologies for the prevention and treatment of the most common diseases;	implementation of new technologies and equipment for quality medical care, treatment, and pharmaceuticals;
energy and energy efficiency;	broad application of cleaner production technologies and environmental protection measures;
	mastering new technologies for energy transportation, implementation of energy-efficient and resource-saving technologies, mastering alternative energy sources;
Information and communication technologies;	development of modern information and communication technologies, robotics.

Source: compiled from https://zakon.rada.gov.ua/laws/show/2623-14#Text and https://zakon.rada.gov.ua/laws/show/3715-17#Text

Strategic innovation priorities are further detailed in medium-term priorities up to 5 years.[122] The latter also takes into account the priority thematic areas of scientific research and scientific-technical developments approved in April 2024.[123] Some of them are directly related to low-emission development goals, such as:

- systems for generating and transporting electrical and thermal energy;
- fuel bases, transportation, and utilisation systems;
- technologies for the development and use of new types of fuel, renewable and alternative energy sources and types of fuel;
- energy efficiency and energy saving, energy resource markets;
- environmentally balanced energy security;
- new resource-saving, energy-efficient, and environmentally safe processes for obtaining competitive substances, materials, and products;

[122] https://www.kmu.gov.ua/npas/deiaki-pytannia-vyznachennia-serednostrokovykh-priorytetnykh-napriamiv-innovatsiinoi-s78750724

[123] https://zakon.rada.gov.ua/laws/show/476-2024-%D0%BF#Text

- environmentally balanced and efficient land use;
- modelling and forecasting of environmental conditions, technologies for mitigating negative impacts;
- technologies for monitoring the ecological state of natural and artificial ecosystems;
- innovative technologies for the conservation and sustainable use of natural resources (mineral raw materials, land, soil, water, and biotic resources);
- circular economy technologies.

Science, technology, and innovation policy is developed and implemented by the following state bodies[124]:

- The Ministry of Education and Science formulates and implements state policy in the fields of education and science, manages scientific, technological, and innovation activities, and facilitates technology transfer. The MES carries out government oversight of educational institutions (of all ownership forms), including scientific and scientific-technical activities, as well as its subordinate enterprises, institutions, and organisations;
- The Ministry of Economy, Environment and Agriculture ensures the development and implementation of state policy in the field of innovation in the real sector of the economy;
- The Ministry of Digital Transformation formulates and implements state policy in digital innovations and technologies;
- The Ministry of Defence formulates and implements state policy in innovation within strategic industries.

The key institutions through which state funding for R&D is allocated in Ukraine, in accordance with defined priority areas, are:

- the Ministry of Education and Science;
- the National Academy of Sciences;
- the National Research Foundation.

In turn, financial support for innovation is provided by:

- The Innovation Development Fund (Ukrainian Startup Fund) — grants non-repayable financial support on a competitive basis to private-sector enterprises engaged in innovation activities with the aim of commercialising their results, and
- The State Finance Institution for Innovations, whose main instrument is providing credit support for innovation and investment projects.

In 2023, the MES adopted a Roadmap for the Use of Science, Technology, and Innovation to Achieve the Sustainable Development Goals. Its objective is to increase the contribution of the science, technology, and innovation system to the National Sustainable Development Goals by addressing specific assigned tasks. This roadmap promotes integrating the Innovation Development Strategy until 2030 with measures to support research and innovation outlined in other national and sectoral

[124] https://stip-pdf-generator.showroom.buddyweb.fr/pdf_countries/Ukraine.pdf

strategic documents.[125] These documents pay significant attention to the need to develop and support R&D and innovations related to climate neutrality and low-emission technologies.

In turn, the Energy Strategy of Ukraine until 2050 outlines the following measures related to science and technology development:

- use of existing scientific developments of domestic scientific and educational institutions, financing (co-financing) their implementation, and implementation of pilot projects;
- ensuring proper and sufficient funding for academic and sectoral science, with priority given to the implementation of applied research in priority areas of energy sector development, followed by the practical application of research results;
- carrying out research focused on creating new technologies with high commercialisation potential;
- government support for scientific and educational institutions' participation in international research projects and providing relevant recommendations;
- large-scale deployment of innovative technologies for burning renewable and alternative fuels in Ukraine's economy to generate energy with the aim of replacing fossil fuels;
- development and deployment of cost-effective technologies for capturing, converting, and storing carbon dioxide, including into biomethane, to reduce the carbon footprint and decarbonise the economy;
- scientific research and development of industrial technologies in the field of waste and biomass processing to obtain "green" products of basic chemical synthesis— such as synthesis gas (syngas), methanol, propylene, butylene, etc.—to substitute fossil feedstocks;
- scientific and technological progress in the development of RES and alternative fuels;
- encouraging scientific organisations to conduct research in the field of energy efficiency and hydrogen technologies;
- stimulating the attraction of off-budget funds for the implementation of innovative projects, the creation of technology parks and innovative business incubators, the attraction of venture capital for the deployment of new developments in the energy sector, ensuring the fastest possible organisation of production and market introduction of new high-tech products.

National Goals until 2030

The key objectives in the field of scientific, technical, and innovation policy related to achieving low-emission development are defined in the Strategy for the Formation and Implementation of State Policy on Climate Change until 2035[126]. In accordance with SC2 — Mitigation of Climate Change and Ensuring a Socially Just and Economically Efficient Transition to Low-Emission Development of the State, Ukraine plans to:

[125] https://mon.gov.ua/static-objects/mon/sites/1/news/2024/01/03/Dorozhnya.karta.vykoryst.nauky.tekhnolohiy.ta.innovatsiy-03.01.2024-1.1.pdf

[126] The Strategy for the Recovery, Sustainable Development, and Digital Transformation of Small and Medium-Sized Enterprises for the Period up to 2027, approved by the Resolution of the Cabinet of Ministers of Ukraine dated 30 August 2024. (Official Gazette of Ukraine, dated 25.09.2024, No. 82, Article 4867) https://zakon.rada.gov.ua/laws/show/483-2024-%D1%80#Text

- reduce greenhouse gas (GHG) emissions to 35% of the 1990 level;
- reduce GHG emissions from heat and electricity production by 85% compared to the baseline in 1990;
- increase the annual volumes of GHG removal;
- increase the share of electricity generation from RES to 20%;
- increase the share of energy produced from renewable and low-emission sources in the overall final energy consumption structure;
- reduce the energy intensity of GDP;
- increase the total volume of investment in scientific research on climate change and the development of low-carbon technologies;
- create new jobs and increase the share of innovative enterprises in regions to address the issue of closing fossil fuel extraction, processing, and/or combustion enterprises.

The Strategy for Recovery, Sustainable Development, and Digital Transformation of Small and Medium-Sized Enterprises (SMEs) until 2027[127] also aims to achieve the strategic goal of "Promoting Innovative Development, Digital Transformation, and the "green transition". At the operational level, its implementation includes measures such as:

- Operational objective 2.1. Promoting Innovation Activity. A key indicator of successful fulfilment will be achieving the following goals by 2027: science intensity of GDP (proportion of public and private spending on research and development relative to GDP) at 0.7%; the number of innovation-active SMEs reaching 4,500 (compared to 1,822 in 2020); Ukraine's ranking in the Global Innovation Index at 47th out of 132 (compared to 49th in 2021);
- Operational objective 2.2. Strengthening Digital Transformation. Key performance indicators of successful fulfilment include reaching the following goals by 2027: the share of enterprises with at least a basic level of digital intensity at 80% (EU average was 69.7% in 2022); the share of enterprises sending invoices electronically at 60% (EU average in 2020 was 32%);
- Operational objective 2.3. Stimulating the "Green Transition", which includes spreading sustainable practices, ensuring SME energy efficiency, and encouraging circular economy practices. The outcomes of this operational goal include increasing SME environmental responsibility, financial support for energy efficiency and circular economy measures, and promoting sustainable production management among SMEs. A key indicator of successful fulfilment will be increasing the share of recycled waste in total generated waste to 15% (6% in 2020).

Additionally, the Ukraine Facility strategic document envisions the development of a Circular Economy Strategy in 2026, which will propose detailed measures to stimulate SMEs' transition to circular practices.

To achieve the goals outlined in the above-mentioned strategic documents, scientific R&D and innovations will be funded by state and local budget funds, international donors, businesses, etc.

[127] https://www.kmu.gov.ua/npas/pro-skhvalennia-stratehii-vidnovlennia-staloho-rozvytku-ta-tsyfrovoi-transformatsii-maloho-i-s821300824

State financing of R&D related to low-emission strategy objectives may be carried out through the implementation of targeted government programmes and special competitions for scientific and technical projects under the MES, the NAS and the NRFU. Ukraine also actively participates in the EU Framework programmes for research and innovation, the International European Innovation and Scientific-Technical Programme EUREKA, NATO's Science for Peace Programme, and the Euratom Research and Training Programme.

The Innovation Development Fund (Ukrainian Startup Fund) supports the commercialisation of developments. In addition to budget financing, it attracts international donor funds and actively collaborates with numerous innovation ecosystem entities in Ukraine and Europe.

To stimulate innovation activity, Ukraine plans to expand the powers and financial capacities of the Innovation Development Fund, as well as increase funding for industrial innovation, including through financial and credit institutions and investment funds.[128]

National Goals until 2050

The National Economic Strategy until 2030[129] envisions innovative, forward-looking economic growth considering Sustainable Development Goals and achieving climate neutrality.

In turn, the Energy Strategy of Ukraine until 2050 defines energy sector neutrality as one of the strategic energy development goals. It is planned that 100% of electricity and heat will be produced from carbon-neutral sources by 2050. Achieving this target will require the implementation and development of cutting-edge technologies for energy production, storage, and distribution, as well as the necessary scientific and technical support.

National Competitiveness Goals

The National Economic Strategy until 2030 includes strategic goals such as "Enhancing the Competitiveness of Industrial Products Manufactured in Ukraine through the Implementation of Resource- and Energy-Efficient Technologies" and "Increasing the Competitiveness of Ukrainian Goods and Services, Creating a Positive Country Image, and Ensuring the Presence of Ukrainian Manufacturers in International Markets."

The government will focus particularly on the "dual transition" (a combination of the "green" transition and digital transformation). Stimulating economic recovery in regions based on dual transition principles is one of the objectives of the State Strategy for Regional Development for 2021–2027.[130] [131]Similar objectives and goals are mentioned in the SME Strategy, the Ukraine Facility Plan etc.

The SME Strategy in terms of competitiveness includes the following goals:

- Promoting innovation activity: creating a favourable innovation environment for SMEs, including establishing cooperation with research institutions and innovation networks to enhance their innovation potential and digital integration;

[128]NES 2030, p. 148. Source: https://www.kmu.gov.ua/storage/app/uploads/public/604/13e/648/60413e6481b69340709542.doc

[129] On approval of the National Economic Strategy until 2030: Order of the Cabinet of Ministers of Ukraine No. 179 of 3 March 2021. URL: https://www.kmu.gov.ua/npas/pro-zatverdzhennya-nacionalnoyi-eko-a179

[130] https://zakon.rada.gov.ua/laws/show/695-2020-%D0%BF#Text

[131] https://www.ukrainefacility.me.gov.ua/wp-content/uploads/2024/03/plan-ukraine-facility.pdf

- Strengthening Digital Transformation: building on the progress made in digital transformation, adopting a comprehensive approach to business digitalisation, and fully leveraging digital opportunities for SME development, including their integration into the global commercial digital space. To this end, Ukraine is developing a network of digital innovation hubs, 12 of which have received European status.

Goal 4: "Enhancing Competitiveness and Increasing Exports" primarily includes measures to promote domestic businesses in international markets and integrate them into global value chains.

Key policy initiatives in the field of competitiveness include[132]:

- targeted programmes of the government and regional authorities;
- EU programmes such as Competitiveness of Enterprises and SMEs (COSME), Digital Europe, and Single Market Programme in terms of strengthening the competitiveness and resilience of small and medium-sized enterprises;
- grant programmes and projects of international technical assistance and donors.

Key Measures for Science and Innovation

Based on the objectives set by this strategy, the main policy measures for low-emission development in the field of scientific and innovation activities should include instruments to stimulate both the supply and demand for relevant scientific, technical, and innovative solutions, in particular:

- Increasing funding for R&D in areas and projects aimed at reducing carbon emissions, with subsequent implementation of results;
- Introducing relevant scientific and technical programmes and R&D competitions, including within the framework of the NRFU;
- Strengthening the financial capacity of the Innovation Development Fund and the State Innovation Financial and Credit Institution to support innovative low-emission development projects;
- Promoting the development and implementation of new low emission technologies;
- Advancing and stimulating the "dual transition" and circular economy, including the digital transformation of enterprises, by supporting the activities of digital innovation hubs, voucher schemes, grants, etc.;
- popularising and facilitating the integration of ESG principles into corporate governance and considering carbon impact criteria when making financing decisions for scientific, technical, and innovation projects.

These measures should be taken into account by government authorities when developing activity plans and programme documents.

[132] https://business.diia.gov.ua/

4. ASSESSMENT OF SOCIO-ECONOMIC IMPACTS

4.1. MACROECONOMIC EFFECTS

The implementation of a consistent and long-term low-emission development policy in Ukraine brings both advantages and risks to various economic sectors. This, in turn, is expected to lead to structural changes in the national economy, a transformation of the labour market and professional education, improvements in infrastructure solutions, and adaptations to budget allocations at all levels.

Understanding the anticipated macroeconomic effects of this Strategy will allow for timely and effective responses, ensure the correct policy directions, and develop appropriate measures.

This section of the Strategy provides an empirical assessment and analysis of macroeconomic effects and offers conclusions regarding key elements of economic, budgetary, and investment policies that should accompany its implementation. These policies aim to ensure the Strategy's positive impact on economic development while avoiding unmitigated negative burdens on different economic actors.

The macroeconomic analysis underlying the development of this Strategy considers two economic development scenarios, as outlined in Section 2.1:

1. WEM — a scenario based on existing measures aimed at achieving moderate climate goals; this serves as the baseline for assessing deviations caused by the implementation of low-carbon development policies;
2. NZE — a net-zero GHG emissions scenario that reflects the achievement of the most ambitious climate goals and aligns with EU climate policy; the scenario projects outcomes derived from the TIMES-Ukraine energy system model, specific indicators of energy sector development and GHG emission pricing levels.[133]

An updated version of the dynamic general equilibrium model UGEM, based on extended input-output tables and Ukraine's national accounts, was used to model and empirically assess macroeconomic effects. Its dynamic component reflects changes in household consumption and savings volumes, as well as capital investment volumes across economic sectors. It is evident that an ambitious climate policy will directly influence household spending distribution and businesses' investment decisions. Therefore, the general equilibrium modelling approach was identified as the most appropriate for calculating the macroeconomic effects of the Strategy's implementation.

Undoubtedly, investments in reducing GHG emissions will contribute to environmental improvements in Ukraine. However, such investments will not automatically enhance economic attractiveness, stimulate GDP growth or improve social conditions. The expected investment burden on central and regional budgets, households, and private enterprises may quickly lead to a reduction in other economically significant expenditures and incentives for development. At the same time, it

[133] he marginal GHG emission price level borrowed from the TIMES-Ukraine model is interpreted in the UGEM macroeconomic model as an "environmental tax on carbon dioxide emissions" — UAH per tonne of CO_2 — and is used to calculate the total "carbon" revenues in the economy.. This tax is technically modelled as one that applies to all system-wide GHG emissions. That is, it is assumed that the current tax base of the environmental tax will be reviewed and expanded in the future, though not earlier than 2031.

is important to recognise that accompanying regulatory, budgetary, and investment policies will directly determine whether GDP levels under net-zero policies will ultimately be higher or lower than the baseline GDP level projected under the WEM scenario.

Global experience, particularly that of EU countries, demonstrates that the implementation of an environmental tax on carbon dioxide emissions (in monetary units per tonne of CO_2) is one of the most effective instruments for incentivising economic actors to achieve emission reductions and make corresponding investments in climate-friendly technologies. Nevertheless, during the simulation of climate policy scenarios for the Ukrainian economy, it became evident that the manner and targeted directions of utilizing the funds obtained from this environmental tax are decisive factors. They determine whether Ukraine's economy will cope with the additional investment burden, and whether an ambitious climate policy will ultimately lead to positive macroeconomic effects or, conversely, reduce the aggregate level of economic activity in the country.

Thus, when modeling the macroeconomic scenarios, the following alternative options for utilizing revenues from the carbon dioxide environmental tax collections were considered:

Option 1. All revenues from the collections of this type of environmental tax are directed to the state budget. Under this option, all categories of budgetary expenditure will be topped up proportionally, in accordance with the pre-defined expenditure structure and the volume of additional funds allocated to the revenue side of the budget via the taxation of carbon dioxide emissions.

Option 2. Revenues from the environmental tax collection are distributed among households. In the macroeconomic model, this option does not assume any impact on household decisions regarding the subsequent deployment of the received funds (although in reality, such funds could be interpreted as investment support for household decisions to direct expenditure towards specific forms of energy conservation or the prevention of energy poverty, the risk of which may intensify due to the expected increase in energy prices consumed by households). The method of distribution of funds among households is irrelevant, as the UGEM model does not provide for any classification of households based on certain criteria.

Option 3. Revenues from the collection of the environmental tax are redirected into the productive sector of the economy. These additional funds for the productive sector can be interpreted as a mitigation of potential investment burdens for producers, who will be forced to review their production processes and make capital investments in order to align with the most energy-efficient or least carbon-intensive technologies. The volume of redirected funds is calculated by the model in accordance with the collection volumes so as to achieve an overall balanced budget.[134]

Option 4. Combined reallocations are carried out from the funds collected via the environmental tax in accordance with the established policy priorities: a portion of the funds will be redirected into the productive sector of the economy, as in the previous option, a portion will be distributed among households, and the remainder will be directed towards public investment.

