



REPORT ON DAMAGES TO INFRASTRUCTURE FROM THE DESTRUCTION CAUSED BY RUSSIA'S MILITARY AGGRESSION AGAINST UKRAINE AS OF NOVEMBER 2024

Authors:

Dmytro Andrienko

Dmytro Goriunov

Vladyslava Grudova

Julia Markuts

Taras Marshalok

Roman Neyter

Igor Piddubnyi

Inna Studennikova

Dmytro Topolskov

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PREFACE

This report presents the results of an assessment of the damages to Ukraine's economy caused by Russia's military aggression. The report covers the period from February 2022 to November 2024. Damages mean complete or partial destruction to the physical infrastructure of Ukraine because of the full-scale war.

The assessment of damages was carried out by the analytical team of Kyiv School of Economics (KSE) together with the Ministry of Communities and Territories Development, the Ministry of Economy, and in cooperation with other relevant ministries and the National Bank of Ukraine.

The overall damages assessment was carried out in accordance with the World Bank's methodology, using a significant amount of microdata collected by the relevant authorities and local civil and military administrations since the beginning of the full-scale war. The assessment methodology involves the use of direct and indirect methods, statistical data and certain assumptions, in particular regarding the extent of damages in areas where active hostilities are still ongoing, where physical inspection is limited due to danger (e.g. mined areas), or which are located in the territories occupied by the aggressor.

Information sources and methodology depends on the asset type. To estimate the value of damaged or destroyed assets, average values are calculated based on data from the State Statistics Service, relevant ministries, the Prozorro system, etc., with adjustment factors applied according to the level of damage to the assets. Information from financial statements as of the latest available date is used to assess the value of damaged or destroyed assets of large commercial facilities and identified institutions¹.

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¹ The research methodology is described in more detail in the materials of the working group "Audit of damages incurred as a result of the full-scale war": <https://www.kmu.gov.ua/storage/app/sites/1/recoveryrada/ua/audit-of-war-damage.pdf>

KEY RESULTS

Since the beginning of the full-scale Russian military invasion, the total amount of damages to buildings, infrastructure and inventories has amounted to almost \$170 billion. Compared to the previous assessment, as of the beginning of 2024, the amount increased by \$12.6 billion (8%).

The largest share of damages was caused to residential buildings (\$60 billion) and transport infrastructure (\$38.5 billion). The damages of the energy sector amount to \$14.6 billion, the assets of industry, services and construction — \$14.4 billion. Another \$10.3 billion is made up of damages to the agricultural sector and land resources. The total damage to public sector facilities (social facilities and institutions, educational, scientific and healthcare institutions, cultural facilities, sports facilities, administrative buildings, etc.) is about \$16.3 billion.

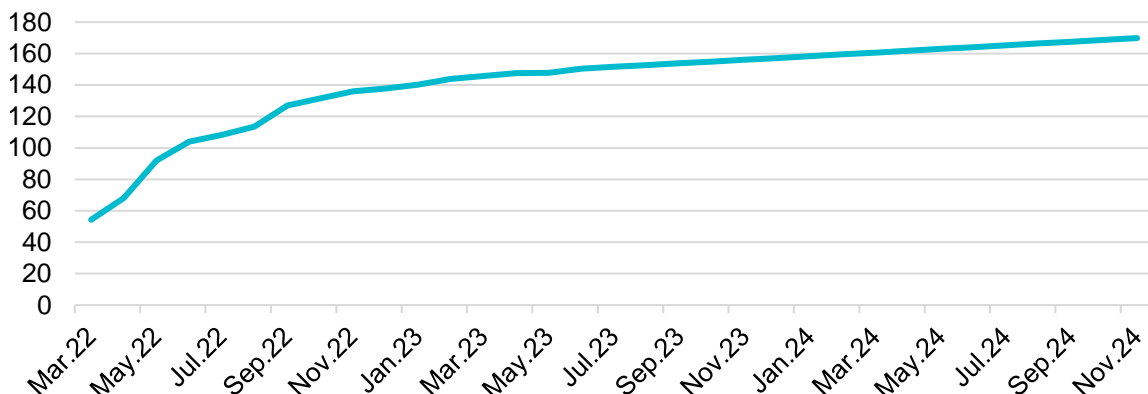
Table 1. Total estimate of infrastructure damages as of November 2024.

Property type	Assessment of damages, \$ billion	Share of damages by property type, % of total sum	Previous assessment of damages, \$ billion	Dynamics
Residential buildings	60,0	35,3%	58,9	1,9%
Infrastructure	38,5	22,7%	36,8	4,6%
Energy sector*	14,6	8,6%	10,0	46,0%
Assets of enterprises, industry	14,4	8,5%	13,1	9,9%
Agriculture and land resources	10,3	6,1%	10,3	0,0%
Education	7,3	4,3%	6,8	8,8%
Forest fund	4,5	2,7%	4,5	0,0%
Healthcare	4,3	2,5%	3,1	32,3%
Culture, tourism, sports	4,0	2,3%	3,1	29,0%
Municipal services and utilities*	3,5	2,0%	3,5	0,0%
Transport vehicles	3,5	2,0%	3,1	12,9%
Trade	2,8	1,7%	2,6	7,7%
Digital infrastructure	1,2	0,7%	0,5	140,0%
Administrative buildings	0,8	0,4%	0,5	60,0%
Social sector	0,2	0,1%	0,2	0,0%
Financial sector	0,04	0,01%	0,04	0,0%
Total	169,8	100%	157,2	8,0%

Source: KSE calculations * district heating was moved from utilities to energy, because CHPPs produce both electricity and heat. For comparison purposes, such as transformation was also done for previous figures.

