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Environmental and socio-economic consequences of the war and the green industrial recovery programme in Ukraine

Evidence from NICE

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Introduction

Measuring the socio-economic and environmental impacts of armed conflicts in the short term is a challenging task that requires considering factors like casualties, displacement of people, economic disruptions, infrastructure damage, and social instability. Even more challenging is evaluating the consequences of the recovery program of ongoing wars. This work aims to fill this gap by analyzing the environmental and socio-economic impacts of the war and the green recovery program in the context of the full-scale invasion of Ukraine in 2022.

In this document we discuss the methodology and results of an analysis of the environmental and socio-economic implications of the war and the planned Recovery Programme in Ukraine. Our contribution relies on the UNIDO National Impacts of Circular Economy (NICE) tool. The origin of the tool is to assess the net socio-economic impact of circular projects in terms of results, prominent drivers, the relevance of direct vs indirect effect, etc., within a simple, tractable and transparent simulation framework. In this context, the scope of the NICE tool utilization is broadened to investigate the impact of the war on economic, social and environmental indicators and perspectives for Ukraine green recovery. The analysis includes the study of variables relevant for circular economy such as materials consumption and other relevant indicators for inclusive and sustainable industrial development. Scenarios are based on an updated version of the NICE tool developed by Albaladejo et al. (2023) and provide sensitivity tests.

This work is structured as follows. Section 2 describes the methodology behind the NICE tool. Section 3 assesses the war's impact on the environmental performance of the Ukrainian economy, while Section 4 analyses the environmental and socio-economic consequences of the Ukrainian Green Recovery Programme, together with the effects of closing the gap concerning the EU in terms of productivity and efficiency. In Section 5, a summary of the program's contributions will be provided, along with a discussion of the environmental and socio-economic implications of both the war and the planned Green Recovery Programme in Ukraine.

The NICE tool

The basis for the analysis is the NICE tool developed within a former UNIDO project (Albaladejo et al., 2023). It is a static modeling tool based on an input-output model and data from the EORA26 world input-output table for 2016 (Lenzen et al., 2012; 2013).[1] The tool was initially developed to evaluate the socio-economic and environmental consequences of projects supported by UNIDO in the field of circular economy. The tool allows us to assess and decompose (direct, indirect, induced effects) the impact of demand and supply shifts on several socio-economic and environmental variables accounting for inter-sectoral relationships. Despite the tool being explicitly developed for considering shifts related to circularity, it allows us to view a wide array of possible scenarios.

The tool considers the country a small economy (compared to the global economy). This assumption allows us to ignore potential feedback loops (i.e., domestic shocks affecting foreign economies, which, in turn, have consequences for the focal country). The economy is described by its national input-output table (with a 26-sector disaggregation) and the input-output table of imported intermediates (aggregated across all partner countries). The technical coefficient matrix A (i.e., direct requirement) and the Leontief matrix L (i.e., total requirements) are calculated and used to evaluate how shifts in demand influence sector-level output. Changes in the sector-level production are then associated with changes in environmental (CO2 emissions and material use) and socio-economic (labor and value added) variables utilizing fixed output coefficients.

The NICE tool is based on the Leontief model and shares its main assumptions. The first assumption is that a corresponding change in supply meets any shift in the demand for intermediate inputs. Also, no adjustment in prices is allowed within the model. Implicitly, the model also needs to assume a slack capacity for primary inputs (labor and capital), whose supply accommodates shifts in demand. A second assumption relates to the stability of the technology, defined as the Leontief total requirement matrix, which does not change over time. Finally, no substitution is allowed (in principle) between domestically produced and imported intermediates. While all these assumptions apply to the basic version of NICE, a few are removed with ad hoc modifications in the present modeling exercise. For example, in one scenario, we consider constraints in the supply of male and female labor.

Data about the structure of the Ukrainian economy (and the corresponding input-output table) were adapted to account for the absence of economic relationships between those areas of Ukraine under the direct control of the Ukrainian government and occupied territories during the war. The access to domestic intermediate inputs (i.e., the input-output matrix) is rescaled accordingly.[2]

Key points:

- Input-output modeling based on the NICE tool (details of the base model in Albaladejo et al., 2023).
- Demand-driven model, but also valuable for evaluating supply-side shocks.
- Base year: 2016 (latest available from EORA), adapted to replicate 2021 macro-economic figures.
- Most up-to-date information from various sources to build the different scenarios.
- Significant uncertainty about the actual 'magnitude' of the different figures: results should be interpreted in the other channels' direction and relative (rather than absolute) magnitude.

[1] For the purpose of the current report, the tool was updated to 2021 to accommodate changes in macro-economic aggregates (GDP, employment and CO2 emissions), while information about the input-output structure has been considered at its 2016 values.

[2] Sector-specific output of occupied regions has been estimated by combining aggregate (i.e., all manufacturing together) gross output statistics by region and further decomposing macro sectors (especially manufacturing) into sub-sector using data on export by detailed product and by region.

Assessment of the consequences of the war on the environmental performance of the Ukrainian economy

The war-induced substantial changes in the structure of the Ukrainian economy. Some sectors collapsed as companies were located in occupied areas (e.g., steel production in Mariupol). Some other sectors experienced labor shortages due to refugees leaving the country and men involved in war operations. The need for military equipment and weapons induced a reconversion of the economy. The power sector was an explicit military target, leading to shortages in electricity supply and radical changes in the energy mix. All these changes led to a radical change in the economy's structure and, consequently, in its economic and environmental performance. The analysis provides evidence about different CO2 emissions and material use scenarios.

The war's impact is analyzed using three components, as summarized in Table 1. Furthermore, a comprehensive assessment of the overall impact is carried out.

Table 1 | The summary of the components, their impact on the structure and model assumptions

