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SUN 4Ukraine

Report on Provisional Climate Neutrality Targets & Gap to Target

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Executive Summary

This report serves as a cornerstone for understanding Ukraine's greenhouse gas (GHG) emissions profile at a time of profound national upheaval and transformation. It also acts as a critical building block in guiding investment decisions relating to the region's reconstruction and development. Set against the backdrop of ongoing conflict and the urgent need for reconstruction, the report traces the evolution of Ukraine's emissions, the drivers behind them, and the country's ambitious climate commitments.

Mapping historical trends, identifying key emission drivers and aligning with Ukraine's climate commitments creates an evidence-based platform for prioritising low-carbon solutions and resilient infrastructure. These insights can be leveraged by investors, policymakers and development partners to channel resources into projects that accelerate decarbonisation, enhance energy security and support sustainable economic recovery.

Ukraine's journey since independence has been marked by dramatic demographic and economic shifts. The population has steadily declined, shaped by low birth rates, high mortality, and, most recently, the mass displacement caused by the Russian's full-scale invasion from February 24th, 2022 ("an estimated 3.7 million people are internally displaced within Ukraine, while around 6.9 million have sought refuge in Europe and beyond"[1]). Economically, the country has experienced cycles of contraction and recovery, with the most recent full-scale invasion leading to a sharp downturn. Yet, even amid adversity, Ukraine's climate policy has grown more ambitious, with a clear commitment to reducing emissions and building resilience.

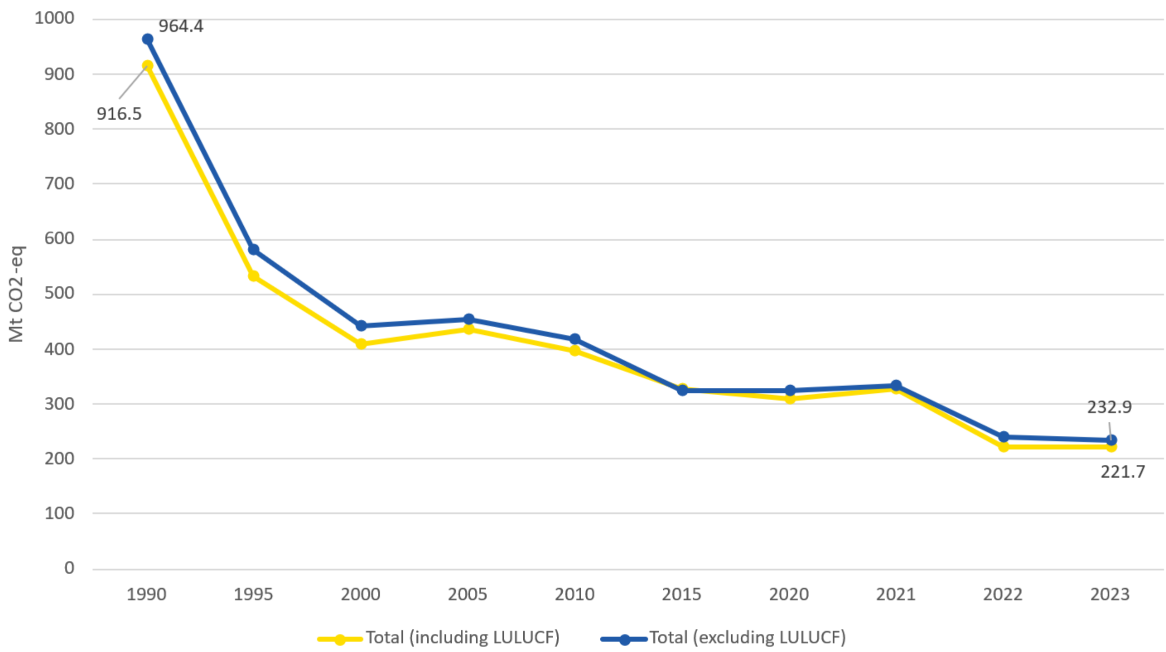

Figure 1 Trends in aggregate direct action GHG emissions, $MtCO_2e$[2]

[1] Crisis in Ukraine, https://www.iom.int/crisis-ukraine
[2] Arup based on Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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The report details how, over the past three decades, Ukraine's GHG emissions have fallen significantly - by more than 75% since 1990. This decline is largely attributed to structural changes in the economy, reduced industrial activity, and improvements in energy efficiency.

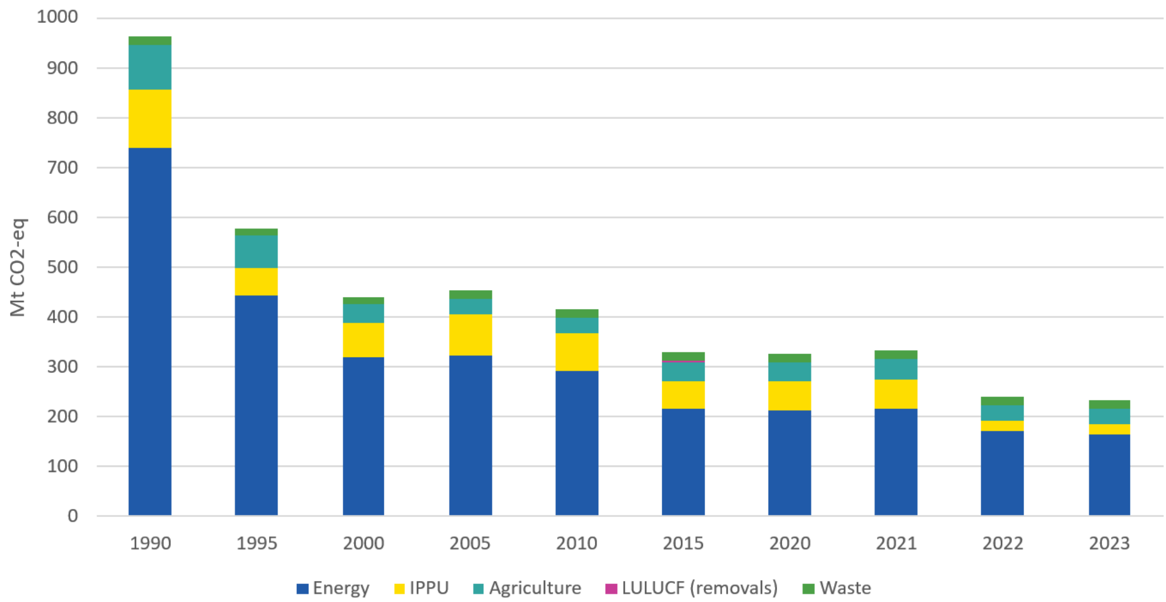

Figure 2 Trends in aggregate direct action GHG emissions by sector, $MtCO_2e$[3]

The energy sector remains the largest source of emissions, followed by industry, agriculture, and waste. Each sector is examined, revealing both the progress made and the challenges that persist. For example, while energy-related emissions have dropped, coal and natural gas still play a major role, and the war has caused sharp, temporary reductions due to infrastructure damage and population loss. Meanwhile, agriculture and waste management continue to significantly contribute to the national emissions profile, with methane from landfills and livestock, and nitrous oxide from fertilisers, remaining persistent issues.

[3] Arup based on Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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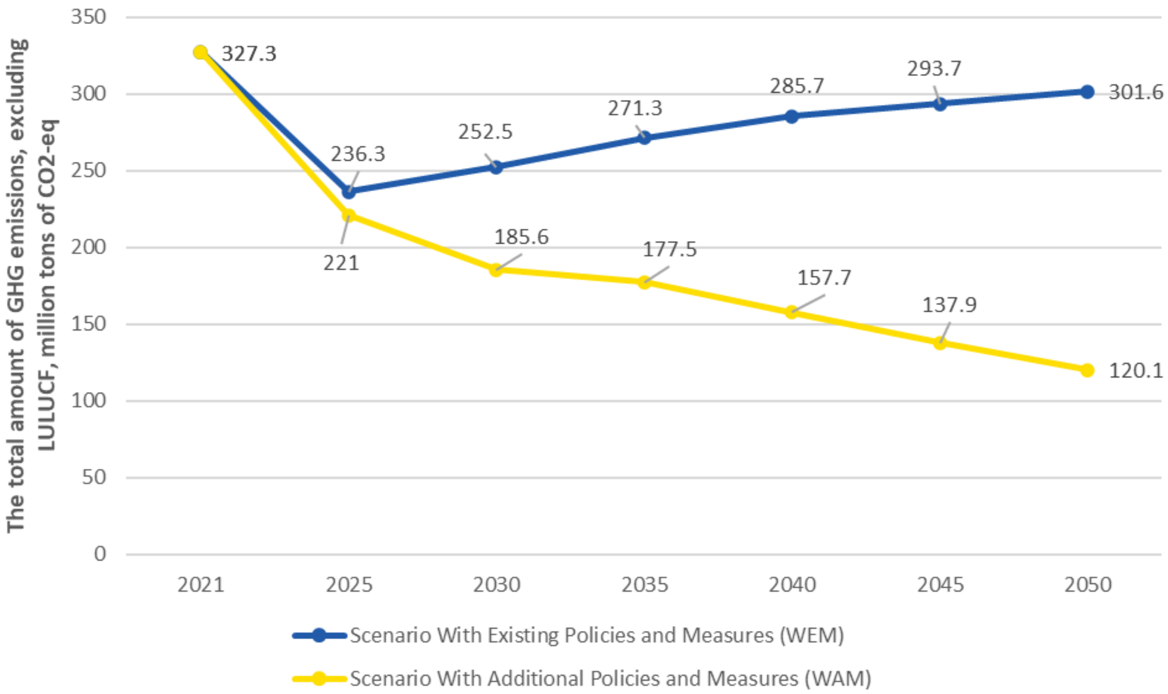

Figure 3 The main results of modelling in the field of GHG emissions in Ukraine according to 'with existing measures' (WEM) and 'with additional policies and measures' (WAM), $MtCO_2e$[4]

Looking forward, the report presents two scenarios for Ukraine's emissions trajectory. Under the "With Existing Measures" (WEM) scenario, emissions are projected to rebound as the economy recovers, potentially reaching 301.6 $MtCO_2e$ by 2050. In contrast, the "With Additional Measures" (WAM) scenario demonstrates the potential for deep decarbonisation, with emissions falling to just 120.1 $MtCO_2e$ by 2050, about 13% of 1990 levels. These projections highlight the critical importance of policy choices, international support investment, and technological innovation in shaping Ukraine's climate future.

