Report

Rebuilding Ukraine: Investment Opportunities *in* Innovative *and* Sustainable Construction

Private sector opportunities

October 2025

In partnership with

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation
Швейцарська Конфедерація

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Acknowledgements

This report was prepared by Antoine Coste and Victoria Tetyora, both in IFC's Country Advisory and Economics team for Europe. Oleksiy Imas (consultant) was a core team member for the analysis and drafting. The team worked under the guidance of Ines Rocha, Javier Suarez, and Lisa Kaestner.

The report is based on the deep dive analyses of selected innovative and sustainable construction materials and solutions performed by IFC with the help of EY Ukraine in 2024. The project was funded by Switzerland whose support is gratefully acknowledged and highly appreciated.

The team is grateful for the feedback and input received from colleagues at IFC and the World Bank at different stages of the project, including Sacha Backes, Adalberto Guerra Cabrera, Lucio Castro, Alberto Criscuolo, Tom Farole, Michelle Marie Farrell, Yekaterina Foster, Tengiz Gogotishvili, Ellen Hamilton, Prashant Kapoor, Denis Medvedev, Mai Nguyen, Ommid Saberi, Marek Stec, Margarita Talavera, Shawn W. Tan, Oksana Varodi, Eduard Yakubov, and Marcia Yu. The analysis also benefited from feedback and suggestions received from stakeholders in Ukraine, including the Ukrainian Association of Building Materials Producers, and the Kyiv School of Economics.

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Acronyms

AAC	Autoclaved Aerated Concrete
BEC	Building Energy Code
BFRP	Basalt Fiber-Reinforced Polymer
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CDW	Construction and Demolition Waste
CE	Conformité Européenne (European Conformity)
CO_2e	Carbon Dioxide Equivalent
CWDMR	Construction Waste and Debris Management and Recycling
DREAM	Digital Restoration Ecosystem for Accountable Management
EDGE	Excellence in Design for Greater Efficiencies
EU	European Union
FDI	Foreign Direct Investment
GFA	Gross Floor Area
GHG	Greenhouse Gas
GoU	Government of Ukraine
HVAC	Heating, Ventilation, and Air Conditioning
IDP	Internally Displaced Person
IFC	International Finance Corporation
IFI	International Financial Institution
JV	Joint Venture
LCA	Life Cycle Assessment
LC3	Limestone Calcined Clay Cement
M&A	Mergers and Acquisitions
MFB	Multi-Family Building
NECP	National Energy and Climate Plan
OPC	Ordinary Portland Cement
PVC	Polyvinyl Chloride
R&D	Research and Development
RDNA4	Fourth Rapid Damage and Needs Assessment
SAM	Serviceable Addressable Market
SFH	Single-Family House
SSSU	State Statistics Service of Ukraine
TAM	Total Addressable Market

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Executive Summary

BACKGROUND AND OBJECTIVES

Rebuilding Ukraine is a historical challenge. Ukraine's infrastructure and building stock have been heavily damaged since the start of Russia's invasion in February 2022. As of end 2024, 13 percent of the total housing stock had already been damaged or destroyed, and a large share of the country's infrastructure has been affected in all major sectors (e.g., energy, transport, telecommunication, industrial, social). Total investment needs for recovery and reconstruction were estimated at over half a trillion dollars over a decade, with housing accounting for the largest share. Ukraine's economy has been deeply affected by the invasion, although it has proven resilient and has started to rebound, and public finances are strained. Moreover, the invasion has had major social impacts, including a steep decline in living standards, which puts the issue of housing affordability in sharp focus. It has also led to massive population displacement, with much uncertainty remaining about future returns.

Scaling up private investment and innovation can turn the reconstruction into an opportunity to modernize Ukraine's housing stock and construction industry. The recent destruction and challenges, including steeply rising construction costs and severe labor shortages, have come on top of longstanding weaknesses in the housing and construction sectors. This notably relates to the use of outdated processes and lack of technological innovation in materials production, as well as to low building quality inflating the sector's energy and carbon intensity. The construction industry will need to scale up and modernize to respond to the large reconstruction needs and enable Ukraine to improve the sector's performances and align with global market trends and European Union (EU) standards.

This study investigates the role that innovative and sustainable construction materials and technologies can play in Ukraine's reconstruction, with a focus on private investment opportunities. It seeks to contribute to several policy priorities, including (i) repairing and rebuilding quality and affordable housing fast to address the population's needs (especially multi-family buildings – MFBs), (ii) ensuring efficient use of scarce energy, materials and labor, and (iii) improving building energy efficiency and resilience. Additionally, it seeks to align with the Government of Ukraine (GoU)'s objectives to decarbonize the economy, strengthen energy security, and meet EU accession requirements. While GoU has a key role to play in Ukraine's reconstruction and recovery, the determinant factor will be the capacity to mobilize private capital, both domestic and foreign, to increase production capacity and introduce innovative technologies.

HIGH-POTENTIAL CONSTRUCTION MATERIALS AND TECHNOLOGIES

The construction industry remains an important sector in Ukraine and its share in the economy is likely to increase during the reconstruction. The construction value chain, from material production to real estate development, is dominated by the private sector, mostly by local companies although international firms are present in some materials (e.g., cement, insulation wool) and construction segments. Despite shortcomings in professional standards, poor reporting practices and a legacy of controversial construction projects by some developers, the construction industry has been quite effective over the past decade in producing new real estate in significant quantity, if not quality, and has proven resilient during the ongoing crisis.