Components	What?	How?	Assumptions made
1. Occupied regions: Interruption of production in areas that are or have been under the temporary military control of the Russian Federation	Reduction in the demand for intermediates in other regions (demand shock); import-substitution (supply shock)	Demand shock is proportional to the share of production by sector in occupied regions; supply shock is modeled as a switch from domestic to imported intermediates. See section 3.1	It is assumed that occupied regions did not purchase any intermediate inputs from regions under the control of the Ukrainian government during the conflict. The corresponding reduction in the demand for intermediate inputs is simulated, assuming that this was not compensated by increased demand for intermediates from domestic or foreign companies.
2. Reconversion of the economy: Reconversion of production for military uses	Structural change to machinery & equipment, transport, construction	Sensitivity analysis of various values of structural change See section 3.2	Positive demand shocks those sectors that most likely provide military equipment and services. The three main sectors were: 1. electrical and machinery (which includes weapons and ammunition); 2. transport equipment (including transport equipment for military purposes); 3. construction (construction, maintenance and repairing of infrastructure used for military purposes). The magnitude of the shock (+30% in the first two sectors, +20% for construction) is just indicative.
3. Labour shortages: Displacement of workers to support the military effort and to escape the conflict	- Labor shortages due to conscription of males: Constraint to production in male-dominated sectors - Labor shortages due to refugees (primarily female): Constraint to production in female-dominated sectors (but partly compensated by internal displacements)	With a constant employment coefficient of output, production (and demand for intermediates) is reduced proportionally to employment decline. See section 3.3	To calculate sector-specific potential shortages, we consider: 1. For males, full mobilization of about one million males; sector-specific shortages are computed by considering the share of male employees over total employees of each sector (source: ILOStat); 2. For females, we consider about 1.5 million female refugees abroad (six million female refugees in the first weeks of the conflict, 4.5 of whom returned to Ukraine). This component just considers shortages once the first two components are accounted for. For example, it could be that output reduction due to 'occupied regions' for a particular sector already predicts a decreased output that the reduced labor force can fully absorb. Output reduction to labor shortages is assumed to be proportional to the relative magnitude of the shortage (i.e., fixed coefficient of labor-per-output).

Data source: UNIDO elaboration.

Business interruption and disruption of productive sectors in Russian-occupied areas

As for the first component, "Occupied regions," consideration is given to the interruption of production in regions that are or have been under the military control of the Russian Federation. Occupied regions exerted a relevant demand for intermediate input in regions that remain under the

control of the Ukrainian government. This component simulates a full collapse of this demand, which is not compensated by other sources of demand. For this component, it is assumed that these regions do not purchase any intermediate inputs from regions under the control of the Ukrainian government during the conflict. The corresponding reduction in intermediate inputs is simulated, assuming that this was not compensated by the increased use of intermediates produced by other domestic or foreign companies.

The required information is an estimate of how much output of each sector is located in the occupied regions and the coefficient of disruption (for simplicity, we start with 100%). The available data is aggregated at the sector level. Hence, we use pre-war regional (Oblast) exports (and/or GDP) as a proxy for production (and we have 2-digit and by region) and to identify specialization. Results are shown in Table 2.

Component 1: % of reduction at the sectoral level is obtained by assuming a 100% reduction from occupied regions.

Table 2 | Share of Ukrainian output in the occupied region over total Ukrainian pre-war (2021) output

	Sector	Share of Ukrainian output in the occupied region over total Ukrainian pre-war (2021) output
1	Agriculture	13.10%
2	Fishing	13.10%
3	Mining and Quarrying	17.10%
4	Food & Beverages	5.40%
5	Textiles and Wearing Apparel	1.80%
6	Wood and Paper	5.30%
7	Petroleum, Chemical and Non-Metallic Mineral Products	7.90%
8	Metal Products	53.00%
9	Electrical and Machinery	15.80%
10	Transport Equipment	8.00%
11	Other Manufacturing	0.90%
12	Recycling	21.10%
13	Electricity, Gas and Water	18.70%
14	Construction	5.40%
15	Maintenance and Repair	6.60%
16	Wholesale Trade	6.60%
17	Retail Trade	6.60%
18	Hotels and Restaurants	7.50%
19	Transport	5.90%
20	Post and Telecommunications	4.30%
21	Financial Intermediation and Business Activities	8.40%
22	Public Administration	13.30%
23	Education, Health and Other Services	10.30%
24	Private Households	11.40%
	Total	14.30%

Notes: gross output by sector (1 letter, NACE rev. 2) and region from the State Statistics Service of Ukraine. The composition of gross output by region and 2-digit sector for manufacturing was inferred from data on the export of manufacturing products by 2-digit product and region (source: State Statistics Service of Ukraine). Occupied regions: Donetska, Zaporizhska, Luhanska, and Khresonska.

Data source: UNIDO elaboration on data from State Statistics Service of Ukraine.

Reconversion of production for military purposes

The second component involves the reconfiguration of production for military purposes. The need to sustain the war effort required a reconversion of the Ukrainian economy. This component evaluates the likely impact of such reconversion. As no data is available, some arbitrary value is assessed to hint at the potential effects.

For this component, positive demand shocks are introduced in those sectors that most likely provide military equipment and services. The war's needs call for an increased production of weapons, military equipment and transportation means and an increased demand for construction (and reconstruction). This component evaluates the likely impact of such reconversion. As no data is available, some arbitrary value is assessed to hint at the potential effects. The three main sectors are 1. electrical and machinery (which includes weapons and ammunition); 2. transport equipment (including transport equipment for military purposes); 3. construction (construction, maintenance and repairing of infrastructure used for military purposes). The magnitude of the shock (+30% in the first two sectors, +20% for construction) is just indicative. Table 3 reports a summary of the component.

Component 2: Increase in gross output of selected industries: machinery & equipment, transport, construction.

Table 3 | Reconversion of the Ukrainian economy

	Sector	% increase in gross output		Sector	% increase in gross output
1	Agriculture	-	13	Electricity, Gas and Water	-
2	Fishing	-	14	Construction	20%
3	Mining and Quarrying	-	15	Maintenance and Repair	-
4	Food & Beverages	-	16	Wholesale Trade	-
5	Textiles and Wearing Apparel	-	17	Retail Trade	-
6	Wood and Paper	-	18	Hotels and Restaurants	-
7	Petroleum, Chemical and Non-Metallic Mineral Products	-	19	Transport	-
8	Metal Products	-	20	Post and Telecommunications	-
9	Electrical and Machinery	30%	21	Financial Intermediation and Business Activities	-
10	Transport Equipment	30%	22	Public Administration	-
11	Other Manufacturing	-	23	Education, Health and Other Services	-
12	Recycling	-	24	Private Households	-
				Total	2.70%

Notes: figures about the extent of the reconversion of the Ukrainian economy to sustain the war effort cannot be found in either official or unofficial sources. The presented numbers are just indicative and serve the purpose of evaluating the orders of magnitude of the effects.

Data source: UNIDO elaboration.

Labor shortages and employment gaps

The war implied the shift of many male workers to military operations and the move of refugees (mostly female) to other countries. We consider one million male workers involved in any way (directly or indirectly) in military operations and about 1.5 female workers leaving the country as refugees (some data point to six million, 4.5 of which returned). In the short term, labor shortages imply a reduction in production. The simulation considers the gender composition of workers

in each sector in 2020 (ILOStat data) and assumes no substitutability (male for female and across sectors).