[4] Arup based on Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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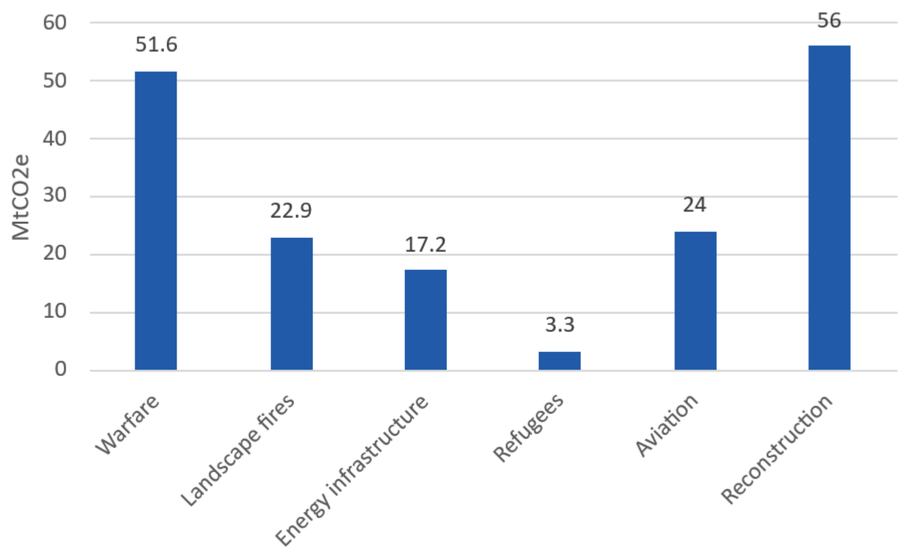

Figure 4 GHG Emissions associated with war, $MtCO_2e$[5]

One of the key issues addressed in the report is the impact of the Russian full-scale invasion (since 24th February 2022). The war has not only disrupted economic and social life but has also generated substantial additional emissions. Over the first two years of conflict, war-related emissions reached 175 million tonnes of CO_2 equivalent, with the destruction of infrastructure and active warfare as the primary sources. The climate cost of these emissions is estimated at over USD 32 billion, emphasising the global significance of the conflict's environmental footprint.

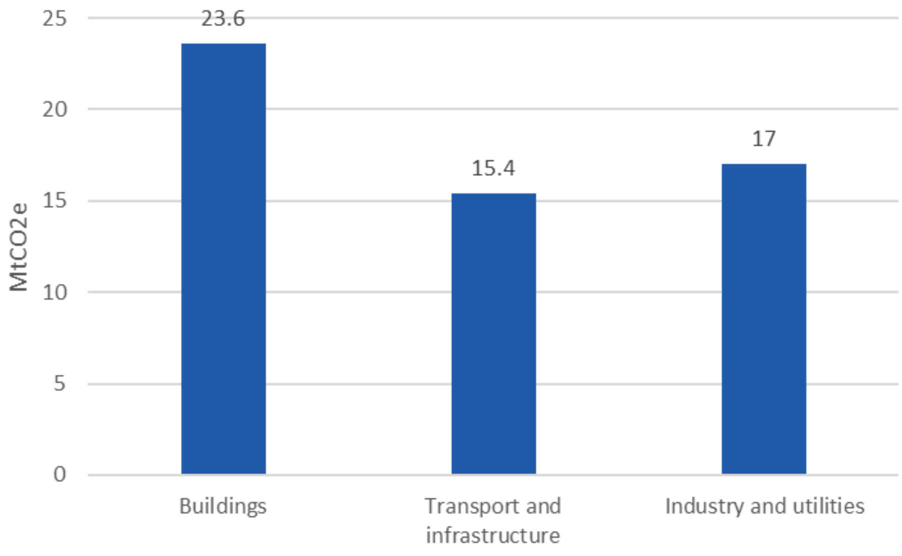

Figure 5 Overview of emissions from reconstruction of civilian infrastructure after 2 years of war, $MtCO_2e$[6]

The total GHG emissions from reconstruction during the 24 months of the war are estimated at 56 $MtCO_2e$.

[5] Arup based on de Klerk, Lennard, et al. *Climate Damage Caused by Russia's War in Ukraine*. 13 June 2024, https://en.ecoaction.org.ua/wp-content/uploads/2024/06/Climate-Damage-Caused-by-War-24-months-EN.pdf
[6] Arup based on de Klerk, et al. *Climate Damage Caused by Russia's War in Ukraine*.

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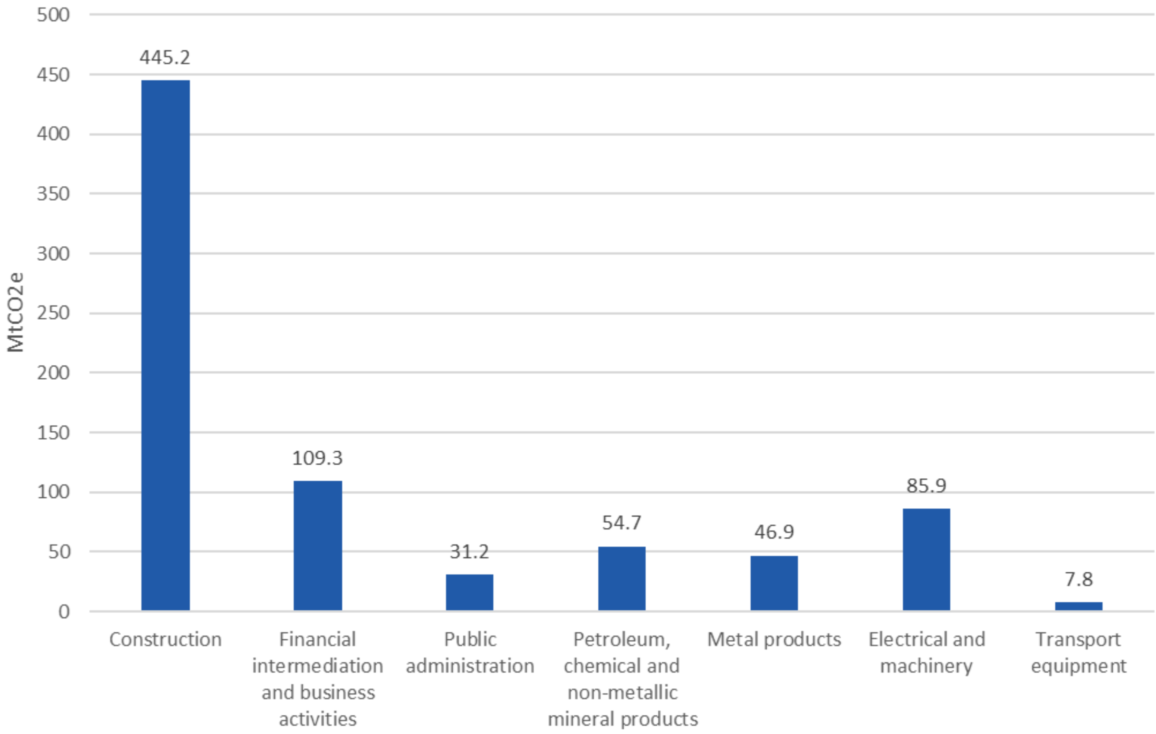

Figure 6 Overview of emissions from reconstruction of infrastructure considering next 10 years, $MtCO_2e$[7]

This report also addresses the immense challenge of reconstruction over a period of ten-years. The anticipated USD 486 billion rebuild of Ukrainian infrastructure is projected to generate 781 million tonnes of CO_2e over the span of a decade. The construction sector alone will account for more than half of these emissions, emphasising the need for low-carbon strategies and climate-smart rebuilding.

The reconstruction process offers a strategic opportunity to build back better by embedding sustainability and low-carbon principles into Ukraine's economic recovery. Leveraging insights into the most affected sectors enables targeted strategies that stimulate local investment in green industries, renewable energy, and resource-efficient technologies. This approach not only addresses urgent infrastructure needs but also strengthens long-term resilience, creates high-quality jobs, and positions Ukraine as a competitive player in the emerging low-carbon economy. Aligning recovery efforts with climate objectives will accelerate the transition toward climate neutrality while meeting growing domestic and regional demand for sustainable products and services.

At the same time, Ukraine's path to climate neutrality is shaped by the dual imperatives of post-war reconstruction and ambitious climate commitments. Achieving these goals requires robust policy frameworks, integration of low-carbon technologies across all sectors, and strong international partnerships. Transparent monitoring, adaptive governance, and a focus on resilience will be essential to ensure that recovery is sustainable and aligned with the country's vision for a climate-neutral future.

[7] Arup based on Kobayakawa Toru, *Estimating the Carbon Footprint of Post-War Reconstruction: Toward a "Greener" Recovery of Ukraine*. September 2024, https://www.jica.go.jp/english/jica_ri/publication/discussion/__icsFiles/afieldfile/2024/09/04/Discussion_Paper_No.24.pdf

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Key words

Greenhouse Gas Emissions, Emissions Baseline, Nationally Determined Contribution, War-related Emissions, Reconstruction

Abbreviations and acronyms

Acronym	Description
°C	Degree Celsius
BTR	Biennial Transparency Report
CCS	Carbon Capture and Storage
CH_4	Methane
CMA	The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
CO_2e	Carbon Dioxide Equivalent
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbons
ICT	Information and Communication Technology
IDP	Internal Displaced Persons
INDC	Intended Nationally Determined Contribution
IPPU	Industrial Processes and Product Use
LEDS	Low Emission Development Strategy
LULUCF	Land Use, Land-Use Change and Forestry
MSW	Municipal Solid Waste
$MtCO_2e$	Million Metric Tonnes of CO_2 Equivalent
N_2O	Nitrous Oxide
NDC	Nationally Determined Contribution
PFC	Perfluorocarbons
SF_6	Sulphur Hexafluoride
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
WAM	With Existing Measures Scenario
WEM	With Additional Measures Scenario

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Introduction

The National GHG Baseline report is a foundational document that provides a clear and comprehensive understanding of greenhouse gas emissions (GHG) in Ukraine.

Its main purpose is to outline the principal sources of emissions, spanning sectors such as energy, industry, agriculture, land use, and waste, and to present a detailed historic overview of how these emissions have evolved over time.

Demographic and Economic Overview

Ukraine has experienced significant demographic and economic shifts over the past three decades. According to the State Statistics Service of Ukraine, the Ukrainian population has declined steadily since independence, with the most recent official estimates placing the population at approximately 33.3 million in 2024[8], down from over 51.9 million in 1990.