In absolute terms, the largest increase in damages occurred in the energy sector (+\$4.6 billion), as the enemy deliberately targeted electricity generation and distribution. Also, large new damages were recorded in transport infrastructure, social sectors and enterprise assets. In relative terms, the largest dynamics were observed in administrative buildings (+60%), as well as in energy (+46%), as well as in healthcare (+32%), and culture, tourism and sports (+29%). Digital infrastructure was even more dynamic, but in this case, it is not indicative, since in the previous report the estimate was not updated due to lack of data.

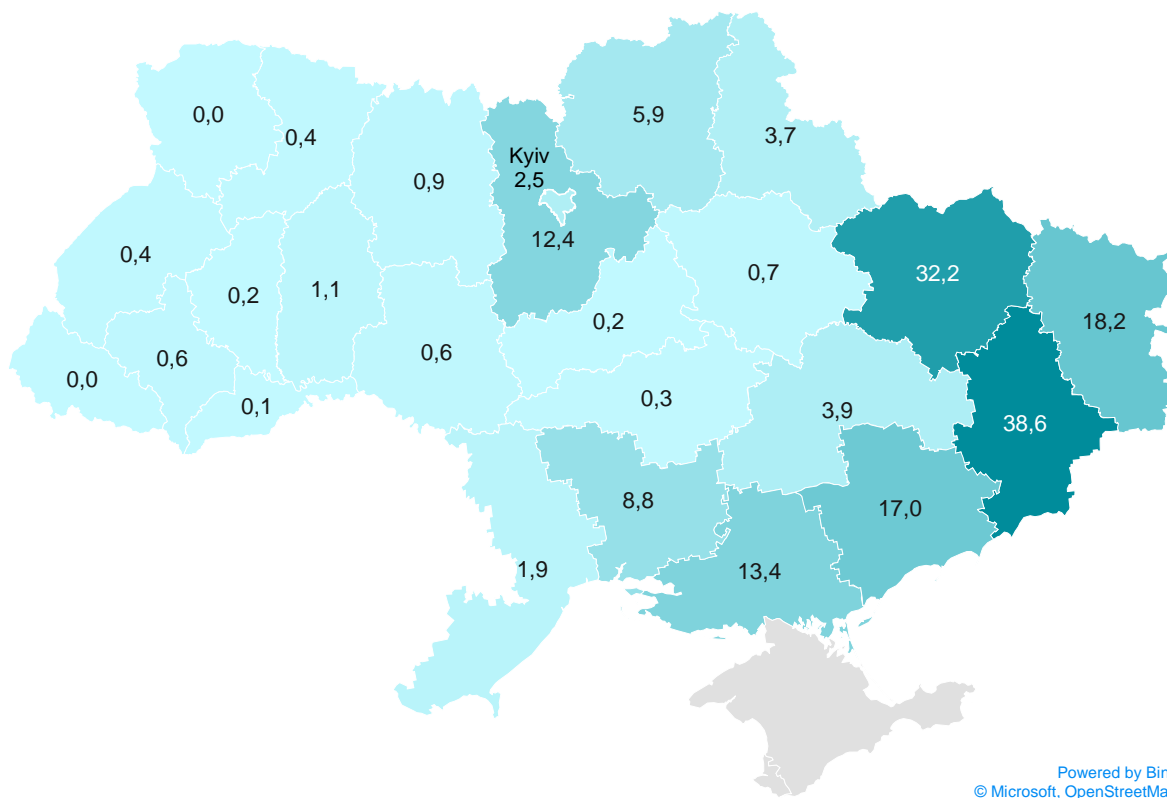
Chart 1. Dynamics of the aggregate assessment of damages to the Ukrainian economy, \$ billion.



Source: KSE

Geographically, the frontline regions were the most affected. Ten regions that were invaded, share a border with the Russian Federation or access to the sea account for more than 90% of the total amount of damages. However, the enemy continues to strike at assets in other regions, so the Dnipropetrovsk region is also among the badly affected regions.

Map 1. Distribution of damages by regions, \$ billion.



Powered by Bing
© Microsoft, OpenStreetMap

Source: KSE. The sum for regions is slightly lower than the total amount of damages, since there is no regional breakdown for some sectors and subsectors.

A photograph of a dilapidated brick building with a basketball hoop in the foreground. The building is in a state of significant disrepair, with missing windows and crumbling masonry. The sky is clear and blue. The basketball hoop is a simple metal structure with a white backboard and a red border. The overall scene suggests a neglected urban environment.

01

**SOCIAL
SECTOR**

Residential and administrative buildings

Damages to the housing stock amount to almost \$60 billion². This is the largest item of damages, accounting for more than a third of the total amount. Active shelling of cities with missiles and artillery is a part of Russia's combat tactics, which lead to significant destruction of housing stock in cities and towns, especially those located near the front line. As a result of the hostilities of the Russian Federation, more than 50% of the housing stock in a significant number of cities and towns was damaged or destroyed.

The housing stock of large cities in the East suffered the greatest destruction. These are Mariupol, Kharkiv, Chernihiv, Severodonetsk, Rubizhne, Bakhmut, Maryinka, Lysychansk, Popasna, Izyum and Volnovakha. For example, in Severodonetsk, 90% of the housing stock was damaged, Bakhmut and Maryinka have almost no undamaged buildings. occupation of part of the territory of Ukraine, as well as throughout the rest of the country due to regular missile attacks.

The total number of destroyed or damaged housing facilities is about 236 thousand buildings, of which 209 thousand are private (individual) houses; 27 thousand are apartment buildings; 0.6 thousand are dormitories.

The total area of damaged or destroyed objects by shelling is about 90 million square meters³, or 9% of the total area of the housing stock of Ukraine (or 6.5%, if we take into account the level of damage). According to the results of detailed site-by-object technical inspections of houses, this ratio may vary. The area of houses in the flood zone amounted to another 4.8 million square meters, in total, this left about 1.4 million households (about 3.4 million people) homeless or with damaged housing.

Table 2. Assessment of damages to residential buildings.