In accounting for labor shortages, the simulation already incorporates Component 1 ('Occupied regions') and Component 2 ('Reconversion of the economy'). Thus, it identifies and isolates the additional reductions in production. Constraints to production in male-dominated (resp. female-dominated) sectors will be simulated by assuming that sectoral production (and demand for intermediates) is reduced proportionally to employment decline (with constant gender-specific employment coefficient of output). Results are reported in Table 4.

Table 4 | Output gap driven by shortage of male and female employment

	Sector	Total reduction of output due to the gap of employees	Reduction of output net of Component 1 (section 3.1) and Components 2 (section 3.2)
1	Agriculture	-17.50%	-7.70%
2	Fishing	-15.40%	-
3	Mining and Quarrying	-15.90%	-3.70%
4	Food & Beverages	-17.80%	-11.00%
5	Textiles and Wearing Apparel	-21.40%	-14.00%
6	Wood and Paper	-15.70%	-
7	Petroleum, Chemical and Non-Metallic Mineral Products	-16.90%	-9.50%
8	Metal Products	-16.30%	-1.10%
9	Electrical and Machinery	-16.30%	-39.10%
10	Transport Equipment	-17.00%	-
11	Other Manufacturing	-16.10%	-4.70%
12	Recycling	-16.00%	-
13	Electricity, Gas and Water	-16.50%	-3.20%
14	Construction	-14.40%	-2.70%
15	Maintenance and Repair	-15.40%	-
16	Wholesale Trade	-16.00%	-
17	Retail Trade	-19.60%	-8.00%
18	Hotels and Restaurants	-20.10%	-
19	Transport	-15.50%	-6.30%
20	Post and Telecommunications	-18.40%	-
21	Financial Intermediation and Business Activities	-18.00%	-10.40%
22	Public Administration	-19.70%	-
23	Education, Health and Other Services	-21.00%	-4.10%
24	Private Households	0.00%	-
	Total	-17.10%	-9.00%

Notes: We assume fixed output coefficients of male and female output to estimate the output reduction due to employment gaps (first column). This means that output is reduced by a relative amount, equal to the largest relative decrease of male or female employment. However, the output reduction might not be binding as output could have been reduced due to components 1 and 2. In the second column, we compute the additional output reduction due to employment gaps (if binding). For example, the output reduction in the Wood and Paper sector due to components 1 and 2 was larger than 15.7%, which is the one predicted by the employment gap.

Data source: UNIDO elaboration on data from State Statistics Service of Ukraine and ILOStat.

Damages to energy sectors

The ongoing conflict and targeted attacks on energy infrastructure have caused extensive damage across the country, leading to disruptions in gas and district heating networks and electricity supplies. As reported by UNDP[3] in June 2023 and summarized in Table 5, the amount of electricity generated in Ukraine decreased from 15 TWh in January 2022 to 8.9 TWh in April 2023. Although a 9.7% increase in the first quarter of 2023 compared to the fourth quarter of 2022, a reduction of 32.5% has been registered concerning the same period in 2021. Overall damages are due to energy infrastructures being physically damaged or in territories outside government control during the war. The decline in electricity consumption has been heterogeneous across regions, with the ones most affected by the conflict being the most heavily hit (Table 6). When considering damages by category of generation technology (Table 7), data suggest a substantial share of the capacity of nuclear and thermal power plants (TPP) fell into occupied territories. Overall, this led to a significant change in the energy mix (Table 8) of the power sector, with a substantial reduction in nuclear, which was compensated by an increased importance of hydroelectric power plants (HPP).

Overall, the implication of these damages to the electricity sector led to an increased reliance on electricity imported from abroad and substantially reduced reliability of the whole electricity infrastructure. The quantification in terms of socio-economic and environmental impacts is very challenging, however. The extent to which (localized) shortages affected industrial production in different areas is unknown. Also, the change in energy mix had both 'positive' (e.g., increased hydro) and negative (e.g., use of less efficient TPP) consequences. The large degree of uncertainty led us to ignore an explicit assessment of the changes in the electricity generation sector within the NICE tool.

Table 5 | Damages to energy infrastructures

Type of energy assets	Currently available (April 2023)	Damages (%) concerning 2021
Electricity consumption	32.4 TWh	-33.5%[1]
Electricity generation	8.9 TWh ·TPP: 6,004 MW ·Nuclear: 7,680 MW ·RES: 6,225 MW ·HPP and PSPP: 4,719 MW	-29% ·TPP: -65% ·Nuclear: -44% ·RES: -24% ·HPP and PSPP: -29% ·Wind: over 90%[2] ·Solar: over 30%[2]
Power generation capacity (total and maneuverable)	18.3 (4.6) GW	-51% (-68%)

Note: Thermal power plant (TPP); Renewable energy source (RES); Hydroelectric power plant (HPP); Pumped storage power plant (PSPP). [1] See Table 6 for region-specific change and Table 7 for energy mix in electricity consumption. [2] A large number of wind and solar power plants located in southern Ukraine are currently in areas under the temporary military control of the Russian Federation, are damaged or are in the combat zone. See Table 8 for energy mix in electricity generation.

Data source: UNDP (2023).

[3] Report "TOWARDS A GREEN TRANSITION OF THE ENERGY SECTOR IN UKRAINE - Update on the Energy Damage Assessment" (June 2023).

Table 6 | Reduction in electricity consumption by region (April 2023 concerning April 2021)

Region	Reduction in electricity consumption	Region	Reduction in electricity consumption
Donetska	71%	Chernihivska	11%
Khresonska	89%	Chernivetska	2%
Luhanska	100%	City of Kyiv	15%
Zaporizhska	50%	Khmelnytska	0%
Dnipropetrovska	37%	Kyivska	14%
Ivano-Frankivska	31%	Lvivska	4%
Kharkivska	37%	Rivnenska	13%
Kirovohradska	37%	Ternopilska	3%
Mykolayivska	37%	Volynska	7%
Odeska	36%	Vinnytska	7%
Poltavska	25%	Zhytomyrska	19%
Sumska	28%	Zakarpatska	0%
Cherkaska	4%		

Data source: UNDP (2023).

Table 7 | Energy mix in electricity consumption

	MW Dec-21	Share (%) Dec-21	MW Feb-23	Share (%) Feb-23	MW Feb 2023 *Occupied or damaged*	Share (%) Feb-23 *Occupied or damaged*
Nuclear	12,620	51.00%	7,818	50.60%	6,000	39.40%
TPP	6,320	25.60%	3,201	20.70%	6,730	44.20%
CHP	1,995	8.10%	1,208	7.80%	704	4.60%
Hydro	1,894	7.70%	2,482	16.10%	559	3.70%
Pumped-storage HPP	729	2.90%	596	3.90%	324	2.10%
Solar and wind	1,163	4.70%	150	1.00%	903	5.90%
	24,721		15,455		15,220	

Note: Thermal power plant (TPP); Combined Heat and Power (CHP); Hydroelectric power plant (HPP).