The implementation of policy under the NZE (Net-Zero Emissions) scenario with different options for utilizing revenues from the carbon dioxide environmental tax collections will lead to sign-opposite

[134] In the macroeconomic model, the redirection of funds into the productive sector of the economy is reflected technically by a reduction in "net taxes" on capital assets and personal income, which can be interpreted as taxes on/subsidies to corporate profits and an increase/decrease in the price per unit of hired labour. It must be unequivocally stated that this technical representation does not constitute direct guidance for reforming the tax base. Nonetheless, it becomes clear that the implementation of the Strategy must be accompanied by a prudent distribution of revenues from environmental tax collections and corresponding adjustments to fiscal policy after 2031.

effects on the GDP level in the long term (Fig. 4.1). Indeed, the last modeled option — the option of combined transfers of additional budget revenues — will make it possible to increase the GDP level by more than 10% by the year 2050. Conversely, implementing the Strategy while simultaneously directing the revenues received from the environmental tax into the state budget without their subsequent targeted use could place an additional burden on the economy and cause a decline in the annual GDP level by nearly 6%. It is worth noting that the policy represented by Option 3, which involves using the revenues obtained from the environmental tax to mitigate the burden placed on manufacturing enterprises by the implemented measures of the Strategy, will also have a positive aggregate effect on the GDP level, though significantly smaller than with the combined approach to utilizing the received funds.

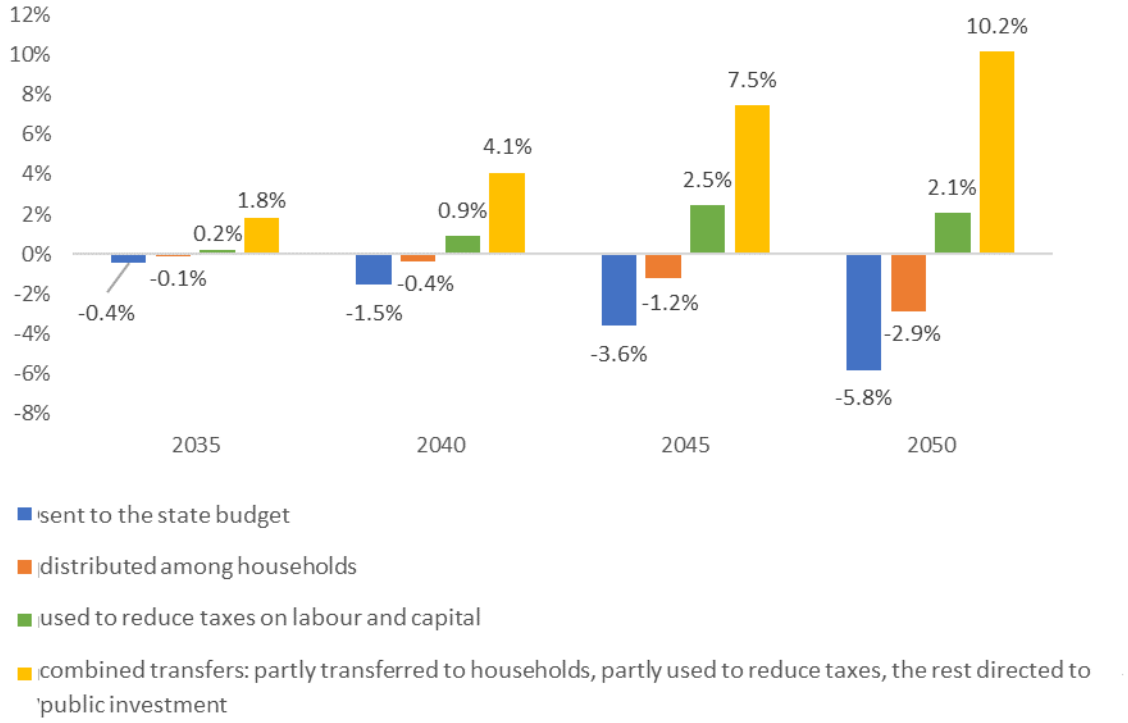


Fig. 4.1. Change in real GDP under alternative options for utilizing revenues from the carbon dioxide environmental tax collection, % of the baseline level

Regarding the macroeconomic effects in the short and medium term, we conclude that apart from Option 4 (the combined option) and, accordingly, a prudent and well-planned utilisation of revenues from environmental tax collections on carbon dioxide emissions, the implementation of the Strategy will have almost no impact on the level of GDP: under all other "simple" options, the resulting deviations of GDP from the baseline level in 2035 do not exceed 0.4%, which is, in fact, within the margin of error, considering the long-term forecasting horizon. At the same time, the combined approach to using carbon tax revenues will allow for a significant positive effect on GDP already in the first decade.

In addition to the obvious need to monitor the achievement and preservation of the positive impacts of implementing the Strategy on the overall level of GDP, additional state efforts should be directed at controlling the process of economic recovery after the significant losses and destruction caused by the war, steering the course of adaptation of the economic structure, the spread of new technologies, the establishment of new high-tech sub-sectors in energy and industry, changes in business models, and so on. It is estimated that implementing the Strategy will almost eliminate

some sectors of the economy (such as coal mining), while others will significantly grow and expand production volumes (such as information technology and the food industry). Subject to the combined utilisation of additional budgetary revenues from the environmental tax collection, the aggregate output of goods and services in 2050 will not undergo significant changes: the estimated growth of 2% remains within the margin of error (Fig. 4.2[135]). Accordingly, it can be expected that, in fact, half of the economy's sectors, especially those where climate policy presents challenges and burdens, will eventually close production and lay off workers.

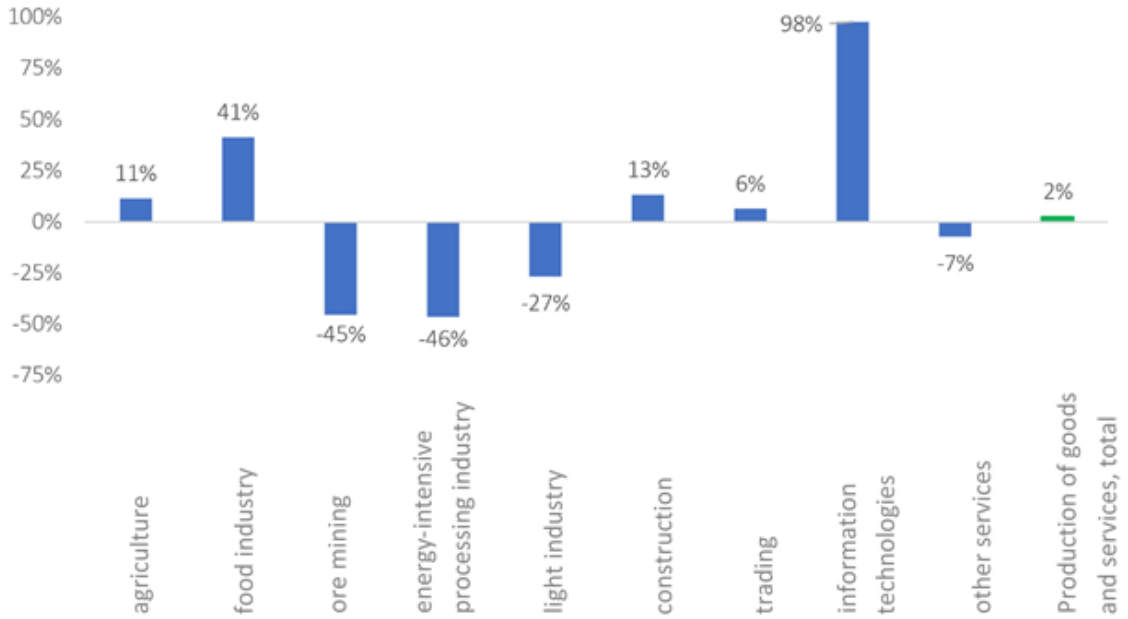


Fig. 4.2. The change in the production level of goods and services in 2050 under the condition of the combined use of revenues from the carbon dioxide environmental tax collection, % relative to the baseline level

Thus, taking into account the risks associated with ambitious climate policies, the correct use of funds, the direction of capital investments, and the corresponding mitigation of investment burdens will help neutralise potential negative effects on the country's economy in the future and enhance the positive ones.

It is clear that the modelled dynamics of economic development over the next 25 years cannot be equated with forecasting in any of the scenarios. During the period of active hostilities, the level of uncertainty and errors regarding modelling results will remain high. Therefore, the assessment of macroeconomic effects should be carried out each time the Strategy undergoes updates and improvements in accordance with the requirements of subsequent decades. This will allow for the refinement of economic development indicators, taking into account new realities of the future, both climatic and geopolitical, and appropriately adjusting the measures aimed at implementing low-carbon development policies. This observation also applies to the necessity of reviewing and correspondingly adjusting individual components of fiscal policy after 2031. As the modelling results have demonstrated, it is precisely the balanced and effective utilisation of additional budgetary funds, which will accrue as a result of strengthening the environmental tax on carbon dioxide

[135] The figure does not show the energy sectors and fuel extraction. They are presented in the previous sections on the transformation of Ukraine's energy sector.

emissions, that will play a pivotal role in determining the direction and amplitude of the impact of the Strategy's measures on the economic system and the subsequent development of the country.

Despite the significant decline in the country's GDP in 2022, the destruction of energy infrastructure, the outflow of the workforce, and other challenges of martial law, Ukraine's economy remains resilient. This is due to substantial financial support from partner countries, the effective reform course towards EU accession, and the Armed Forces of Ukraine, which enable the country to maintain relatively stable economic activity and innovation in the rear regions and preserve the economic attractiveness of these areas. Timely allocation of external support remains critical for maintaining macroeconomic, monetary, and fiscal stability and, therefore, an important precondition for the successful implementation of this Strategy.

4.2. HUMAN CAPITAL AND LABOUR MARKET

Current State Overview

The success and stability of the transition to a low-emission economy will be ensured by the dynamic development of the labour market and the effective use of human capital.

The armed aggression by the Russian Federation has exacerbated already existing issues related to the formation and utilisation of human capital in Ukraine. Under the conditions of armed conflict, structural and territorial changes, shifts in labour force demands, large-scale population displacement, and mobilisation, employment problems have deepened, and labour market imbalances formed before the war have been intensified, namely:

- an outdated employment structure that does not meet modern demands. *The sectoral employment structure was characterised by being relatively stable and slow to change*; however, such uniformity does not indicate sufficient opportunities to provide employment and low unemployment levels in Ukraine;
- educational and qualification disproportionality in the national labour market, manifesting in an over-education of the employed population. That is, almost 25% of workers in the most basic jobs held professional or higher education degrees. The economy of the country did not produce enough jobs for people with medium or higher professional education.
- regional and sectoral unevenness in the distribution of labour demand and increased salary differentiation;
- a relatively high level of de-formalisation of labour relations. Almost 25% of employed individuals worked in the undeclared segment of the labour market.
- low wage levels, which contributed to the formation of a significant layer of working poor.

Current challenges facing Ukraine's social sphere include a significant decrease in the labour force. According to the National Bank of Ukraine (NBU), the 15–70 age group had decreased by almost 25% as of early 2024 compared to 2021. Significant factors contributing to the reduction of the labour force include demographic losses, occupation, emigration, mobilisation and the transition of a substantial part of the population into the economically inactive group — due to difficulties in finding employment for internally displaced persons, the need to care for family members, an increase in the number of pensioners and a shortage of skills that are increasingly in demand in the transformed economy. These factors create a structural deficit of labour resources, which directly limits the country's human capacity to implement decarbonisation measures.

The Ministry of Economy estimates the labour shortage in the job market at nearly 30%, while the NBU reports that in 2023, 44% of enterprises faced staffing difficulties due to mass reductions in workforce caused by mobilisation, and 24% due to emigration. According to updated data[136], the number of Ukrainian migrants worldwide exceeds 6.9 million, of whom approximately 1.7 million were employed in Ukraine before departure — about 11% of the pre-war economically active population. The loss of this segment of the labour potential is particularly critical for the implementation of technological solutions in the low-carbon development sector, which require highly qualified personnel with cross-sectoral "green" competencies in energy efficiency, renewable energy, resource management and digital transformation.

[136] UNHCR – August 2025 https://data.unhcr.org/en/situations/ukraine?utm

Due to the cessation of regular labour force surveys after 2022, the accuracy of unemployment estimates is somewhat limited. According to updated forecasts by the NBU, although unemployment remains high, it has declined from 21% in 2022 to 14.2% in 2024, with an expected rate of 11.9% by the end of 2025 and a further decrease to 10.6% in 2026[137]. At the same time, mobilisation processes have altered the gender distribution of labour demand. Currently, labour shortages are felt in sectors traditionally dominated by men, such as retail, manufacturing, construction, logistics, transportation and agriculture. The share of women employed in these traditionally male-dominated positions is increasing, which is transforming the gender structure of employment in "brown" sectors. This trend opens potential for expanding women's participation in green economy sectors, provided there is targeted educational, institutional and human resource policy focused on inclusiveness and adaptation to the needs of a decarbonised economy.

As the eastern regions of Ukraine have been most affected by the war, with the most common sectors being those undergoing decarbonisation processes, internally displaced persons (IDPs) from these regions are predominantly wage workers who require the implementation of specific active labour market policies for their adaptation and acquisition of new competencies needed for a low-emission economy. The reasons for their low employment rates are both personal (psychological trauma, mismatch between job opportunities and expectations regarding job quality, the need to care for small children or sick relatives) and systemic (insufficient job opportunities in regions with high IDP populations, underdeveloped vocational retraining and upskilling systems, bureaucratic obstacles for job seekers, mismatch between existing qualifications and local labour market demands).

Among the current risks of accumulation and utilisation of human capital, the following should be highlighted:

Further deepening of the acute demographic crisis. The demographic security threats to Ukraine are expected to intensify under the impact of war shocks. At the same time, given that the possibilities for the comprehensive processing of demographic and social statistics are limited during martial law, the analysis of the structure and dynamics of the workforce can only be performed based on estimated data. So, according to the Demographic Development Strategy of Ukraine until 2040, with a population of 35.8 million as of July 2024, the forecasted population could decrease to 28.9 million by 2041, and to 25.2 million by 2051. According to the KSE Human Capital Chartbook[138], in 2025 the population of Ukraine had already declined to 37.9 million, of which over 10.3 million are pensioners and 4.6 million are internally displaced persons. Kyiv School of Economics (KSE) calculations[139] align with the estimates of the UN Department of Economic and Social Affairs; meanwhile, according to IMF data, the population of Ukraine, which stood at 33.38 million people at the beginning of 2026, will increase to 33.9 million people by 2030[140].

Increased inequality and poverty, including extreme forms. During the war in Ukraine, the scale and depth of poverty have increased significantly, driven by the loss of jobs, housing, livelihoods and a general decline in economic activity. According to the criterion of monthly consumption below the actual subsistence minimum, 39% of the population was living in poverty in pre-war 2021, rising to

[137]NBU Inflation Report – Q1 2025 – https://bank.gov.ua/admin_uploads/article/IR_2025-Q1.pdf?v=11
[138]KSE Human Capital Chartbook https://kse.ua/wp-content/uploads/2025/05/Ukraine-Human-Capital-Chartbook-2025.pdf
[139] World Population Prospects 2024, https://population.un.org/wpp/
[140] Ukraine and the IMF. https://www.imf.org/en/countries/ukr

67% in 2023[141]. According to the World Bank Poverty and Equity Brief – Ukraine, April 2025[142], the poverty rate by international methodology (i.e., the share of the population living on less than USD 5.5 per day in purchasing power parity) increased by 19 percentage points, reaching 24% in 2024. Additionally, based on the results of the nationwide sample survey conducted from December 2023 to February 2024, over 50% of households reported a deterioration in their financial situation compared to the pre-war period, and 44% reported reduced access to basic social services. This poverty trend could significantly constrain the growth of demand for goods and services in the low-carbon economy and complicate the implementation of a just transition policy without additional compensatory mechanisms.

The differentiation of the social environment caused by large-scale internal displacement poses a major challenge for the implementation of Ukraine's Low-Carbon Development Strategy. As of 7 August 2025, 4.57 million internally displaced persons[143], were officially registered in Ukraine, resulting in a significant concentration of socially vulnerable groups in regions with limited infrastructural capacity. The mismatch between the professional skills of IDPs and the needs of transformed labour markets, the increased pressure on healthcare, education and social protection systems, and the limited access to housing, digital services and retraining opportunities create structural barriers to the implementation of decarbonisation measures. Without integrative mechanisms, there is a risk of marginalisation of certain territories and social groups, reducing the effectiveness and equity of the transition to a low-carbon economy.

Growing digital inequality in the context of the green transformation. In the transition to a low-carbon economy, the demand for digital skills, access to online education, electronic employment services and remote work is increasing. At the same time, a significant portion of the population remains digitally vulnerable. According to the Ukraine Labour Market Profile – 2025/2026[144], over 40% of people aged 55+ lack basic digital skills, and more than 18% of households in rural areas do not have stable internet access. According to the results of the fourth digital skills study of Ukrainians, conducted by the Ministry of Digital Transformation every two years to measure progress and identify further steps in the development of digital literacy, 96% of Ukrainians possess digital skills, and 58% of the population (aged 18 to 70) possess a basic or higher level of digital literacy[145]. According to Digital 2025: Ukraine – DataReportal[146], as of early 2025, Ukraine had 31.5 million internet users, representing 82.4% of the population. However, digital accessibility remains uneven across regions. This digital divide limits access to new forms of employment, complicates professional adaptation, and reduces inclusiveness in green economy sectors, where digital competence is a basic requirement for integration.