The full-scale invasion of Ukraine has intensified the country's demographic crisis, driving unprecedented levels of emigration. Since 2022, armed aggression and territorial occupation have forced around five million people (primarily women and children) to leave Ukraine, many with no intention of returning. This mass outflow, combined with internal displacement, declining birth rates, and high mortality, has created severe labour market imbalances, forced population movement and external migration in Ukraine. The separation between government-controlled and occupied territories further complicates demographic dynamics. As it now stands, there are 1,158 women per 1,000 men in Ukraine. [9]

Economically, Ukraine's GDP has followed a volatile trajectory, shaped by the impacts of conflict. After a sharp contraction in the 1990s, the early 2000s saw a period of moderate growth, hindered by the 2008 global crisis, and the 2014 and 2022 invasions. The Ministry of Finance reports that GDP growth was positive in the years preceding the full-scale war, but the conflict has led to a significant contraction, with recovery prospects closely tied to reconstruction and international support. Today, we see the economy's expected growth rate at 2% in 2025.[10]

Population and GDP Projections to 2050

According to the First Biennial Transparency Report of Ukraine (2025), macroeconomic projections anticipate that Ukraine's GDP will grow at an average annual rate of 5.0% (2023–2025), 5.4% (2026–2030), 4.6% (2031–2040), and 2.8% (2041–2050), with sectoral growth driven by construction, processing industry, and trade.

Table 1 Macroeconomic forecast: annual average GDP growth rates by sector, %[11]

	2022	2023-2025	2026-2030	2031-2040	2041-2050
GDP	-28.8	5.0	5.4	4.6	2.8

[8] International Monetary Fund, W*orld Economic Outlook. Global Economy in Flux, Prospects Remain Dim*, October 2025, https://www.imf.org/en/publications/weo/issues/2025/10/14/world-economic-outlook-october-2025#statistical
[9] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf
[10] International Monetary Fund, W*orld Economic Outlook. Global Economy in Flux, Prospects Remain Dim*
[11] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement.*

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Demographic forecasts from the Institute of Demography and Social Research project a continued population decline, from 41.2 million in 2022 to 30.1 million by 2050. The share of urban population is expected to remain above two-thirds, while the number of households will decrease, reflecting ongoing demographic and economic challenges.

Table 2 Demographic Forecast: Population, million[12]

	2022	2025	2030	2035	2040	2040	2050
Population (million)	41.2	30.4	34.5	33.5	32.4	31.3	30.1

Economic Profile and Fiscal Deficits

Ukraine's economy is characterised by a diverse industrial base, significant agricultural output, and a growing services sector. Key industries include metallurgy, machinery, chemicals, and food processing, with agriculture remaining a vital export sector. The full-scale war has disrupted industrial production, particularly in the east, and shifted economic activity towards central and western regions. GDP growth is currently being driven by defence spending, agricultural exports and recovering metallurgical production. However, it is expected to slow by 2% in 2025 due to infrastructure damage and energy disruptions. Poverty has surged by 1.8 million people, reaching 9 million since the invasion.[13]

Ukraine's rapid advancement in high-tech sectors in recent years demonstrates its exceptional ability to innovate under pressure and quickly scale complex systems. This trajectory not only highlights the nation's technical resilience, but also its capacity to absorb, adapt to, and master cutting-edge technologies. These capabilities can be redirected towards civilian applications in peacetime to foster a robust ecosystem for safety, defence, and critical infrastructure solutions. Ukraine's experience in developing and deploying advanced systems in challenging conditions positions it as a strong contender for leadership in emerging technology domains, offering significant potential for knowledge transfer, industrial growth, and global competitiveness.

Fiscal deficits have widened in recent years, reflecting increased defence spending, social support for displaced populations, and reconstruction needs. Defence and security spending is forecasted to rise to 26.3% of GDP in 2025, while the budget deficit is projected to remain near 20% of GDP, pushing public debt towards 110% of GDP in 2025. The Ministry of Finance has implemented medium-term budget planning and sought international financial assistance to stabilise public finances, but debt levels remain elevated.[14]

Geographical and Climate Profile

Ukraine is the largest country entirely within Europe, characterised by predominantly flat terrain, fertile soils, and a temperate continental climate, with subtropical features only along the southern Crimean coast. Its vast steppe and forest-steppe zones support extensive agriculture, while the Carpathian Mountains and Black Sea coast add environmental

[12] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf
[13] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*
[14] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*

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diversity.[15] Climatic conditions vary regionally: the west and northwest experience milder, wetter weather, while the east and southeast are warmer and drier. Average January temperatures range from −8°C in the northeast to +4°C in Crimea, and July averages span +17°C in the northwest to +23°C in the south.

Climate change impacts are increasingly evident. Over the past 60 years, Ukraine has warmed at 0.4–0.6°C per decade, exceeding European and global averages.[16] Winters have become milder, with January temperatures rising by 2.3°C, and summer temperatures increasing by 1.4°C since the early 1990s.[17] Frost-free periods have lengthened by up to 40 days, and heatwaves above 30°C are more frequent.[18] Future projections indicate further warming: by mid-century, average annual temperatures could rise by 1.2–1.5°C, and by 2100 by 2.9–3.3°C, with summer peaks up to 4.3°C higher under high-emission scenarios.[19]

These changes pose significant challenges for agriculture, water resources, and urban infrastructure, reinforcing the need for adaptation strategies such as climate-resilient farming, improved water management, and infrastructure upgrades.

[15] Ukraine's. *Ministry of Environmental Protection and Natural Resources of Ukraine Annual National Inventory Report for Submission under the United Nations Framework Convention on Climate Change and the Paris Agreement*. 1990, mepr.gov.ua/wp-content/uploads/2025/03/Ukraine_NID_2025.pdf.
[16] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf
[17] Ukraine's. *Ministry of Environmental Protection and Natural Resources of Ukraine Annual National Inventory Report for Submission under the United Nations Framework Convention on Climate Change and the Paris Agreement*.
[18] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*
[19] Ukraine's. *Ministry of Environmental Protection and Natural Resources of Ukraine Annual National Inventory Report for Submission under the United Nations Framework Convention on Climate Change and the Paris Agreement*.

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1 GHG Emissions

1.1 Total GHG Emissions in Ukraine

Table 3 Trends in aggregate direct action GHG emissions by sector, $MtCO_2e$[20]

Sector	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	Current year compared to base year (%)
Energy	740.1	442.5	321.7	323.8	293.5	215.4	213.6	215.4	170.4	164.0	-77.8
IPPU	117.7	57.9	67.2	80.9	75.7	57.1	57.5	60.3	21.6	21.1	-82.1
Agriculture	89.6	62.6	36.8	32.7	31.5	36.2	37.7	41.7	32.5	33.0	-63.2
LULUCF (removals)	-47.9	-46.0	-33.4	-18.2	-21.0	4.1	-15.5	-5.4	-15.7	-11.2	-76.7
Waste	16.9	16.3	15.9	16.5	16.5	16.1	16.4	16.1	14.8	14.8	-12.5
Total (including LULUCF)	**916.5**	**533.4**	**408.3**	**435.7**	**396.2**	**328.9**	**309.7**	**328.1**	**223.5**	**221.7**	**-75.8**
Total (excluding LULUCF)	**964.4**	**579.4**	**441.7**	**453.9**	**417.2**	**324.8**	**325.2**	**333.5**	**239.2**	**232.9**	**-75.9**
Total (including LULUCF, indirect CO_2)	**916.5**	**533.4**	**408.3**	**435.7**	**396.2**	**328.9**	**309.7**	**328.1**	**223.5**	**221.7**	**-75.8**
Total (excluding LULUCF, indirect CO_2)	**964.4**	**579.4**	**441.7**	**453.9**	**417.2**	**324.8**	**325.2**	**333.5**	**239.2**	**232.9**	**-75.9**

In 2023, the energy sector accounted for 74% of total national GHG emissions, representing the largest share.
Agriculture is the second-largest contributor, accounting for 15% of emissions. This is followed by industrial processes and product use (IPPU), accounting for 10% of emissions. Waste management adds a further 7%.
Finally, the smallest segment is Land Use, Land Use Change and Forestry (LULUCF), which is marked as -5%.

[20] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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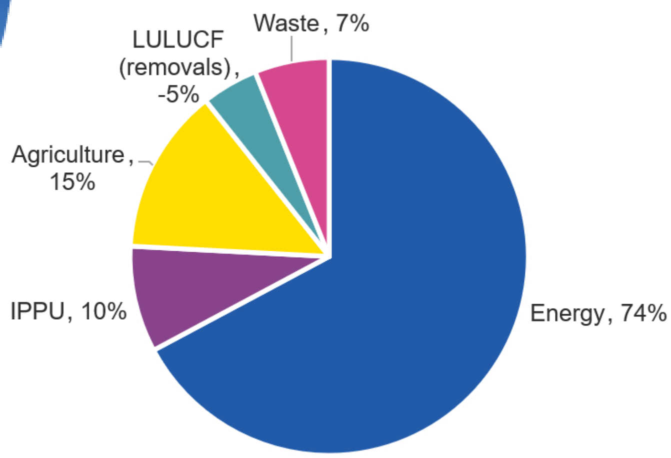

Figure 7 GHG emissions by sector in 2023, $MtCO_2e$[21]

1.1.1 Energy

The energy sector is the single largest source of global greenhouse gas (GHG) emissions, primarily due to carbon dioxide (CO_2) released from burning fossil fuels for electricity, heat, and transport. Additional emissions arise from oil and gas extraction, refining, and methane leaks during production and distribution.

In Ukraine, energy remains the dominant contributor to GHG emissions, accounting for around 74% of total emissions in 2023 (excluding LULUCF). Most emissions stem from fuel combustion in power generation, manufacturing, transport, and other industries, alongside fugitive emissions from fuels.

Since 1990, energy-related emissions have fallen by nearly 75.8%, reflecting structural changes, reduced industrial activity, and efficiency gains. However, coal continues to play a major role in electricity generation, while natural gas dominates residential heating. The 2022–2023 war caused sharp declines in emissions due to infrastructure damage and population displacement.

Ukraine's mitigation strategies focus on expanding renewable energy, improving energy efficiency, introducing carbon pricing, and implementing policies to reduce methane emissions, including participation in the Global Methane Pledge. The energy sector is the largest source of greenhouse gas emissions, so its decarbonisation through market reforms, investment in new generation capacity, and integration with EU energy markets is critical for achieving climate goals and sustainable economic growth.[22]

1.1.2 Industrial Processes and Product Use (IPPU)

The IPPU sector accounts for roughly 10% of Ukraine's greenhouse gas (GHG) emissions, primarily from cement, iron and steel, ammonia, and Chemicals production. Unlike energy-related emissions, these are process-driven, arising from chemical reactions and raw material use rather than fuel combustion. Key factors include production volumes, technology choices, and feedstock composition.