Data source:UNDP (2023).

Table 8 | Energy mix in electricity generation

	Apr-21	Apr-23
RES	7.30%	7.10%
HPP and Pumped-storage HPP	8.50%	17.40%
CHP	6%	4.30%
TPP	20.50%	22%
Nuclear	57.70%	49.20%

Note: Renewable energy source (RES); Thermal power plant (TPP); Combined Heat and Power (CHP); Hydroelectric power plant (HPP).

Data source: UNDP (2023).

Results

Results from the NICE tool are summarized in Table 9 and Figures 1 and 2. Figure 1 illustrates the calculated effects of each component on employment, value added, CO2 emissions and material use, and their total impacts. In Figure 2, changes are expressed in terms of ratios.

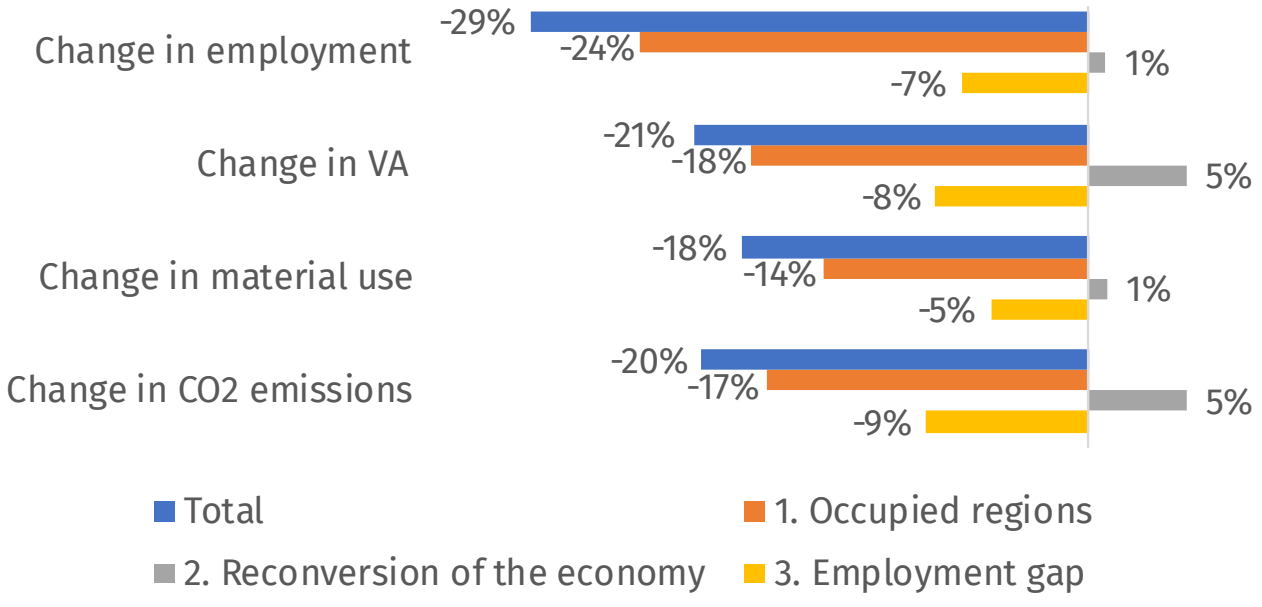
Table 9 | Simulated environmental and socio-economic consequences of the war by component

[levels]	Change in CO2 emissions	Change in VA	Change in employment	Change in material use
1 Occupied regions	-17.00%	-17.80%	-23.70%	-14%
2 Reconversion of the economy	5.20%	5.10%	0.90%	1%
3 Employment gap	-8.60%	-8.10%	-6.60%	-5%
Total	*-20.40%*	*-20.80%*	*-29.40%*	*-18%*

[ratios]	Change in VA/L	Change in MU/L	Change in MU/VA	Change in CO2/L	Change in CO2/VA
1 Occupied regions	-5.90%	9.70%	3.80%	6.70%	0.80%
2 Reconversion of the economy	-4.30%	0.10%	-4.20%	4.30%	0.00%
3 Employment gap	1.50%	1.50%	3%	-2.00%	-0.50%
Total	*-8.60%*	*11.20%*	*2.60%*	*9.00%*	*0.40%*

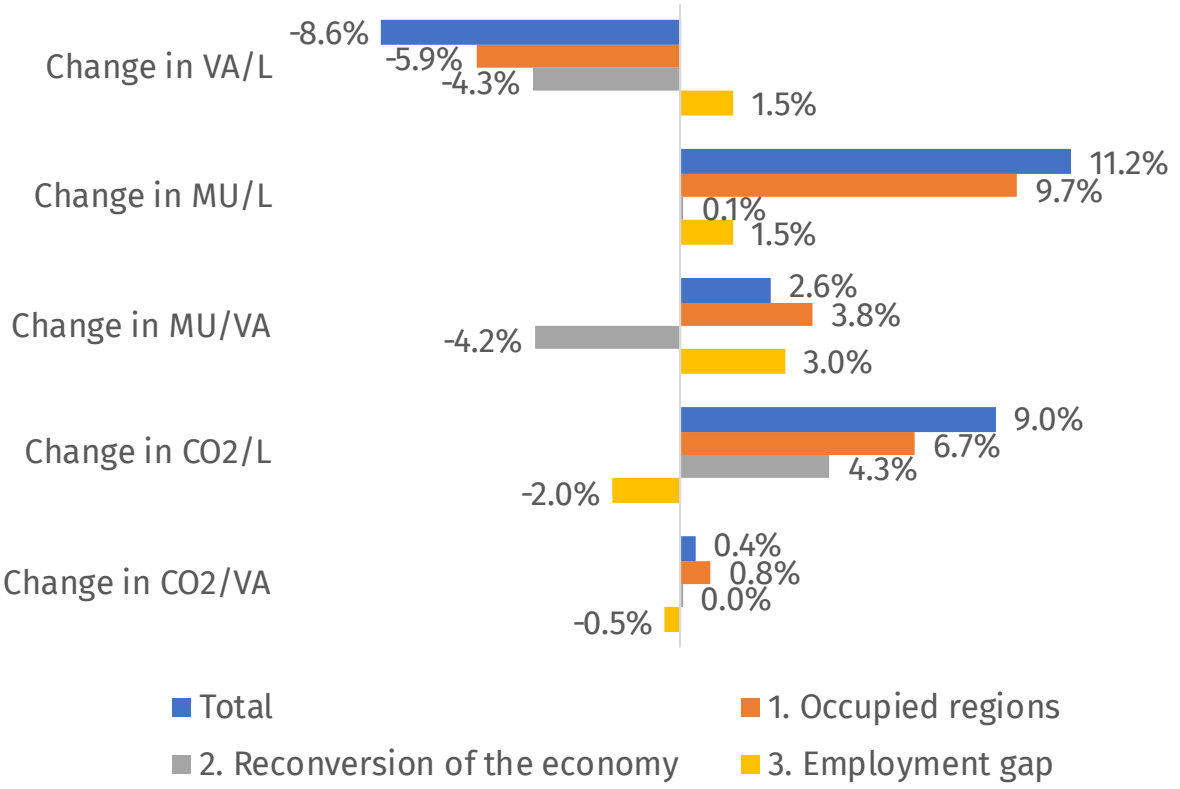
Data source: UNIDO elaboration on EORA26 data, ILOStat data and data from State Statistics Service of Ukraine.