The fragmentation of the vocational education system and *its limited adaptation to the cross-sectoral needs of the green economy* pose a critical risk to implementing the Low-Carbon Development

[141] The socio-economic status of Ukrainian households, based on the results of the nationwide sample survey on the socio-economic status of households conducted from December 2023 to February 2024, is available at: https://www.unicef.org/ukraine/documents/social-economical-state-2023-24

[142] *Ukraine Poverty and Equity Brief : April 2025 (English).* Poverty and Equity Brief Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/099525004222548766

[143] Internally displaced persons (IDP) - https://www.ioc.gov.ua/analytics/dashboard-vpo

[144] Ukraine Labour Market Profile – 2025/2026 - https://www.ulandssekretariatet.dk/wp-content/uploads/2025/01/Ukraine-LMP-2025-final.pdf

[145] Digital and AI Literacy Study in Ukraine. Ministry of Digital Transformation, 2025 https://osvita.diia.gov.ua/uploads/3/16239-povna_doslidzenna_cifrovoi_ta_si_gramotnosti_v_ukraini_2025_pptx_pptx.pdf

[146] DIGITAL 2025: UKRAINE - https://datareportal.com/reports/digital-2025-ukraine

Strategy. As of 2025, only 12% of vocational education programs had been adapted to the requirements of decarbonised sectors[147], indicating insufficient integration of environmental and digital competencies into curricula. The lack of cross-sectoral "green" skills restricts labour mobility, complicates the reskilling of workers from carbon-intensive sectors, and creates new structural imbalances in the labour market. Without systematic updates to vocational education content and mechanisms for forecasting demand for green competencies, the human capital base necessary for decarbonisation efforts is at risk.

Loss of youth potential due to emigration and lack of prospects As of August 2025, according to UNHCR Ukraine Situation[148], the number of Ukrainian refugees worldwide exceeded 6.9 million, over 60% of whom are women and working-age youth. Such demographic selectivity in emigration creates a long-term risk of losing innovative human capital, which is critical for implementing technological solutions in decarbonisation. The absence of attractive conditions for professional development, affordable housing, social protection, and institutional support in Ukraine contributes to the prolonged outflow of skilled youth, reducing human capacity in green transformation sectors — particularly in renewable energy, digital engineering, resource management, and climate innovation.

Institutional instability and fragmentation of human capital governance: In the post-war period, there is a dispersion of functions among central executive bodies, regional administrations and international partners, complicating the coordination of human capital development policies in the context of green transformation. The lack of a single operational center for managing decarbonisation workforce planning, weak integration of climate objectives into education and professional policy, and limited community capacity for strategic human resource planning create risks of uncoordinated actions, duplication of functions, and loss of efficiency. This may result in delays in implementing key components of the Strategy, reduced investment attractiveness and restricted access of the population to new forms of employment.

In the post-war period, the human capital development policy should focus on promoting the redistribution of the workforce across sectors, territories, and types of employment to implement the principles of a low-emission economy and increase labour productivity in priority industries. A key task for Ukraine's socio-economic policy is to transition from a model based on cheap labour to one based on high wages and effective labour in low-emission industries.

Existing legal framework

The global decarbonisation framework in the form of the Sustainable Development Goals (SDGs) serves as the foundation for the strategic vision for human capital development in Ukraine. The SDGs were adapted to the national context by Presidential Decree No. 722/2019 of 30 September 2019, "On the Sustainable Development Goals of Ukraine until 2030", which sets priorities for sustainable development, including environmental security, social cohesion and human capital development. The document is based on UN General Assembly Resolution No. 70/1 of 25 September 2015 and reflects Ukraine's international commitments within the framework of European integration.

By Presidential Decree No. 225/2021 of 2 June 2021, the Human Development Strategy was enacted, defining human development as a key aspect of national security. The Strategy includes a system of

[147] Ukraine Labour Market Profile – 2025/2026: https://www.ulandsse635989kretariatet.dk/wp-content/uploads/2025/01/Ukraine-LMP-2025-final.pdf
[148] https://data.unhcr.org/en/situations/ukraine?utm

indicators to monitor, plan, and evaluate social investments in human capital, covering education, healthcare, employment, and social protection. In 2024–2025, the provisions of this Strategy were integrated into the draft new Employment Strategy, with an emphasis on the green transition, digital transformation and inclusivity.

Within the EU-supported Ukraine Facility economic support program, human capital development has been identified as one of five key priorities. Ukraine's plan submitted to the European Commission in April 2024 envisages implementing policies on employment, vocational education, social housing, healthcare, culture, gender equality and deinstitutionalisation of care. In June 2025, the EU approved the first tranche of funding, with a strong focus on developing human resources for the green transition — including reforms in vocational education, support for the employment of internally displaced persons (IDPs), veterans, and youth, as well as the establishment of regional retraining centers for decarbonised sectors.

In response to demographic challenges, the Cabinet of Ministers of Ukraine approved the Demographic Development Strategy of Ukraine until 2040 by Resolution No. 922-p of 30 September 2023. The document is based on the principles of human-centricity, inclusivity and equal opportunities, aiming to improve key socio-demographic indicators by enhancing the resilience of the state and society. Strategic goals include activating the maximum number of citizens capable of working, notably through the development of green energy technologies, which will create new employment and career growth opportunities in low-carbon sectors. In 2025, the Ministry of Social Policy developed the first package of regional demographic plans, including measures to promote employment in sectors of the green transition.

Based on these strategic documents, the Ministry of Economy published the draft National Employment Strategy until 2030 in 2025. The document aims to achieve high labour productivity, create socio-economic conditions for expanded workforce reproduction and build human capital adapted to the needs of a decarbonised economy. The Strategy provides for the creation of a national registry of green professions, the integration of environmental competencies into educational standards and the launch of pilot programs in energy-efficient construction, waste management, renewable energy and climate innovation. The Strategy is being developed with the support of GIZ under the REYOIN project, which promotes the socio-economic integration of IDPs, veterans, youth and other vulnerable groups.

Priority policies and strategic priorities

Reducing CO_2 emissions will have a significant impact on human capital, labour markets, and employment. The structure of the economy and production will change, fostering labour mobility. The sectors most affected will include energy, transport, agriculture, and service industries. The effects can be divided into short-term and long-term. In the short term, employment in traditional extractive industries will decrease, but immediate proportional increases in green jobs should not be expected. If the right measures are taken to ensure a fair and inclusive transition to a low-emission and sustainable economy, it can create quality jobs, alleviate poverty, and reduce inequality. The decarbonisation policy should include a quality aspect of job creation to be fairer and more socially acceptable.

Thus, implementing strategic measures to adapt national economies while preserving and creating jobs and becoming more resilient in this process becomes more relevant. According to ILO

estimates, by 2030, 18 million jobs can be created worldwide (approximately 24 million created and about 6 million lost) through adherence to sustainable development policies and reducing GHG emissions by 41%. Another 6 million jobs can be created worldwide by 2030 through the introduction of circular economy principles. The most significant impact will be sustained by such segments of the national labour market as construction, mining industries, and RES-based power generation.

Strategic priorities for the development of human capital in the context of ensuring the effectiveness of a low-emission economy

Strategic Priority 1. Building an inclusive, innovative, and decarbonised economy based on equal access to quality education, healthcare services, and scientific achievements.

Main Tasks:

- ensuring socio-economic stability in the transition to a low-emission economy based on the adaptability, flexibility, and transformative capacity of institutions;
- ensuring accessibility and quality of education and healthcare services;
- developing social infrastructure to ensure a high quality of life;
- forming cross-cutting "green" competencies in society;
- integrating science, education, and business to ensure inclusive economic development;
- promoting STEM education;
- developing energy-saving and energy-efficient culture in society, carrying out informational and explanatory work;
- creating conditions for the adaptation of veterans and forming an inclusive social environment;
- creating additional guarantees for youth employment, providing them with their first job, and expanding opportunities for productive employment of older people, IDPs, persons with disabilities, and veterans in the context of the formation of a low-carbon economy;
- overcoming gender stereotypes regarding vocational education.

A successful and inclusive transition to a low-carbon economy will not happen automatically. It is based on dynamic labour markets that promote job creation and enable people to move easily between jobs, sectors, and regions. This defines the formulation of the next strategic priority.

Strategic Priority 2. Shaping a flexible labour market based on decent work and the opportunity to realise professional competencies.

Main tasks:

- developing measures to minimise the effects of structural unemployment, both professional and sectoral, that will arise in the transition to a low-emission economy;
- developing vocational education in line with labour market needs and a low-emission economy, which requires monitoring labour market conditions, improving and updating educational curricula based on competencies in accordance with the needs of the low-carbon economy and professional standards, developing professional standards for new professions that a low-emission economy will require. This particularly applies to professions related to "eco-friendly" work and energy-efficient technologies. For instance, skills related

to the installation, operation, and maintenance of energy-saving equipment are required to use energy-efficient building technologies. The role of numerous skills in using RES and implementing measures to conserve natural resources and reduce harmful GHG is also crucial.

- developing and implementing measures for the unshadowing of the labour market and regulating non-standard forms of employment;
- ensuring the quality of vocational education and developing adult education according to the requirements of the green economy, implementing retraining and qualification upgrading programmes for professions needed by the green economy, and ongoing monitoring;
- constantly forecasting the labour market in professional terms to study development trends, effectively distributing and reallocating labour both at the regional and national levels;
- ensuring two-way communication with employers and developing social dialogue;
- improving the procedure for granting grants and microgrants to start businesses and develop businesses in the low-emission economy sector, which will create new jobs;
- ensuring a flexible system for retraining and requalification of workers released from outdated sectors as a result of the spread of decarbonisation measures in the economy.

Strategic Priority 3. Strengthening Institutional Capacity and Digital Transformation for Human Capital Management in the Context of Decarbonisation

Main tasks:

- Developing an integrated human capital management system encompassing education, employment, social protection and professional mobility in green economy sectors.
- Digitalisation of labour market forecasting, monitoring, and assessment processes with consideration of climate goals, including the creation of a national registry of green professions.
- Establishing a unified platform for retraining, upskilling and career support for workers displaced from carbon-intensive sectors.
- Institutionalisation of the principles of a just transition in legislation, regional strategies and budget planning.
- Development of the human resource capacity of local governments for managing employment transformation, including training, knowledge exchange, and engagement with international technical assistance.
- Ensuring inter-agency coordination among the Ministry of Economy, Ministry of Education and Science, Ministry of Social Policy, and regional administrations for the implementation of human capital policies in the context of decarbonisation.
- Implementation of mechanisms to assess the social impact of decarbonisation measures on employment, including indicators on gender equality, inclusion and regional balance.
- Creation of conditions for attracting investments in human capital development, including through public-private partnerships in green education, innovation and retraining.

4.3. JUST TRANSITION POLICY

The just transition policy is an integral part of a successful economic decarbonisation process. According to the International Labour Organisation (ILO),[149] a just transition means "greening the economy in a way that is as fair and inclusive as possible to everyone concerned, creating decent work opportunities and leaving no one behind".

Decarbonisation involves gradually phasing out fossil fuels and closing both extraction and power generation capacities, which, in turn, creates negative socio-economic consequences for towns where such enterprises are located. Typically, these communities are mono-industrial, often built around mines, power plants, and other facilities specifically as towns for their workers.

Current State Overview

In recent years, Ukraine has made some positive progress in defining the concept of a just transition, particularly in coal regions, as reflected in the Energy Strategy of Ukraine until 2050, the National Energy and Climate Plan until 2030, and other strategic documents. Planning for the just transition in coal regions continues actively, despite the full-scale aggression of the Russian Federation.

In May 2020, the Ukrainian Cabinet of Ministers created the Coordination Centre for the Transformation of Ukraine's Coal Regions.[150] It includes relevant government officials, heads of state administrations, members of the Verkhovna Rada, representatives of coal mining enterprises, trade unions, and associations of local government authorities. In particular, members of the Coordination Centre were tasked with analysing the real state of the economy and social protection of mining towns and proposing options for new directions of local economic development and job creation.

During the first meeting of the Coordination Centre on 8 October 2020, heads of the Ministry of Energy and the Ministry for Communities and Territories Development of Ukraine presented the projects of the Concept for Reforming the Coal Industry and the National programme for the Transformation of Coal Regions of Ukraine until 2027.[151] The government planned to finance transformation measures from the state budget (including a separate funding stream within 50% of the State Regional Development Fund), local budgets, and international technical assistance and financial organisations.

On 22 September 2021, the government approved the Concept of the State Target Programme for the Just Transition of Coal Regions until 2030.[152] This is the first document in the history of independent Ukraine aimed at comprehensively addressing the socio-economic problems of certain communities after the closure of coal mines.

The Concept focuses on the following key areas:

- diversification of the local economy in coal regions;

[149] Guidelines for a just transition towards environmentally sustainable economies and societies for all: https://globalcompact.at/wp-content/uploads/2022/09/wcms_432859.pdf

[150] Resolution of the Cabinet of Ministers of Ukraine dated 13 May 2020 "On the Establishment of the Coordination Centre for the Transformation of Coal Regions of Ukraine" of 13 May 2020, https://zakon.rada.gov.ua/laws/show/391-2020-%D0%BF

[151] Representatives of mining towns will now be able to influence the transformation of coal regions:https://ecoaction.org.ua/predstavnyky-mist-zmozhut-vplyvaty.html

[152] Resolution of the Cabinet of Ministers of Ukraine dated 22 September 2021 "On Approval of the Concept of the State Target Programme for the Fair Transformation of Coal Regions of Ukraine for the Period Until 2030" of 22 September 2021,https://zakon.rada.gov.ua/laws/show/1024-2021-%D0%BF#Text

- development of distributed generation based on RES and the implementation of energy efficiency measures;
- social support for miners and their families;
- training and skills development for fired workers;
- creating favourable conditions for the development of SMEs;
- introduction of new legislative instruments to support investors who create jobs in mining regions.

It was also foreseen that, in a few years, separate transformation plans would be developed for each mining community. A State Target Programme for the Just Transition of Coal Regions was supposed to be developed within the next six months, but the process was delayed due to the full-scale invasion by the Russian Federation in February 2022.

On 18 October 2023, the Deputy Minister for Communities and Territories Development announced that the government plans to resume the drafting of the State Target Program and complete it in the first quarter of 2024.[153] The programme outlined methods and tools for diversification, as well as support mechanisms from the government and partners, to develop local economies in coal communities sustainably.

In June 2025, the State Target programme was officially adopted[154]. A key innovation of the document is the expanded definition of "coal communities", which now includes not only traditional mining communities but also communities hosting power generation facilities (TPP/CHP).

The Program's objectives are to be achieved through the implementation of priority programmatic measures in the following areas:

- Structural transformation of the local economy;
- Mitigation of negative social impacts from the closure and transformation of coal enterprises and the development of human capital;
- transition to RES and increasing energy efficiency;
- Resolution of environmental issues and climate change mitigation.

The estimated financing of the programme amounts to UAH 30.4 billion, including: UAH 4.38 billion from the state budget; UAH 5.5 billion from local budgets; UAH 20.5 billion from other sources, primarily international assistance.

Furthermore, active processes were taking place at the local level in several regions and communities.

In May 2019, the Platform for Sustainable Development of Coal Towns of Donetsk Region was created. It includes six coal towns, three local NGOs, and the Donetsk Oblast Chamber of Commerce

[153] How to transform the economy of coal communities in times of war: Conclusions of the annual high-level forum,https://ecoaction.org.ua/transformuvaty-ekonomiku-vuhilnyh-hromad.html

[154] Resolution of the Cabinet of Ministers of Ukraine No. 711 of 18 June 2025 "On Approval of the State Target programme for Just Transition of Ukraine's Coal Regions until 2030": https://zakon.rada.gov.ua/laws/show/711-2025-%D0%BF#Text

and Industry[155]. By 2021, the number of towns in the Platform had grown to 9, thus including all the mining communities in Donetsk Oblast.

The culmination of its work was the development of the Strategy for the Transformation of Coal Towns of Donetsk Region (Pokrovsk, Myrnohrad, Dobropillia, Novohrodivka, Selydove, Vuhledar, and Toretsk) until 2030.[156] The Strategy included principles of sustainable development and focused on strengthening partnerships between territorial communities for socio-economic development, diversifying the economy, changing the image of the territories, reducing GHG emissions, and improving the welfare of the population through economic transformation and the development of innovative enterprises. It proposed strategic directions such as changing the economic structure, attracting investments, developing small and medium-sized businesses, human capital, RES and energy efficiency. This Strategy was developed during 2020–2021 and was supposed to be adopted by local councils of coal communities at the beginning of 2022, which did not happen due to the full-scale Russian invasion.

In 2021, the "Support for Structural Changes in Coal Regions of Ukraine" project, implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the Federal Ministry for Economic Affairs and Climate Action (BMWK), was officially launched.[157].

Initially, two pilot communities were selected: Sheptytskyi (Lviv Oblast) and Myrnohrad (Donetsk Oblast). Russia's full-scale invasion in February 2022 made work in Myrnohrad almost impossible as originally planned. Assistance is currently being provided to develop the Community Recovery Plan, which incorporates principles and mechanisms for a just transition.

On the other part, Action Plans for the just transition have been developed and adopted for the coal microregion of Lviv Oblast (the city of Sheptytskyi and several surrounding communities)[158]. It includes three strategic goals:

- Energy transition and a clean environment in the microregion to support the livelihoods of multiple generations and social groups;
- A new competitive economy for the coal microregion;
- A coal microregion adapted to the new social needs of its residents.