[21] Arup based on Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf
[22] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*

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Since 1990, IPPU emissions have fallen by more than 82%, largely due to the outflow of investment capital, unstable export dynamics, contraction of the domestic market, as well as the discrepancies in established "raw material-production-sales" connections in the regions of the country.[23] Carbon dioxide (CO_2) remains the dominant gas, but (CH_4) emissions from Carbide and Petrochemical and carbon black production, nitrous oxide (N_2O) from nitric acid production, and fluorinated gases (HFCs) from refrigeration and electrical equipment are significant contributors. While overall emissions have declined, HFC emissions have increased with the growing use of cooling systems. [24] [25]

IPPU emissions pose unique challenges because they often involve gases with high global warming potential, such as HFCs, PFCs, and SF_6. These cannot be mitigated through energy efficiency alone. Effective strategies include shifts to electric steelmaking. Carbon capture and storage (CCS) and circular economy principles will be critical for long-term reductions.

Monitoring and reporting IPPU emissions is essential for compliance with frameworks like the UNFCCC. Accurate data enables targeted policies and supports climate commitments. As industries modernise, integrating low-emission technologies and sustainable practices will be key to achieving deep decarbonisation in this sector.

1.1.3 Agriculture

Agriculture is a significant source of greenhouse gas emissions in Ukraine, accounting for about 15% of total emissions, with agricultural soils (71%) followed by enteric fermentation (20%). primarily methane (CH_4) and nitrous oxide (N_2O). Methane arises mainly from enteric fermentation in ruminant livestock and anaerobic conditions in rice paddies, while N_2O is released through fertiliser application and manure management. These emissions are biologically driven, making them harder to mitigate than energy-related emissions.

Minor sources include manure management and urea application. Key determinants include livestock numbers, fertiliser use, manure management, and crop structure. Since 1990, emissions have declined by approximately 63% compared to the base year, largely due to reduced livestock and fertiliser use, though recent years show slight increases in soil emissions linked to cropping changes.

Mitigation and adaptation strategies include agroforestry, ICT adoption to reduce GHG emissions, climate-smart irrigation, and integration of renewable energy into farming systems. Policy frameworks increasingly link agricultural sustainability with food security and climate resilience, positioning this sector as central to achieving net-zero targets.[26]

1.1.4 Land Use, Land Use Change and Forestry (LULUCF)

The LULUCF sector covers greenhouse gas (GHG) emissions and removals from land management activities, including forestry, agriculture, and land-use changes. Unlike other sectors, LULUCF can act as both a source and a sink of carbon. Activities such as deforestation, peatland drainage, and land conversion release carbon dioxide (CO_2), while

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[23] Diachuk, Dr Oleksander, et al. First Biennial Transparency Report of Ukraine under the Paris Agreement. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

[24] Ukraine's. Mi*nistry of Environmental Protection and Natural Resources of Ukraine Annual National Inventory Report for Submission under the United Nations Framework Convention on Climate Change and the Paris Agreement*. 1990, mepr.gov.ua/wp-content/uploads/2025/03/Ukraine_NID_2025.pdf

[25] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*

[26] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*

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afforestation, reforestation, and sustainable forest management enhance carbon sequestration.

Globally, LULUCF plays a critical role in climate mitigation. Forests and soils store vast amounts of carbon, making their conservation and restoration essential for achieving net-zero targets. However, pressures from agriculture, urbanisation, and resource extraction often lead to land degradation and biodiversity loss, increasing emissions.

In Ukraine, LULUCF acts as a net carbon sink, removing approximately -11 $MtCO_2e$ in 2023. Forest land provides the largest removals, while cropland has shifted from a sink to a source due to soil management practices and crop changes. Key factors which influence LULUCF include land conversion, forest fires, peat extraction, and management approaches. Although overall removals have declined since 1990, afforestation and sustainable land management could strengthen this sector's contribution to climate neutrality.[27]

1.1.5 Waste

The waste sector accounts for about 6.4% of Ukraine's greenhouse gas (GHG) emissions, primarily methane (CH_4) from landfills and N_2O from wastewater treatment. Methane is released during the anaerobic decomposition of organic material in landfills, while N_2O arises from treatment processes. Although its share of total emissions is smaller than energy or agriculture, the sector's impact is significant because methane has a global warming potential far greater than carbon dioxide.

Emissions are driven by population size, waste generation rates, composition, and management practices. High organic content in municipal waste and reliance on landfill disposal amplify methane emissions, while inefficient wastewater systems increase N_2O output. Since 1990, emissions have declined by around 12.5%, supported by methane recovery systems and improved wastewater treatment. However, recycling and composting rates remain low, and landfill disposal is still widespread.

Future reductions in Ukraine hinge on enhanced measures such as biogas utilisation, thermal treatment, and systemic changes in consumption patterns. Mitigation strategies include expanding anaerobic digestion for organic waste, improving landfill gas capture, and promoting behavioural shifts to reduce waste generation. Accurate monitoring and reporting under frameworks like the UNFCCC remain essential for tracking progress and meeting climate commitments. While often overlooked, the waste sector offers substantial opportunities for emission reductions through technological innovation and circular economy practices.[28]

[27] Ukraine's. *Ministry of Environmental Protection and Natural Resources of Ukraine Annual National Inventory Report for Submission under the United Nations Framework Convention on Climate Change and the Paris Agreement*. 1990, mepr.gov.ua/wp-content/uploads/2025/03/Ukraine_NID_2025.pdf

[28] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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1.2 Nationally Determined Contribution

Ukraine, as a member of the Paris Agreement, has committed to ambitious climate action despite significant challenges posed by war, economic crises, and the COVID-19 pandemic. Its first Intended Nationally Determined Contribution (INDC), submitted in 2016, set a target of limiting greenhouse gas emissions to no more than 60% of 1990 levels by 2030 and reaching carbon neutrality by 2060. Building on this, Ukraine updated its NDC in July 2021 to reflect enhanced ambition and alignment with long-term climate goals.

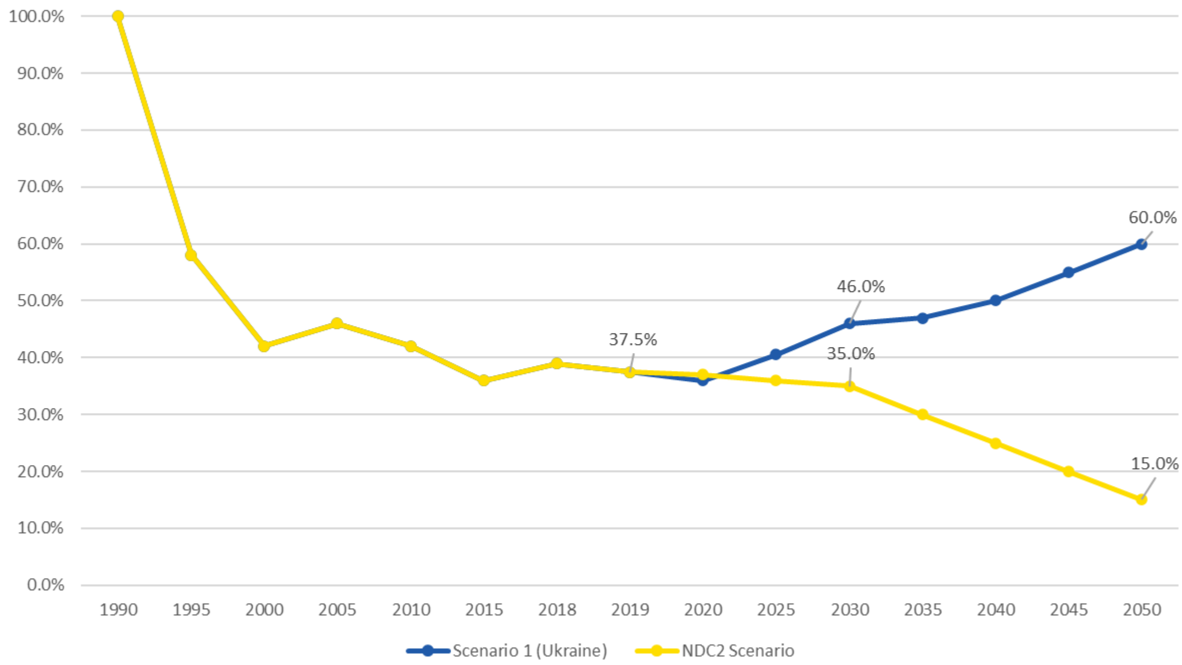

Figure 8 Updated Ukraine's NDC scenarios[29]

Under the updated NDC, Ukraine pledges an economy-wide net domestic reduction of 65% in GHG emissions by 2030 compared to 1990 levels, without reliance on international credits. This represents a legally binding target and a progression from the previous Intended Nationally Determined Contribution (INDC). The base year for calculations is 1990, when emissions totalled 916.5 $MtCO_2e$ (including LULUCF). The updated NDC also sets a long-term vision of achieving carbon neutrality by 2060, as outlined in the National Economic Strategy to 2030.

Ukraine's NDC covers all major sectors: Energy, Industrial Processes and Product Use (IPPU), Agriculture, Land Use, Land-Use Change and Forestry (LULUCF), and Waste, and includes all greenhouse gases not controlled by the Montreal Protocol (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3). The commitment applies across Ukraine's internationally recognised borders, although data gaps exist for temporarily occupied territories. Emission estimates for these areas rely on expert assessments, and the NDC will be adjusted once full territorial control is restored.

[29] Arup based on Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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Beyond mitigation, Ukraine's NDC emphasises adaptation, aiming to establish a baseline for climate resilience by 2030 in line with Article 7 of the Paris Agreement. This includes measures to reduce vulnerability in key sectors such as agriculture, energy, and infrastructure.

Implementation of the NDC spans 2021–2030, supported by domestic policies promoting energy efficiency, renewable energy development, and structural reforms. Despite severe disruptions from Russia's full-scale aggression, Ukraine continues to advance climate policy, integrating decarbonisation into its recovery and reconstruction plans. The government has committed to transparent reporting and will update reference indicators as methodologies improve or territorial conditions change.

Ukraine's approach is firmly domestic, excluding international offsets, but the country remains open to cooperative approaches under Article 6 of the Paris Agreement, provided they align with CMA guidance.[30] Achieving these targets will require sustained international support, private sector investment, and robust governance to ensure progress toward a low-carbon, climate-resilient future.[31]

[30] UNFCCC, *Guidance operationalizing the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement,* https://unfccc.int/sites/default/files/resource/cma3_auv_5_transparency.pdf
[31] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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2 Projections of Greenhouse Gas Emissions and Removals

2.1 Total Projected GHG Emissions in Ukraine

Ukraine's greenhouse gas emissions are classified under several key contributors as detailed below. However, it is important to note that the figures for overall GHG emissions exclude gas emissions and removals from land use, land use change and forestry (LULUCF). This omission is due to the lack of reliable data that can be collected as a result of Russia's full-scale military invasion of Ukraine. As such, no forecast of GHG emissions from this sector has been conducted. Projections for other sectors are also impacted by scarcity of data and are subject to uncertainty stemming from war and martial law-related issues. Figures are projected from the 2021 data gathered from the National Inventory of Anthropogenic Emissions from Sources and Absorption by Sinks of Greenhouse Gases in Ukraine for 1990-2021.