Figure 1 | Ukraine's simulated environmental and socio-economic consequences (levels) of the war by component



Data source: UNIDO elaboration on EORA26 data, ILOStat data and data from State Statistics Service of Ukraine.

Figure 2 | Simulated environmental and socio-economic consequences (ratios) of the war by component



Data source: UNIDO elaboration on EORA26 data, ILOStat data and data from State Statistics Service of Ukraine.

As can be seen, the overall reduction of CO2 emissions due to the war has been around 20%, in line with the reduction of material use (-18%), gross value added (-21%) and smaller than employment change (-29%). Overall, the largest effects of the war are driven by the halting of production in areas that are or have been under the temporary military control of the Russian Federation, followed by the labor shortage. The reconfiguration of the industry for military and reconstruction purposes does mitigate some of the adverse consequences but falls short of fully offsetting them.

These results, combined, imply a slight increase in the CO2 emission intensity of value added and a larger increase in the CO2 emission intensity of employment (+9%). Similarly, the intensity of material use of value added reported a slight increase (+2.6%), while a larger increase was recorded in material use intensity of employment (+11%). On the contrary, the considered changes led to a reduction of labor productivity by almost 9%. CO2 emissions per worker increase due to components 1 and 2, while they decrease due to component 3. As for material use per worker, components 1 and 3 are contributing to an increase, while component 2 contributes to a decrease. This phenomenon arises from the fact that employment experiences larger changes than CO2.

On the other hand, value added per worker increases in the case of labor shortages but declines in the remaining components. This can be attributed to the fact that value added decreases proportionally more than employment in the case of labor shortages. Conversely, in the component where we consider that production is halted in areas that are or have been under the temporary military control of the Russian Federation, there is a more pronounced decrease in employment relative to value added. As for CO2 emissions per unit of value added remain largely unaffected by the various components, indicating that these two variables move proportionally. Instead, material

use per unit of value added exhibits an overall increase, driven mainly by components 1 and 3, partly compensated by a negative contribution of component 2. The decline of production predicted by the NICE is in line with the registered fall in industrial production since the beginning of the war. The fall in industrial production is reflected in employment, material use and CO2 emissions.

Key results:

- The net effect of the identified channels through which the conflict influenced the Ukrainian economy was substantially negative regarding economic variables (-21% gross value added, -29% employment) and environmental pressures (-18% material use, -20% CO2 emissions).
- The average CO2 intensity and material intensity of the Ukrainian economy increased.
- Most of the decline in economic variables and environmental pressures was driven by the disruption of the internal supply chain due to the temporary military occupation of Ukrainian regions, which was about 2-3 times as large as the negative contribution of employment gaps.
- The simulated positive impact of the reconversion of the Ukrainian economy only slightly compensated for the economic collapse.

Environmental and socio-economic consequences of the Green Recovery Programme in Ukraine

This section analyses the findings from the NICE tool concerning the environmental and socio-economic consequences of the Green Recovery Programme in Ukraine.[4] The Ukrainian government's proposal for the 2023 recovery needs implies a substantial change in the Ukrainian economy and massive infrastructural investments. The present analysis evaluates labor demand's environmental and socio-economic implications and gross value added generation by considering the 'investment push' to the economic structure.

More specifically, two dimensions have been accounted for, as summarized in Table 10. Firstly, the planned/desired investments are assessed based on the preliminary information from the Green Recovery Programme. Secondly, two additional scenarios have been considered for the post-reconstruction performance of the Ukrainian economy in terms of convergence to the EU or Eastern EU regarding labor productivity and environmental efficiency, respectively. We consider scenarios where Ukrainian sectors close their labor productivity and environmental efficiency concerning gaps in the average of EU27 or Eastern EU countries, respectively.

We first consider labor productivity improvements, leading to more output for each labor unit. Then, we consider the extent to which improved productivity is compensated by improved environmental efficiency.

Key points:

- Scenarios about post-war reconstruction and recovery
- Analysis based on the Ukraine Green Recovery Programme
- Analysis based on closing the gap concerning average labor productivity and environmental efficiency in EU27 and East EU.
- Consideration of the impact of the investments (direct and indirect) as well as their consequences (structural change, productivity, environmental efficiency)

Table 10 | The summary of the components, their impact on the structure and model assumptions

	Components	What?	How?	Assumptions
1	Environmental and socio-economic consequences of the Green Recovery Programme in Ukraine	Increased demand for selected sectors	Attribution of planned intervention to sectors and evaluation of total effects	It is assumed that all investments use products and services made in Ukraine.
2	Convergence to EU	Closing the gap concerning the EU in terms of productivity and efficiency	Improvement in labor productivity and environmental efficiency	The distance between labor productivity (output per employment) and CO2 emissions intensity (CO2 per unit of output) is reduced by half concerning, respectively: 1.EU27 average 2.Eastern EU average

Data source: UNIDO elaboration.

[4] https://www.unido.org/green-recovery-vision-ukraine

Socio-economic and environmental consequences of reconstruction

The Ukrainian government's 2023 recovery needs (Green Recovery Programme) proposal implies a substantial change in the Ukrainian economy and massive infrastructural investments. The analysis here evaluates the environmental and socio-economic (labor demand and gross value added generation) implications by considering the 'investment push' to the economic structure.

We assume that the financing is implemented for each item of the recovery need. We allocate the expenditure/investment for each item to specific sectors in the EORA classification. The allocation of expenditures by item and sector is reported in the Appendix. As the NICE tool is static, the evaluation considers the cumulated effects, rescaled by total figures corresponding to one year. These numbers should thus be interpreted with caution, as many of the plans will span over multiple years. It should also be noted that we consider the impact of the amount of money used for the investment, not its consequence in terms of economic recovery, structural change, improved productivity, etc. Finally, the basic assumption is that investments are used to purchase Ukrainian goods and services. The planned and desired investments for reconstruction are allocated to different sectors, as reported in the Annex. The baseline assumption is that all investments use local production. This means that baseline results represent an upper bound. In a sensitivity analysis, a more realistic assumption is made about the share of sector-specific output needed for the investment sourced abroad.