Following the example of Sheptytskyi, a similar Action Plan for Just Transition was also developed for the Volyn Coal Microregion (Novovolynsk, Poromiv, Lytovezh).[159]

Additionally, in summer 2025, the European Investment Bank (EIB), with support from the German government, announced the creation of a new programme — Just Transition and Just Resilience for

[155] Ukraine: Grassroots Local Cooperation through the Platform for Sustainable Development of Coal Towns of Donetsk Region: https://www.wri.org/update/ukraine-grassroots-local-cooperation-through-platform-sustainable-development-coal-towns

[156] Announcement of the publication of the draft Strategy for the Transformation of Coal Communities of Donetsk Region:https://myrnograd-rada.gov.ua/news/23492-povidomlennya-pro-oprilyudnennya-projektu-strategiyi-transformaciyi-vugilnix-gromad-doneckoyi-oblasti

[157] Facilitating a just transition for Ukraine's coal regions. Just Transition & Green Energy Sector Recovery Ukraine: https://www.giz.de/en/worldwide/133998.html

[158] Action Plan for the Just Transition of the Coal Microregion of Lviv Oblast for the Period up to 2030: https://sheptytskarada.gov.ua/spravedlyva-transformatsiia/p-1264

[159] In Lutsk, the Action Plan for the Just Transition of the Volyn Coal Microregion was presented: https://volynonline.com/u-luczku-prezentuvaly-plan-dij-zi-spravedlyvoyi-transformacziyi-volynskogo-vugilnogo-mikroregionu/

Ukraine (JTR-U) — with the possibility of contributions from international donors (the first EUR 19.6 million was provided by the German government)[160]. Coal communities will be able to access both grants and loans to implement their own just transition projects.

In 2023–2024, the Association of Coal Communities was also created.[161] With GIZ's support, as part of the above-mentioned project, the founding meeting of the Association took place on 9 November 2023, and it was officially registered under Ukrainian law in early 2024. The Association consists of 24 communities dependent on coal mining enterprises and TPPs/CHPPs. Six communities located in the frontline zone and occupied territories of Donetsk and Luhansk Oblasts are honorary members. In total, the Association includes representatives from 8 regions.

The Association aims to promote the just transition of mono-industrial territorial communities dependent on coal mining and thermal generation, represent community interests in just transition, energy transition, and recovery from the consequences of war, and support local and regional development.

Existing Legal Framework, Strategic Documents, Goals

At COP26 in Glasgow, Ukraine joined the Powering Past Coal Alliance (PPCA), an international coalition seeking commitments from governments and the private sector to phase out coal. The Ukrainian government set 2035 as the target year for the gradual closure of state-owned power plants.

However, only three months after the coal phase-out date was announced — without being legally codified in national legislation, regulations, or strategies — Russia's full-scale invasion of Ukraine began, putting most plans on hold. The energy infrastructure suffered heavy attacks in the winter of 2022–2023, and all forces and resources were focused on defending the country, creating uncertainty regarding which plans could still be realised and which were currently unfeasible during active hostilities.

On 21 April 2023, the Cabinet of Ministers adopted a new Energy Strategy until 2050. While the full text is not publicly available, it envisions reducing coal generation and aiming for its complete phase-out by 2035. Coal generation will be replaced by combined CHPPs and TPPs using natural gas/biomethane, as well as CHPP plants running on biomass (solid municipal waste, agro-industrial waste, wood, etc.). The Energy Strategy does not distinguish between state-owned and private generating capacities. It uses 2035 as the final year for coal abandonment in electricity production.

Before the Ukraine Recovery Conference in London in the summer of 2023, the Deputy Minister of Energy confirmed[162] that Ukraine did not plan to use coal for electricity generation after 2035. This was the first public statement by the Ukrainian government affirming that previously announced plans remained valid.

Furthermore, the Ukraine Plan for the 2024–2027 period, developed within the framework of the Ukraine Facility, also states that Ukraine remains "committed to the gradual phase-out of coal use in electricity generation by 2035" and that "the approach to reconstruction that Ukraine will apply will

[160] EU expands support for Ukraine with new financing of almost €600 million for energy, transport and business resilience: https://www.eib.org/en/press/all/2025-282-eu-expands-support-for-ukraine-with-new-financing-of-almost-eur600-million-for-energy-transport-and-business-resilience

[161] Official website of the Association of Coal Communities of Ukraine: https://accu.in.ua/

[162] Amid war, Ukraine recommits to phasing out coal power by 2035: https://poweringpastcoal.org/press-releases/amid-war-ukraine-recommits-to-phasing-out-coal-power-by-2035/

also have a critical impact on Ukraine's green transformation. … In this context, one of the key objectives will be to ensure a sharp reduction in the production and consumption of fossil fuels and to facilitate the phase-out of coal in Ukraine by 2035, whilst simultaneously taking measures to mitigate negative socio-economic consequences for vulnerable groups"[163].

The National Energy and Climate Plan (NECP) of Ukraine until 2030, adopted in June 2024, also indicates that "the Energy Strategy of Ukraine confirms the previously announced plans, including the reduction of coal generation, leading to its complete phase-out by 2035'.[164] However: "the feasibility of achieving this goal by 2035 will be assessed after the full-scale invasion of the Russian Federation ends, taking into account the condition and available capacities remaining in operation after the termination of hostilities." The NECP specifies one special just transition measure, specifically the development and adoption of a State Target Programme for the Just Transition of Coal Regions until 2030.

Policy Priorities Until 2050

An overview of the current situation underscores that just transition processes in Ukraine are inextricably linked to coal regions. As an example of progress made, **full and successful decarbonisation of the economy requires expanding the scope and understanding of just transition beyond the current focus on one specific type of region. Other carbon-intensive and mono-industrial communities, such as those dependent on the extraction of gas, oil, and other fossil fuels, as well as fossil fuel-dependent industrial enterprises that will scale down their operations or close completely, must also be covered by the government's just transition policy**. Meanwhile, positive examples and lessons learned from working with coal regions should be used to implement the principles and definitions of just transition in other sectors.

The priority should be the diversification of the local economy of carbon-intensive and single-industry communities through the creation of "green jobs". Particular attention should be paid to the sectors that will contribute to the energy transition, resilience, and post-war reconstruction of Ukraine: the localisation of the production of energy-efficient building materials and RES components. Overall efforts to promote transition and job creation should also consider the need to create new opportunities for women, veterans returning from the front lines, and internally displaced persons.

In general, the development of special local Just Transition Plans is necessary. These plans should take into account the existing experience and methodology of developing and adopting Territorial Just Transition Plans within the EU's Just Transition Mechanism. As an initial step, these plans should detail the transition process to be implemented in the relevant area to achieve a climate-neutral economy. Each plan should describe the just transition process formed at the national level. Based on it, challenges related to the transformation of individual communities should be assessed.

The assessment should include only those challenges directly related to the transformation or closure of high-emission activities, and may, for example, rely on the following questions[165]:

[163] Ukraine Facility Plan: https://www.ukrainefacility.me.gov.ua/en/

[164] National Energy and Climate Plan for the Period up to 2030 | Ministry of Economy, Environment and Agriculture: https://me.gov.ua/Documents/Detail?lang=uk-UA&id=17f558a7-b4b4-42ca-b662-2811f42d4a33&title=NatsionalniiPlanZEnergetikiTaKlimatuNaPeriodDo2030-Roku

[165] Commission staff working document on the territorial just transition plans: https://ec.europa.eu/regional_policy/sources/funding/just-transition-fund/swd_territ_just_trans_plan_en.pdf

- What is the relative importance of transforming sectors in the regional economy? What is the potential for regional economic diversification? Is there an adequate system of business support in the area? Will the transition affect small, medium and/or large business entities?
- How many jobs will potentially be lost due to transformation or the closure of enterprises, including through early retirement? How does this number compare to overall employment in the area and, in relevant cases, specific communities or companies?
- What are the needs for retraining or upskilling, considering both the projected development in transforming sectors and the skills required for economic diversification?
- What needs and development goals exist for regional economic sectors, workers, and local communities as a result of the transformation process?
- Is the education and training sector adapted to the challenges of the transformation? Does it have systems for exchanging information with local companies about their current and future skills needs? Does the education system have autonomy and the ability to respond in a timely manner to the skills needs of companies in the community or companies that may be willing to invest in the community? Do guidance, counselling, and prior learning recognition systems work in practice? Are they easily accessible to job seekers? Do companies invest in the qualification of their employees, and how does this happen in practice?
- Does the transition to climate neutrality have broader social consequences, such as impacts on community cohesion, living conditions, energy poverty, or access to municipal services in general?
- Is there a risk of depopulation associated with the transition to a climate-neutral economy? Does the transformation impact youth?
- Is it necessary to address the negative environmental impacts post-transformation, such as impacts on soil or water quality, ecosystem health, or land restoration?

Local Plans should also **outline the types of measures/projects planned to be supported to ensure a just transition**. Taking into account Ukraine's future accession to the EU, these measures/projects must comply with Regulation (EU) 2021/1056 of the European Parliament and of the Council of 24 June 2021 on the establishment of the Just Transition Fund, since not all potential and planned projects in carbon-intensive and single-industry communities can automatically be considered as aligned with the objectives of a just transition.

Local Plans should be developed and adopted through a process facilitated by regional or local authorities, ensuring that it is effective within the broader governance context existing in the region or community. In addition to effectiveness, this model **should include the views of various concerned parties and ensure their involvement in the process at early stages of development, with ongoing support throughout**.

4.4. GENDER EQUALITY POLICY

Ukraine has chosen a democratic path of development and directs its legislative and state activities to establish gender parity between women and men in all areas of public life. The main principles of gender development in Ukraine are outlined in the Constitution (Article 24), which emphasises that citizens are equal before the law and that no privileges or restrictions shall exist based on race, skin colour, political, religious, or other beliefs, gender, ethnic and social origin, property status, place of residence, language, or other characteristics.

Ukraine has undertaken international obligations to promote women's rights and has therefore developed a national legal framework to achieve this goal. Despite the relatively well-developed institutional mechanism for developing and implementing gender policy in Ukraine, ensuring its operation across all branches of government presents challenges. The legal framework regulating gender equality covers many areas of life, including social and labour relations. However, effective mechanisms for implementing legislation to ensure equal rights and opportunities for women and men are lacking.

Incorporating a gender-sensitive approach is critically important when developing the LT-LEDS in Ukraine, as the impacts of climate change are not gender-neutral. Women, girls, and vulnerable groups are particularly affected by the consequences of climate change, which exacerbates existing gender inequalities. Limited access to resources such as clean water, land, and energy resources, restricted opportunities for decision-making, and lack of necessary information and technology make women more vulnerable to climate challenges. In the context of ongoing armed aggression in Ukraine, considering gender aspects becomes even more significant, as war aGHGravates social and economic challenges, creating additional barriers to adaptation and recovery. A gender-sensitive approach also contributes to integrating women's professional potential into strategic planning and implementing the LT-LEDS, which in turn supports sustainable development, social justice, and resilience in the long run.

Women make up 24% of the workforce in the energy sector, while women employed in other areas of economic activity account for 54%[166]. The renewable energy sector lacks opportunities for women's involvement, as they require more comprehensive training in STEM. Women often perform low-skilled and non-technical jobs in the energy sector and are underrepresented in leadership positions. Ukraine currently leads in the number of women participating in professional and technical fields. Thus, according to the State Statistics Service, as of February 2025, women head 36.2% of enterprises. Ukraine also ranks first in terms of involving girls in education within general secondary and higher education institutions, yet a gender gap still remains in such specialties as pedagogy, IT, agriculture, During the full-scale war in Ukraine, women are increasingly occupying positions for which men were previously hired. For instance, in 2023, 1.2 thousand women found employment in construction through the State Employment Service, making up 38% of all those employed in this sector.

The transport sector, due to mobilisation and migration during the hostilities in Ukraine, is suffering the most from a shortage of specialists. Nearly 2,000 women work in public electric transport. Moreover, women and men use transport differently, face different barriers, and have different needs, especially regarding mobility, access to work, and safety. Integrating gender aspects into

[166] https://ua.boell.org/sites/defoult/files/genger_in_energy_report_2019.pdf

transport policy will not only ensure equal opportunities for all but will also contribute to overall reductions in carbon emissions, as more effective and inclusive transport solutions generally lead to greater environmental sustainability.

Although women represent a significant share of the workforce in agriculture and predominate in food production, they often cannot fully realise their potential, and their families face negative consequences such as poverty and lack of food security. In agriculture, women are often involved in livestock care and small-scale farming, while men typically take on leadership roles in larger farms. This division of labour means that women are directly involved in activities that lead to methane emissions in animal husbandry, such as feeding and manure management. Due to socio-economic barriers, women often have limited access to financial resources, technologies, and training necessary to implement climate-smart practices in agriculture.

A gender-sensitive approach to waste management will contribute to achieving long-term climate goals. If they have access to appropriate resources, training, and decision-making processes, women can play a key role in reducing waste and cutting GHG emissions.

Including a gender-sensitive approach in the LT-LEDS in Ukraine is an important step towards ensuring equality and improving the effectiveness of climate change adaptation. The gender aspect allows for a deeper assessment of the impact of climate change on different population groups, particularly women, girls, and people with disabilities, who are vulnerable to ecological challenges.

The integration of a gender-inclusive approach will include the following main focus areas:

Expanding opportunities for all and enhancing women's participation in decision-making at all levels. Considering a gender approach enables more active engagement of women in key sectors that play a crucial role in reducing GHG emissions. Ensuring gender equality and inclusivity improves social mobility and opens new opportunities for all groups of the population. Involving women in the development and implementation of low-carbon solutions will help increase employment, skill development, and innovation across various economic sectors.

Integrating issues related to the protection of women's rights and gender equality into climate and environmental legislation. Ensuring that advocacy efforts highlight specific vulnerabilities and women's contributions to combating climate change and implementing climate-friendly solutions.

Developing gender-sensitive policies in the energy, transport, and agriculture sectors, actively involving women in sustainable development initiatives. Developing locally adapted gender-sensitive plans for reducing greenhouse gas emissions. This includes targeted support for women in implementing low-emission technologies, access to energy resources, and climate-smart agricultural practices.

Raising awareness about the interdependence of gender equality and social inclusion and climate change. Conducting information campaigns about the importance of gender-sensitive climate policy, especially in rural areas and underserved regions. Raising awareness can help break gender stereotypes and promote a more inclusive approach to climate change adaptation at the local level.

Implementing an effective monitoring and evaluation system across economic sectors to track levels of participation, income levels, and access to decision-making roles, including the creation of a national gender and climate change database.

Providing technical and financial support for gender-oriented climate programmes in Ukraine, especially those that integrate women into the green economy.

A gender-sensitive approach to the LT-LEDS development, monitoring, and implementation processes allows for a more comprehensive assessment of the specific needs and potential of different population groups. This will lead to more effective adaptation to climate change and mitigation of its impacts. Using gender-disaggregated indicators and gender analysis helps create a complete picture of the impact of climate change and ensures equal participation of all groups in decision-making processes. Moreover, integrating a gender perspective contributes to enhancing the transparency, effectiveness and sustainability of climate policy, which is important for fulfilling Ukraine's international commitments under the Paris Agreement, the Lima Work Programme on Gender, and the Gender Action Plan.

5. IMPLEMENTATION AND UPDATING OF THE STRATEGY

5.1. IMPLEMENTATION OF THE LONG-TERM LOW EMISSION STRATEGY

The Strategy is implemented through the execution of measures outlined in the National Energy and Climate Plan, which is approved by the Cabinet of Ministers of Ukraine. The implementation of the Strategy is ensured by central executive authorities, other state authorities, the authorities of the Autonomous Republic of Crimea, and local governments responsible for implementing state climate policy, with the involvement of consultative, advisory, or other supporting bodies on climate change issues.

5.2. MONITORING AND EVALUATION OF THE IMPLEMENTATION

The implementation of this Strategy is monitored and evaluated by the Ministry of Economy in accordance with the procedure for monitoring the implementation of policies and measures for climate change mitigation and adaptation, which is approved by the Cabinet of Ministers of Ukraine.

Monitoring and evaluation of the implementation of this Strategy are conducted with the participation of central executive authorities, other state authorities, the authorities of the Autonomous Republic of Crimea, and local governments, which ensure the implementation of state climate policy, as well as consultative, advisory, or other supporting bodies on climate change issues.

Monitoring and evaluation of the implementation of the Strategy are carried out to assess the effectiveness of the implementation of policies and measures for climate change mitigation and adaptation to ensure the achievement of goals of the national climate policy, in particular, ***achieving climate neutrality in Ukraine by 2050, as well as the intermediate goal of reducing GHG emissions by at least 65 per cent by 2030 compared to the 1990 level.***

The implementation of this Strategy is evaluated using the following target indicators:

- the share of energy generated from RES in the gross final energy consumption structure must be at least 27% in 2030;
- primary and final energy consumption in Ukraine in 2030 should not exceed 91,468 thousand and 50,446 thousand TOE, respectively;
- forest coverage of Ukraine's territory should be at least 17.5% of the total area of the country by 2030;
- electric transport should account for at least 10% of the total number of newly acquired vehicles.