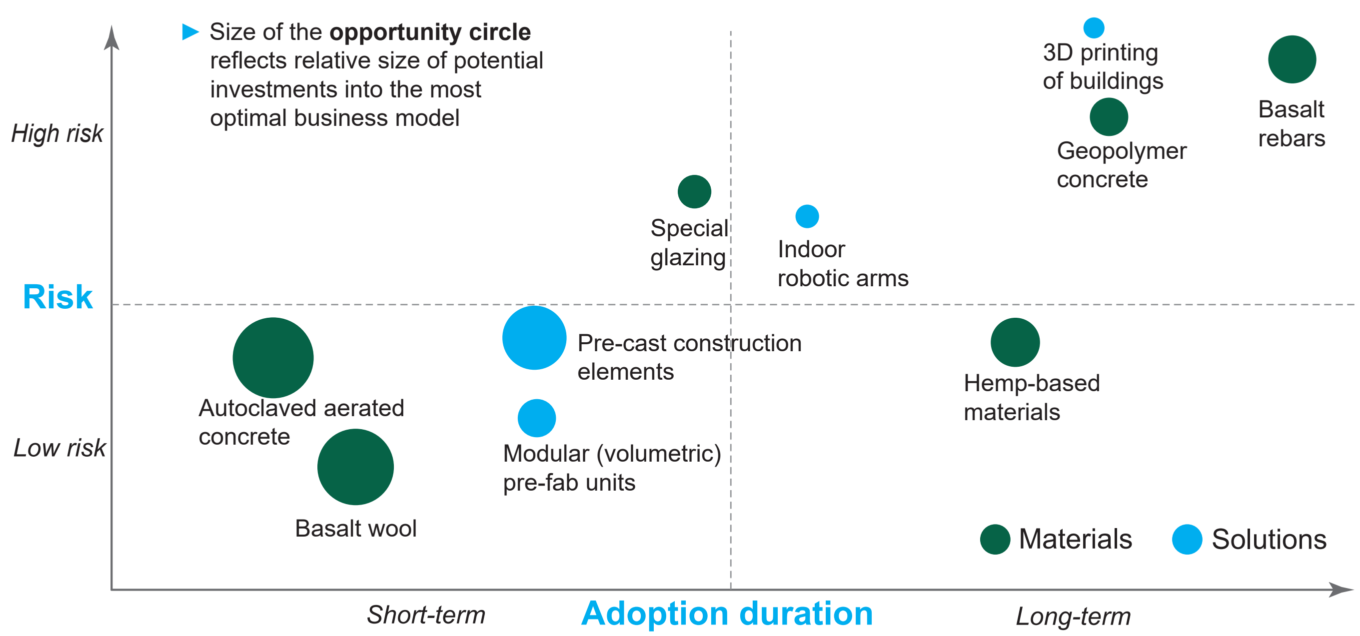
The reconstruction of Ukraine will require large volumes of construction materials, both traditional and more innovative ones. According to several estimates, domestic production should be able to fill most of the expected surge in basic materials demand (e.g., cement/concrete, steel, bricks, mineral wool), as investments planned by Ukrainian and international players should help fill potential supply gaps or replace previously imported materials (e.g., float glass). On the other hand, scaling up the use of alternative construction solutions remains a largely untapped opportunity to build back more efficiently and sustainably. However, their adoption in Ukraine has historically lagged advanced economies for different reasons, including a low focus on energy efficiency and sustainability in construction and lack of supporting policies, complex certification procedures for new materials and the lack of specialized testing laboratories, developers' and end customers' lack of familiarity, etc.

The study focuses on an illustrative subset of high-potential construction materials and technologies with large long-term addressable markets and opportunities for entry of new investors in Ukraine (Table A). These were selected using several prioritization criteria (e.g. replicability and scalability, automation, environmental sustainability, economic benefits, affordability, EU alignment), resulting in a mix of solutions already used in Ukraine that could be scaled up in the short term and opportunities that could be developed over a longer horizon (Figure A). Several shared characteristics make them particularly suitable to the Ukrainian post-invasion context and build back better agenda. These include better technical performance than traditional alternatives, relative affordability, local availability of raw materials, higher energy efficiency, lower environmental footprint, factory standardization enabling faster and higher quality on-site construction, and process automation.

Table A. Selected construction materials and technologies

Efficient and sustainable materials	High-speed construction solutions
Autoclaved aerated concrete (AAC) blocks and panels	Pre-cast concrete elements
Basalt-based materials (wool, rebar)	Prefabricated modular volumetric units
Geopolymer cement/concrete	Indoor robotic arms
Hemp-based materials (wool, hempcrete)	3D printing of buildings
Special glazing products (low-e glass, safety glass)	

Figure A. Selected materials and solutions: reward-risk-adoption opportunity map



Source: IFC estimates

- **The potential market for innovative construction materials during Ukraine's reconstruction is considerable.** Acknowledging the significant uncertainty about reconstruction needs and based on several adjustments and hypothesis, Table B summarizes this report's estimated market opportunity over the next decade for each of the selected materials and solutions.[1] These represent hundreds of million square meters of construction and are substantial enough to warrant attention from both global and local players. Additionally, several materials could tap export opportunities on top of addressing local market needs, notably low-carbon alternatives.

Table B. 10-year Serviceable Addressable Market (SAM)

Materials/solutions*	GFA (mln m²)		Materials/units required**		
	Low	High	Low	High	Unit
Basalt wool	210	400	4	8	mln tons
AAC	45	85	18	34	mln m3
Special glazing	50	90	36	65	mln m2
Hempcrete	10	20	1.5	3.0	mln tons
Geopolymer cement	60	115	30	58	mln tons
BFRP rebars	35	65	0.5	0.9	mln tons
Pre-cast elements	30	60	n/a	n/a	n/a
3D printing of buildings	0.5	1	10	50	gantry systems
Indoor robotic arms	70	130	n/a	n/a	n/a

In the current Ukrainian market context, different market entry models for private investors are likely to be better suited for each material and solution. For each, this depends on several factors, including current market competitiveness, pre-existing conditions, development maturity, investor interest/pledges during the invasion. Based on expert judgement, historical transaction experience in Ukraine and stakeholder interviews, Table C presents a high-level assessment of the range of market entry options and their suitability for particular materials and solutions, which are further discussed in the report.

Table C. Suitability assessment of potential market entry models in current Ukrainian context

	1. M&A	2. Brown-field	3. Green-field	4. Loans	5. Venture	6. Raw materials	7. R&D	8. Equipment lease	9. Services
AAC	+++	+	+	++	+	+			
Basalt wool	+++	+	+	+++					
Pre-cast elements	++	+++	++	++	+	+	+		
Modular (volumetric) prefab	+	+	+++	++	++				

[1] See the main report for details about the assumptions and calculations.

	1. M&A	2. Brown-field	3. Green-field	4. Loans	5. Venture	6. Raw materials	7. R&D	8. Equipment lease	9. Services
Hemp-based products	++	+++	+++	+	++	+++	++		
Special glazing		+++	+	+		++			
Geopolymer cement		++	++	+	+++	++	+++		
BFRP	++	++	++	+	++		+++		
Indoor robotics			+	+	+++		+++	+++	++
3D printing of buildings			+	+	+++		+++	+++	+++

+++ (best suited)   ++ (average)   + (possible but unlikely)

Source: IFC assessment

POTENTIAL AGGREGATE ECONOMIC AND ENVIRONMENTAL BENEFITS

Scaling up the production and use of innovative and sustainable construction solutions could bring EUR 4 billion in private investment and contribute to creating over 17 thousand direct and indirect jobs (Table D). These substantial economic benefits are derived from the estimated market opportunities in the different materials and technologies. The realization of these opportunities would also generate other direct benefits, including additional tax revenue and new export opportunities, as well as more indirect benefits, such as the development of supply linkages with local companies, transfers of technology and know-how, reduced energy consumption from buildings, etc.