Results are summarized in Table 11 and Figures 3 and 4. Figure 3 illustrates the alterations in individual variables, while Figure 4 demonstrates the impact on the ratios. The plan would significantly influence employment, with effects nearly twice as pronounced as those on Value Added (VA), material use and CO2 emissions. This is particularly noteworthy given the strong correlation between development and quality of employment.

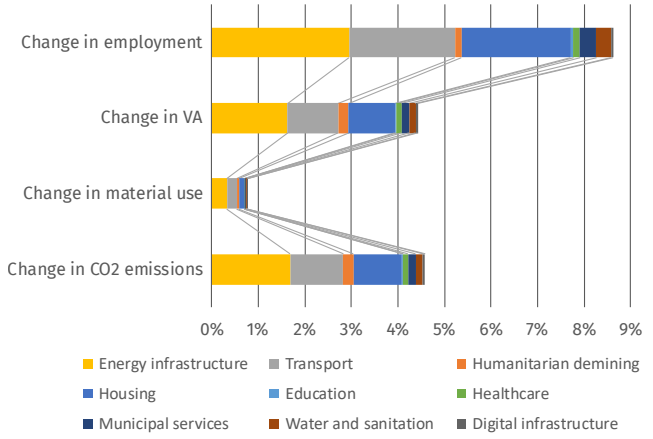
Table 11 | Simulated environmental and socio-economic consequences of reconstruction investments

	Change in CO2 emissions	Change in VA	Change in employment	Change in CO2/VA	Change in VA/L	Change in CO2/L
Energy infrastructure	1.70%	1.70%	3.00%	0.10%	-1.40%	-1.30%
Transport	1.20%	1.10%	2.30%	0.10%	-1.20%	-1.10%
Humanitarian demining	0.20%	0.20%	0.10%	0.00%	0.10%	0.10%
Housing	1.10%	1.00%	2.40%	0.00%	-1.40%	-1.30%
Education	0.00%	0.00%	0.10%	0.00%	0.00%	0.00%
Healthcare	0.10%	0.10%	0.10%	0.00%	0.00%	0.00%
Municipal services and cross-sectoral infrastructure	0.20%	0.20%	0.40%	0.00%	-0.20%	-0.20%
Water and sanitation	0.20%	0.10%	0.30%	0.00%	-0.20%	-0.20%
Digital infrastructure	0.10%	0.00%	0.10%	0.00%	0.00%	0.00%
Total	4.70%	4.50%	8.80%	0.20%	-4.30%	-4.10%

Notes: Results are based on simulation on the NICE tool. The total effects of investments are rescaled by one-year figures even if many plans span multiple years.

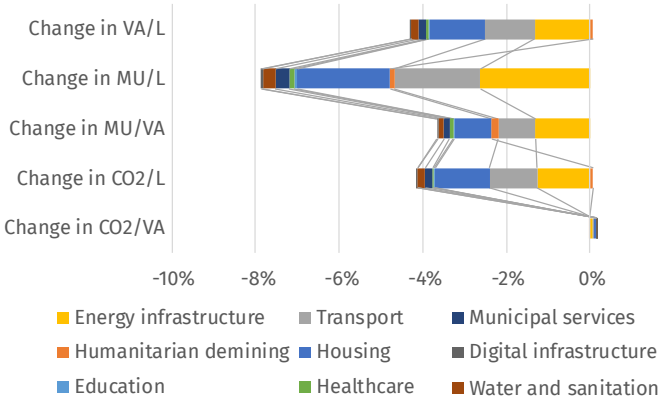
Data source: UNIDO elaboration on EORA26 data, ILOStat data, data from State Statistics Service of Ukraine and Ukraine Priority Recovery Needs for 2023, Ukrainian Ministry for Restoration.

Figure 3 | Ukraine's simulated environmental and socio-economic consequences (levels) of reconstruction investments



Data source: UNIDO elaboration on EORA26 data, ILOStat data, data from State Statistics Service of Ukraine and Ukraine Priority Recovery Needs for 2023, Ukrainian Ministry for Restoration.

Figure 4 | Ukraine's simulated environmental and socio-economic consequences (ratios) of reconstruction investments



Data source: UNIDO elaboration on EORA26 data, ILOStat data, data from State Statistics Service of Ukraine and Ukraine Priority Recovery Needs for 2023, Ukrainian Ministry for Restoration.

Indeed, the recovery plan is expected to substantially boost the Ukrainian economy, leading to a 4.5% increase in value added, a 4.7% increase in CO2 emissions and as much as an 8.8% increase in employment. This will result in a stable carbon intensity of value added, while labor productivity and carbon intensity of employment is expected to decrease.[5] More than half of the boost in all variables arises from investments in the reconstruction of the energy infrastructure and transport, followed by housing.

The program's potential to create jobs would lead to a substantial decrease in the ratios of CO2 per worker and value added per worker. However, there would be a slight increase in the ratio of CO2 per value added.

Key results

- The investments foreseen within the Green Recovery Programme for Ukraine are expected to stimulate the economy substantially.
- Most of the impacts will arise for projects related to the reconstruction, repair and renewal of the energy and transport infrastructures and for projects related to housing.
- The program will, ceteris paribus, worsen labor productivity but improve environmental efficiency, as it will favor labor-intensive and environmentally efficient sectors.
- As investments are meant to improve the economic situation of the various sectors, the negative impact on aggregate labor productivity due to compositional change is expected to be partly or fully counterbalanced by increases in sector-level productivity.
- For the same reason, improvements in environmental efficiency are likely to be larger than the ones simulated in this section, as investments within the Green Recovery Programme are meant to improve sector-specific environmental performance.

[5] It should be noted that the predicted change in relative measures (CO2/VA, VA/L, CO2/L) is just due to changes in the composition of the Ukrainian economy because of the reconstruction.

Closing the gap concerning the EU in terms of productivity and efficiency

The upgrade and renovation of Ukraine's economic system are expected to improve the economy's economic productivity (i.e., labor productivity) and environmental efficiency (i.e., CO2 intensity of value added). Improved productivity increases the output that can be produced with a certain number of inputs (labor). Ceteris paribus, this leads to a proportional increase in the level of sectoral emissions if there is no improvement in environmental efficiency. Environmental efficiency improvements are added to productivity improvements to consider their overall impact on aggregate environmental performance.