The sources of information used for monitoring and evaluating the implementation of this Strategy include:

- climate change forecasts in the latest version at the time of evaluation;

- the National Inventory Report on anthropogenic GHG emissions from sources and their removal by sinks in the latest version at the time of evaluation;
- the Single Register for monitoring, reporting, and verifying GHG emissions,
- information on the results of implementing policies and measures for climate change mitigation and adaptation, as well as the results of achieving the goals of the national climate policy, provided by central executive authorities in accordance with parts one and two of the Law of Ukraine "On the Main Principles of State Climate Policy in Ukraine",
- recommendations developed by the Scientific and Expert Council on Climate Change and Ozone Layer Protection following the evaluation of state policies for compliance with the goals and principles of national climate policy,
- information provided by other state authorities, the authorities of the Autonomous Republic of Crimea, and local governments regarding the implementation of state climate policy to ensure effective monitoring and evaluation of the implementation of state climate policy.

The implementation of this Strategy is monitored annually based on information on the results of the implementation of policies and measures for climate change mitigation and adaptation, as well as the outcomes of achieving the objectives of the national climate policy, which the central executive authorities provide to the Cabinet of Ministers of Ukraine in accordance with Article 23(1) of the Law of Ukraine "On the Main Principles of State Climate Policy".

The evaluation of the implementation of this Strategy is carried out in the fifth year of its implementation to determine the preparation of proposals for review and updating (if necessary).

During the evaluation, the Ministry of Economy takes into account the results of evaluating state policies for compliance with the goals and principles of national climate policy, carried out by the Scientific and Expert Council on climate change and ozone layer protection, as well as recommendations for taking appropriate measures.

Following the evaluation of the implementation of this Strategy, the Ministry of Economy prepares an evaluation report, submits it to the Cabinet of Ministers of Ukraine, and publishes it on its official website.

5.3. REVIEW AND UPDATE OF THE LONG-TERM LOW EMISSION DEVELOPMENT STRATEGY

The Strategy shall be reviewed and updated, if necessary, every five years with a 30-year planning period. This Strategy will be reviewed after the restoration of territorial integrity within internationally recognised borders and based on verified information.

The Strategy must be reviewed and updated to ensure consistency, scientific justification, consideration of new challenges, and achievement of the goals of national climate policy.

To ensure consistency in the development of state climate policy, the review and update of the Strategy are carried out simultaneously with the development or review of Ukraine's Nationally Determined Contribution to the Paris Agreement, which is carried out according to the rules and guidelines approved by decisions of the Conference of the Parties to the United Nations Framework Convention on Climate Change and decisions of the Conference of the Parties to the United Nations

Framework Convention on Climate Change serving as the meeting of the Parties to the Paris Agreement.

The Strategy review includes a review of medium-term goals and target indicators of state climate policy.

The review of the Strategy is based on:

- climate change forecasts in the latest version at the time of the review;
- information on the volume of anthropogenic GHG emissions from sources and their removal by sinks according to the latest version of the National Inventory Report on anthropogenic GHG emissions and their removal by sinks at the time of the review;
- results of the evaluation of the implementation of the Strategy.

ANNEXES

APPENDIX 1. EXTRACT FROM THE REQUIREMENTS FOR BUILDINGS WITH NEAR-ZERO ENERGY CONSUMPTION

Maximum values of the primary energy consumption from non-renewable energy sources in buildings with near-zero energy consumption for new constructions.

Primary energy consumption from non-renewable energy sources			
1	Residential buildings (number of floors):		
	1–3	68	59
	4–9	49	41
	10–16	44	38
	17 times and more	40	35
2	Public buildings (number of floors):		
	1–3	[21Λ_{bci}+9]	[18Λ_{bci}+7]
	4–9	[17]	[13]
	10 times and more	[14]	[12]
	Certain types of public buildings:		
4	Hotel buildings	32Λ_{bci}+29	26Λ_{bci}+29
5	Educational institution buildings	[32Λ_{bci}+12]	[28Λ_{bci}+12]
6	Pre-school education buildings	[19]	[14]
7	Buildings of healthcare facilities	[17]	[13]
8	Commercial buildings	[19Λ_{bci}+9]	[13Λ_{bci}+8]

Maximum values of the primary energy consumption from non-renewable energy sources in buildings with near-zero energy consumption in case of reconstruction.

Primary energy consumption from non-renewable energy sources			
1	Residential buildings (number of floors):		
	1–3	110	93
	4–9	77	64
	10–16	68	59
	17 and over	64	55
2	Public buildings (number of floors):		
	1–3	[34Λ_{bci}+13]	[29Λ_{bci}+12]
	4–9	[28]	[20]
	10 and over	[23]	[16]
	Certain types of public buildings:		
4	Hotel buildings	52Λ_{bci}+47	43Λ_{bci}+47
5	Educational institution buildings	[52Λ_{bci}+20]	[46Λ_{bci}+20]
6	Pre-school education buildings	[29]	[24]
7	Buildings of healthcare facilities	[28]	[22]
8	Commercial buildings	[31Λ_{bci}+16]	[22Λ_{bci}+13]

APPENDIX 2. METHODOLOGY FOR MODELING THE DEVELOPMENT OF UKRAINE'S ENERGY SYSTEM IN THE TIMES-UKRAINE MODEL

The TIMES-Ukraine model is a linear optimisation model of the energy system (bottom-up type), which thoroughly describes all energy flows in Ukraine.

In the TIMES-Ukraine model, Ukraine's energy system is divided into seven sectors (Fig. D2.1), which includes all energy flows from the extraction of primary energy resources to their final consumption, with intermediate stages of transformation (processing, production of secondary energy resources, etc.), import, export, and transportation. This corresponds to the methodological approach of the State Statistics Service, which in turn is harmonised with the relevant methodologies of the European Commission (Eurostat) and the International Energy Agency (MEA).

TIMES-type models contain a significant number of technologies across various sectors of the energy system, providing information about different types of energy, technologies, etc. Currently, the TIMES-Ukraine model includes nearly 2000 technologies, both existing in Ukraine and those available in international markets that could be implemented in Ukraine. Data sources for cost and technical characteristics include materials from the IEA, the Danish Energy Agency (DEA), the National Renewable Energy Laboratory (NREL), relevant associations in Ukraine, scientific institutions, and energy companies.

The TIMES-Ukraine model develops energy and environmental forecasts according to the methodological guidelines of the UN Framework Convention on Climate Change. Recently, the model has been capable of achieving net-zero GHG emissions across the economy, which has been highlighted in a number of publications in leading journals.

The TIMES-Ukraine model's database contains economic and energy data for 2005–2020, as well as estimates of the relevant data for 2022, considering future changes. The main sources of the database are statistical observations from the State Statistics Service, the NBU, data from Ukrainian ministries and agencies, housing and municipal services, energy generating and supply companies, relevant associations, academic institutions, and others. In addition, data from international organisations (IEA, IAEA, OECD, IMF, World Bank, UN, etc.) are used for energy-economic forecasting.

Energy system models, such as TIMES-Ukraine, are typically used for long-term analysis of energy system development pathways worldwide and are widely used in the European Union at both the pan-European and national levels. By changing assumptions about demand for useful energy, technologies, prices, or other external variables, numerous scenarios can be created and analysed, including scenarios for decarbonising the building sector. Initially, a scenario (or a set of scenarios) is developed without implementing the relevant measures (Baseline, business as usual scenario). Then, policy scenarios (e.g., policies to improve energy efficiency, promote RES, reduce greenhouse gases, or decarbonise the energy system) are developed by imposing additional constraints or targets on the energy system (or its component, such as the building sector) to assess the impacts (effects) of implementing the studied policies. The result of the modelling is the evaluation of the least costly solutions for the entire energy system under the given conditions and constraints.

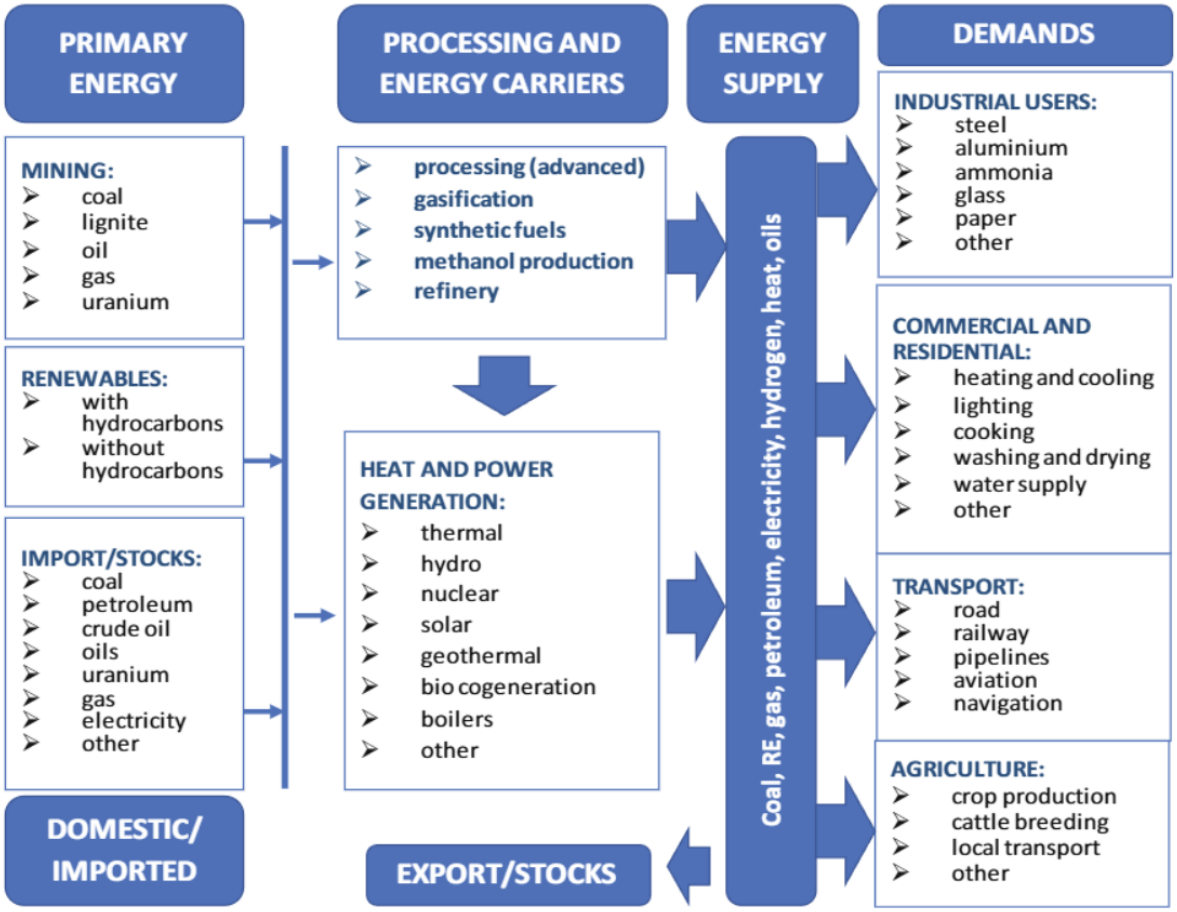


Fig. D2.1. The basic structure of the energy system in the TIMES-Ukraine model

The TIMES-Ukraine model was used to prepare several strategic documents approved by the Ukrainian government in 2016–2021, including the National Energy Efficiency Action Plans for 2020 and 2019–2030, the Expected Nationally Determined Contribution of Ukraine to the Paris Agreement and its updated version, the Low Emission Development Strategy of Ukraine until 2050, the Building Thermal Modernisation Strategy of Ukraine until 2050, and more.

In recent years, the Institute for Economics and Forecasting of the National Academy of Sciences of Ukraine has been applying and developing this model in cooperation with US national labouratories, including the Pacific Northwest National Laboratory, the National Renewable Energy Laboratory (NREL), the Argonne National Laboratory, and the Lawrence Berkeley National Laboratory as part of the Net Zero World initiative. For example, in December 2023, at COP28 in Dubai, the results of modelling the post-war low-carbon development of Ukraine's energy sector were presented as part of the Ukrainian pavilion's programme, and these results were also published in a report. Recently, a joint study with the DIXI group, REKK, the Austrian Institute of Technology, and the Regulatory Assistance Project was conducted on long-term decarbonisation pathways for Ukraine’s power sector, where the TIMES-Ukraine model was used in combination with the EPMM and Green-X models.

Table D.2.1 A short list of promising technologies for the production of electricity and heat

Technologies	*Capital expenditure (CAPEX), EUR/kWh*										
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	***Efficiency (electrical), %***	***capacity utilisation factor, %***	***Service life, years***	***Heat production coefficient***
Thermal power plants (TPP) and combined heat and power plants (CHPP)											
NPP											
New large power units	4400							33	88	60	0.03
Extending the service life of existing power units	254							33	80	30	0.04
New small modular reactors (160 MW)	4400							33	90	80	0.04
Nuclear high-temperature reactor with hydrogen production	7,650–6,885							33	94	60	0.1–0.12
Gas (natural/biomethane/synthetic methane)											
Combined cycle gas turbine	1000							60	50	35	0.15
Open cycle gas turbine	600							40	50	30	0.15
Quick-start gas piston engine (maneuvering power)	1000							50	75522	35	–
Combined cycle gas turbine + Carbon capture	2450							51	50	35	0.05
Open cycle gas turbine + Carbon capture	2050							34	50	30	0.05
Combined cycle CHPP	800							50	50	35	0.84
Open cycle CHPP	920							45	50	35	0.95
Extension of the operating life of existing CHPPs	280–650							19–43	50	15	1.1–3.0
Combined cycle CHPP + Carbon capture	2250							45	50	35	0.84
Bioenergy											
TPP using wood biomass	2800	2750	2700	2650	2600	2550	2500	24	50	30	–
TPPs burning household waste	2900	2850	2800	2750	2700	2650	2600	23	50	30	0.3
Biogas TPP	3200	3200	3200	3200	3200	3200	3200	42	50	30	–
TPP using wood biomass + Carbon capture	3650							24	50	30	–
Biogas TPP + Carbon capture	5350							42	50	30	–
TPP using energy crops + Carbon capture	3750							24	50	30	–
CHPP using wood biomass	3400	2850	2800	2750	2700	2650	2600	20	50	35	2.0
CHPP using waste biomass	3400	2950	2850	2850	2900	2750	2700	19	50	35	1.9
CHPP using energy crops	3400	3150	3100	3050	3000	2950	2900	20	50	35	2.0
CHPP using wood biomass + Carbon capture	4450							20	50	35	1.5
CHPP using energy crops + Carbon capture	4450							20	50	35	1.5
Wind power plants (WPP)											
Onshore wind power plants	1100	1075	1050	1000	950	900	850	–	32	30	–
Offshore wind power plants	2120	1960	1800	1700	1680	1660	1640	–	42	30	–
Solar power plants (SPP)											
Industrial solar power plants without tracker	750	725	700	630	560	510	475	–	12.5	25	–
Industrial solar power plants	920	850	800	720	645	590	540	–	14.5	25	–

Technologies	*Capital expenditure (CAPEX), EUR/kWh*										
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	***Efficiency (electrical), %***	***capacity utilisation factor, %***	***Service life, years***	***Heat production coefficient***
with tracker											
Roof solar power plants	900	875	850	800	750	700	600	–	13.5	25	–
Geothermal power plants (GPP)											
Geothermal power plant	4,300–3,600							–	35–55	25	–
Hydroelectric power plants (HPP)											
Small hydroelectric power plants	3,250–3,080							–	30	40	–
Large hydroelectric power plants	3,300–3,100							–	33–36	60	
Pumped storage power stations	1980							–	26	60	–
Battery energy storage systems (BESS), EUR/kWh											
Electric batteries	1042	832	622	508	394	324	255	92	17	25	–
Underground hydrogen storage	980	750	700	650	600	550	500	100	100	30	–
Hydrogen tank storage, large volumes	4600	3600	3400	3200	3000	2800	2500	100	100	22	–
Hydrogen tank storage, small volumes	2650	2075	1900	1800	1700	1600	1500	100	100	22	
Fuel cells (Hydrogen)											
Fuel cell TPP and CHPP	2530	1125	1125	844				50	60	10	0.64
Heating plants (Boiler plants)											
Gas boiler plant (with the possibility of bio- or synthetic methane)	300							92	50	40	–
Boiler plant using wood biomass	145	142	140	138	136			85	50	35	–
Boiler plant using industrial waste biomass	350	320	300	280	270	260	250	80	50	35	–
Aerothermal energy boiler plant	1100							250	50	25	–
Hydrogen boiler plant	390							64	50	35	–
Other important technologies											
Direct air carbon capture (DAC)	2.32	2.05	1.86	1.8	1.7	1.6	1.5	0.014-0.007 PJ/kt CO_2	90	25	–
Methanation	600	500	450	400	350	300	250	75–83 (H_2)	95	25	–
Direct reduction iron (DRI) production from hydrogen	360	355	350	345	340	333	324	17 PJ H_2/mt	85	40	–
Low-carbon production of iron ore concentrate	96							64–75	1	30	–
Alkaloid electrolyser	650	500	450	375	300	275	250	67–75	97	25–35	–
Proton exchange membrane (PEM) electrolyser	925	800	650	550	450	425	400	58–71	97	20–30	–
Solid oxide electrolyser cell (SOEC)	4500	3200	1900	1620	1340	1060	780	77.5–83.5	91	10–20	–
Steam methane reforming, high capacity	10.6							77	90	20	–
Steam methane reforming, low capacity	22							69	80	20	–
Solar steam methane reforming, high capacity	9.8							120	90	20	–
Solar steam methane reforming, low capacity	27							60	90	20	–
Biomass gasification for hydrogen production, high capacity	63.4	47.6						50	90	20	–
Biomass gasification for hydrogen production, low capacity	111	95						33	71	20	–
Steam ethanol reforming	234							67	90	20	–

APPENDIX 3. DESCRIPTION OF SCENARIOS, MODELING METHODOLOGY AND INVESTMENT NEEDS IN THE WASTE SECTOR

Description of GHG Reduction Scenarios in the Waste Management Sector

The WEM scenario (scenario with existing measures) of the National Low-Carbon Development Strategy (NLCDS) corresponds to the WEM scenario of Ukraine's National Energy and Climate Plan for the period up to 2030. This scenario is based on the current waste management regulations of Ukraine as of September 2024, considering general macroeconomic and socio-demographic forecasts across sectors. The WEM scenario assumes that the National Waste Management Strategy until 2030 and the National Waste Management Plan until 2030 will be only partially implemented by 2030[167], with full implementation occurring gradually over the forecast period. This scenario assumes that Ukraine will achieve the Sustainable Development Goals by 2030, including reducing untreated wastewater, increasing per capita food consumption, and decreasing water consumption per unit of GDP. It also corresponds to the implementation of the provisions of the Second NDC (Nationally Determined Contribution) for the period up to 2050 in terms of waste management and takes into account the introduction of measures to implement Ukraine's climate policy as part of its participation in the global initiative to reduce methane emissions, the "Global Methane Pledge". Specifically, the WEM scenario envisions reducing the share of HW landfilling to 70% by 2030 and 30% by 2050, increasing the share of biogas utilisation at landfills to 15% by 2030 and 36% by 2050, and constructing new composting facilities with lower specific GHG emission factors.