Table D. Potential direct investment CAPEX and new jobs

Material / solution	Unit	Extra capacity needed, mln units*	10-year additional cumulative capacity range**	CAPEX per unit, EUR	CAPEX, mln EUR	Direct jobs	Indirect jobs***
Geopolymers	tons	8	30 – 58	170	1,360	4,000	2,500
Concrete pre-cast	m^2 GFA	6	30 – 60	250	1,500	2,000	1,200
Basalt wool	tons	0.7	2.9 – 6.9	600	420	2,100	1,000
Basalt rebars	tons	0.1	0.5 – 0.9	4,200	420	2,000	1,000
Hempcrete	tons	0.5	1.5 – 3.0	40	20	400	250
AAC	m^3	1	0 – 15	100	100	400	200
3D printing for construction	gantry system + workshop	50	0.5 – 1	1	50	100	100
Special glazing	m^2	8	0 – 8	9	72	60	40
Total					3,942	11,060	6,290

Source: IFC analysis, based on industry expert interviews, publicly available data on transactions

Scaling up the use of sustainable materials and solutions could make a decisive contribution to the needed decarbonization of Ukraine's construction sector. This sector is a major source of GHG emissions globally and in Ukraine, and decarbonizing it is essential for Ukraine to meet its international commitments and EU requirements, as well as to remain competitive in export markets. Due to their production processes and technical performances, alternative construction materials and solutions are a promising way to reduce energy and raw material consumption across different stages of the construction value chain, which can be leveraged early to decarbonize the sector in parallel with investments in clean energy. Based on the estimated addressable markets and considering GHG savings from production processes and building performance compared to traditional options, high-level estimates suggest that total potential savings could reach up to 79 million tons CO_2e over a decade (Table 12). Assuming emissions grow in line with projected GDP recovery during this period, this would represent around 2.5 percent of Ukraine's total cumulative emissions. The estimated savings are equivalent to permanently taking over 1.6 million gasoline-fueled passenger cars off the roads, or about 20-25 percent of the pre-invasion car fleet. They could contribute to achieving the target Ukraine committed to under the Paris Agreement and reflected in the National Climate and Energy Plan (NECP) approved in 2024, i.e. to reduce national GHG emissions by 65 percent by 2030 (compared to the 1990 level) to 321 million tons CO_2e.

Obstacles to private investment and needed reforms or interventions

POLICIES, REGULATIONS AND STANDARDS

The adoption of new, more sustainable construction materials and technologies in Ukraine is undermined by the lack of adequate regulations and standards across the value chain. The modernization of Ukraine's outdated construction legislation has gradually gained momentum over the past decade. Reforms have intensified since 2022, focusing on harmonization, streamlined procedures, and attracting investment for reconstruction and local production. The policy framework on building energy efficiency has also been developed, but it can be further strengthened and better enforced**.** Lack of specific construction standards and/or unclear regulations for innovative materials and solutions also prevent their broad use. Overall, there is still significant scope to strengthen the implementation of Ukraine's construction legislation and to continue aligning it with the EU's evolving standards (e.g. Regulation 2024/3110 of November 2024), notably on matters related to materials and building sustainability. Moreover, voluntary green building standards can be an important complement to mandatory energy efficiency regulations by promoting best practices and market transformation, but their use remains marginal in Ukraine.

ACCESS TO FINANCING

Access to long-term finance is one of the key constraints that can hold back greenfield or brownfield investment in the supply of construction materials in Ukraine. Banks, which dominate the domestic financial sector, have historically provided limited project financing loan facilities or M&A financing, leaving many firms to finance investments out of their own balance sheet. Capital markets, another important source of debt and equity financing in developed markets, remain nascent in Ukraine despite plans to support their development. Likewise, access to external financing for investment projects is difficult for most firms. GoU has developed several support programs for private investment in recent years, such as "invest nanny" and industrial parks, which can benefit projects in the construction materials sector.

Developing green finance is another relatively unexplored avenue to foster invest-

ment in the production of sustainable construction materials. Globally, corporate and government-issued sustainability-linked bonds with terms linked to achieving certain targets or green bonds have been rapidly growing instruments to channel funds to sustainable projects. These instruments are not yet well developed in Ukraine in the absence of sufficiently mature regulatory and institutional frameworks, and they remain underutilized in the construction sector. Adapting and mobilizing these tools could significantly expand access to capital for both new and ongoing investments.

BOOSTING DEMAND

Support will likely be required at least initially to make sustainable construction more affordable and attractive to end-users. A critical challenge is bridging the affordability gap associated with many innovative and sustainable materials, which often carry an initial price premium even if they can lead to energy and financial savings over the building lifecycle. This is especially the case for materials with less mature market penetration levels, such as geopolymer and low-carbon cement/concrete, basalt FRP rebars, hemp-based materials, and special glazing. Green mortgages and demand-incentivizing programs can stimulate their interest in sustainable buildings and help bridge this gap.

Embedding sustainability criteria in the selection of public investment projects could help stimulate demand for innovative and sustainable construction materials and reduce costs. Public investment will be a major driver of Ukraine's reconstruction, and the ongoing modernization of Ukraine's public investment management framework is an opportunity to foster sustainable construction. Many projects remain of relatively low technical quality. Architects and developers are often unfamiliar with innovative and sustainable construction materials and solutions, while public authorities behind projects tend to lack incentives to prioritize sustainability and resilience. Increasing the weight given to energy efficiency, resilience and sustainability/circularity in the competitive selection of projects to be financed could shift incentives for municipalities to prepare more sustainability-focused projects.

OTHER CONSTRAINTS

Several other issues can undermine the uptake of new materials and solutions in the Ukrainian construction market. They notably include the following:

- **Perceptions and market readiness:** In the absence of sufficient experience, both households and industry professionals are likely to resist change and to question the quality, safety and durability of construction built using new generation technologies. Awareness raising and evidence-based trust building targeting both the supply and demand sides of the industry are critical to ensure market entry and scaling success.

- **Skills and knowhow:** Lack of skilled workforce and required expertise is a significant risk when attempting to introduce new or lesser-known materials and solutions, requiring adapted (re) training initiatives and vocational education programs.

- **Quality infrastructure:** The lack of testing equipment, certification and traceability systems makes it difficult to certify compliance with standards and can undermine trust in claims about material content, performance, or origin (especially for recycled materials). This can also increase the time and cost burden on manufacturers seeking certifications, such as CE marking required for export to the EU.

- **Circularity framework:** The absence of clear regulatory guidance on and enforcement of end-of-life recycling creates uncertainty around circularity, including unclear cost forecasts and low preparedness for future reforms to foster material recycling.

1. Introduction

Background

Ukraine's infrastructure and building stock have been heavily damaged since the start of Russia's invasion in February 2022. The 4th Rapid Damage and Needs Assessment (RDNA4), prepared by the World Bank Group with the Government of Ukraine (GoU) and international partners, estimated total direct damages at $176 billion by end 2024 (World Bank 2025).[2] The housing sector accounts for the largest share ($58 billion, almost a third of the total), as 13 percent of the housing stock was damaged or destroyed, affecting over 2.5 million households. A large share of the energy, transport and telecommunication infrastructure, as well as facilities in the education, health, commerce and industry sectors, have also been affected. For instance, 3,373 educational institutions (about 10 percent of the stock) have suffered damage, including 385 that were destroyed.