Two scenarios are considered. First, we consider halving the sector-specific productivity and environmental efficiency gap concerning the EU27 average. Second, we consider a halving of the sector-specific gap in productivity and environmental efficiency with respect to the average of Eastern EU countries (Estonia, Latvia, Lithuania, Poland, Hungary, Slovakia, Czechia, Slovenia, Bulgaria, Romania). Whenever the Ukrainian economy's pre-war productivity and environmental efficiency were better than the benchmark, we consider no further improvement.

Results are summarized in Table 12. Firstly, we evaluate output growth (and, consequently, VA and CO2 emissions) driven by improved productivity for unchanged environmental efficiency. Secondly, we also account for likely improvements in environmental efficiency by assuming partial convergence to EU or Eastern EU levels.

Table 12 | Simulating improvements in labor productivity and environmental efficiency

	Output	VA	CO2 (same env eff)	CO2 (also closing half the gap in terms of env eff)	CO2/VA (same env eff)	CO2/VA (also closing half the gap in terms of env eff)
1/2 gap w.r.t. EU27	171.30%	185.30%	184.40%	59.90%	-0.30%	-43.90%
1/2 gap w.r.t. Eastern EU countries	66.50%	74.00%	74.30%	50.80%	0.20%	-13.30%

Data source: UNIDO elaboration on EORA26 data, ILOStat data and data from State Statistics Service of Ukraine.

Partial convergence to EU or Eastern EU productivity can contribute to a substantial growth in Ukrainian gross value added: +185% for partial convergence to EU and +74% for partial convergence to Eastern EU. However, if the emission intensity of the Ukrainian economy remained unchanged, emissions would increase by almost the same proportion.

However, assuming partial convergence also in terms of environmental efficiency would only partly compensate for the increase in the absolute level of emissions despite the substantial improvement in environmental efficiency. In terms of ratio, these figures imply about 44% and 13% reductions in the CO2 emissions intensity of VA in case of closing half the gap in environmental efficiency with respect to, respectively, EU27 and Eastern EU countries.

Key results

- Even a limited convergence to EU or Eastern EU productivity levels can significantly increase value added.
- The same degree of convergence to EU or Eastern EU standards is not enough to compensate for increased emissions, and further efforts are needed.
- Assuming partial convergence in improved productivity and environmental efficiency, results suggest a non-negligible reduction in CO2 emissions intensity of VA (-44% and -13% in case, respectively, of halving the gap with respect to EU27 and Eastern European countries).

Conclusions and policy implications

The study has examined the environmental and socio-economic consequences of the war on Ukraine's economy and the potential outcome derived from the Green Recovery Program. The empirical results are based on the NICE tool, a static modeling tool based on an input-output model.

The impact of the war has been simulated, accounting for three components: 1) the interruption of production in areas that are or have been under the temporary military control of the Russian Federation; 2) the reconversion of the economy for military uses; 3) labor shortages due to conscription of male and outgoing refugees.

With respect to pre-war figures, the NICE tool suggests that the conflict led to a decline in both economic and environmental indicators: the net effect of the identified channels through which the conflict influenced the Ukrainian economy was substantially negative both in terms of economic variables (-21% gross value added, -29% employment) and environmental pressures (-18% material use, -20% CO2 emissions). At the same time, the average CO2 intensity and material intensity of the Ukrainian economy increased.

Most of the decline in economic variables and environmental pressures was driven by the declining demand for intermediates from economic activities located in Ukrainian regions occupied by the Russian army and the consequent disruption of the internal supply chain due to the temporary military occupation of Ukrainian regions, which was about 2-3 times as large as the negative contribution of employment gaps. The simulated positive impact of the reconversion of the Ukrainian economy only slightly compensated for the economic collapse.

The investments foreseen within the Green Recovery Programme for Ukraine are expected to stimulate the economy substantially. The effect of the increased demand coming from the Ukraine Green Recovery Programme would only partially compensate for the collapse, as it is estimated to contribute to just a 4.5% increase in value added and an 8.8% increase in employment. Most of the impacts will arise for projects related to the reconstruction, repair and renewal of the energy and transport infrastructures and for projects related to housing. At the same time, these relatively small impacts rely on the local availability of inputs, labor, capital, entrepreneurs, materials, energy, etc.). Bottlenecks and shortages would lead to even smaller positive impacts. The program will, ceteris paribus, worsen labor productivity but improve environmental efficiency, as it will favor labor-intensive and environmentally efficient sectors.

As investments are meant to improve the economic situation of the various sectors, the negative impact on aggregate labor productivity due to compositional change is expected to be partly or fully counterbalanced by increases in sector-level productivity. For the same reason, improvements in environmental efficiency are likely to be larger than the ones simulated in this section, as investments within the Green Recovery Programme are meant to improve sector-specific environmental performance.

However, if the plan will also contribute to improved productivity and environmental efficiency of the Ukrainian economy with respect to pre-war levels, this could reverse the picture. Indeed, even a limited convergence to EU (or Eastern EU) productivity levels can significantly increase value added. For example, if the plan would contribute to halving the gap in productivity and emission intensity with respect to the average EU27, this would result in a more than doubling of GDP. However, this increase in economic outcome is likely associated with increased environmental pressure. The same degree of convergence to EU or Eastern EU standards is not enough to compensate for increased emissions, and further efforts are needed. Thus, it is critical to reconstruct back 'better' using state-of-the-art technologies. Assuming partial convergence in terms of improved productivity and environmental efficiency, results suggest a non-negligible reduction in the intensity of CO2 emissions of VA.

Considering the ongoing conflict, it is projected that the recovery package, even with substantial

efforts in selected sectors such as energy, construction, and machinery (+30% growth), will only partially alleviate Ukraine's economic losses. A full recovery to pre-war levels is expected to be achievable only in the medium to long term. These recovery efforts are anticipated to have the most significant impact in sectors where resources are concentrated. Therefore, the strategic prioritization of sectors is of paramount importance.

As the recovery progresses, there is likely to be a resurgence in emissions. Thus, the reconstruction phase provides a valuable opportunity to steer production towards a more environmentally friendly path through investments in green infrastructure. It is worth noting that labor gains may surpass gains in value added, mainly when the recovery package targets labor-intensive sectors. Consequently, a dual approach is required to focus on enhancing productivity, aligning with the overarching goal of EU policy, which centers on achieving convergence with EU standards.