The WAM scenario (scenario with additional measures) of the National Low-Carbon Development Strategy (NLCDS) corresponds to the WAM scenario of the National Energy and Climate Plan for the period up to 2030, which assumes strict compliance with the provisions of the Waste Management Law adopted in 2022, as well as with recently adopted strategic planning documents regarding waste management. This scenario is based on the assumption that the National Waste Management Plan of Ukraine until 2033 and the Action Plan of the National Waste Management Plan of Ukraine until 2033 approved on 27 December 2025 will be implemented on time and in full. Specifically, the WAM scenario envisions reducing the share of HW landfilling to 30% by 2030 and 20% by 2050, increasing the share of biogas utilisation at landfills to 28% by 2030 and 36% by 2050, and constructing new waste composting facilities with lower specific CH_4 and N_2O. emission rate.

It should be noted that, unlike the WEM scenario, under the WAM scenario, the increase in the share of biogas utilisation at HW landfills until 2030 will primarily occur through the wider deployment of biogas recovery technologies rather than through flaring. This is because the approval of the National Waste Management Plan of Ukraine until 2033 and the Action Plan for the National Waste Management Plan of Ukraine until 2033 will facilitate the development of new regional HW landfills while simultaneously decommissioning outdated HW disposal sites.

NZE (Net-Zero Emissions) scenario of the LT-LEDS corresponds to the circular economy scenario of the National Energy and Climate Plan until 2030 in the area of modern HW management in Ukraine. Unlike all the other scenarios, the NZE scenario also envisions the development of modern wastewater treatment infrastructure starting in 2026. Specifically, this scenario envisions reducing the share of HW landfilling to 30% by 2033 and to 1% by 2050; increasing the share of biogas utilisation at landfills to 28% by 2030 and 60% by 2050; and constructing new waste composting

[167]Repealed due to the approval on 27 December 2024 of the National Waste Management Plan of Ukraine until 2033 and the Action Plan of the National Waste Management Plan of Ukraine until 2033.

facilities with significantly lower specific CH_4 and N_2O emission rates. The NZE scenario also envisages that methane recovery from wastewater treatment will reach 16% by 2030 and 94% by 2050 through mandatory methane tanks at wastewater treatment plants and biogas recovery and flaring. At the same time, per capita N_2O emissions from protein consumption will drop to 66.5 g N_2O/person/year by 2030 and 15.8 g N_2O/person/year by 2050 as a result of the increased depth of wastewater treatment from nitrogen-containing compounds (nitrates and nitrites).

The key forecast GHG emission modelling indicators for the Waste sector are presented in Table D.3.1.

Table. D.3.1. The Key Forecast GHG Emission Modelling Indicators for the Waste Sector

Indicator		Units	2021/ 2022	2030			2050		
				Scenario			Scenario		
				WEM[2]	WAM[3]	NZE[6]	WEM[2]	WAM[3]	NZE[6]
HW management practices	Reuse	%	1.5[1]	8.0	7.7	7.7	10.0	10.0	10.0
	Recovery	%	6.7[1]	15.0	38.2	38.2	50.0	55.0	51.0
	Recycling	%	5.5[1]	10.0	26.2	26.2	34.0	35.0	37.0
	Composting	%	1.2[1]	5.0	12.0	12.0	16.0	20.0	24.0
	Incineration	%	1.7[1]	7.0	7.7	7.7	10.0	15.0	28.0
	Landfilling	%	90.0[1]	70.0	46.4	46.4	30.0	20.0	1.0
Volumes of HW generation		t/person /year	0.364[4]	0.394	0.394	0.394	0.480	0.480	0.480
Composition of HW (after sorting and recycling)	Paper and cardboard	%	13.7[4]	13.4	14.3	14.3	11.2	11.9	9.8
	Textile	%	3.9[4]	4.6	6.6	6.6	8.9	10.2	12.3
	Food waste	%	31.8[4]	36.1	38.5	38.5	42.1	36.6	30.4
	Wood	%	1.8[4]	2.1	3.0	3.0	4.0	4.6	5.5
	Green waste	%	3.6[4]	1.2	1.7	1.7	2.4	2.7	3.2
	Personal care products	%	1.4[4]	1.6	2.3	2.3	3.2	3.6	4.3
	Rubber and leather	%	1.9[4]	2.2	3.2	3.2	4.3	4.9	5.9
	Plastics	%	12.9[4]	14.0	11.4	11.4	10.1	9.7	9.3
	Glass	%	12.2[4]	6.6	5.2	5.2	2.7	3.1	3.0
	Ferrous metals	%	2.0[4]	2.2	1.5	1.5	1.0	1.2	1.4
	Non-ferrous metals	%	0.4[4]	0.7	0.4	0.4	0.3	0.4	0.5
	Hazardous waste	%	0.5[4]	0.5	0.4	0.4	0.2	0.3	0.3
	Other non-organic waste	%	13.9[4]	14.7	11.6	11.6	9.6	10.9	13.9
Landfill gas utilisation		%	11.4[5]	15.2	27.8	27.8	36.0	36.0	60.0
Flaring		%	0.0[5]	3.8	3.8	3.8	6.0	6.0	6.0
Recuperation		%	11.4[5]	11.4	24.0	24.0	30.0	30.0	54.0
Biological treatment, specific CH_4 emission rate		g/kg	4.00[5]	2.00	2.75	2.75	2.00	1.00	0.037
Biological treatment, specific N_2O emission rate		g/kg	0.30[5]	0.15	0.21	0.21	0.15	0.075	0.067
Baseline N_2O emission factor from protein consumption by the population		g/person/ year	75.8[5]	107.9	107.9	66.58	97.9	97.9	15.88
Methane utilisation in wastewater treatment		%	0.00[5]	0.00	0.00	15.7	0.00	0.00	94.0[9]
Flaring		%	0.00[5]	0.00	0.00	0.00	0.00	0.00	9.0[9]

Recuperation	%	0.00[5]	0.00	0.00	15.7	0.00	0.00	85.0[9]
Specific water consumption per unit of GDP	Index up to 2015	0.88[4]	0.70	0.70	0.70	0.70	0.70	0.70

1 Analysis of the state of the household waste management sector in Ukraine for 2022; according to the Ministry of Infrastructure

2 WEM scenario of the National Energy and Climate Plan of Ukraine until 2030

3 WAM scenario of the National Energy and Climate Plan of Ukraine until 2030

4 Calculated based on Report 3. Modeling Report. Support to the Government of Ukraine on Updating its Nationally Determined Contribution (NDC)», доступного за посиланням: https://mepr.gov.ua/wp-content/uploads/2023/07/Modeling-Report-3.pdf

5 National Cadastre of anthropogenic emissions from sources and removals by sinks of greenhouse gases, greenhouse gas emissions in Ukraine for 1990–2022; according to the MENR data

6 Implementation of circular economy in the National Energy and Climate Plan of Ukraine until 2030 (see waste management sector)

7 Emission indicators in 2050 will reach minimum values of the recommended specific emission factors according to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, available at: https://www.ipcc-nGHGip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_4_Ch4_Bio_Treat.pdf

8 Specific N^2O emission rates will gradually decrease by 2050 to similar levels observed in Germany in 2021 based on the results of the national greenhouse gas inventory, available at: https://unfccc.int/documents/627938

9 Methane utilisation indicators from wastewater treatment will gradually reach levels similar to those observed in the United Kingdom in 2021 based on the results of the national greenhouse gas inventory, available at: https://unfccc.int/documents/627795

Under the WEM scenario, between 2020 and 2025, GHG emissions in the Waste sector will decrease from 16.3 million tonnes of CO_2-eq to 14.4 million tonnes of CO_2-eq, or 11.4%. From 2026 to 2030, total GHG emissions in the waste management sector will increase slightly, reaching 14.6 million tonnes of CO_2-eq by 2030. The expected slight increase in emissions during the 2026–2030 period will be caused by the return of citizens from abroad and the intensification of nitrification-denitrification processes at wastewater treatment facilities due to an increase in protein consumption due to a higher quality of life. This will affect the rise in N_2O emissions from household wastewater management. Subsequently, after 2030, when a local peak in GHG emissions is expected in the Waste sector under the WEM scenario, forecasted GHG emissions in the sector will gradually decrease, reaching 11.1 million tonnes of CO_2-eq by 2050, which will be 66% of the 1990 level.

Under the WEM scenario, the structure of GHG emissions in the Waste sector will not undergo significant changes. Landfill sites for solid waste will continue to be the main source of GHG emissions in the sector, contributing 55–60% of the total emissions, which is comparable to the 2020 value of 54%. The share of emissions related to wastewater management will be 39–43% until 2050, which is slightly higher than the 2020 value of 46%. The sole source in which a gradual increase in GHG emissions is expected is the biological treatment of solid waste, emissions from which will rise from 7.4 thousand tonnes of CO_2 equivalent (0.05% of total sectoral emissions) in 2020 to 67.0 thousand tonnes of CO_2 equivalent in 2030, and will reach a value of 229.0 thousand tonnes of CO_2 equivalent (2.1% of total sectoral emissions) in 2050. The widespread adoption of composting organic HW components, specifically food waste and food industry waste, at all stages of production and consumption, as well as green waste, will cause this manifold increase in emissions from the biological treatment of solid waste. At the same time, it is important to note that composting organic HW components is an effective method for reducing GHG emissions, particularly when considered an alternative to landfilling. The specific GHG emissions from composting the same amount of organic material are dozens to hundreds of times lower than the corresponding values for anaerobic decomposition processes in landfills, i.e., their burial. GHG emissions from thermal waste treatment

methods will constitute 0.1% of the waste management sector's total emissions. These are the smallest source of emissions in the sector, as they include waste treatment activities without subsequent energy recovery. The latter activity is included in the energy sector, where it is accounted for as the use of RES and alternative fuels. A detailed breakdown of emissions by category in the waste management sector until 2050 is provided in Fig. D.3.1.

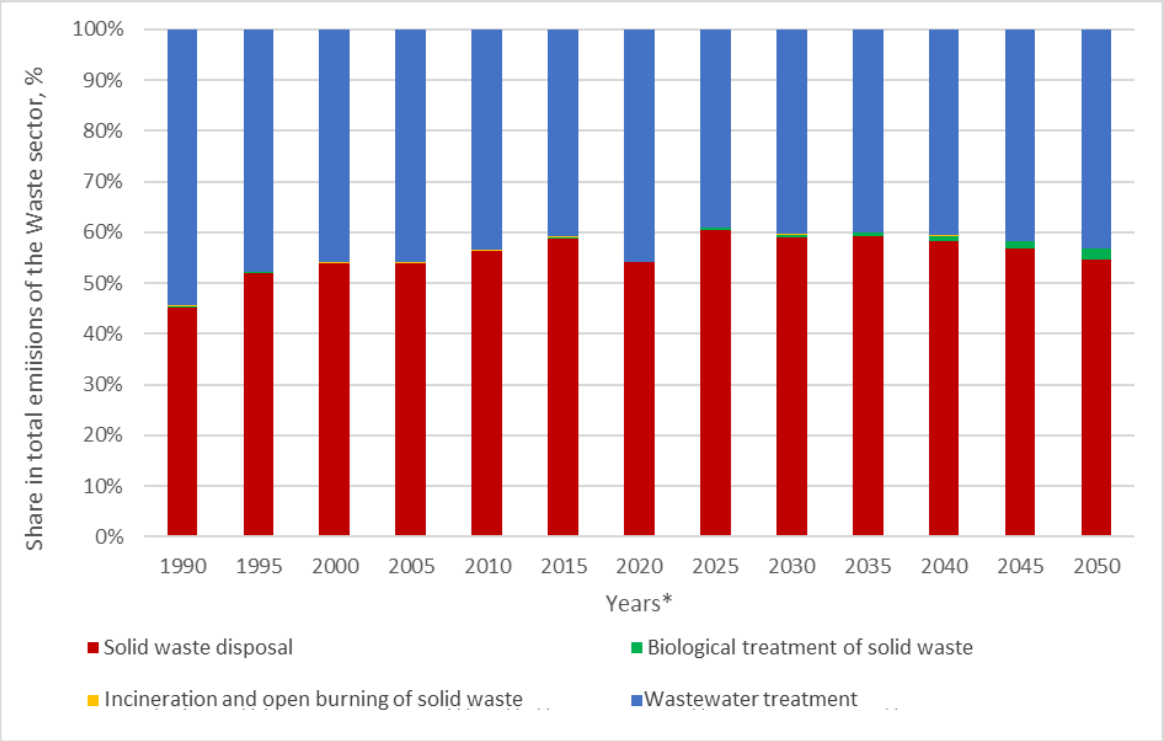


Fig. D.3.1. Structure of GHG emissions in the Waste sector under the WEM scenario

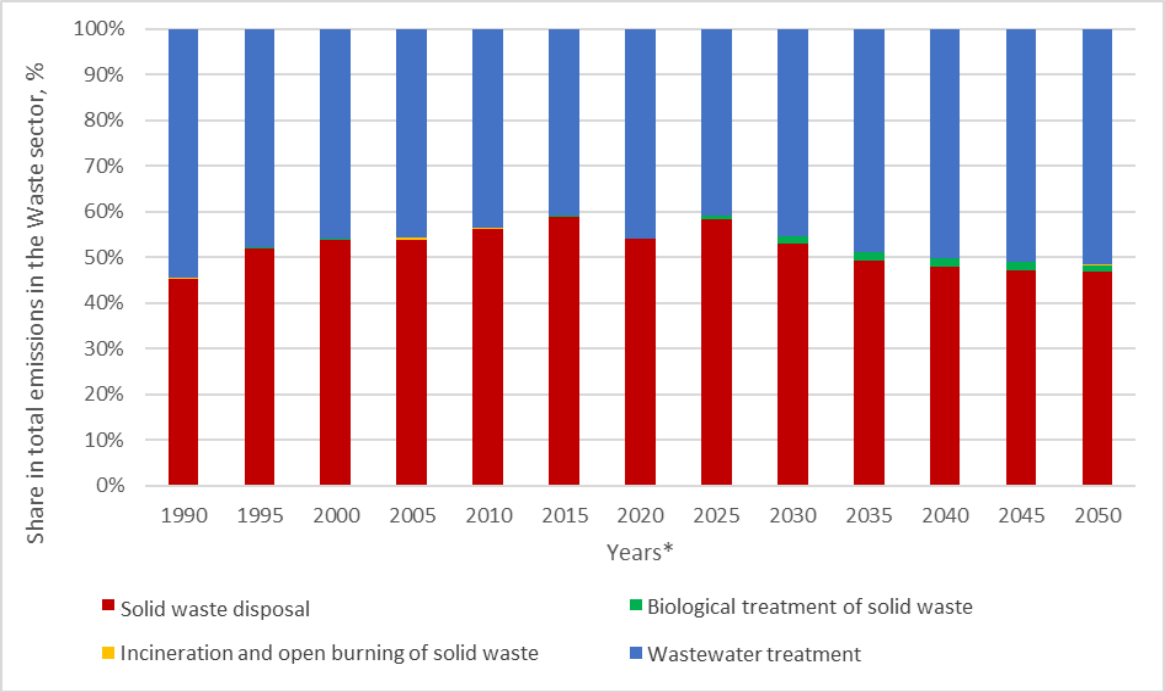
** for the 1990–2020 period — statistical data, and for the 2025–2050 period — forecast data; by IPCC categories.*

Under the WAM scenario, GHG emissions in the Waste sector will steadily decrease and reach 13.0 million tonnes of CO_2-eq by 2030, which will be 23% lower than the 1990 emissions level. Emissions will continue to decrease further, and by 2050, they will amount to 9.3 million tonnes of CO_2-eq, 45% lower than the 1990 level.

Under the WAM scenario, the structure of emissions in the Waste sector will undergo significant changes compared to 2020. The share of GHG emissions from solid waste disposal sites will decrease from 54% in 2020 to 53% in 2030, and further to 47% by 2050. The share of emissions caused by wastewater management will increase starting from 2030, reaching 51% in 2050, compared to 46% in 2020. As in the WEM scenario, under the WAM scenario, the only source where a significant increase in GHG emissions is expected is the biological treatment of solid waste, with emissions rising from 7.4 thousand tonnes of CO_2-eq in 2020 to 210.2 thousand tonnes of CO_2-eq in 2030, and then gradually decreasing to 142.1 thousand tonnes of CO_2-eq (1.5% of total sector emissions) by 2050. (1.5% of total sectoral emissions) in 2050. The intensive spread of composting organic HW in Ukraine will cause a manifold increase in emissions from the biological treatment of solid waste up to 2030.