The First Biennial Transparency Report of Ukraine under the Paris Agreement presents the latest modelling and forecasting results for greenhouse gas emissions in Ukraine, categorised by sector. The analysis presents two scenarios: 'With Existing Policies and Measures' (WEM) and 'With Additional Policies and Measures' (WAM).

Table 4 The main results of modelling in the field of GHG emissions in Ukraine according to 'with existing measures' (WEM) [32]

	2021	2025	2030	2035	2040	2045	2050
Scenario With Existing Policies and Measures (WEM)							
The total amount of GHG emissions, excluding LULUCF, million tons of CO_2e	**327.3**	**236.3**	**252.5**	**271.3**	**285.7**	**293.7**	**301.6**
Sectors of energy, industrial processes and product use	268.1	188	199	214	227	234	241.5
Agriculture	47	37	42	46	48	50	51
Land use, land use change and forestry	14.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Waste sector	12.1	11.3	11.5	11.3	10.7	9.7	8.6
The share of GHG emissions from the level of 1990, excluding LULUCF %	**34.7**	**25.9**	**27.6**	**29.6**	**31.2**	**32.0**	**32.9**
Sectors of energy, industrial processes and product use	31.8	22	24	25	27	28	29
Agriculture	54.1	43	48	52	55	57	58

[32] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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	2021	2025	2030	2035	2040	2045	2050
Land use, land use change and forestry and forestry	221	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Waste sector	97.6	91	86	85	79	72	63
GHG emissions (excluding LULUCF) per capita, tonnes of CO_2e	**7.9**	**7.8**	**7.3**	**8.1**	**8.8**	**9.4**	**10**

Table 5 The main results of modelling in the field of GHG emissions in Ukraine according to 'with additional measures' (WAM) scenario[33]

	2021	2025	2030	2035	2040	2045	2050
Scenario With Additional Policies and Measures (WAM)							
The total amount of GHG emissions, excluding LULUCF, million tons of CO_2e	**327.3**	**221.0**	**185.6**	**177.5**	**157.7**	**137.9**	**120.1**
Sectors of energy, industrial processes and product use	268.1	173	134	122	101	81	62
Agriculture	47	37	41	46	48	49	51
Land use, land use change and forestry	14.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Waste sector	12.1	11	10.6	9.5	8.7	7.9	7.0
The share of GHG emissions from the level of 1990, excl. LULUCF %	**34.7**	**24.1**	**20.3**	**19.4**	**17.2**	**15.0**	**13.1**
Sectors of energy, industrial processes and product use	31.8	22	19	16	15	12	9
Agriculture	54.1	42	47	52	55	56	58
Land use, land use change and forestry and forestry	221	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Waste sector	97.6	42	47	50	52	54	55
GHG emissions (excluding LULUCF)	**7.9**	**7.3**	**5.4**	**5.3**	**4.9**	**4.4**	**4**

[33] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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	2021	2025	2030	2035	2040	2045	2050
per capita, tonnes of CO_2e							

Under the WEM scenario, total GHG emissions (excluding LULUCF) drop sharply from 327.3 $MtCO_2e$ in 2021 to 236.3 $MtCO_2e$ in 2025 as a result of the Russian full-scale invasion. However, they gradually rise again, reaching 301.6 $MtCO_2e$ by 2050, which is about 33% of the 1990 level. This indicates that without additional measures, emissions will increase over time as economic and industrial activity recovers. In contrast, under the WAM scenario, emissions continue to decline, falling to 120.1 $MtCO_2e$ by 2050, or 13.1% of the 1990 level, demonstrating the effectiveness of implementing additional policies.

2.1.1 Energy and IPPU

Forecasts of GHG emissions until 2050 in the UN IPCC sectors "Energy" and "Industrial Processes and Product Use" are calculated for both WEM and WAM scenarios using the TIMES-Ukraine model.[34] As such, 2020 numbers are not statistical, but the outputs of the model. Modelling results infer that even under a rapidly recovering Ukrainian economy in the post-war period, it is possible to avoid an increase in GHG emissions in the energy and IPPU sectors through the application of the "build back better" approach. This involves the implementation of energy efficiency measures, the expansion of renewable energy source usage, and the undertaking of other decarbonisation and technological modernisation efforts.

Table 6 GHG emissions in the "Energy" and "Industrial processes and product use", $MtCO_2e$[35]

Scenario	2020	2025	2030	2035	2040	2045	2050
WEM	268.1	188	199	214	227	234	241.5
WAM	268.1	173	134	122	101	81	62

Under the WEM scenario, 2025 GHG emissions are forecasted to decrease by 28% on 2020 levels, then gradually creep upwards in line with economic growth, with the 2050 figure projected to still be below 2020 levels. Conversely, the WAM scenario predicts steadily decreasing GHG emissions compared to the 2020 figure, reaching 49% less by 2030, and 76% less by 2050. Furthermore, the WAM scenario lends support to the feasibility of net-zero GHG emissions in the electricity and heat generation sectors before 2050, with potential negative CO_2 emissions through the harnessing of bioenergy and carbon capture and storage (CCS) technologies.

In the gas type dimension, the WEM scenario displays increasing emissions across all gases following the decrease between 2020-2025. The WAM scenario paints a different picture, with CO_2 and CH_4 emissions effectively reduced, illustrating the impact of additional climate policies and how they may meaningfully contribute towards the Global Methane Pledge. However, N_2O and HFC emissions continue to rise under both scenarios, implying that additional targeted policies and measures may be required to mitigate the damage from their emissions.

[34] TIMES-Ukraine, https://www.timesukraine.tokni.com/about
[35] Diachuk, Dr Oleksander, et al. First Biennial Transparency Report of Ukraine under the Paris Agreement. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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Regarding industrial emissions arising from fuel combustion and industrial processes, both projected volumes and their structure differ vastly under WEM and WAM scenarios. Most notably, the WAM scenario predicts 2050 emissions resulting from ammonia production to reduce to under an eighth of 2020 levels, while the WAM scenario anticipates ammonia emissions to effectively double over this timeframe. This stark contrast can be attributed to the implementation of more efficient technological chains and the use of CCS in hydrogen production from natural gas. Furthermore, emissions from the metallurgy sector significantly decrease under both scenarios due to the shift towards electric steel production, while sectors such as the chemical industry (excluding ammonia production) increase their emissions over time under both scenarios due to the growing nature of the industry.

GHG emissions in the buildings sector are separated into residential and commercial subsectors. The majority of emissions from residential buildings and a significant portion of the services sector are derived from meeting the demand for space heating. Through the implementation of baseline scenario targets of the strategy of building thermal modernisation by 2050, and adopting advanced, energy-efficient technologies such as heat pumps, emissions from heating have the potential to halve in residential buildings and decrease to a third of 2020 levels in commercial buildings under the WAM scenario. Emissions from cooking and water heating in residential buildings are also projected to decrease substantially through the electrification of these demands and the substitution of natural gas with biomethane. However, even under the WAM scenario, the share of CH_4 from combustion may grow in commercial buildings as biomass for heating and other activities grow in use.

In 2021, Ukraine's transport sector accounted for 41% of all atmospheric emissions and 29% of CO_2 emissions, a marked increase on 2020 figures in both relative and absolute terms. While the level of car ownership in Ukraine remains relatively low at 239 passenger cars per 1,000 people compared to 574 in the EU (2023), emissions from Ukrainian road transport are still significant due to an outdated fleet. The average age of cars in Ukraine is rising year on year, reaching 23.2 years in 2023 compared to the EU average of 11.8 years. This is a trend that shows no signs of reversing, as in 2023, 40% of new car registrations were for vehicles over 10 years old, with cars over 10 years old accounting for 85.8% of the total vehicle fleet. Due to the full-scale war, freight transport volumes have dropped significantly, with air transport plummeting by 100%, maritime transport falling by 85%, rail transport by 48%, and road transport reducing by 22%. The WAM scenario emphasises the potential for significant emissions reductions in the transport sector, with the only major emitters in 2050 expected to be freight road transport and aviation. Despite the expected growth in energy demand for transport due to increased economic activity, decoupling is possible after 2025 through the utilisation of advanced and sustainable biofuels, direct electrification, and hydrogen. Under the WAM scenario, emissions from transport are expected to be 60% less in 2050, compared to the 2020 level.[36]

2.1.2 Agriculture

Table 7 GHG emissions in the "Agriculture" $MtCO_2e$[37]

Scenario	2020	2025	2030	2035	2040	2045	2050
WEM	47	37	41	46	48	49	51
WAM	54.1	42	47	52	55	56	58

[36] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf
[37] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*

Based on projected data, GHG emissions under the WEM scenario (reflecting the current limited implementation of legislation) where policy development, adoption, and execution all experience significant delays, there will be a gradual increase in GHG emissions from 2025 to 2050. While GHG emissions stemming from agriculture are projected to decrease by 10 million tonnes from 2021 to 2025 to 37 million tonnes of CO_2e, this figure is expected to rise in the following years to 42 million tonnes in 2030, 48 million tonnes in 2040, and 51 million tonnes in 2050. This 2050 projection amounts to a 58.1% proportion of the 1990 GHG figure.

The greening of agriculture demands environmentally responsible development of the industry, entailing the adoption of information and electronic communication technologies, the enhancement of soil cultivation techniques, advancements in crop production methods, and the sustainable development of animal husbandry, both in terms of breeding practices and manure management.

With consideration for these priorities and objectives for sustainable, climate-oriented development, the WAM scenario places emphasis on expanding the implementation of two key agricultural policies aimed at reducing GHG emissions:

- Promotion of organic crop production development to expand to 1.1 million hectares and reduce GHG emissions by 1.1 $MtCO_2e$
    - While organic crop production is long recognised, its full potential remains underutilised
    - In the Ukrainian context, it could play a significant role in adapting to climate change, mitigating its effects, and preserving biodiversity, positioning it as a key strategy in the “green transformation” of agriculture
- Dissemination of the use of information and electronic communication technologies in crop reduction aiming to reduce emissions by 0.4 $MtCO_2e$
    - The integration of information and electronic communication technologies in crop production may significantly contribute to the sustainable development of agriculture
    - Their application enables effective land monitoring, environmental control, and the optimisation of agricultural interventions and practices

When accounting for historical trends in agricultural development, and the uncertainty surrounding the end of hostilities, the employment of these practices and technologies is expected to be at a limited scale. On the other hand, even partial utilisation of their potential will contribute to the reduction of GHG emissions from agriculture. Under the WAM scenario, GHG emissions are projected to reach 41.4 million tonnes of CO_2e in 2030, 47.8 million tonnes in 2040, and 50.7 million tonnes of CO_2e in 2050, approximately 57.8% of the amount recorded in 1990.[38]

2.1.3 LULUCF

Due to the devastation of more than 2,000km of frontline as a result of the Russian full-scale invasion of Ukraine, it was found to be impossible to obtain reliable data on the LULUCF sector in time for the Ukrainian National Energy and Climate Plan (NECP) preparation. As such, the development of a reasonable forecast of the LULUCF’s GHG emissions has not been conducted. It is estimated by the Ministry of Environmental Protection and Natural Resources that around 3 million hectares of forests have been damaged, almost a third of Ukraine’s total forest area (10.4 million hectares).