Types of costs	Initial number of facilities, thous. pcs	Destroyed, thous. pcs	Damaged, thous. pcs	Damage assessment, \$ bln.
Multi-apartment buildings	180,0	7,0	19,8	49,9
Individual buildings	9 163,9	70,7	125,8	9,4
Dormitories	7,1	0,2	0,4	0,7
Total	9 351,0	77,8	146,1	60,0

Source: Data of the State Statistics Service, data of the Ministry of Development of Communities and Territories of Ukraine, Order of MinRegion No. 53 dated 17.02.2022, data of regional military administrations, market data; calculations of MinDevelopment together with KSE.

² When calculating damages, the values of the indirect cost of housing construction by regions of Ukraine as of January 1, 2022, approved by the Order of the Ministry of Regional Development of Ukraine No. 53 dated February 17, 2022, as well as other components of the cost of substitution, which were calculated on the basis of market values and expert assumptions, were used as baseline.

³ When calculating the total area of individual houses, apartment buildings and dormitories, the average area of buildings was used, which was calculated as an arithmetic mean based on the analysis of object-by-object data on damage and destruction in the context of regions and in the context of building types. Based on the results of detailed object-by-object technical inspections of houses, these values may change.

Damages to administrative buildings amount to \$0.8 billion. Because of hostilities, 883 administrative buildings were destroyed or damaged, including 813 buildings of state and local government bodies, and 70 centers for the provision of administrative services.

Healthcare

Damages to healthcare facilities amount to \$4.3 billion. In total, at least 1554 healthcare facilities have been damaged or destroyed since the beginning of the war. The calculation of damages includes the assessment of damage to health care facilities, which include hospitals, clinics, dentists, consultative and diagnostic centers, outpatient clinics, blood centers, medical offices, laboratories, medical warehouses, forensic examination bureaus, etc.

Data on the destruction of relevant health care facilities was received from the Ministry of Development. To calculate damages, information on the book value of each of the types of objects is used, as well as data from open sources on the degree of damage to objects.

Damages to healthcare facilities accounts for 2.5% of the total cost of Ukraine's damages. By type of healthcare facilities, hospitals (515) and outpatient clinics (465) were destroyed or damaged as a result of the war, with hospitals accounting for 70% of the cost of all damage to the industry. Almost half of the damages to the healthcare sector are concentrated in three regions — Donetsk, Mykolaiv and Kharkiv.

Table 3. Assessment of damages to the healthcare sector.

Types of costs	Initial number of facilities, pcs	Destroyed, pcs	Damaged, pcs	Damage assessment, \$ bln.
Hospitals	1 135	126	389	3,0
Polyclinics, dentistry, diagnostic centres	1 138	48	109	0,4
Outpatient clinics		111	354	0,2
Blood centres	28	4	6	0,0
Other (medical offices, laboratories, medical warehouses, dormitories, forensic bureaus)		140	267	0,7
Total	X	429	1 125	4,3

Source: Ministry of Development of Communities and Territories of Ukraine, KSE calculations.

Education and science

Damages to educational institutions amount to \$7.3 billion. In total, because of hostilities, about 4 thousand buildings were damaged or destroyed. educational institutions. Institutions include preschool education institutions (kindergartens), secondary (schools), out-of-school, pre-higher education (colleges and technical schools), higher (institutes, universities, academies), specialized, specialized, vocational education, as well as adult educational institutions, including postgraduate education. The main damages to education facilities relate to secondary and preschool education institutions.

Despite the fact that active hostilities were carried out in 11 regions, educational institutions were damaged in 22 regions. The greatest damages to educational institutions are in Donetsk, Kharkiv, Kherson, Mykolaiv, Dnipropetrovsk and Zaporizhzhia regions. There are no damages to educational institutions in Volyn, Ivano-Frankivsk and Chernivtsi regions.

Table 4. Assessment of damages to education and science.

Types of costs	Initial number of facilities, pcs	Destroyed, pcs	Damaged, pcs	Damage assessment, \$ bln.
Secondary education institutions	13,991	229	1,810	3.7
Institutions of pre-school education	13,875	110	1,111	1.2
Vocational education institutions	694	17	187	1.0
Higher education institutions	386	3	97	0.5
Institutions of professional higher education	248	12	150	0.3
Out-of-school education institutions	1,351	21	158	0.4
Specialised education institutions	310	0	23	0.0
Institutions of special education	273	3	41	0.1
Adult education institutions, including postgraduate education	n/a	1	3	0.0
Total	X	398	3,579	7.3

Source: Ministry of Development of Communities and Territories of Ukraine, KSE calculations.

Social protection

Damages to the infrastructure of social services provided by the state amount to \$0.2 billion. As a result of large-scale hostilities in various regions of Ukraine, 160 social protection facilities were damaged, including destroyed or damaged social centers, geriatric institutions, sanatoriums, children's camps and orphanages, boarding schools, and institutions for working with the homeless. The largest share in the total number and cost of damage belongs to social centers — 48 institutions, sanatoriums — 46 institutions, and boarding schools — 31 institutions.

The assessment is based on data provided by the Ministry of Communities and Territories Development. The sector includes social infrastructure facilities subordinated to the Ministry of Social Policy.

Among social facilities, the smallest number of destroyed or damaged institutions and, accordingly, damages compared to other infrastructure facilities in the country were documented. The damaged social protection facilities are in Kyiv and in the following regions: Kyiv, Donetsk, Dnipropetrovsk, Zhytomyr, Zakarpattia, Zaporizhzhia, Luhansk, Mykolaiv, Sumy, Odesa, Kharkiv, Kherson, Chernihiv. The destroyed social facilities are located in Luhansk, Donetsk, Dnipropetrovsk, Zaporizhzhia, Kyiv, Mykolaiv, Sumy, Kharkiv, Kherson, Chernihiv regions and in the city of Kyiv.

Table 5. Assessment of damages to the social protection sector.