The introduction of modern composting technologies for organic HW components with lower methane and nitrous oxide emission coefficients will gradually decrease GHG emissions from the biological treatment of solid waste after 2030. GHG emissions from thermal waste treatment

methods (note: without energy recovery) will increase from 0.1% of total emissions in the waste management sector in 2020 to 0.2% by 2050. Although these emissions will not increase in absolute terms, a significant reduction in GHG emissions from other sources will cause their share to increase within the sector. A detailed breakdown of emissions by specific activities in the waste management sector until 2050 is provided in Fig. D.3.2.



*for the 1990–2020 period — statistical data, and for the 2025–2050 period — forecast data; by IPCC categories.

Fig. D.3.2. Structure of GHG emissions in the Waste sector under the WAM scenario

Under the NZE scenario, GHG emissions in the Waste sector will steadily decrease and reach 11.9 million tonnes of CO_2-eq by 2030, which will be 30% lower than the 1990 emissions level. Emissions will continue to decrease further at an accelerating pace, and by 2050, they will amount to 2.8 million tonnes of CO_2-eq, 83% lower than the 1990 level.

Under the NZE scenario, the structure of emissions in the Waste sector will also undergo significant changes compared to 2020. For instance, landfill sites for solid waste will continue to be the main source of GHG emissions, but their share will increase from 54% in 2020 to 58% in 2030 and 75% in 2050. The share of emissions caused by wastewater management will increase starting from 2030, reaching 22% in 2050, compared to 46% in 2020. As in the other scenarios, under the NZE scenario, the only source where a significant increase in GHG emissions is expected is the biological treatment of solid waste, with emissions rising from 7.4 thousand tonnes of CO_2-eq in 2020 to 210.2 thousand tonnes of CO_2-eq in 2030, and then gradually decreasing to 59.4 thousand tonnes of CO_2-eq (2.1% of total sector emissions) by 2050. (2.1% of total sectoral emissions) in 2050. The intensive spread of composting organic HW will cause a manifold increase in emissions from the biological treatment of solid waste up to 2030.

The introduction of cutting-edge composting technologies for organic HW components with significantly lower methane and nitrous oxide emission coefficients will gradually decrease GHG emissions from the biological treatment of solid waste after 2030. GHG emissions from thermal waste treatment methods (note: without energy recovery) will increase from 0.1% of total emissions

in the waste management sector in 2020 to 0.6% by 2050. Although these emissions will not increase in absolute terms, a significant reduction in GHG emissions from other sources will cause their share to increase within the sector. A detailed breakdown of emissions by specific activities in the waste management sector until 2050 is provided in Fig. D.3.3.

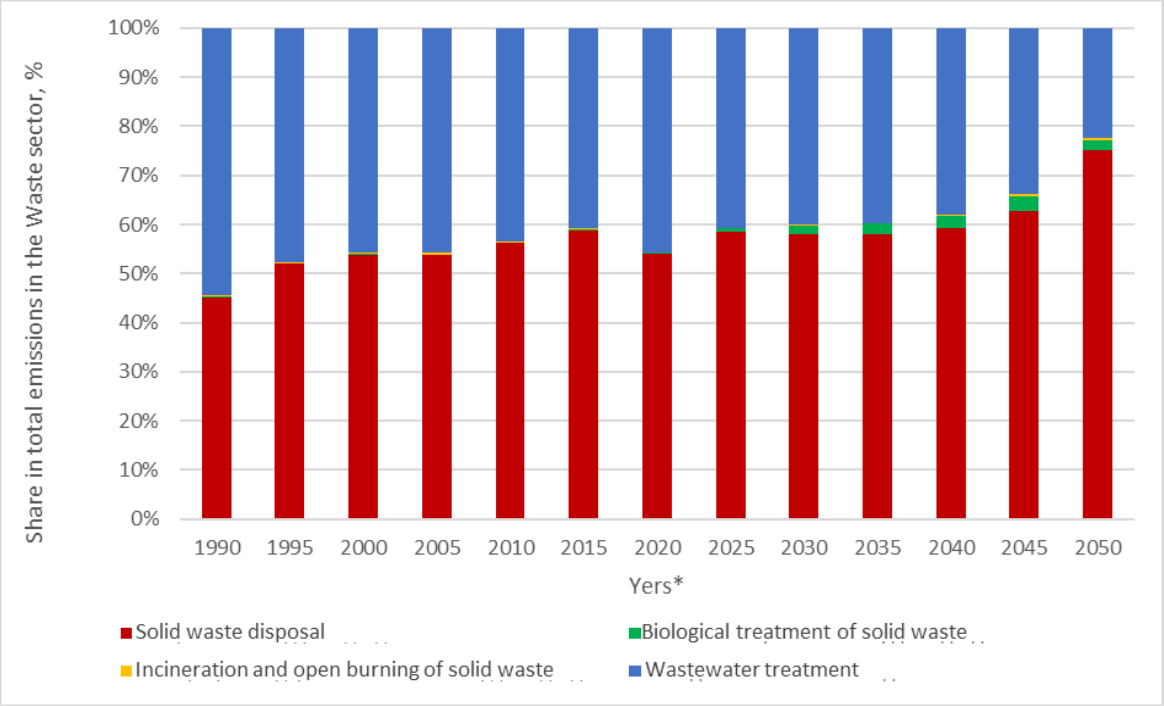


Fig. D.3.3. Structure of GHG emissions in the Waste sector under the NZE scenario

** for the 1990–2020 period — statistical data, and for the 2025–2050 period — forecast data; by IPCC categories.*

Methodology for Forecasting Greenhouse Gas Emissions in the Waste Sector

The modelling of LT-LEDS scenarios in the "Waste" sector was carried out based on baseline GHG emission data for 2021, as reported in the National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of GHGs (2024 submission). The methodological approaches used for calculating projected GHG emissions are fully aligned with the methodological principles on which the Waste sector of the National Inventory of Anthropogenic Emissions from Sources and Absorption by GHG Sinks in Ukraine for the period from 1990 to 2022 was based. A list of potential waste management practices and corresponding available technologies was determined based on scientific reports and national strategic documents on the implementation of modern waste management technologies in Ukraine[168, 169][170]. During the modelling in the Waste sector, the following indicators and trends were used by categories, with specific indicators for the sector highlighted in italics:

[168] Technology Needs Assessment Report. Mitigation. Technology Prioritisation. Output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UN Environment) and the UNEP DTU Partnership (UDP) in collabouration with the University of Cape Town. – Kyiv. – 2019. – 119 pp. Available at: https://tech-action.unepdtu.org/wpcontent/uploads/sites/2/2019/08/tna-01-mitigation-ua-final-190731.pdf

[169] Report 3. Modeling Report. Support to the Government of Ukraine on Updating its Nationally Determined Contribution (NDC). – Kyiv. – 2019. – pp. 137, Available at: https://mepr.gov.ua/wp-content/uploads/2023/07/Modeling-Report-3.pdf

[170] National Energy and Climate Plan until 2030. Approved by Resolution of the Cabinet of Ministers of Ukraine No. 587-p of 25 June, 2024. Available at: https://me.gov.ua/Documents/List?lang=uk-UA&id=76f559ff-4fc5-4441-b73a-1ff1a5b781cf&tag=NatsionalniiPlanZEnergetikiTaKlimatuNaPeriodDo2030-Roku

Landfilling of Solid Waste: population, per capita volume of household waste (HW) generation, waste management practices (share of landfilling, reuse, recycling, composting, incineration), population coverage by centralised waste collection systems, construction of new sanitary (deep controlled) landfills for HW, composition of HW, share of flaring, and landfill gas recovery. The mass balance model for MW used in the modelling of GHG emissions in the "Waste" sector is presented in Fig. D3.4, from which the following basic positions of mathematical modelling arise:

1. The total volume of HW generated corresponds to the sum of officially and illegally landfilled HW.[171] The initial data for estimating HW generation volumes are the population, the coverage of the population by centralised SHW collection systems, and the per capita volume of SHW generation.
2. After estimating the volume of HW generated, these volumes are divided into individual waste component flows, the magnitude of which is determined based on their component (morphological) composition. These flows include: paper and cardboard, food and food industry waste at all stages of production and consumption, green waste, wood, personal hygiene items, rubber and leather, textiles, and non-biodegradable components (including ferrous metals, non-ferrous metals, glass, plastic, hazardous and other inorganic materials). Waste not covered by centralised collection systems is disposed of in uncontrolled shallow landfills.
3. Food waste, food industry waste at all stages of production and consumption, and green waste form the flow for composting (biological processing), the volume of which is determined by the overall composting share.
4. Glass forms the flow for reuse, the volume of which is determined by the reuse share.
5. Paper, cardboard, and non-biodegradable components (especially plastic and metals) form the recycling flow, the volume of which is determined by the overall recycling share.
6. The remaining portion of HW is divided into two flows: incineration and landfilling, which in turn are determined by the incineration share.
7. Distribution by types of disposal sites is determined by the construction of new sanitary landfills for HW.

[171] Undefined practices (e.g., home composting, grey recycling, etc.).

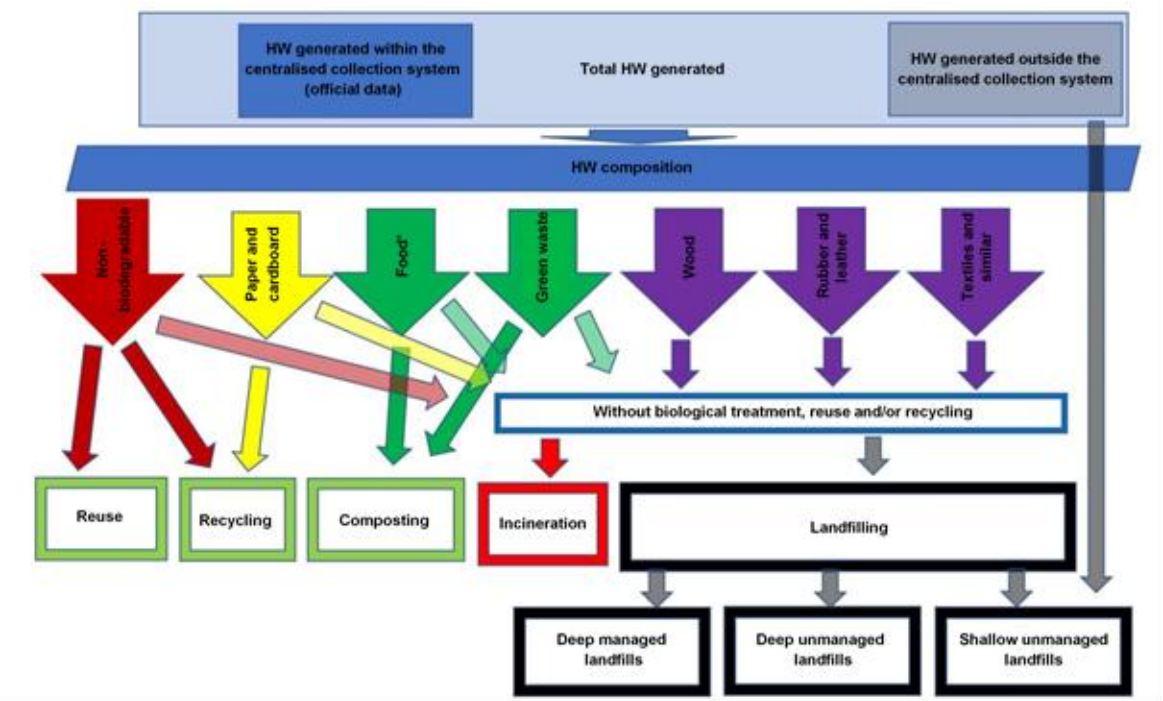


Fig. D.3.4. General Model Diagram for Mass Balance of HW (Mass Flow)

** Food and Food Industry Waste at All Stages of Production and Consumption*

Biological Processing (Composting) of Solid Waste: population, indicators of industrial and agricultural sector development, *per capita volume of HW generation, composting share, and composting technologies*.

Wastewater Treatment and Discharge: population, the share of the urban and rural population, development indicators for sectors (energy, steel industry, agriculture, food industry, etc.), *the share of treatment and discharge; per capita consumption of meat, dairy products, and fruits, development of technologies, the share of flare gas burning and methane recovery formed during wastewater treatment*.

Incineration and open burning of waste: GDP growth, indicators of industrial sector development, *specific legislation for the category (prohibition of waste burning without energy use).*

The "do no significant harm" principle in the context of the development of thermal waste treatment technologies.

The principle "Do No Significant Harm" is fundamental in prioritising the development of technologies in the context of sustainable development of the country. It is based on the concept that activities that cause a significant negative impact on environmental goals, as defined in Article 17 of Regulation EU 2020/852, should not be encouraged.

Considering that only modern thermal waste treatment technologies can comply with the "Do No Significant Harm" principle, and taking into account the five-step waste hierarchy defined in Directive 2008/98/EC, where thermal treatment methods are ranked second-last, thermal waste treatment technologies are used in a limited manner in all three scenarios: WEM, WAM, and NZE. According to the WEM scenario, the share of thermal treatment will reach 7% by 2030 and 10% by 2050; in the WAM scenario, it will reach 8% by 2030 and 15% by 2050; in the NZE scenario, it will reach 8% by 2030 and 28% by 2050. These figures are significantly lower than those of European

countries that have made significant progress in transitioning to a circular economy: for example, the share of thermal treatment of municipal waste in Switzerland is about 48%, in Belgium — 46%, in Sweden — 59%, and in Denmark — 39%. See Fig. D.3.5 for detailed information on solid household waste management indicators in European countries for 2022.

Moreover, it is possible that in the long term, with the further development of thermal waste treatment technologies, the role of these technologies in waste management in Ukraine could be revised to intensify their spread, provided the "Do No Significant Harm" principle is adhered to.

Target Indicators for Thermal Waste Treatment in Ukraine in the WEM, WAM, and NZE Scenarios: on one hand, these have been aligned with regulatory documents in the waste management sector in Ukraine, and on the other hand, they comply with recommendations provided through various international technical assistance projects aimed at sustainable and low emission development of waste management systems in Ukraine, including:

- The international technical assistance project "Assessment of Technological Needs in Ukraine"[172] for the waste sector, conducted from 2018 to 2020 with GEF funding and implemented by the UN Environment and UNEP DTU Partnership.

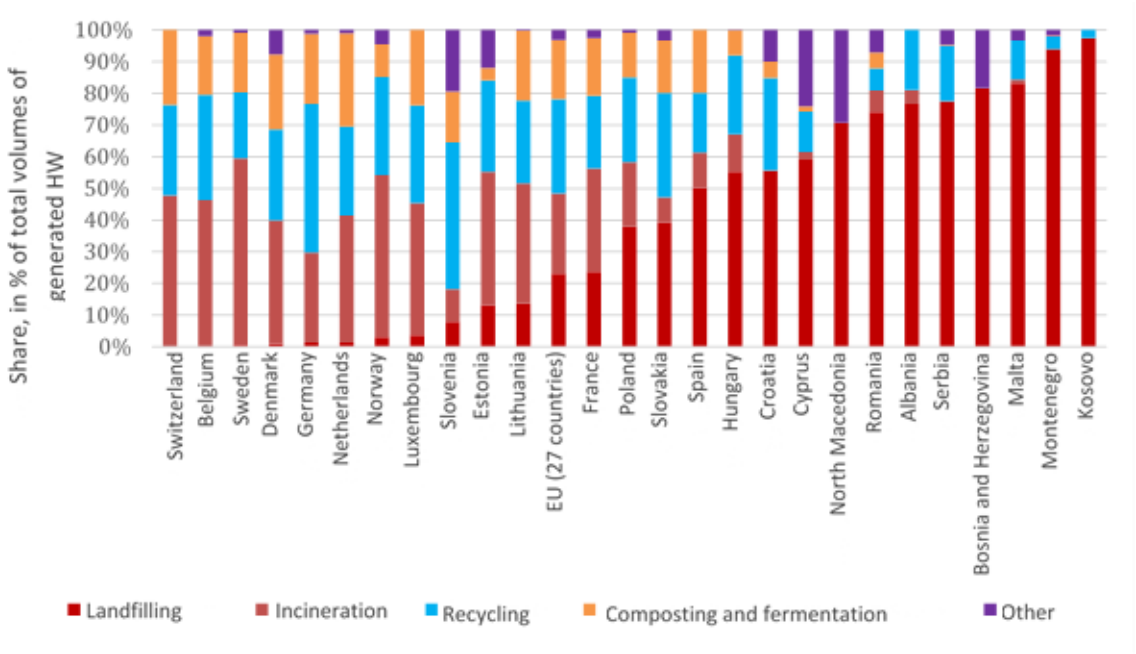


Fig. D.3.5. Waste Management Statistics in European Countries as of 2022

Source: Eurostat, 2024: https://ec.europa.eu/eurostat/data/database

- The international technical assistance project "Supporting Investment in the Sustainable Management of Municipal Solid Waste in Ukraine,"[173] with financial support from the Multi-Donor Trust Fund for Ukraine, implemented by the European Bank for Reconstruction and Development in 2017.