[38] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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Currently, Ukraine is reviewing its LEDS (Low Emission Development Strategy) and will base future forecasts of LULUCF emissions on its most recently obtained assessments. The next Ukrainian BTR will be supplemented with these relevant forecasts and this methodology.[39]

2.1.4 Waste

Table 8 GHG emissions in the "Waste" $MtCO_2e$[40]

Scenario	2020	2025	2030	2035	2040	2045	2050
WEM	12.1	11	10.6	9.5	8.7	7.9	7.0
WAM	97.6	42	47	50	52	54	55

In the projection of GHG emissions from the waste sector, the WAM scenario assumes strict adherence to the Law "On Waste Management", adopted in 2022. It is based on the full implementation of the draft National Waste Management Plan of Ukraine until 2033 and the draft Action Plan for the National Waste Management Plan of Ukraine until 2033, which were expected to be approved in 2024[41].

The WAM scenario envisions municipal solid waste (MSW) to be reduced to a 30% share of landfilling by 2033, and to a 20% share by 2050, increasing the share of biogas utilisation at landfills to 23% by 2030 and 36% by 2050, in tandem with the construction of new waste composting facilities with low specific emission factors for CH4 and N2O.

In contrast to the WEM scenario, the increase in biogas utilisation at MSW until 2030 under the WAM scenario will primarily be achieved through broader adoption of biogas recovery technologies at MSW landfills opposed to flaring. This is in line with the approval of the "National Waste Management Plan of Ukraine until 2033"[42] aiding in the development of new regional MSW landfills, while simultaneously decommissioning outdated disposal sites.

Steady decreases in waste management GHG emissions are projected under the WAM scenario. The 2021 GHG emissions figure of 12.1 million tonnes of CO_2e is forecasted to decrease to 11 million tonnes in 2025 and then projected to lessen to 7 million tonnes by 2050. This marks a significant change from the WEM scenario, where waste sector GHG emissions are projected to be 8.6 million tonnes in 2050. As such, these projections signify that waste CO_2e emissions can be greatly reduced through policy implementation.

While GHG emissions from waste are projected to trend downwards on the whole from 2021 to 2050, in both WEM and WAM scenarios, one source that is expected to significantly increase its emissions from 2025 to 2030 is the biological treatment of solid waste. This expected increase can be attributed to the rapid expansion of composting practices for MSW in Ukraine. However, its subsequent gradually decreasing emissions from 2030 to 2050 is linked to the

[39] Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf
[40] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*
[41] In 2024, the full, comprehensive National Waste Management Plan of Ukraine until 2033 was approved.
[42] National Waste Management Plan of Ukraine until 2033, https://mepr.gov.ua/wp-content/uploads/2023/12/proyekt-Natsionalnyj-plan-upravlinnya-vidhodamy-23.11-002.docx

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implementation of modern composting technologies with lower methane and nitrous oxide emission factors[43].

[43] Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf

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3 GHG Emissions Associated With War

3.1 GHG emissions by sector

Russia's full-scale invasion of Ukraine has caused widespread destruction, severely damaging homes, schools, hospitals, and other essential public facilities. As a result, many citizens have been left without critical resources such as water, electricity, and healthcare. Beyond the harm to Ukraine's natural environment, the conflict also impacts the global climate by releasing substantial amounts of carbon dioxide and other greenhouse gases (GHGs) into the atmosphere.

This document covers emissions during the first two years of the war, from 24 February 2022 to 23 February 2024. The analyses were performed by Ecoaction in the report "Climate Damage Caused by Russia's War in Ukraine".[44]

This assessment estimates that emissions linked to 24 months of conflict have reached 175 million tonnes of CO_2 equivalent (tCO_2e), resulting in climate-related damages exceeding USD 32 billion, based on an assumed carbon price of USD 185 per tonne of CO_2. In the initial months, most emissions stemmed from the large-scale destruction of civilian infrastructure, which will require extensive reconstruction. Two years on, the primary sources of emissions are now a combination of active warfare, landscape fires, and damage to energy infrastructure.

Table 9 Geographical distribution of emissions for each sector[45]

Sector	Emissions ($MtCO_2e$)	Government-controlled Ukraine	Occupied territories in Ukraine[46]	Russia & Belarus	Rest of the world
Warfare	51.6	20%	55%	22%	3%
Landscape fires	22.9	50%	50%	-	-
Energy infrastructure	17.2	11%	2%	2%	85%
Refugees	3.3	30%	5%	10%	55%
Aviation	24.0	-	-	10%	90%
Reconstruction	56.0	40%	40%	-	20%
Total	175	27%	36%	8%	29%

3.1.1 Warfare

This section covers all GHG emissions directly associated with military operations by both Russian invading forces and Ukrainian defence forces. It includes fuel use by military equipment and logistics systems; the embodied emissions of ammunition used during the

[44] de Klerk, Lennard, et al. *Climate Damage Caused by Russia's War in Ukraine*. 13 June 2024, https://en.ecoaction.org.ua/wp-content/uploads/2024/06/Climate-Damage-Caused-by-War-24-months-EN.pdf

[45] de Klerk, et al. *Climate Damage Caused by Russia's War in Ukraine*.

[46] Autonomous Republic of Crimea and the City of Sevastopol (full occupation), parts of Donetsk Oblast, parts of Luhansk Oblast, parts of Zaporizhzhia Oblast, parts of Kherson Oblast and parts of Kharkiv Oblast

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conflict, including manufacturing, propellants, and emissions at the point of firing and impact; the embodied emissions of military equipment destroyed or damaged; and emissions associated with the construction of fortifications, largely driven by concrete use. These activities collectively represent the operational carbon footprint of conducting the war.

Table 10 Total emissions from warfare[47]

Component	Emissions ($MtCO_2e$)
Fossil fuel consumption – Russia	35.2
Fossil fuel consumption – Ukraine	9.4
Emissions from ammunition use	4.1
Military equipment	0.5
Construction of fortifications	1.9
Supply of equipment	0.5
Total emissions from warfare	**51.6**

Across the first two years of the conflict, warfare activities generated 51.6 $MtCO_2e$. It is driven overwhelmingly by fuel use which accounts for ~86% of total warfare emissions, with fuel use by Russia contributing to over two-thirds of the total. Significantly lower fuel consumption by Ukraine is explained by the benefits of interior lines of defence for Ukraine, fewer personnel involved and reliance on lighter equipment and vehicles, as well as longer supply-chain distances for the attacking country. A major assumption underpinning this calculation is that fuel consumption above baseline peacetime levels is fully attributable to the war.

Ammunition use forms the next largest component of warfare emissions at 8%. The emissions include the manufacturing of artillery rounds, missiles and other explosives used during the war, and contributions from firing (e.g. due to the combustion of a propellant) and point of impact (e.g. due to the detonation of a warhead). Manufacturing of ammunition and explosives account for ~82% of the total estimated climate impact from ammunition use, while the emissions at the point of firing and point of impact represent the remainder. While artillery dominated early combat, the second year saw declining stocks of artillery shells, causing a reduction in artillery fire intensity.

The destruction and damage of military equipment contributes in a smaller but still significant manner in the share of warfare emissions, based on embodied emissions from the manufacturing of tanks, armoured vehicles, trucks, aircraft, and other machinery lost in combat. Losses are derived from visually confirmed equipment destruction data, actual losses are likely higher; therefore, emissions have been adjusted upward by assuming that at least 20% of losses are not visually confirmed. Lastly, emissions from fortification construction account for a relatively small proportion of the total, but remain relevant due to heavy reliance on concrete, a carbon-intensive material.

Together, these components illustrate that warfare emissions are primarily driven by fossil fuel usage and ammunition production, with additional contributions derived from equipment losses and fortification construction.

[47] de Klerk, Lennard, et al. *Climate Damage Caused by Russia's War in Ukraine*. 13 June 2024, https://en.ecoaction.org.ua/wp-content/uploads/2024/06/Climate-Damage-Caused-by-War-24-months-EN.pdf

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3.1.2 Landscape fires

Landscape fires are a natural occurrence. However, over the past 24 months of the war, their size and intensity in Ukraine have risen sharply on both sides of the frontline. Shelling and other warfare activities have sparked numerous fires, and with insufficient firefighting resources, these blazes have often burned out of control. Total emissions from these fires are estimated at 22.9 million tCO_2e.

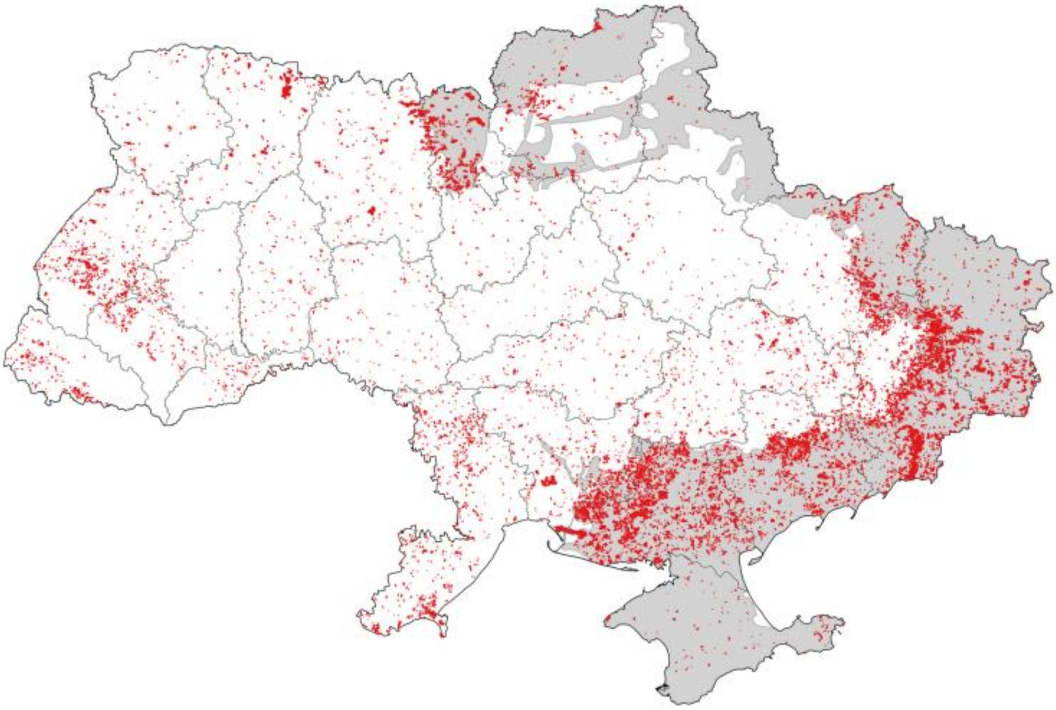

Figure 9 Landscape fires during 24 months of war with areas or armed conflict and occupied territories marked in grey[48]

3.1.3 Energy Infrastructure

During the initial weeks of the war, Russian forces targeted numerous Ukrainian fossil fuel depots and refineries, resulting in the combustion of large quantities of oil products and significant greenhouse gas emissions. Extensive attacks on Ukraine's electricity network led to uncontrolled leaks of SF_6, the most potent greenhouse gas. Further emissions occurred due to damage and destruction of natural gas transport and distribution infrastructure, as well as a prolonged fire on a natural gas production platform in the Black Sea.