Types of costs	Initial number of facilities, pcs	Destroyed/Damaged, pcs	Damage assessment, \$ bln.
Children's homes	n/a	6	0.003
Residential institutions	n/a	31	0.1
Geriatric facilities	n/a	14	0.01
Social centres	n/a	48	0.04
Homeless shelters	n/a	1	0.0001
Health resorts	n/a	46	0.1
Children's camps	n/a	14	0.02
Institutions for people released from prison	n/a	0	0.0
Total	n/a	160	0.207

Source: Ministry of Development of Communities and Territories of Ukraine, Ministry of Social Policy, KSE calculations.

Culture, sports, and tourism

Damages to the infrastructure of the cultural, religious and tourism sectors amount to \$4 billion. In total, at least 3921 cultural sites, 399 religious buildings, 343 sports facilities, and 164 tourism facilities have been damaged or destroyed since the beginning of the war.

Since the beginning of the large-scale invasion, the cultural sector has suffered the greatest damages in the entire history of independent Ukraine.

For each country, culture is the basis of self-determination of every citizen, the destruction of cultural objects, such as museums, historical buildings, monuments and works of art by prominent people is a very painful blow for Ukrainians, since with the destruction of each cultural object, a part of the history of Ukraine and the Ukrainian people is also lost.

Among the most painful losses of this war on the cultural front are the Holy Dormition Sviatohirsk Lavra, which is included in the UNESCO register of monuments, the museum of Hryhoriy Skovoroda, the author of world-famous philosophical and artistic works, and even a collection of Scythian gold, which was found by archaeologists in the 50s of the last century. In addition, other important cultural and religious sites, including the Mykolaiv City Palace of Culture "Korabelnyi", Mariupol Drama Theater, Kharkiv National Academic Opera and Ballet Theater. M. V. Lysenko, the Museum of Antiquities in Chernihiv, the Kharkiv House "Slovo" and many others.

The assessment of cultural heritage damages is based on data on the site-by-site list of damaged/destroyed objects provided by witnesses and local administrations, which creates risks of incompleteness of data on the list of damaged objects. Due to the lack of access to most of the affected sites due to their location in areas of hostilities, the list is incomplete and continues to grow.

Currently, the cost of cultural objects is calculated without taking into account the cultural value of these objects, due to the difficulties in remote calculation of such value, as well as the lack of a single and integral register of cultural buildings that would contain detailed data on cultural heritage, art objects, and a list of museum artifacts in each of the objects. Also, given this restriction, at the current stage, the damages to libraries, museum collections etc. were not calculated.

Table 6. Assessment of damages to culture, sports and tourism.

Types of costs	Initial number of facilities, pcs	Destroyed, pcs	Damaged, pcs	Damage assessment, \$ bln.
Religious institutions	n/a	64	335	0.1
Sports culture	16,199	59	284	0.6
Cultural sphere	34,340	541	3,380	3.0
Tourism sector	n/a	50	114	0.1
Total	n/a	714	4,113	4.0

Source: Ministry of Development of Communities and Territories of Ukraine, State Statistics Service, KSE calculations.

An aerial photograph of a lush green agricultural field. In the center-left, a large, white, cylindrical pipe lies horizontally on the ground. To its left, a metal container or bucket is overturned. The field is densely packed with young green plants, likely corn, in neat rows. The lighting is bright, casting shadows on the ground.

02

**PRODUCTIVE
SECTOR**

Industry, construction and services

The total damages to enterprises' assets are estimated at \$14.4 billion. In total, almost half a thousand large and medium-sized private enterprises, as well as state-owned enterprises and tens of thousands of small private enterprises, have been damaged or destroyed since the start of the full-scale war. The true figure is likely to be higher, as not all enterprises are reported, especially those in the temporarily occupied territories.

Enterprises could be divided into two groups. The first was those destroyed by accident or as a collateral damage of shelling of military units and settlements. The second was destroyed intentionally as part of targeted strategic missile strikes. In addition to transport and energy infrastructure facilities described in the relevant sections, these are primarily military and dual-use production facilities. Unlike the first group, which is concentrated in the frontline regions, the second group is evenly distributed throughout Ukraine.

Damages include:

- Damage of fixed assets (the original valuation is used since it is not possible to purchase an asset at its carrying amount in most cases).
- Damage of capital investments in progress.
- Damage to inventories of finished goods and intermediate materials (in most cases, the inventories were located close to the main production facilities).

Depending on the availability of data, damages were calculated in one of the following ways:

- This estimate is used for private enterprises for which the owner has reported its own estimate of damages after verification.
- The financial statements, as of the latest available pre-invasion data, are used for large and medium-sized private enterprises for which the existence and level of damage are known. We distinguish between destruction (100%) and damage (40%).
- We use estimates provided by the ministries and agencies that manage the respective companies (if available, otherwise financial statements are used, as in the case of private companies) for public utility companies.
- The indirect calculation based on the level of damage to residential property in the regions is used for small private enterprises as an interim indicator.
- The value of assets (through ratios to revenue based on the financial statements of legal entities) was first estimated for individual entrepreneurs, and then damages were calculated similarly to small private enterprises.

The main conclusions regarding the damage enterprises are as follows:

1. Business assets are the fourth largest item of infrastructure damage (yielding the third position to energy). It accounts for almost 9% of total damages.

- In terms of industries, metallurgy suffered the most. In particular, two of the largest enterprises on the list of damaged/destroyed were destroyed — Azovstal and Illich Iron and Steel Works (both in Mariupol).
- In terms of regions, the Donetsk region suffered the most, accounting for almost half of the total damages incurred by the enterprises. Significant damage was also caused in the Kharkiv, Luhansk, and Kyiv regions.

Table 7. Assessment of damages to the industrial sector, construction and services.

Types of costs	Initial number of facilities, pcs	Destroyed, pcs	Damaged, pcs	Damage assessment, \$ bln.
Large and medium-sized private enterprises	5,270	92		7.7
Small private enterprises and individual entrepreneurs	78,060	n/a	n/a	4.8
State-owned enterprises	1,665	348		1.9
Total	84,995	n/a	n/a	14.4

Source: Ministry of Development of Communities and Territories of Ukraine, State Statistics Service, public data, KSE data and calculations.