[2] Unless otherwise specified, all quantitative data presented in this chapter has been directly sourced or synthesized from the RDNA4 Report.

The invasion has had major social impacts and has led to massive population displacement, with much uncertainty remaining about future returns. In 2023, 36 percent of Ukrainians lived in poverty and 9 percent in extreme poverty, an increase of 15 and 8 percentage points, respectively, compared to 2021 (Cherenko 2024). As of early 2025, around 6.9 million Ukrainians were registered as refugees outside of Ukraine and 3.6 million as internally displaced persons (IDPs), representing almost a quarter of the 2021 population (UNHCR 2025, IOM 2025). This has worsened the demographic decline experienced in Ukraine since the fall of the Berlin Wall, due notably to migration and low fertility. While a significant number of refugees have already returned to Ukraine, continued attacks have resulted in further emigration waves since 2024. Estimations of the number of refugees that may return after the cessation of hostilities vary, but it seems likely that a significant share will remain abroad (particularly women with young children) and that the lifting of travel restrictions will lead to some departures.[3] In addition to a decrease in security risks and uncertainty, addressing issues regarding housing, employment and basic services (e.g. healthcare, education) will be crucial to encourage returns.

Ukraine's economy has been deeply affected by the invasion, although it has proven resilient and has started to rebound. Sound policies and strong external support have helped GoU maintain macrofinancial stability throughout the crisis. After contracting by almost 29 percent in 2022, Ukraine's GDP has grown modestly since 2023 despite continued attacks, including major targeted attacks on the power infrastructure resulting in an energy supply crisis, and increasingly severe labor shortages, which have particularly affected traditionally male-dominated sectors, including construction. However, in 2024 the economy remained over a fifth smaller than in 2021 and it will take several more years to fully recover. The trade balance has been negative since 2022 and is expected to remain so in the medium-term. Public finances have been strained, and significant efforts will be required to restore fiscal and debt sustainability, reinforcing the need to mobilize domestic and foreign private capital to finance reconstruction efforts. However, as of mid-2025, FDI inflows remained below 2021 levels, with reinvested earnings by multinationals companies already present in the country accounting for the largest share since 2023.

The reconstruction of Ukraine will require a massive increase in investments over a long period of time. The RDNA4 estimated that, as of end-2024, total recovery and reconstruction needs over 10 years already reached $524 billion (almost three times Ukraine's estimated GDP in 2024), with housing accounting for the largest share at $84 billion. Thousands of emergency repairs and reconstruction projects have already been launched to rebuild critical housing, energy and other infrastructure, with support from GoU, local governments international partners and domestic organizations. The GoU notably created a centralized Registry of Damaged and Destroyed Property to monitor damages and repairs and has supported affected households through various compensation programs.

Strengthening the private sector in construction value chains is crucial for reconstruction. Ukraine's construction sector was lagging regional peers in both investment per capita and output before the invasion, and will need to develop considerably. With expanded capacity, domestic production could fill most of the expected surge in materials demand, saving on reconstruction costs, to the extent it would be cheaper than imports, and could tap export opportunities.[4] Investments planned by Ukrainian and international players should help fill potential supply gaps

[3] Based on survey data collected in end 2024, one study estimated that the number of refugees staying abroad could range between 1.7 million (optimistic) and 2.7 million (pessimistic), while the lifting of travel restrictions could result in 290 thousand (optimistic) to 532 thousand (pessimistic) new departures (CES 2025).

[4] An early assessment estimated that, as of end-2022, up to 90 percent of the construction materials needed could be supplied by Ukrainian manufacturers, representing 100,000 jobs, $5.6 billion in wages and $4.4 billion in tax revenue (USAID 2023). Some estimates suggest that the construction industry's contribution to GDP could increase to 10 percent in the reconstruction phase, up from around 4 percent before the invasion (GMK Center 2025).

for some key materials, such as float glass[5], cement/concrete and mineral wool (EY 2024, USAID 2023). However, the uptick in demand, combined with factors including factory destructions, the energy crisis, supply chain disruptions and depreciation of the Ukrainian Hryvnia, has resulted in average price increases of 40-60 percent for construction materials between February 2022 and May 2025 (Interfax Ukraine 2025). Labor shortages due to mobilization and emigration have also inflated salaries for both skilled and unskilled jobs, up 15-40 percent per year in material manufacturing and construction (KSE 2024), with many companies reporting difficulties staffing their projects with enough qualified workers. Overall, these factors have resulted in construction costs almost doubling since 2022, a trend that was expected to continue as of May 2025. This has amplified construction value chain operators' efforts to optimize costs, including through materials and technologies enabling savings on energy, material and labor costs.

It is essential to establish an enabling environment for private investment to flow into the construction sector after the invasion. Global construction companies have shown strong interest in Ukraine's reconstruction prospects, illustrated by the large attendance at various international exhibitions and conferences since 2023 (NY Times 2023).[6] However, few investors, especially foreign ones, have been willing to start large construction or manufacturing projects while the invasion is ongoing. Considerable uncertainty remains, particularly about the timing of reconstruction, the magnitude of needs and the level of demand in different regions. The GoU has notably sought to reduce risk levels by developing war risk insurance and to reward early investors. Targeted government initiatives and reforms will also be needed to reduce other constraints likely to hold back private investment in new construction materials and technology, related to the regulatory framework and standards/certification systems, as well as the availability of adequate financing mechanisms and skilled labor.

The reconstruction is an opportunity to modernize Ukraine's housing stock and construction industry. The recent destruction comes on top of longstanding weaknesses in the housing and construction sectors. Most multi-family buildings (MFBs) date from the Soviet period, have exceeded their design lifespan and are highly energy inefficient, due to both design and deferred maintenance (World Bank 2025). Buildings accounted for 40 percent of Ukraine's energy consumption before 2022, with energy intensity and reliance on fossil fuels far exceeding European averages (WWF and BCG 2022). The production of basic construction materials has also been highly energy intensive and partly reliant on obsolete technologies, such as wet processing for cement. In line with the GoU's objective to "build back better", investment should as much as possible be directed in priority towards projects integrating energy efficiency, clean energy and material circularity (BPIE 2024). The RDNA4's assessment of reconstruction needs is therefore based on the transition to modern, low-carbon and resilient construction, consistent with global trends and European Union (EU) standards. Globally, digitalization and the use of new techniques and materials are reshaping the industry. In emerging markets, the evidence shows that greening construction value chains and aligning with international green building standards can yield major financial and carbon savings, as well as large investment opportunities, although it requires adequate financing options (IFC 2023). In Europe, there has also been a growing focus on better managing construction and demolition waste (CDW) and making construction value chains more circular (EEA 2023).

5 There has been no domestic production of float glass in Ukraine since 2014 and all needs were met through imports before the invasion, primarily from Russia and Belarus.

6 For instance, the 4th international exhibition and conference "*ReBuild Ukraine: Construction & Energy*", which took place in Warsaw on November 13th-14th, 2024, was attended by 5,500 participants from 30 countries and about 500 international exhibiting companies.