[172] https://tech-action.unepccc.org/wp-content/uploads/sites/2/2021/09/tap-mitigation-report-ukraine-2021-08-31-1.pdf
[173] http://publications.chamber.ua/2017/F_B/WMStrategy_ukr.pdf

The capital costs required to implement the WEM, WAM, and NZE scenarios were calculated based on the technical and economic indicators determined in the Technological Needs Assessment in Ukraine (GHG Emission Reductions) report[174]. Appendix II, "Technology Card for Selected Technologies — Waste," evaluates the economic calculations for deploying each proposed waste management technology under Ukrainian conditions. The total required funds for implementing the scenarios were calculated based on the feasibility and technological constraints of applying each individual technology, among which the following were analyzed in detail:

- methane capture at landfills and waste disposal sites for energy production;
- closure of old landfills and waste disposal sites and construction of flare systems (incineration, bio-covering, passive ventilation, etc.);
- construction of new regional sanitary HW landfills;
- waste sorting (sorting resource-rich components of HW for further processing of the remaining waste by other technologies);
- aerobic biological treatment (composting) of food and garden park waste;
- mechanical-biological waste treatment with biogas and energy production (anaerobic decomposition of organic HW components);
- mechanical-biological waste treatment with the production of alternative fuel (SRF) for the cement industry;
- mechanical-biological waste treatment with the production of alternative fuel (RDF) for district heating and/or electricity generation;
- incineration of HW residuals for municipal heating and/or electricity generation;
- gasification/pyrolysis of waste for large energy generation plants;
- Biological stabilisation of waste;
- Anaerobic treatment of wastewater sludge.

To implement the WEM scenario in the "Waste" sector, approximately EUR 1.06 billion in capital investments will be required by 2030 (inclusive). Overall, implementation of the WEM scenario will require about EUR 5.14 billion in capital investments in the waste management sector over 2024–2050.

To implement the WAM scenario, approximately EUR 2.05 billion will be required by 2030 (inclusive). In total, the WAM scenario will require about EUR 8.05 billion in capital investments in the waste management sector over 2024–2050.

To implement the NZE scenario, the same amount of investment as for the WAM scenario will be required by 2030 (inclusive), i.e. EUR 2.05 billion. In total, the NZE scenario will require about EUR 16.06 billion in capital investments in the waste management sector over 2024–2050.

The results of calculations of the funds required to implement each LT-LEDS scenario, shown as cumulative totals and broken down into five-year intervals up to 2050, are presented in Tables D.3.2 and D.3.3.

[174] Technology Needs Assessment in Ukraine. Technology prioritisation. Mitigation, Waste sector, UNEP DTU Partnership (2019). Available at: https://tech-action.unepdtu.org/country/ukraine/

Table. D.3.2. Capital investments in the Waste sector by scenarios, cumulative total by 2050, mln EUR

	2025	2030	2035	2040	2045	2050
WEM Scenario	297.7	1050.8	2043.1	3057.2	4090.3	5137.4
WAM Scenario	578.6	2054.1	3564.8	5070.5	6566.5	8053.6
NZE Scenario	696.3	3724.7	6797.2	9886.3	12977.4	16057.6

Table. D.3.3. Capital investments in the Waste sector by scenarios, by periods up to 2050, mln EUR

	2024–2025	2026–2030	2031–2035	2036–2040	2041–2045	2046–2050	Total
WEM Scenario	297.7	753.1	992.3	1014.1	1033.1	1047.0	5137.4
WAM Scenario	578.6	1475.5	1510.7	1505.7	1496.1	1487.1	8053.6
NZE Scenario	696.3	3028.4	3072.5	3089.1	3091.0	3080.2	16057.6

APPENDIX 4. METHODOLOGY FOR FORECASTING GREENHOUSE GAS EMISSIONS IN THE AGRICULTURE SECTOR

In the "Agriculture" sector, the estimation and forecasting of GHG emissions were carried out for the following categories of agricultural activity, namely: "Enteric Fermentation", "Manure Management", "Rice Cultivation", "Agricultural Soils", "Liming" and "Urea Application".

To ensure the continuity and legacy of the national GHG inventory, the 2006 IPCC methodology (2006 IPCC Guidelines for National Greenhouse Gas Inventories Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. – URL: https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html) and the coefficients used to estimate GHG emissions in the "Agriculture" sector of the National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of GHG in Ukraine for 1990–2022 were applied to forecast GHG emissions under the WEM scenario.

The data source for activity levels for the period 1990–2022 was the national GHG inventory database. The assessment of GHG emissions for 2030–2050 was carried out on the basis of projected activity data published in Annex 2 to the National Energy and Climate Plan for the Period up to 2030, approved by the Resolution of the Cabinet of Ministers of Ukraine dated 25 June 2024, No. 587-r.

For modelling GHG emissions up to 2050 under the WAM and NZE scenarios, key indicators of planned measures, as well as trends and objectives of sustainable agricultural development, were used. Based on these inputs, and taking into account the potential for their implementation, projections of GHG emission reductions in the relevant categories of agricultural activities were developed and applied to the baseline development model of the Agriculture sector (the WEM scenario).

Given the agricultural development targets defined in the National Energy and Climate Plan up to 2030, the measures considered appropriate for reducing GHG emissions in livestock production focus on changes in qualitative characteristics rather than on regulating livestock numbers, as assumed in the WEM scenario. In particular, the use of protein-rich concentrated feeds (bypass products) enables regulation of methane formation potential during enteric fermentation. The inclusion of up to 20% bypass products in the total amount of concentrated feed in cattle diets can result in a reduction of methane emissions exceeding 10%. The use of bypass products is, however, a cost-intensive measure and therefore requires substantial public support and incentives. Bypass products represent a relatively new direction in the development of livestock feeding systems and have the potential to improve overall production efficiency.

Manure management practices offer significant mitigation potential, not only through the use of animal manure in biogas plants for methanogenesis, but also through a set of measures related to manure collection, transportation, storage and application. The configuration of potential measures is determined by the production capacities of livestock complexes; accordingly, the trend toward grouping agricultural enterprises by livestock numbers served as a key factor in projecting GHG emission reductions.

The orientation toward the development of regenerative and environmentally sustainable agriculture determined the set of measures aimed at reducing GHG emissions in crop production.

The intensification of information and telecommunication technologies acted as a driver for the optimisation of farming practices. Assumptions were made regarding the effectiveness of these technologies in influencing the quantitative and qualitative parameters of agrotechnical practices (such as the number of operations, the area of their application, fuel consumption volumes, etc.) and the resulting impact of these changes on GHG emissions.

Organic crop production is a hallmark of environmentally safe agricultural production and therefore occupies a special place in the strategy for sustainable agricultural development. The development and implementation of organic crop production require not only adequate quantities of organic fertilisers and appropriate crop variety selection, but also soils suitable for organic production. The availability of soils suitable for organic crop production, together with the corresponding infrastructure, served as the key regulating factor in the modelling process.

Taking into account many years of agricultural practice, it is assumed that organic crop production alone is unable to fully meet the needs of domestic and external markets for crop production. Therefore, a combined farming approach is envisaged, which also relies on the use of nitrogen-based mineral fertilisers, the application of which results in significant direct and indirect GHG. emissions. By their chemical nature, nitrogen mineral fertilisers consist of nitrogen-containing salts characterised by relatively low stability. This leads to increased application rates and frequency, as it is well known that approximately 14–15% of nitrogen mineral fertilisers are lost immediately during application. New forms of mineral fertilisers with slow-release or controlled-release nitrogen are capable of partially or fully addressing the issue of excessive application rates and repeated fertilisation practices. The key factor for modelling the volumes of application of nitrogen fertilisers with slow or controlled release of the active substance is their economic efficiency, as well as the availability of public support for the implementation of this measure.

APPENDIX 5. METHODOLOGY FOR FORECASTING GREENHOUSE GAS EMISSIONS IN THE LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR

For the preparation of forecasts of GHG emissions and removals in the LULUCF sector, a bottom-up approach was applied. This approach enables the creation of synergies between current GHG inventory data prepared in accordance with the requirements of the UNFCCC and the Paris Agreement, and assessments of future activity levels and factors that have a significant impact on GHG emissions and removals.

Forest land and cropland are the two main land-use categories in this sector, accounting for 95% of total GHG emissions and removals within the LULUCF sector. Accordingly, activities within these two categories were the primary focus of the forecasting exercise. Other land-use categories (excluding harvested wood products) were assumed to remain at the average levels observed during 2015–2020.

The calculation methods and emission factors applied were identical to those used in the national GHG inventory. For forest land, changes in carbon stocks in the living biomass pool were estimated using the gain–loss method (see the latest available National Inventory Report). In particular, for forest land remaining forest land, it was assumed that no significant changes in forest management practices would occur in the future. This assumption is also indirectly supported by the absence of any strategic policy documents in the forestry sector that would envisage fundamental reforms in forest management.

To estimate future changes in carbon stocks on forested land, average rates of carbon stock change per hectare observed in previous years (2017–2021) were applied. This reflects the assumption that new forest establishment will take place using standard forest management practices and typical tree species.

Under the BAU scenario, the average area of afforestation for 2017–2021, amounting to 2.4 thousand hectares, was used, reflecting the absence of future plans and dedicated funding for this activity .

Scenario 1 assumes that the average afforestation area observed during 2005–2015 can be achieved, provided that a similar state programme, “Forests of Ukraine for 2005–2015”, is adopted. In particular, it amounts to 23.70 thousand hectares.

Scenario 2 reflects a balance between realistic and ambitious annual afforestation targets. Specifically, the maximum afforestation area achieved during 2005–2015 is considered a sound and realistic benchmark. Accordingly, the annual afforestation area under this scenario is 37.84 thousand hectares.

Calculations for agricultural land were carried out across three main types of activities: orchards and other woody vegetation (shelterbelts), changes in carbon stocks in mineral soils resulting from crop production, and the use of organic soils.

The calculation of changes in carbon stocks in living biomass is based on the current methods used in the national GHG inventory, i.e. on emission factors applied for orchards. A uniform assumption regarding the establishment of new orchards (approximately 900 hectares annually) is applied across all scenarios.

With regard to shelterbelts, the BAU scenario does not include the creation of new shelterbelt areas and assumes only their maintenance at the current level. Scenario 1 additionally assumes the establishment of 1 thousand hectares of forest shelterbelts per year, while Scenario 2 assumes 2 thousand hectares per year.

The calculation of changes in carbon stocks in mineral soils is based on a nitrogen flow model used for the preparation of the national inventory report on anthropogenic GHG emissions by sources and removals by sinks. The model incorporates data on cultivated areas, crop yields, application of mineral and organic fertilisers, practices related to cereal straw management, and several other factors.

In order to ensure synergy between the recently developed NECP and this Strategy, identical projected values for cultivated areas, crop yields and fertiliser application rates were applied across all scenarios.

The current greenhouse gas inventory assumption is that all cereal straw is used for purposes other than soil incorporation, which has been retained in the BAU scenario. In Scenario 1, 20% of straw is left on fields as a measure to reduce fertiliser use and promote the incorporation of organic matter. In Scenario 2, this share increases to 40%.

Measures aimed at reducing direct and indirect N_2O emissions from fertiliser application are included in several strategic documents. However, due to the absence of clear incentives to promote such practices, the BAU scenario assumes the continued use of conventional fertilisers.

Planned measures in the area of fertiliser management are expected to ensure a 20% reduction in GHG emissions under Scenario 1, while under Scenario 2 this reduction is projected to reach 30%.

For the assessment of GHG emissions from organic soils of cropland and grasslands, methodologies from the 2006 IPCC Guidelines are applied. Under Scenario 1, greenhouse gas emission reductions were modelled assuming the conversion of 50% of currently used organic soils from cropland to grasslands. Scenario 2 provides for the conversion of all organic soils used for crop production to grasslands and other areas covered by herbaceous vegetation.

The harvested wood products category was assessed using a linear correlation with macroeconomic growth in the production of wood, paper and printing products, which was applied uniformly across all scenarios.

APPENDIX 6. METHODOLOGY FOR ASSESSING MACROECONOMIC EFFECTS OF LOW-CARBON DEVELOPMENT POLICY IN UKRAINE

To assess the economy-wide impacts of low-carbon development scenarios in Ukraine, a dynamic version of the Ukrainian General Equilibrium Model (UGEM) was applied. Ukrainian General Equilibrium Model). The UGEM model is based on a static model developed and described by M. Chepeliev (2014)[175], augmented with additional dynamic mechanisms (TRPC, 2014)[176], as well as further improvements and updates introduced in the course of assessing the economic impacts of

[175] Chepeliev, M. 2014. Simulation and economic impact evaluation of Ukrainian electricity market tariff policy shift. Economy and forecasting, 1(1), 1-24. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2608980

[176] Thompson Reuters Point Carbon (TRPC). 2014. Improving the existing carbon charge in Ukraine as an interim policy towards emissions trading – Detailed Report. http://www.ebrdpeter.info/uploads/media/report/0001/01/9705b0af32bc096636a81554c185d9181b49d916.pdf

Ukraine's Second Nationally Determined Contribution (NDC) (EBRD, 2020)[177] and in the preparation of this Strategy.

The UGEM model has been widely applied for economic assessments in the development of various energy and environmental measures and strategic documents in Ukraine. In particular, it has been used for macroeconomic modelling of GHG emission pricing and emissions trading mechanisms in Ukraine within the EBRD project "Readiness for Emissions Trading in the EBRD Region"[178]. The model was also applied to the economic assessment of Ukraine's Low Emission Development Strategy under the USAID project "Municipal Energy Reform" (GOU, 2017)[179]. In addition, UGEM was used for the economic analysis of different scenarios for Ukraine's Nationally Determined Contributions (NDCs) under the MERP initiative, for assessing the economic impacts of Ukraine's Second NDC, as well as within several other international technical assistance projects.

UGEM is a recursive dynamic computable general equilibrium (CGE) model calibrated for a single-country economy. All producers of goods and services are allocated across 88 sectors, covering the entire economy of Ukraine. Producers are assumed to maximise profits, while households maximise utility. Firms produce goods and services using capital, labour and intermediate inputs. Domestic producers sell their output either on the domestic market or abroad. On the domestic market, final goods and services are purchased by households or the government, or used as inputs into capital formation. Households receive labour income and returns on capital, as well as transfer payments. The government collects revenues through taxation and provides transfers and subsidies to households and producers. To represent production and consumption processes, the UGEM model employs constant elasticity of substitution (CES) production functions[180]. In the core production block, a nested CES structure is used, which separately accounts for energy intermediate inputs, non-energy intermediate inputs, and value added (labour and capital).

UGEM is formulated as a static model that is solved sequentially, period by period. The capital stock is updated in each period based on the rate of capital depreciation and the inflow of investment. labour supply evolves at a predetermined rate based on labour force projections.

The energy sector in UGEM is represented by seven industries: coal mining; natural gas and oil extraction; coke and refined coke products, including fuels for furnace combustion; petroleum products; electricity generation and distribution; natural gas distribution; and heat supply. Electricity generation is further disaggregated into seven distinct generation technologies: coal, gas, nuclear, hydropower, wind, solar, and other energy sources (primarily biomass-based electricity generation). Other components of the energy layer include coal, oil, gas, coke, and petroleum products.

The key input data for the model are derived from input–output tables, extended energy balances, national accounts, and detailed international trade statistics. These inputs are organised in the form of a social accounting matrix (SAM). The various data sources are reconciled using the RAS method and cross-entropy techniques.

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[177] European Bank for Reconstruction and Development (EBRD). 2020. Support to the Government of Ukraine on Updating its Nationally Determined Contribution (NDC). Final Report. https://mepr.gov.ua/files/images/Final%20Technical%20Synthesis%20Report%20for%20Ukraine%20Updated%20NDC.pdf

[178] Known as the PETER project — Preparedness for Emission Trading in the EBRD Region.

[179] Government of Ukraine (GOU). 2017. Ukraine Low Emission Development Strategy. Kyiv, November 2017. https://unfccc.int/sites/default/files/resource/Ukraine_LEDS_en.pdf

[180] Elasticity of substitution reflects the relative changes in the quantities of goods or services consumed that arise in response to corresponding relative changes in prices. Constant elasticity of substitution — CES.

The starting point for constructing the UGEM database for this strategy was Ukraine's 2020 input–output table. This ensured consistency in the choice of a common base year across all models applied within the project. The 2020 input–output table represents 42 sectors of the Ukrainian economy (SSSU, 2021)[181] and can therefore be directly incorporated into UGEM. A significantly more detailed 2005 table, comprising 79 production sectors (SSSU, 2007)[182], was additionally used to further disaggregate the 2020 table structure into 81 sectors. The next step in database construction involved integrating the extended energy balance into the input–output table. Ukraine's extended energy balance was matched with the 2020 table and used for further disaGHGregation into additional energy sectors. Oil and gas extraction was split into separate "oil extraction" and "gas extraction" sectors, while electricity generation — represented as a single sector in the 2020 tables — was disaggregated into seven generation technologies, as noted above. The constructed energy flows and their corresponding values were reconciled using a cross-entropy balancing method to ensure a fully balanced database, as required by the methodological properties of a social accounting matrix.

Due to the war, Ukraine's economy has experienced significant negative shocks and structural changes. Accounting for these changes in the development of the baseline scenario was therefore a crucial step to accurately reflect the current state of the Ukrainian economy and to obtain meaningful results. Accordingly, the baseline scenario incorporates adjustments to demographic, macroeconomic and sectoral economic indicators, as well as relevant projections that take into account the impacts of the war and the subsequent economic recovery.

[181] State Statistics Service. 2021. Ukrainian Input-Output Table at Basic Prices for 2020. http://www.ukrstat.gov.ua/
[182] State Statistics Service of Ukraine. 2007. Ukrainian Input-Output Table at Consumer Prices for 2005 (extended program). http://www.ukrstat.gov.ua/