Commerce

The total amount of damages to the sector since the beginning of the full-scale war in Ukraine is \$2.81 billion. The amount consists of two parts — the damages to retail and the damages to shopping centers.

Damages to retail enterprises reach \$2.43 billion. We are talking about shops, pharmacies, kiosks and gas stations. The amount does not include retail objects of individual entrepreneurs. Information on damages to retail enterprises was obtained as a result of the analysis of data from three waves of a study conducted by the Ukrainian Council of Shopping Centers (the first wave was conducted jointly with the Association of Retailers of Ukraine).

The study was conducted through a standardized online survey of top managers of retail companies. Representatives of 301 companies, including both network and non-network trading enterprises, took part in the survey. At the same time, a number of respondents were interviewed 2-3 times during different waves of the study. According to the results of the study, at least 2.9 thousand retail outlets received significant damage.

Damages to shopping centers are \$381 million. Shopping centers are not participants in the retail market, but provide space to retailers to carry out professional activities. According to the ICSC definition, a shopping center is a commercial real estate object that is planned, built and managed as a whole, includes shops and common areas, with an area suitable for rent of at least 5,000 sq. m.

The Ukrainian Council of Shopping Centers (UCSC) maintains a register of shopping centers and collects data on their damages. According to the Council, there are 286 shopping centers in the part of Ukraine controlled since 2014, of which 9 were destroyed and 23 were damaged. The assessment of damage by the expert method took into account the area and nature of the damage, based on the construction cost of \$800-1100 per 1 sq. m, depending on the type of object. The calculation of damages to shopping centers does not include damages to tenants (equipment and goods), since they are already taken into account in the damages of retail enterprises.

Table 8. Assessment of damages to retail.

Types of costs	Initial number of facilities, pcs	Destroyed, pcs	Damaged, pcs	Damage assessment, \$ bln.
Retail facilities	40,277	n/a	n/a	2.4
Shopping centres	286	9	23	0.4
Total	40,563	n/a	n/a	2.8

Source: State Statistics Service, Ukrainian Council of Shopping Centers, Retail Association of Ukraine.

Agriculture, land resources and forestry

Damages to the agro-industrial complex of Ukraine are \$10.3 billion.

Assessment of damages to the agro-industrial complex and agricultural infrastructure includes the following main components: losses of agricultural machinery; loss of elevators and other granaries; damage and destruction of reclamation systems; loss of animal husbandry from the death of animals and from the slaughter of animals due to the impossibility of keeping them; losses of perennial crop producers due to damage to plantations; beekeeping losses; loss of factors of production and finished products due to their damage and theft. Damages are estimated by indirect methods, a combination of relevant state and regional statistics, as well as data from surveys of agricultural producers.

Unlike most other categories, real estate is not the largest item of damages.

The largest share of damages belongs to damages due to agricultural machinery, as a result of which the estimated damages of agricultural producers amount to more than \$5.8 billion. The second largest category is damages due to destruction and theft of manufactured products, the total value of destroyed and stolen products is estimated at \$1.9 billion.

The infrastructure for storing agricultural products suffered significant damages.

The total capacity of destroyed granaries reaches 11.4 million tons of manufactured products, and the capacity of damaged granaries reaches 3.3 million tons of simultaneous storage capacities. The cost of restoring destroyed facilities is estimated at \$1.8 billion.

Damages to the forest stock as a result of forest fires are estimated at \$4.5 billion.

This corresponds to 83 million cubic meters of wood. According to the Zoya Environment Network, the total area of forest fires in the territories where active hostilities took place reaches almost 298 thousand hectares. Hectares. Such an area of forest fires exceeds the average annual area of forest resources that were destroyed as a result of fires throughout

Ukraine by more than 50 times. One of the key factors of such a volume of forest fires is the complication of extinguishing forest fires in the territories where active hostilities are taking place or have been carried out. Even in the liberated territories, the fight against forest fires is significantly complicated due to the threat of mine pollution.

Table 9. Assessment of damages to agriculture and land resources.

Types of costs	Measurement unit	Initial number of facilities	Destroyed	Damaged	Damage assessment, \$ bln.
Agricultural machinery	psc	764,323	130,603	50,521	5.8
Grain storage facilities	thous. t	75,084	11,351	3,341	1.8
Dead animals (including poultry and fisheries)	thous. heads	203,292	1,899	11,963	0.2
Destroyed apiaries	colonies	2,272,740	86,902	192,526	0.0
Perennial crops	ha	197,100	16,364		0.4
Destroyed and stolen inputs	t	962,951	135,993		0.1
Destroyed and stolen finished agricultural products	t	25,486,613	4,037,542		1.9
Aquaculture and fishing facilities	psc	2102	228		0.0
Total	n/a	n/a	n/a	n/a	10.3

Source: Calculations of the KSE Agrocentre (Centre for Food and Land Use Study).

Financial sector

Damages to the financial sector amounted to \$44 million. This assessment includes its main component — banks, while information on non-bank financial institutions and stock market entities was limited.

The property of banks came under fire. According to the results of bank surveys conducted by the NBU, as of December 2023⁴, the residual value of banks' property that was lost, destroyed, or controlled amounted to \$21 million (compared to previous data, the estimate has been lowered again; the regulator has not published new estimates since then). About half of it is real estate, the other half is other property (ATMs, furniture, computers, etc.). Financial institutions do not have accurate information about the destruction or loss of the rest of the property. It will be possible to finally assess the damages only after the end of the war or at least after the liberation of the territories.

In the occupied territories, the Russians robbed banks. By the beginning of May 2022, the volume of banknotes lost due to robbery or seizure of branches amounted to UAH 470 million. Banks destroyed about UAH 60 million of national currency banknotes and took them out for further exchange at the NBU.