Study objectives and scope

This study investigates the role that innovative and sustainable construction materials and technologies can play in Ukraine's reconstruction. Its objective is to assess the scope for, and potential impacts of, scaling up private investment in such construction solutions, the needed financing volumes, and the required enabling reforms and interventions. In so doing, the report intends to inform the GoU, construction sector stakeholders and international community of opportunities for private investors and measures critical for unlocking them. It seeks to contribute to several policy priorities, including (i) speedy repairing and rebuilding of quality and affordable housing to address the population's needs (especially MFBs), as well as other social infrastructure, (ii) ensuring efficient use of scarce energy, materials and labor, and (iii) improving building energy efficiency and resilience. Additionally, it seeks to foster reconstruction efforts' compatibility with the GoU's decarbonization strategy, its policies to strengthen energy security, as well as with EU accession requirements.

A core focus of the study is on identifying viable opportunities for the private sector to invest and develop new markets. While GoU has a key role to play in Ukraine's reconstruction and recovery, the determinant factor will be the capacity to mobilize private capital, both domestic and foreign, to increase production capacity, introduce innovative technologies, strengthen competitiveness in European and global value chains, etc. The study discusses different modalities of private sector engagement related to construction materials and solutions manufacturing, ranging from greenfield investment and privatization to leasing and service provision. Just as importantly, significant private sector involvement is needed in end markets for these materials and solutions, including the development of residential real estate, healthcare and education facilities, and more.

The study provides an overview of opportunities and challenges related to the use of innovative and sustainable materials and technologies for Ukraine's reconstruction. The rest of the report is structured as follows: first, it briefly presents the different solutions considered and discusses their applicability to Ukraine's context; then, it estimates the magnitude of linked market opportunities and identifies possible entry modes for investors; the potential economic and environmental benefits of scaling up the use of these solutions are then analyzed; finally, the report identifies the obstacles that should be addressed for this potential to materialize, related particularly to regulations, financing and other constraints, suggesting interventions that could be taken by GoU and its international partners, industry players and financing ins titutions.

2.
High-potential construction materials and technologies

Overview of Ukraine's construction value chain and real estate market

The construction industry is an important sector in Ukraine's economy, although its weight has been declining. Before the invasion, the production of construction materials employed around 130 thousand people in Ukraine and the value of production reached $16 billion in 2021 (USAID 2023). In 2021, construction materials accounted for about a quarter of Ukraine's goods export, dominated by iron and steel.[7] Excluding materials production, the construction sector accounted on average for about 4.2 percent of jobs (691,000 people as of 2021) and 2.8 percent of GDP during the decade to 2021 (Figure 2).[8] This share has historically been the lowest among countries in Central and Eastern Europe, the Caucasus, and Western Balkans regions (Figure 3). It decreased further below 2 percent in 2022-2023, although it has slightly rebounded in 2024.

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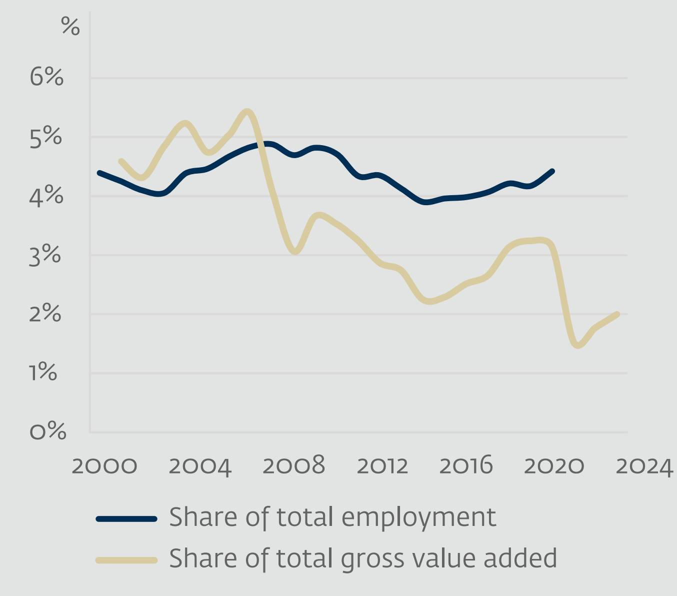
7 *Source:* Observatory of Economic Complexity (*https://oec.world/en/profile/country/ukr*).

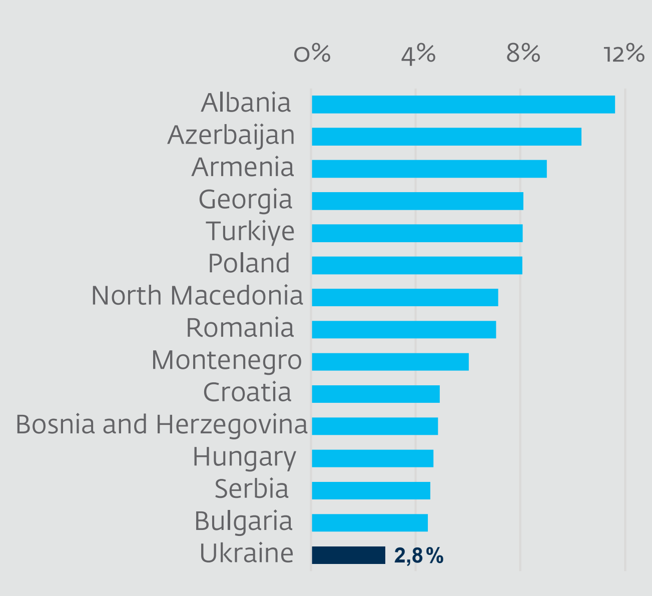
8 *Source:* State Statistics Service of Ukraine.

Figure 1. Evolution of the construction sector's economic weight in Ukraine



Source: State Statistics Service of Ukraine (SSSU)

Figure 2. Construction sector's share of GDP (average 2012-2021)



Source: United Nations Economic Commission for Europe

- **The private sector has gradually come to dominate the construction sector since Ukraine's independence.** The general trend has been a transition from a system dominated by state-owned and technologically outdated general contractors to an expansive ecosystem dominated by private operators. Although data is limited, official statistics suggest that there were about 71 thousand legally registered entities in the construction sector in 2020, comparable to the number of companies in the agriculture and manufacturing sectors.[9] The construction value chain can be broadly split into three categories: (i) Real estate developers, often acting as integrated operators designing, building and owning their projects;[10] (ii) General contractors, providing project design, management and construction services, and generally specialized in specific market segments; and (iii) Design and architectural management and specialized construction firms. The available data suggest that general contractors specializing in transport and industrial infrastructure lead the market,[11] with only a few residential and commercial real estate developers operating on a similar revenue scale. There are practically no state-owned construction companies operating on the market, except in the design and architecture segment where specialized state-controlled institutes provide their services to projects, particularly in infrastructure.[12]

- **The market is dominated by local companies, with foreign presence in several categories.** Domestic producers have dominated construction material manufacturing, particularly in metals and low CAPEX subsectors (e.g., concrete, bricks, AAC), while international corporations are present in some capital-intensive subsectors (e.g. cement) and mid-CAPEX subsectors (e.g., insulation wool). In the developer segment, several foreign investors have stepped in over the past two decades, mostly bringing financing and management capacity. While the residential real

[9] *Source:* State Statistics Services of Ukraine.