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Image: Tom Fisk on Canva

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Appendix

Table A1 | Allocation of investments to sectors of the Ukraine Priority Recovery Needs for 2023, presented in August 2023 by the Ministry for Restoration

Investment	Value (USD)	Sector(s)	% allocated to sector(s)
Energy infrastructure	**4,200,000,000**		
- reconstruction of substations and other high-voltage equipment	593,500,000	9, 15, 14, 21	40, 20, 20, 20
- construction of interconnectors jointly with Slovakia and Romania	90,000,000	9, 14, 21	40, 30, 30
- installation of static synchronous compensators	40,000,000	9, 15, 14, 21	40, 20, 20, 20
- restoration/repair of thermal generation	177,000,000	15, 9, 14, 21	40, 20, 20, 20
- restoration/repair of distribution systems	210,000,000	15, 9, 14, 21	40, 20, 20, 20
- installation of gas turbines	275,000,000	9, 14, 21	40, 30, 30
- regional heating projects	9,500,000	9, 14, 21	40, 30, 30
- restoration of boiler houses, networks, ...	6,000,000	15, 9	60, 40
- protection and reconstruction of 22 energy infrastructure facilities and protection of 150 energy infrastructure facilities	1,062,000,000	14, 9, 15, 21	40, 20, 20, 20
- purchase of 2 billion cubic meters of gas and import of up to 1GW of electricity from the EU	1,200,000,000	-	-
Transport	4,300,000,000		
- Restoration of destroyed and emergency road bridges	425,000,000	15, 21	80, 20
- Reconstruction of 14 railway traction substations	31,300,000	15, 21, 8	70, 15, 15
- 330 railway bridges	81,700,000	15, 21	80, 20
- Development and maintenance of roads and railway transport	651,000,000	15, 21	80, 20
- Procurement of modular bridges, equipment and materials for emergency repair	50,000,000	8, 15, 21	70, 15, 15
- Procurement of rails, fasteners, fuel, electricity...	220,000,000	-	-
Humanitarian demining	**500,000,000**		
- Provision of equipment for demining	350,800,000	9	100
- Funding of NGO and mine action operators	54,500,000	23	100
- Education and capacity development	50,000,000	23	100
Housing	**1,900,000,000**		
- Restoration of multiapartment buildings	106,500,000	14, 15, 21	70, 15, 15
- Humanitarian response to housing	165,300,000	14, 15, 21	70, 15, 15
- Restoration and modernization of damaged buildings	26,400,000	14, 9, 15, 21	40, 20, 20, 20
- Restoration of housing destroyed by the Kakhovka dam	36,200,000	14, 15, 21	70, 15, 15
- Capital repairs of apartments in Kyiv	17,500,000	14, 15, 21	70, 15, 15
- Purchase of special equipment for dismantling in Kyiv	8,000,000	10	100
- Pilot for processing construction waste	42,300,000	14, 9, 12	60, 30, 10
- Arrangement of housing for IDPs by repairing residential facilities	88,700,000	14, 15, 21	70, 15, 15
- Reimbursement of costs for homeowners for temporary accommodation if 500k IDPs	112,000,000	-	-
- Acquisition of housing for IDPs	46,750,000	-	-
- Acquisition of accommodation for IDPs ...	900,000	-	-
- Subsidy to local budgets for housing purchase for IDPs (military)	89,300,000	-	-
- Provision of temporary housing (modular buildings)	6,800,000	14	100
- Housing emergency recovery support	800,000,000	14, 15, 21	70, 15, 15
- Capital repair of 330 multi-apartment buildings	396,000,000	14, 15, 21	70, 15, 15
- Providing 9,200 certificates to citizens whose homes were destroyed	480,200,000	-	-

- Purchase of special equipment for dismantling, removal and processing of construction waste	149,700,000	10	100
Education	**121,000,000**		
- Bomb shelters in schools and school bus acquisition	68,000,000	10, 14	50, 50
- Renewal of the provision of educational services in the affected communities	39,000,000	23	100
- Establishment of safe digital learning centers and teacher training and education materials	14,000,000	23	100
Healthcare	**216,000,000**		
- Advanced medical equipment and recovery/modernization of other healthcare facilities	100,000,000	9, 14	70, 30
- Creation of mobile brigades and equipping and reconstruction of primary care centers	14,000,000	14, 15, 21	70, 15, 15
- Procurement and installation of advanced medical equipment in hospitals	32,000,000	9	100
- Restoration of 27 hospital facilities	38,000,000	14, 15, 21	70, 15, 15
- Medical equipment, specialized sanitary transport, generators and recovery and modernization of ...		9, 10, 14, 15, 21	30, 20, 20, 20, 10
- KNP of the Izyum City Council Central City Hospital of ...	32,000,000	-	-
Municipal services and cross-sectoral infrastructure	290,000,000		
- Restoration of schools, kindergartens, hospitals, administrative buildings	178,000,000	14, 15, 21	70, 15, 15
- Ukraine public buildings energy efficiency	19,000,000	14, 15, 21	70, 15, 15
- Reconstruction/modernization of communal infrastructure facilities	9,000,000	14, 15, 21	70, 15, 15
- Procurement of equipment for the utility sector at the level of local self-government bodies	40,000,000	9	100
- Energy efficiency of public buildings and solid household waste	32,800,000	14, 15, 21	70, 15, 15
- Energy efficiency in communities	2,800,000	14, 15, 21	70, 15, 15
Water and sanitation	**420,000,000**		
- Project "Development of water supply and sanitation system in Mykolaiv"	6,600,000	14, 15, 21	70, 15, 15
- Water in Chernivtsi City	27,200,000	14, 15, 21	70, 15, 15
- Water enterprises equipment	23,000,000	9	100
- Project to improve water supply in Kyiv	31,000,000	14, 15, 21	70, 15, 15
- Construction of arterial water pipelines	41,000,000	14, 15, 21	70, 15, 15
- Urban infrastructure development project	77,000,000	14, 15, 21	70, 15, 15
- Restoration of water supply and sanitation facilities in Kyiv	19,000,000	14, 15, 21	70, 15, 15
- Mikolaiv emergency water project	27,500,000	14, 15, 21	70, 15, 15
Digital infrastructure	**70,000,000**	**9, 21, 14**	**70, 15, 15**
Private sector	2,800,000,000		
- Support for export-oriented enterprises	113,500,000	-	-
- Support the processing industry	338,500,000	-	-
- Support of micro-businesses	125,000,000	-	-
- Expanding access to financing for SMEs under the 5-7-9 program	600,000,000	-	-
- War insurance trust fund	510,000,000	-	-
- Need for additional donor financing from IFC and EBRD	904,000,000	-	-
- Grant support to small farms	120,000,000	-	-
- Energy supply	50,000,000	-	-
- Restoration of the agricultural machinery fleet	50,000,000	10	100
- Modernization, reconstruction and recovery of public irrigation systems to increase the actual irrigation area	30,000,000	14, 15, 21	70, 15, 15

Data source: UNIDO elaboration on data from Ukraine Priority Recovery Needs for 2023, Ukrainian Ministry for Restoration.

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