⁴ Financial Stability Report, December 2023 <https://bank.gov.ua/ua/news/all/zvit-pro-finansovu-stabilnist-gruden-2023-roku>

A photograph of a power substation. In the foreground, a large, complex metal structure, likely a transformer or switchgear support, has collapsed and is lying on the ground amidst tall grass and weeds. The structure is made of dark grey metal beams and plates. In the background, several tall metal towers (pylons) are visible, supporting multiple high-voltage power lines that stretch across the sky. The sky is a clear, pale blue with a few wispy clouds. The overall scene suggests a state of disrepair or a recent accident at the facility.

03

INFRASTRUCTURE

Transport infrastructure

The total volume of damages to transport infrastructure facilities in Ukraine amounted to \$38.5 billion. In the first weeks of the war, Russian troops carried out massive shelling of aviation infrastructure, primarily airfields not only military, but also civilian and military-civilian (dual) use.

The greatest destruction of infrastructure, both in absolute and in value terms, was road infrastructure facilities. Firstly, due to the fact that they naturally become targets of shelling during artillery attacks, and secondly, due to the fact that it is Russian tanks that actively move along Ukrainian roads throughout the entire period of military aggression. In particular, the lines of communication between Russian troops in Ukraine and their rear on the territory of Russia and Belarus ran along the roads.

Table 10. Assessment of damage to infrastructure.

Types of costs	Measurement unit	Initial number of facilities	Destroyed/Damaged	Damage assessment, \$ bln.
Roads of national importance	km	47,000	9,298	9.9
Roads of local importance	km	120,000	9,056	9.6
Municipal roads (cities and other settlements)	km	270,000	8,277	8.8
Bridges and bridge crossings	pcs	11,076	344	2.6
Assets of UZ				4.5
Infrastructure of seaports and inland waterway transport (ports; berths; warehouses; terminals; movable property)				1.0
Aviation	pcs	36	20	2.0
Property of postal operators				0.01
Total	n/a	n/a	n/a	n/a

Source: State Statistics Service, Ministry of Development of Communities and Territories of Ukraine, UZ, Ukrposhta, Nova Poshta, public data, KSE.

Road infrastructure

The destructive effect of the passage of a tank is 2.36 times higher than the effect of the standard load from civilian transport⁵. Such calculations are based on the parameters of the T-72 tank, which is a good approximation in the case of the war in Ukraine, since most of the tanks are similar in physical characteristics or even heavier. The surface layer of roads suffers serious damage due to metal tracks. Also, the destructive effect of tank braking is 2.38 times greater than the effect of the destructive effect of the tank mass

⁵ Damaging Effect of Moving Tank Loads on Flexible Pavement, Journal of Engineering, 2010

on the stretch of the road. Finally, the destructive effect during tank maneuvers is 1.22 times greater than the effect of the destructive effect of the tank's mass on the stretch of the road. The action of the tank is not only horizontal, but also vertical, and the maximum stress, according to research, is at a depth of up to 3 meters, which affects the degree of destruction of not only the surface layer of roads.

The average cost of damage and restoration of one kilometer of road in a city is usually significantly more expensive compared to the cost of roads outside the city (by a third or more), since, in addition to the roadbed, it also involves the construction of communication networks, sidewalks, lighting, etc.

More than 26 thousand km of roads and 344 bridges and bridge crossings of state, local or municipal importance were destroyed. An overview of the condition of roads in the de-occupied regions (Chernihiv, Kyiv, Sumy, Kharkiv regions) confirmed expectations for significant destruction of the road structure as a result of the passage of tanks and other heavy military equipment, which will require the reconstruction of a significant part of the damaged roads. Preliminary estimates showed that the level of road damage reaches 95% and averaged about 10% of the total number of roads in the regions that were occupied by the Russian troops or where they were/are fighting.

The weighted average cost of road reconstruction in 2021 was about UAH 29 million per 1 km of road (excluding the cost of restoring bridge crossings). Taking this into account, the estimate of the damages due to direct road destruction may be about \$28.3 billion in equivalent, in prices at the end of 2021. The assessment of damage and destruction of bridges and bridge crossings adds another \$2.6 billion in damage to infrastructure.

Railway infrastructure

Since the beginning of the invasion, the railway has significantly demonstrated its role as a critical infrastructure facility, taking the brunt of the free evacuation of millions of Ukrainian citizens (as well as a large number of businesses) caught in the war zone; as well as the delivery of critical materials and equipment to these regions. In response, the railway has become an active target for Russian shelling and attacks.

Damages to this sector are estimated at \$4.3 billion. In particular, the railway track, railway stations and stations (both in the government-controlled territory and in the uncontrolled territories) were damaged or destroyed). Also, more than 700 km of railway tracks are located in the temporarily occupied (after 24.02.2024) territory. About 10 thousand buildings were also destroyed or lost. At the same time, there is reason to believe that all the movable property of Ukrzaliznytsia, which was not removed from such territories on time, can be considered completely lost (destroyed or stolen by the troops of the aggressor country).

Aviation sector

The estimate of damages to the industry (airports, airfields, aviation equipment, aeronautical equipment) is about \$2 billion. With the outbreak of hostilities, Russian troops began active missile attacks on all key airfields of Ukraine, trying to deprive it of the ability to provide air defense. As a result, 19 out of 35 airfields were damaged, including 12 civilian and 7 dual-use airfields (excluding military airfields).

Ports and shipping sector

Damages to port infrastructure and related enterprises are estimated at \$0.85 billion. This assessment includes both the infrastructure of seaports and inland water transport facilities that were destroyed as a result of the war. The total damage also included damage caused to the port infrastructure from the accident at the Kakhovka hydroelectric power station.

Russian attacks on ports intensified in 2023-2024, after the completion of the grain corridor agreed with the Russian Federation. During July-October 2024 alone, the enemy carried out almost 60 attacks on the ports of the Odesa region. Almost 300 infrastructure facilities, 177 vehicles and 22 civilian vessels were destroyed or damaged.