[10] As of April 2025, almost 1,300 such companies with at least one completed asset were registered on Dom.Ria, a public database of real estate projects and developers in Ukraine (*https://dom.ria.com/uk/zastroishchiki/*).

[11] Most non-residential infrastructure projects are commissioned by the state through public procurement tenders, a trend that has intensified in the years just prior and during the invasion with repair/reconstruction efforts.

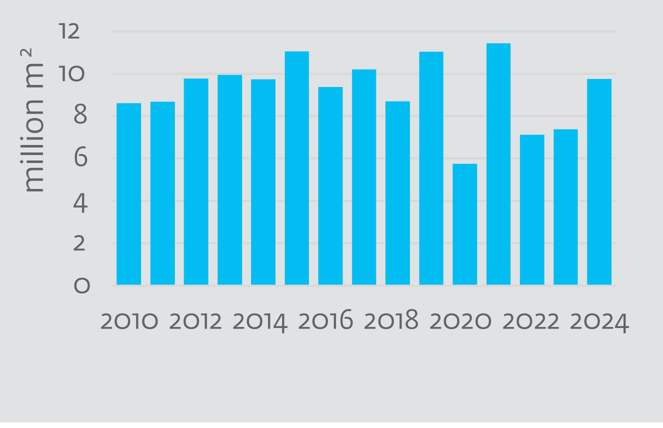
[12] The only large state-controlled developer, Ukrbud, has been prepared for privatization through auctions, and the process was underway as of mid-2025.

estate segment has attracted limited foreign direct investment (FDI), foreign investors, such as Lithuania's BT Invest, have built and managed commercial real estate projects, including shopping malls and retail networks. Likewise, while there are few foreign general contractors, some such as ONUR, one of Turkey's largest construction companies, have actively engaged in large transport infrastructure projects in Ukraine. This status quo may change in the future, as recent updates to Ukrainian legislation significantly simplified the participation of foreign-owned construction operators in Ukraine.[13]

- **Shortcomings in professional standards, poor reporting practices and a legacy of controversial construction projects by some developers have undermined trust in construction companies and stifled their access to external financing.** Developers do not go through any licensing or comply with any enforceable professional code of conduct, and they are not required to bring a minimum of their own equity. They often use leased public land from local governments, with no rules about when such off-plan presales can start to be commercialized. There is no enforcement about the timing of title transfers. In addition, different types of risky and opaque schemes to mobilize payments from clients have left many exposed to significant risks (e.g., uncompleted or delayed construction, poor quality, multiple presales of the same unit, missing permits and authorizations). These factors have contributed to a general lack of trust from homebuyers, banks, and foreign private and institutional investors. As a result, only companies with significant financial stability can operate systemically and deliver projects.

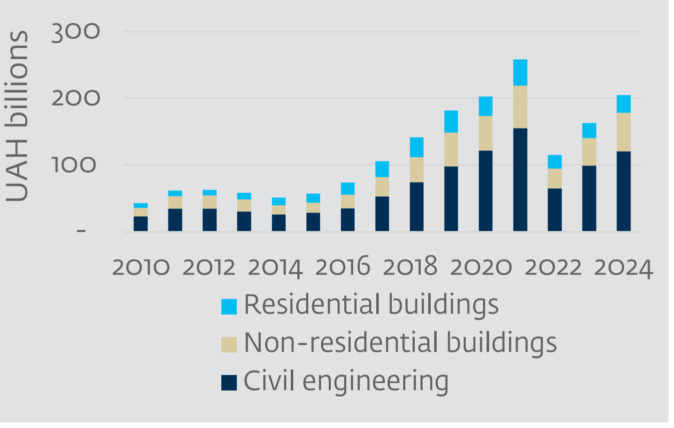
- **Despite these issues, the construction industry has been quite effective over the past decade in producing new real estate in significant quantity, if not quality.** The volume of new housing delivered was relatively stable in the decade preceding the invasion at almost 10 million square meters annually or about 1 percent of Ukraine's total residential stock.[14] After dropping in 2022-2023, it recovered to this level in 2024 (Figure 4). In value terms, the construction market has been driven by projects in the civil engineering and non-residential segments (Figure 5). New construction accounted for about 41 percent of the total value of projects, repairs for 33 percent, and reconstruction and technical re-equipment for 26 percent. Despite the encouraging growth trend, as of March 2025 some experts estimated that it would take 4-5 years for the construction market to recover to 2021 level (GMK Center 2025).

Figure 3. Volume of new housing delivered in Ukraine



Source: SSSU

Figure 4. Value of completed construction projects in Ukraine



Source: SSSU

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[13] Council of Minister of Ukraine Decree #925 (August 9th, 2024).

[14] As of early 2022, there were 8 million residential buildings in the county, with a total living space area of about 890 million square meters.

- **The moderate downturn of construction activity in 2022-2023 and its rebound since then can partly be attributed to the remarkable resilience of the Ukrainian construction materials sector.** The invasion has initially caused significant disruptions, including damage to and destruction of production capacities, especially those located in the eastern regions of Ukraine, and breakdown of critical cross-border supply chains, especially discontinued imports of certain materials that were largely or even exclusively sourced from Russia and Belarus (e.g. float glass)[15]. However, despite initial fears of supply failure in 2022, the sector has quickly adjusted to adverse impact on domestic demand caused by the high prevailing uncertainty, migration dynamics and drop in disposable income, notably by realigning the supply chain routes to the European Union and other large markets, such as Türkiye. In addition to challenging security conditions, major constraints faced by construction materials producers in recent years have included power outages, rising wage and input costs, and severe labor shortages.
- **The affordability of housing will continue to be an important issue in the real estate market.** Housing prices in Ukraine have continued to rise during the invasion, reducing affordability for households. The price-to-income ratio, a key measure of housing affordability, has increased from 10.8 in 2021 to 12.2 by early 2023, and further to 13.1 as of mid-2025.[16] This far exceeds the affordability benchmark of 5.0, indicating that housing is becoming increasingly out of reach for most Ukrainians, due mainly to the decline in living standards and increase in poverty since 2022, as well as to the increasing input costs for new construction. In this context, housing price and affordability will be crucial factors influencing whether individuals pursue homeownership, take on mortgages, or opt for long-term rentals. These pressures present a significant challenge to sustaining medium-term housing demand. In the absence of adequate financing solutions, it will also likely restrain the demand for higher quality, more expensive construction and retrofits using innovative materials and solutions.