Total emissions are estimated at 17.2 million tCO_2e. This figure includes all greenhouse gas emissions resulting from the destruction or burning of oil depots, fuel storage facilities, and refineries; emissions from damaged gas pipelines, including methane leaks; releases of SF_6 from high-voltage electrical infrastructure and damaged switchgear; and emissions linked to large-scale attacks on energy systems within Ukraine and the Russian Federation, such as those targeting the Nord Stream 1 and 2 pipelines.[49]

[48] de Klerk, Lennard, et al. *Climate Damage Caused by Russia's War in Ukraine*. 13 June 2024, https://en.ecoaction.org.ua/wp-content/uploads/2024/06/Climate-Damage-Caused-by-War-24-months-EN.pdf
[49] Arup based on de Klerk, et al. *Climate Damage Caused by Russia's War in Ukraine*.

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Though not directly related to warfare activities, the sabotage of the Nord Stream 1 & 2 pipelines (which most likely would not have occurred without the Russian Federation's act of aggression) is now recorded as the largest transient anthropogenic methane emission event. Additionally, the damage to gas exploration infrastructure in the Black Sea was caused by active combat events and attacks. These events both occurred between 2022 and 2023.

Intensified attacks on oil depots and refineries have been major sources of emissions, with large volumes of stored fuels igniting upon impact. This includes tonnes of fuel burnt due to the attacks on Ukrainian oil products storage facilities (786,000 tCO_2e) and on the territory of Russia and occupied territories of Ukraine (331,000 tCO_2e). These emission figures include direct emissions from combustion and upstream emissions from fuel production, taking the combined total to 1.1 $MtCO_2e$.

SF_6, is used for high-voltage and medium-voltage switchgear for insulation (e.g. gas-insulated switchgear) and breaking (circuit breakers and load break switches) due to its unique characteristics. Per reports, almost half of the high-voltage network facilities were damaged during the intensive attacks on the energy system. Assuming that at least 10% of the SF_6 in Ukraine's electricity system was released, this corresponds to 42.6 tonnes of SF_6, or 1.1 $MtCO_2e$.

Methane emissions arise particularly from pipeline damage, while SF_6 - an extremely potent greenhouse gas, is released when high-voltage substations and switchgear are destroyed. Although smaller in magnitude compared to warfare and landscape fires, these emissions are highly carbon-intensive per incident due to the high global warming potential of the gases involved. SF_6, for instance, has a GWP of 23,500, meaning even limited releases significantly increase totals.

3.1.4 Refugees

Immediately after the invasion on 24 February 2022, many Ukrainians decided to leave their homes. This section covers all GHG emissions from the movement of Ukrainian refugees across borders; emission from internal displacement (IDPs) within Ukraine; and emissions from Russians leaving the country to avoid draft into the military.

Table 11 Total emissions from movement of population displacement[50]

Component	Emissions ($MtCO_2e$)
International refugees from Ukraine	0.77
Transport returning empty to Ukraine	0.77
Refugees in Europe visiting Ukraine	1.24
Internal Displaced Persons in Ukraine	0.24
Russians leaving Russia	0.25
Total emissions from movement of population displacement	**3.27**

[50] de Klerk, Lennard, et al. *Climate Damage Caused by Russia's War in Ukraine*. 13 June 2024, https://en.ecoaction.org.ua/wp-content/uploads/2024/06/Climate-Damage-Caused-by-War-24-months-EN.pdf

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Population displacement resulting from the conflict generated 3.27 $MtCO_2e$ during the first two years. These emissions arise from the direct movement of millions of people fleeing active hostilities or relocating internally, with refugees fleeing abroad acting as the biggest contributor.

Data for refugees (~6 million) and internally displaced persons (IDPs) (~5 million) is calculated by combining official statistics (from UNHCR and IOM) on the number of people moving, with estimates of average travel distances and modes of transport, to determine total passenger-kilometres and related emissions. For Russians leaving the country (~900,000), we have estimated emission on the number of departures and split them by their likely travel mode and destination to calculate emissions. The modes of transportation that were considered include petrol car (4 passengers), national railways, bus, domestic flight (short-haul flight, narrow-body aircraft) and long-haul flight (economy, wide–body aircraft). Refugee and IDP emissions represent a relatively small share of total war-related emissions but remain significant because of the scale and urgency of evacuations.

3.1.5 Aviation

Russia's closure of Siberian airspace for many airlines has severed key east–west routes between Europe and Asia for Western carriers. Similarly, Ukraine's airspace closure to commercial traffic has disrupted flight paths within Europe, particularly in the eastern region, and between Russia and Turkey. Airlines have been forced to take longer detours, resulting in extended flight times, increased fuel consumption, and higher greenhouse gas emissions. The total estimated emissions resulting from this is 24 million tCO_2e.[51]

3.1.6 Reconstruction

The destruction and damage of civilian infrastructure represents a significant aspect of the climate impact of Russia's full-scale war in Ukraine. Numerous buildings, including apartment blocks, hospitals, kindergartens, and commercial and industrial facilities have been damaged or demolished. Utilities, roads, vehicles, and industrial sites have also sustained severe harm. While some reconstruction is already underway, primarily in liberated areas north of Kyiv, east of Kharkiv, and in the Kherson region, the majority of rebuilding, particularly in the eastern and southern regions will only commence once hostilities cease and security is assured. Emissions associated with reconstruction of civilian infrastructure are estimated at 56 million tonnes of CO_2e.

Due to the scope of this task, further details can be found in Chapter 4.

[51] de Klerk, Lennard, et al. *Climate Damage Caused by Russia's War in Ukraine*. 13 June 2024, https://en.ecoaction.org.ua/wp-content/uploads/2024/06/Climate-Damage-Caused-by-War-24-months-EN.pdf

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4 GHG Emissions Associated with Reconstruction

4.1.1 Overview of emissions from reconstruction

From the beginning of Russia's full-scale military invasion until the end of 2023, the total damage to buildings, infrastructure and inventories amounted to almost USD 160 billion. The greatest losses were recorded in residential buildings (almost USD 60 billion) and transport infrastructure (USD 36.8 billion). Damage to the assets of enterprises and industry amounts to USD 13.1 billion, while losses in agriculture and land resources total USD 10.3 billion. The energy sector account for another USD 9 billion in damages. Public sector facilities, including educational and utilities facilities, have suffered approximately USD 11.3 billion in damage. Losses in forests are estimated at USD 4.6 billion, while other losses are estimated at USD 13.2 billion.[52]

Table 12 Total estimate of infrastructure damages for the period of 24 February 2022 – 31 December 2023[53]

Property type	Assessment of damages, USD billion	Share of damages by property type, % of total sum
Housing	58.9	37%
Transport infrastructure	36.8	23%
Assets of enterprises, industry	13.1	8%
Agriculture and land resources	10.3	7%
Energy	9	6%
Education	6.8	4%
Forest	4.6	3%
Utilities	4.5	3%
Other	13.2	8%
Total	**157.2**	**100%**

Reconstruction efforts will require substantial quantities of construction materials such as cement, steel, and asphalt. Transporting these materials to construction sites, along with the construction activities themselves, will consume significant energy. Overall, rebuilding Ukraine will generate considerable greenhouse gas (GHG) emissions.

The reconstruction is divided into three main categories:

- Buildings: This includes the residential sector, healthcare, social services, education and science, culture, religion, sports, tourism, and retail. These are primarily building structures.

[52] de Klerk, Lennard, et al. *Climate Damage Caused by Russia's War in Ukraine*. 13 June 2024, https://en.ecoaction.org.ua/wp-content/uploads/2024/06/Climate-Damage-Caused-by-War-24-months-EN.pdf

[53] Arup based on de Klerk, et al. *Climate Damage Caused by Russia's War in Ukraine*.

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- Transport & Infrastructure: This covers infrastructure, vehicles, and agricultural machinery. It consists of civil engineering works such as bridges and roads, as well as various types of transport vehicles.
- Industry & Utilities: This encompasses the energy sector, industry and business services, digital infrastructure, and utilities. These mainly involve machinery and equipment, along with factory buildings housing the machinery.

The total GHG emissions from reconstruction during the 24 months of the war are estimated at 56 $MtCO_2e$.[54]

Table 13 Overview of emissions from reconstruction of civilian infrastructure after 2 years of war[55]

Category	Emissions ($MtCO_2e$)	Percentage (%)
Buildings	23.6	42%
Transport and infrastructure	15.4	27%
Industry and utilities	17.0	30%
Total	**56**	**100%**

Recovery and reconstruction needs are projected at approximately USD 486 billion over an ambitious 10-year horizon. These estimates cover urgent short-term recovery measures and medium-term reconstruction aimed at building back better modern, low-carbon, and climate-resilient, while excluding requirements already addressed through Ukraine's state budget or international support.[56]

Table 14 Total recovery and reconstruction needs considering next 10 years, USD billion[57]

Property type	Assessment of damages, USD billion	Share of damages by property type, % of total sum
Management of Explosive Hazards	35	7.3%
Housing	80	16.%
Education	14	2.9%
Health	14	2.9%
Social Protection and Livelihoods	45	9.3%
Culture and Tourism	9	1.9%

[54] de Klerk, Lennard, et al. *Climate Damage Caused by Russia's War in Ukraine*. 13 June 2024, https://en.ecoaction.org.ua/wp-content/uploads/2024/06/Climate-Damage-Caused-by-War-24-months-EN.pdf
[55] de Klerk, et al. *Climate Damage Caused by Russia's War in Ukraine*.
[56] The World Bank, the Government of Ukraine, the European Union, the United Nations, *Ukraine Rapid Damage and Needs Assessment (RDNA3)*. February 2024, https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099021324115085807
[57] The World Bank, the Government of Ukraine, the European Union, the United Nations, *Ukraine Rapid Damage and Needs Assessment (RDNA3)*

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Property type	Assessment of damages, USD billion	Share of damages by property type, % of total sum
Energy and Extractives	47	9.8%
Transport	74	15.4%
Telecommunications and Digital	5	1.0%
Water Supply and Sanitation	11	2.3%
Municipal Services	11	2.3%
Agriculture	56	11.6%
Commerce and Industry	68	14.1%
Irrigation and Water Resource Management	11	2.3%
Finance and Banking	2	0.4%

Housing leads the list for reconstruction costs at an estimated USD 80 billion, emphasising the urgent need to restore living conditions for millions of displaced people. Transport follows closely at USD 74 billion, as rebuilding roads and rail networks is critical for reconnecting communities and enabling economic activity. Commerce and industry, at USD 68 billion, along with agriculture at USD 56 billion, represent the backbone of production and livelihoods, requiring substantial investment to revive trade and food security. Energy and extractives are equally vital, with USD 47 billion needed to restore power generation and supply chains, which are fundamental for all other sectors to function. This concentration of needs illustrates that recovery efforts must prioritise core infrastructure and economic enablers to ensure a resilient and sustainable reconstruction process.