Moderate port destruction is due to two factors. Secondly, the aggressor seized or used its own and friendly cargo ships in order to export stocks of grain, ferrous metals, etc., for this it needed working ports. For example, the Metinvest group reported on the occupiers' plans to export 200 thousand tons of products from the factories of Mariupol worth \$170 million. In turn, the theft of 400-500 thousand tons of grain was reported. tons (worth hundreds of millions of dollars) from the four occupied southern regions, which is more than a third of local reserves, and this continued into 2024.

Vehicles

Damages to utilities and private carriers, in particular in relation to destroyed transport, amount to \$0.83 billion — these are destroyed trolleybuses, trams, buses. Damages to public transport are calculated both using indirect methods, taking into account a number of assumptions; and using accurate data on damaged/destroyed municipal property provided by military administrations.

Damages to private passenger vehicles amount to approximately \$2.2 billion or 260 thousand cars. The assessment is based on the available data on the officially registered number of passenger cars, and does not take into account possible damages to passenger vehicles not registered in Ukraine (in particular, the so-called. "Europlates").

The greatest damage to municipal property, which includes public transport, was caused in Luhansk and Donetsk regions, as well as in the

city of Kharkiv. The enemy used heavy weapons on civilian infrastructure, which led to the loss of about 60% of public transport in the Donetsk region and more than 70% in the Luhansk region. In these two regions, the industry for the provision of passenger transportation services by urban and suburban transport was completely destroyed. Most private cars were also lost by citizens in these two eastern regions of Ukraine.

In addition, the damages of vehicles also take into account the destroyed 'Mriya' aircraft in the amount of \$300 million (while the cost of building a new model aircraft may reach a higher value). At the same time, it is likely that the damages to air passenger transport are greater due to the possible destruction of other civilian/cargo aircraft during the shelling of Ukrainian airfields; but in the absence of detailed information on the location of such aircraft at civilian airfields, such an assessment will be carried out at a later stage.

Table 11. Assessment of damages to the transport sector.

Types of costs	Initial number of facilities, pcs	Destroyed/Damaged, pcs	Damage assessment, \$ bln.
Trolleybuses	2,980	344	0.03
Trams	1,922	152	0.2
Buses	241,426	13,812	0.6
Passenger cars*	10,000,000	211,680	2.2
Fire trucks	4,216	1,629	0.1
'Mriya' aircraft	1	1	0.3
Total**	10,250,545	227,618	3.5

Source: Ministry of Development of Communities and Territories of Ukraine, State Statistics Service, Ukroboronprom, public data, KSE calculations

*only officially registered private cars are taken into account, excluding cars imported without customs clearance into the territory of Ukraine

**at the current stage, the following are not taken into account: (1) loss of trucks; (2) loss of other vehicles, including those owned by the authorities; (3) loss of aircraft (except for the 'Mriya' aircraft, the loss of which is publicly available).

Energy sector

Damage to the Ukrainian energy infrastructure was estimated at \$14.6 billion. Both direct and indirect methods of calculating the cost of lost and damaged facilities were used to assess the damage in the energy sector. The cost of damaged facilities is based on the original book value of fixed assets, the cost of current repairs, and the cost of restoration (the market value of replacing the destroyed facilities).

Basic information on damages in the energy sector is provided by the Ministry of Energy, the Ministry of Reconstruction and local military administrations. To assess damages at certain large facilities, an individual approach is used based on information from open sources, owners and managers of enterprises. Data on damage to power generation facilities was collected on an aggregate basis, as well as from

open sources, due to the high risk of dissemination of information on detailed damage to critical infrastructure facilities in a time of war.

The electricity generation and transmission sector has suffered the most from Russian aggression in the energy sector. During October 2022 — February 2023, the Russian Federation carried out targeted and large-scale attacks on such facilities. After that, regular and targeted shelling of energy infrastructure in the frontline regions continued. The estimate of the total amount of damage to these facilities is over \$12 billion. All coal-fired power plants (CPPs) and hydroelectric power plants (HPPs) under the control of Ukraine, as well as 20 combined heat and power plants (CHPPs) have been affected since the beginning of the full-scale invasion.

A significant amount of damage falls on large electricity generation facilities. As a result of one of the massive shelling during the heating and winter period of 2022-2023, 9 units of thermal power plants were damaged, and at least one of them was completely destroyed as a result of a direct hit by a missile. In early June 2023, the Russians blew up and completely destroyed the Kakhovka hydroelectric power plant. Damages from its destruction are currently estimated at \$586 million.

Massive attacks by the Russian Federation since March 2024 have caused critical damage to generation. All TPPs in the controlled territories that are part of the group of power plant operator DTEK were hit, in particular, the power units of the Burshtyn and Ladyzhynska TPPs (more than 4 GW) were disabled. Facilities in the Kharkiv region were significantly damaged: Zmiivska TPP ("Centrenergo") and Kharkiv CHPP-5 were almost completely destroyed.

Also, in the territories occupied by the Russian Federation after February 24, 2022, there are several TPPs (Vuhlehirsk, Zaporizhzhia, Kurakhove and Luhansk), and the Sloviansk TPP is close to the front line, which is why they are regularly shelled by the aggressor.

We estimate the current damages of thermal power generation at \$3.8 billion (TPP) and \$1.6 billion (CHP), hydroelectric power plants (HPPs) and pumped-storage power plants (PSPs) at \$2.5 billion. At the same time, the cost of restoring the lost capacities of such power plants may significantly exceed the estimated damages due to significant physical wear and tear and technological obsolescence of damaged and destroyed equipment.

Producers of electricity from renewable sources (RES) also suffer significant damages. According to the Energy Charter Secretariat, 13% of solar generation capacities are located in the occupied territories, and 8% have been damaged or destroyed; about 80% of wind generation is occupied and part is damaged due to shelling; 2% of bioenergy facilities are under occupation, and at least 4 biogas plants are known to have been destroyed. We estimate the damages to RES electricity producers (excluding large hydroelectric power plants and pumped-storage power plants) at \$281 million.