Expected demand for materials and local production capacity

The reconstruction of Ukraine will require large volumes of construction materials, both traditional as well as more innovative ones. Given the magnitude of destruction and the diversity of affected sectors, it is important to assess the current and projected capabilities of Ukraine's construction materials manufacturing sector vis-à-vis the expected drivers of demand, including the following:

- The variety of construction segments, including residential/commercial buildings and civil infrastructure, will require significant volumes of cement/concrete, rebars, bricks, insulation materials, glazing and polyvinyl chloride (PVC) profiles. Traditional reinforced concrete (monolith) construction with bricks or panels used as non-load bearing wall materials have been a staple of Ukrainian construction for decades and will likely remain so in the reconstruction phase.
- Under a law adopted in July 2023,[17] the requirement for bomb shelters to be included in or adjacent to every new significant construction object will require additional volumes of both concrete and rebars. This will increase the demand for these materials and could open opportunities to introduce more sustainable alternatives.

[15] The production of float glass involves floating molten glass on molten metal and ensure a uniform thickness and flat surface needed for use in construction.

[16] *Source:* (Numbeo 2025)

[17] "*On Amendments to Certain Legislative Acts of Ukraine on Ensuring Civil Protection Requirements during Planning and Development of Territories*" (Law No. 3277-IX, adopted on July 27, 2023).

- The thousands of education and healthcare buildings needing to be rebuilt and upgraded in line with modern standards for such facilities could stimulate the demand for more advanced and sustainable materials while also improving energy efficiency, indoor air quality, etc. of buildings.

- Although they only accounted for 12 percent of damaged housing units as of end-2024, single-family houses (SFHs) represent a large gross floor area and will likely be another important driver of demand for alternative construction materials. Due to the nature of such housing – single floor or low-rise, no insulation synergies with adjacent housing units, etc. – some modern materials that are more energy efficient and greener but have lower load-bearing capacity are particularly suitable to this real estate segment.

Ukraine's construction materials manufacturing sector can continue satisfying domestic demand during the reconstruction, with positive employment impacts. Local production of basic structural materials (e.g., cement, concrete, long steel, dry mixes, roofing materials, ceramics, drywall, paint and varnish, insulation products windows, doors, PVC profiles, etc.) largely met the needs prior to the invasion, amounting to $16 billion in producer prices in 2021. On the other hand, some finishing materials and other products (e.g., float/architecture glass) that were unavailable locally were imported. While production capacity and supply chains have been affected since 2022, most domestic companies have adjusted and prepared to boost supply to meet the expected increase in demand in the reconstruction and recovery period, which should create new jobs in the sector. Recent studies assessing the industry's capacity to do so found either zero or small projected supply/demand gaps for most basic materials, with the notable exception of float glass (EY 2024, USAID 2023). Demand for some materials (e.g., cement, mineral wool) may exceed existing and announced capacities in peak reconstruction years, but gaps should be easy to manage through imports or scaling of existing capacities (acknowledging that doing so can take a long time for some products, such as cement). Importantly, this assessment is based on several restrictive assumptions about the reconstruction, including the following:

- Reconstruction needs based on estimated damages as of end-2024, the magnitude and precision of which may evolve as destruction grows.

- No further loss of major materials production capacity to occur prior to the start of the reconstruction phase.

- One-to-one recovery of destroyed real estate assets in terms of their gross floor areas, assuming partial population return is partly offset by reconstruction under modern standards with larger average unit size and common use areas.

- Status quo in terms of pre-invasion materials and construction technology market shares, although this may be altered in practice by evolving construction sector dynamics, consumer preferences and introduced policies.

- Assumed rebuilding of lost real estate stock in or near the original premises, although a significant share of losses is in the territories temporarily not under GoU control. Coupled with uncertain internal and cross-border migration dynamics, rebuilding the same volumes of real estate within the same regions may prove to be impossible or unnecessary, and actual demand may be largely covered by rebounding regular construction activity.

Rationale for the studied materials and technologies

With no major supply challenges expected for basic materials, scaling up the use of alternative construction solutions remains a largely untapped opportunity to build back more efficiently and sustainably. When adapted to local conditions, modern materials and technologies can provide a mix of economic, environmental and technical benefits. However, their adoption in Ukraine has historically lagged advanced economies for different reasons, including the following:

- A traditionally low focus on energy efficiency in construction, driven by the need to build housing fast, cheap and in bulk, as well as other factors, such as subsidized energy tariffs for households. In the dominant low/mid class construction segments, developers have tended to use cheap, mass-produced and easy to work with materials readily available in Ukraine and neighboring countries, which also enabled them to obtain the highest profit margins.

- The weak quality and enforcement of domestic materials and construction standards, although, as discussed later in this report, this has started to change with the gradual alignment with the EU acquis.

- Complex certification procedures for materials not yet introduced to the Ukrainian market and the lack of specialized testing laboratories, with construction companies generally unwilling to bear the associated costs.

- The near absence of mass-produced modern/innovative construction solutions within Ukraine, resulting from the lack of demand for relatively more expensive and less common options, as well as from low investment in research and development (R&D) and technology transfer in the local materials manufacturing sector.

- The lack of policy framework to encourage developers to shift to more efficient and sustainable construction, including green building certification, financing products and incentives.

Within the universe of construction materials and technologies, the study focuses on an illustrative subset of high-potential options for Ukraine with large long-term addressable markets and opportunities for entry of new investors. These were selected using several prioritization criteria (e.g. replicability and scalability, speed of deployment, level of automation, environmental sustainability and contribution to decarbonization, economic benefits, affordability, alignment with EU standards), resulting in a mix of solutions already used in Ukraine that could be scaled up in the short term and opportunities that could be developed over a longer horizon. Rather than providing an exhaustive review, the selection is meant to illustrate the different types of opportunities that could be pursued given Ukraine's needs, competitive advantages, and challenges that must be addressed. The selected materials and assessment of related opportunities should thus be taken as indicative for the broader categories they belong to.[18] As summarized in Table 1 and in more details in the following sections, the subset includes both efficient and sustainable materials, and high-speed construction solutions. The study also included a spotlight on the specific case of construction waste and debris management and recycling (CWDMR) (Box 1). Each selected construction solution was assessed in a "deep dive" based on desk-based research and interviews (over 50 in total) with Ukrainian and international experts from construction value chains, the public sector, academia and non-government organizations. These deep dives aimed to identify private sector opportunities and measures that would help re-

[18] For instance, geopolymers are selected as an illustration for the broader category of alternative cement/concrete products, which also includes other innovative and sustainable alternatives to traditional products, such as limestone calcined clay cement (LC^3).

alize them.[19] The scope has also been guided by the following considerations:

- *End markets:* While the selected solutions have a wide range of applications in different construction end markets, the focus is on applicability for social infrastructure recovery, i.e. housing, educational, healthcare, culture and commercial (non-industrial) infrastructure stock. Most of the selected solutions can be used for repairs, which are likely to represent the largest share of reconstruction efforts in the short term. However, the study and its assessment of the market opportunities focuses on needs related to the rebuilding of highly damaged buildings and future new construction, which represents the largest long-term opportunities over the time horizon needed for new investors to enter.