If the planned reconstruction investment of USD 486 billion is implemented over a ten-year period, it is expected to generate 781 $MtCO_2e$ emissions, with 87% occurring within Ukraine and the remainder abroad. [58]

Table 15 Overview of emissions from reconstruction of infrastructure considering next 10 years, $MtCO_2e$[59]

Category	Emissions ($MtCO_2e$)	Percentage (%)
Construction	445.2	57%
Financial intermediation and business activities	109.3	14%
Public administration	31.2	4%

[58] The World Bank, the Government of Ukraine, the European Union, the United Nations, *Ukraine Rapid Damage and Needs Assessment (RDNA3)*. February 2024, https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099021324115085807

[59] Kobayakawa, Toru, *Estimating the Carbon Footprint of Post-War Reconstruction: Toward a "Greener" Recovery of Ukraine*. September 2024, https://www.jica.go.jp/english/jica_ri/publication/discussion/__icsFiles/afieldfile/2024/09/04/Discussion_Paper_No.24.pdf

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Category	Emissions ($MtCO_2e$)	Percentage (%)
Petroleum, chemical and non-metallic mineral products	54.7	7%
Metal products	46.9	6%
Electrical and machinery	85.9	11%
Transport equipment	7.8	1%
Total	**781**	**100%**

The construction sector accounts for the largest share of this footprint at 57%, followed by business activities (14%), electrical and machinery (11%), non-metal products (7%), metal products (6%), government activities (4%), and transport equipment (1%).

To put this into perspective, these emissions are equivalent to:

- 4.3 years of Ukraine's pre-war annual territorial CO_2 emissions (181 $MtCO_2e$ in 2021),
- 28% of the EU27's annual emissions (2,805 $MtCO_2e$ in 2022), or
- the combined annual emissions of Germany (634 $MtCO_2e$) and the Netherlands (135 $MtCO_2e$) in 2022.

The reconstruction of Ukraine presents a unique opportunity to align the recovery process with long-term climate objectives. However, the rebuilding process will inevitably involve substantial material use and energy demand, resulting in significant greenhouse gas (GHG) emissions, both operational and embodied. If these emissions are not managed, they could lock in a high-carbon trajectory for decades, thereby undermining national and global climate commitments.

Embodied carbon, which is generated during the production and transport of construction materials, accounts for a large proportion of total emissions. Operational emissions from energy systems further compound this challenge. Addressing these factors requires a strategic approach that integrates sustainability principles into every stage of reconstruction.

This transformation requires systemic measures that prioritise reducing carbon emissions throughout the entire infrastructure lifecycle. Transparent carbon accounting, climate-aligned planning and the integration of low-emission pathways are essential to minimising environmental impact while ensuring resilience and efficiency. By embedding these principles, Ukraine can transform reconstruction into a catalyst for sustainable development, generating jobs and new forms of value, creating infrastructure that supports economic recovery while staying within planetary boundaries.[60]

[60] Kobayakawa, Toru, *Estimating the Carbon Footprint of Post-War Reconstruction: Toward a "Greener" Recovery of Ukraine*. September 2024, https://www.jica.go.jp/english/jica_ri/publication/discussion/__icsFiles/afieldfile/2024/09/04/Discussion_Paper_No.24.pdf

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Conclusion

This report summarises the key evidence required to understand Ukraine's GHG emissions profile, as well as the size and nature of the 'gap to target', in a context defined by both long-term structural change and the disruption of war. It brings together historical emissions trends and the sectoral drivers behind them, in conjunction with Ukraine's nationally communicated climate commitments and forward-looking projections under alternative policy pathways. It also explicitly accounts for the additional GHG burden associated with warfare and the emissions that will be embedded in reconstruction. By doing so, it provides decision-makers and investors with an evidence base to support them in prioritising low-carbon recovery measures, strengthening energy security and steering reconstruction towards resilient, climate-aligned outcomes, rather than locking in carbon-intensive assets.

The report confirms that Ukraine's emissions trajectory since 1990 has been characterised by a significant decline. Total national GHG emissions have fallen by over 75% compared to the 1990 baseline. This reduction is primarily due to major economic restructuring, reduced industrial output compared to the early 1990s and gradual improvements in energy efficiency. The most recent inventory values included in the report indicate total emissions (excluding LULUCF) of 232.9 $MtCO_2e$ in 2023, down from 964.4 $MtCO_2e$ in 1990. Meanwhile, totals including LULUCF stand at 221.7 $MtCO_2e$ in 2023, compared to 916.5 $MtCO_2e$ in 1990.[61]

The conclusion from the sector analysis is that decarbonisation will be driven primarily by the energy system, although targeted approaches are also needed for industry, agriculture, and waste management. In 2023, energy accounted for the largest proportion of national emissions (around 74%), followed by agriculture (around 15%), industrial processes and product use (around 10%), and waste (around 7%). Meanwhile, LULUCF was reported as a net sink (negative proportion). This implies that measures such as the deployment of renewables, improving energy efficiency, introducing market reforms, and reducing methane are necessary, but not sufficient in isolation: industrial process emissions, high-GWP fluorinated gases, agricultural soil and livestock emissions, and landfill methane require dedicated policies, technologies, and monitoring approaches that go beyond general efficiency improvements.[62]

The updated Nationally Determined Contribution (NDC) commits to achieving a net domestic reduction of 65% across the entire economy by 2030 compared to 1990 levels, without relying on international credits. It also maintains a long-term vision of achieving carbon neutrality by 2060. The scope of the NDC covers all major sectors and all GHG emissions not controlled by the Montreal Protocol. It is intended to apply across Ukraine's internationally recognised borders. However, limitations in the availability of data for temporarily occupied territories are acknowledged, as is the need to adjust estimates once full access is restored. Crucially, the report presents this national commitment as a practical framework for prioritising investment, especially since reconstruction choices made in the near term will significantly impact emissions pathways over the decades that follow.[63]

The forward-looking projections presented in the report clarify the interpretation of the 'gap' by showing that policy choices determine whether emissions will rebound with economic recovery or continue to decline through structural transformation. Under the 'With Existing

[61] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf
[62] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*
[63] Diahchuk et al., *First Biennial Transparency Report under the Paris Agreement*

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Measures' (WEM) scenario, total emissions (excluding LULUCF) are projected to fall sharply to 236.3 $MtCO_2e$ in 2025 (due to the impact of war) and then rise gradually to 301.6 $MtCO_2e$ by 2050, indicating a rebound as economic and industrial activity recovers. In contrast, under the 'With Additional Measures' (WAM) scenario, emissions continue to fall, reaching 120.1 $MtCO_2e$ by 2050 (around 13% of 1990 levels), demonstrating the scale of additional reductions that can be achieved through enhanced policies, investment and technological modernisation. The contrast between these scenarios shows that 'build back better' is not just a narrative aspiration, but a quantifiable approach in which energy efficiency, renewable energy, electrification and technological shifts can prevent a post-war increase in emissions even in the event of economic growth.[64]

One of the report's key findings is that the war is not only a humanitarian and economic catastrophe, but also a material climate event resulting in additional emissions and economic damage. During the first two years of the conflict (24 February 2022 to 23 February 2024), it is estimated that war-related emissions totalled 175 $MtCO_2e$. The largest contributors to this total were active warfare and reconstruction, alongside landscape fires, aviation rerouting, damage to energy infrastructure, and population displacement. The report also shows the estimated climate damage cost to be over USD 32 billion (based on an assumed carbon price of USD 185/tCO_2), which highlights that the environmental impact of the conflict is significant and has international relevance. These findings also have strategic implications for recovery planning: reducing future emissions must be considered alongside the restoration of essential services and infrastructure because the resilience of the energy system, rebuilding standards and technology choices will influence both short-term security and long-term climate performance.[65]

The reconstruction assessment reiterates the key point that rebuilding is an inevitable driver of emissions and the most significant short-term lever for shaping the long-term trajectory. The report estimates 56 $MtCO_2e$ of emissions from reconstruction activities during the first 24 months of the conflict, distributed across the following sectors: buildings (23.6 $MtCO_2e$); transport and infrastructure (15.4 $MtCO_2e$); and industry and utilities (17.0 $MtCO_2e$).[66] Looking ahead, the report shows recovery and reconstruction needs of approximately USD 486 billion over ten years. If implemented at this scale, these needs are expected to generate 781 $MtCO_2e$, with the majority of this footprint being accounted for by the construction sector.[67] The report presents reconstruction as a national opportunity, emphasising that aligning rebuilding with low-carbon principles can modernise infrastructure, stimulate green industrial development, create jobs, and increase resilience. This approach can transform recovery spending into a catalyst for structural decarbonisation.

Overall, the report concludes that Ukraine's pathway to climate neutrality is technically feasible, but highly dependent on the speed and extent of additional measures, the reliability of data and monitoring systems, and the extent to which reconstruction adheres to "build back better" principles rather than focusing on the short-term replacement of damaged assets. The

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[64] Diachuk, Dr Oleksander, et al. *First Biennial Transparency Report of Ukraine under the Paris Agreement*. 2025, unfccc.int/sites/default/files/resource/First%20BTR%20Ukraine.pdf
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extent to which the WEM and WAM projections diverge demonstrates that the emissions gap is not fixed; it can narrow with an unmanaged rebound or widen through deliberate policy, investment mobilisation and technology deployment across the energy, industrial, building, transport, agricultural and waste sectors. Finally, by quantifying the climate costs of the war and the implications for emissions of reconstruction, the report emphasises the importance of incorporating emissions management into recovery planning. This will ensure that rebuilding efforts support progress towards climate neutrality.

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