The continuation of active hostilities in a significant part of the territory of Ukraine, as well as targeted massive shelling by the Russian Federation, also led to damage and destruction of electricity transmission and distribution facilities. According to preliminary estimates, the damages caused to the Electricity Transmission System Operator because of the full-scale invasion reaches \$2.2 billion, and to distribution system operators — \$826 million.

In the first months of the full-scale invasion, the Russian Federation targeted oil and oil products processing and storage facilities. Since February 24, 2022, at least 32 oil depots of various sizes and levels of modernization, as well as the fuel stored on them, have been damaged or completely destroyed. According to current estimates, damages caused to the fuel storage sector amounts to almost \$266 million. In addition, the aggressor repeatedly shelled the facilities of the only large oil refineries that were active, Shebelynka (Kharkiv region) and Kremenchuk (Poltava region). Relevant damages are included in the section "Industry, construction and services". The sectoral loss assessment report, which was published in June 2024, included this industry in the energy sector, adding more than \$2.1 billion to the total amount of damages.

Damages to heat supply facilities (excluding thermal power plants) are estimated almost at \$1 billion. Destroyed and damaged heat generation facilities put the passage of winter heating seasons at risk and led to interruptions in the supply of heat energy and hot water. For example, the destroyed Kremenchuk CHPP (Poltava region) covered about 70% of the city's needs, that is, about 180 thousand residents. Community residents who could be left without heat and hot water for the entire heating season, if not for timely repair work. In addition, 925 boiler houses were partially damaged or completely destroyed, most of them in the Kharkiv, Kyiv, Chernihiv, Donetsk and Mykolaiv regions. 214 central heating points were partially damaged or destroyed, more than 354 linear km of heating networks were destroyed.

Table 12. Assessment of damages to the energy sector.

Types of costs	Damage assessment, \$ bln.
Electricity, including:	12,1
<i>Electricity generation</i>	9,0
<i>Electricity transmission</i>	2,2
<i>Electricity distribution</i>	0,8
Oil and gas sector, including:	1,2
<i>Gas transmission</i>	0,8
<i>Gas distribution</i>	0,2
<i>Storage of oil and oil products</i>	0,3
<i>Coal mining industry</i>	0,4
<i>District heating</i>	1,0
Total	14,6

Source: Ministry of Development of Communities and Territories of Ukraine, Ministry of Energy of Ukraine, Energy Charter Secretariat, public data, KSE calculations.

Municipal services and utilities

Damages to water supply and sewerage facilities, and household waste management amount to \$3.5 billion. The infrastructure of housing and communal services became one of the targets of missile and artillery strikes of the Russian Federation. Constant shelling and hostilities made it impossible or significantly difficult to carry out repair work, which led to a prolonged shutdown of water supply systems. In some cities, residents did not receive housing and communal services for a long time and did not have proper access to drinking water (in some settlements, this continues to this day).

For example, due to damage to the water supply, most districts of Mykolaiv were left without centralized water supply for a long time. The water supply system was restored only after the liberation of Kherson in November 2022, and until that moment only technical water was available in the city, drinking water was delivered from other cities in bottles. which led to the need to install generators and accelerated the depreciation of assets.

Table 13. Assessment of damages to the housing and utilities sector.

Types of costs	Measurement unit	Initial number of facilities	Destroyed	Damaged	Damage assessment, \$ bln.
Water treatment plants	pcs	400	7	18	0.36
Sewage treatment plants	pcs	967	23	28	1.03
Water pumping stations	pcs	5,646	109	73	0.24
Sewage pumping stations	pcs	2,908	63	120	0.35
Water supply networks	linear m	98,076,470	1,947,026	0	0.54
Sewerage networks	linear m	37,053,200	582,863	0	0.75
Wells	pcs	22 134	125	34	0.02
Laboratories	pcs	n/a	4	2	0.001
Clean water tanks	pcs	2,129	33	4	0.04
Water towers	pcs	695	101	38	0.02
Containers for household waste collection	pcs	n/a	23,145	0	0.02
Garbage trucks	pcs	3,669	222	0	0.05
Landfills for household waste disposal	pcs	5,969	12	21	0.07
Waste sorting lines	pcs	34	3	2	0.01
Container sites	pcs	n/a.	813	97	0.001
Biogas plants	pcs	21	3	0	0.01
Total	n/a	n/a	n/a	n/a	3.47

Source: State Statistics Service, Ministry of Development of Communities and Territories of Ukraine, regional military administrations, NBU, market data, expert assumptions, розрахунки calculations etc.

Digital infrastructure

Damages to telecom operators are estimated at \$1.2 billion. The sector of electronic communications includes Internet networks of fixed operators, radio networks of mobile operators, backbone networks, as well as electronic communications. Almost a thousand operators of electronic communications of fixed access to Internet networks suffered damages as a result of hostilities. After the de-occupation of settlements, the destruction of networks reached 100%. Thousands of base stations of mobile operators were destroyed.

The determination of the cost of damages for owners of electronic communication network infrastructure of different categories differs.

1. National companies, electronic communications operators that provide electronic communication services to citizens of Ukraine throughout its territory. Damages are determined based on the results of inspection/inspection of destroyed or damaged infrastructure facilities of electronic communication networks, if there is access to them (even if possible in officially uncontrolled territories). The amount of damage is set in physical units (km, pcs., etc.), and is also estimated in money, based on an approximate estimate of the cost of restoration work. In particular, the damages to mobile operators are calculated on the basis of data provided by the largest operator (Kyivstar) and extrapolated to the entire market in proportion to market share.
2. Medium (provide services in several regions), and small (within the region). Damages are calculated through the estimated cost of network restoration/reconstruction or through the average monthly fee for 24 months.