- *Material types:* Finishing materials and solutions, the choice of which is typically driven by consumers from an existing range, were not considered in the study. Instead, the focus has been put on materials used for buildings' outer shell and core (e.g., foundations, load-bearing frames, walls, insulation, roofing, facades and cladding, windows and glazing). The choice for these materials typically rests with construction companies and developers, based on technical features and the balance of affordability vs. material mix compatibility. Such materials also tend to have larger potential serviceable addressable markets.

- *Affordability vs. sustainability:* The study aims to strike a balance between enhanced efficiency and sustainability and affordability for end users. The solutions can be part of decarbonization strategies by enabling material/energy efficient construction or providing substitutes for carbon-intensive materials. However, the study does not cover other important avenues to decarbonize the production of basic materials (e.g. cement, steel, aluminum) by replacing fossil fuels with clean energy, reducing carbon emission associated with traditional processes, or capturing carbon (IFC 2023). The technologies remain costly and/or unviable at large scale, and would require access to more renewable energy resources than is likely to be available in the near future in Ukraine.

Table 1. Selected construction materials and technologies

Efficient and sustainable materials	High-speed construction solutions
Autoclaved aerated concrete (AAC) blocks and panels	Pre-cast concrete elements
Basalt-based materials (wool, rebar)	Prefabricated modular volumetric units
Geopolymer cement/concrete	Indoor robotic arms
Hemp-based materials (wool, hempcrete)	3D printing of buildings
Special glazing products (low-e glass, safety glass)	

19 Key aspects considered included (i) technical characteristics and advantages/limitations; (ii) relevance and viability in the Ukrainian context, including affordability considerations; (iii) trends on the global and Ukrainian markets; (iv) value chain structure and key players; (v) potential market size; (vi) investment opportunities and viable business models; and (vii) regulatory and other constraints to scale up, and needed public support.

EFFICIENT AND SUSTAINABLE CONSTRUCTION MATERIALS

Table 2 presents the main characteristics of the selected efficient and sustainable construction materials.[20]

Table 2. Overview – Efficient and sustainable construction materials

Material	Category	Primary role	Advantages
Autoclaved aerated concrete (AAC)	Walls (load and non-load bearing)	**Alternative to:** bricks and monolithic reinforced concrete construction **Core end markets:** load-bearing wall construction in SFHs, low-rise MFBs and low-rise administrative/ commercial buildings; non-load bearing wall construction in mid- and high-rise MFBs	Well-established and accepted in the Ukrainian market, lightweight, lowest use of energy and raw materials in production amongst core competitive materials and strong insulating properties, highly affordable, versatile, recyclable
Basalt (rock) wool	Thermal insulation	**Alternative to:** glass wool, plastic insulation (XPS/EPS/PU/PE), structural insulated panels[21] **Core end markets:** external thermal insulation in low-, mid- and high-rise MFBs, administrative/ commercial buildings, other civilian infrastructure. Additionally, used extensively as piping systems/HVAC systems thermal insulation	Historical market dominance in the Ukrainian market, lightweight, recyclable, best-in-class insulation material for monolith concrete/ panel buildings – especially for retrofit thermal modernization of old housing stock, affordable
Basalt fiber-reinforced polymer rebars (BFRP)	Foundations, walls, other structural construction elements	**Alternative to:** traditional steel rebars and glass FRP rebars **Core end markets:** all building types, restoration of cultural landmarks/monuments/ historical buildings Additionally, directly tailored to transport infrastructure (roads, railroads, bridges) and construction in marine/ seashore environments	Unique technical features: 100% anti-corrosive/resistant to alkalis and acids and UV-resistant, non-conductive/non-magnetic, does not require welding, extremely lightweight, significantly more environment-friendly than steel rebars
Geopolymer concrete	Foundations, walls, other structural construction elements	**Alternative to:** traditional Ordinary Portland Cement across the full range of cement/concrete construction elements **Core end markets:** all building types	Lower carbon content through partial/full replacement of clinker in cement, superior technical parameters to Ordinary Portland Cement (OPC), versatile usage including for 3D printing cement mixes, abundance of specific industrial byproducts (slag or fly ash) for its binder in Ukraine, enabled by expectation of the EU's Carbon Border Adjustment Mechanism (CBAM) tariffs on clinker cement

[20] See Annex B for more details on each material.

[21] XPS: extruded polystyrene; EPS: expanded polystyrene; PU: polyurethane; PE: polyethylene.

Material	Category	Primary role	Advantages
Hemp-based construction materials (primarily Hempcrete)	Walls (load and non-load bearing)	**Alternative to:** pure concrete and bricks construction **Core end markets:** SFHs, low-rise administrative/commercial/ educational/ healthcare buildings	Carbon-negative material, 100% recyclable, superior technical parameters to alternatives, supports high-speed construction, enabled by Ukraine's agricultural focus, drives wider development of industrial hemp processing ecosystems
Special window/ façade glazing products (Low-E glass, Laminated/ Triplex glass)	Glazing	Specialized glazing with enhanced energy efficiency and safety features **Core end markets:** all building types	Absence of modern float glass production in Ukraine with both simple float glass and Low-E glass 100% imported, growing energy efficiency and building safety demand enabled by rising energy prices, energy crisis and safety considerations

HIGH-SPEED CONSTRUCTION SOLUTIONS

Table 3 presents the main characteristics of the selected efficient and sustainable construction materials.[22]

Table 3. Overview – High-speed construction solutions

Solution	Category	Primary role	Advantages
Pre-cast concrete elements	Pre-cast/ prefab solutions	**Alternative to:** bricks and in-situ monolithic reinforced concrete construction **Core end markets:** all building types	Significant reduction in human labor needs, standardized factory quality of elements, reduction in transportation and in-situ operations costs, versatility of element design, mobility of pre-cast factories, reduced waste and environmental footprint
Prefabricated modular volumetric units	Pre-cast/ prefab solutions	**Alternative to:** in-situ construction of temporary or rapid-need housing and administrative facilities **Core end markets:** rapid disaster recovery needs, temporary housing for construction workers, cheap modular SFHs, ready-made modular specialized room solutions (i.e. kitchen, bathroom pods)	Significant reduction in construction time, cost-efficiency, quick deployment, standardized factory quality, rapid dismantling and/or repurposing
Indoor robotic arms	Robotics	**Alternative to:** human labor tasking in construction (bricklaying, welding, material handling etc.) **Core end markets:** all building types	Process automation, significant reduction in construction time, high precision and efficiency, minimization of construction waste, mobility of equipment

[22] See Annex C for more details on each material.

Solution	Category	Primary role	Advantages
3D printing of buildings	Robotics	**Alternative to:** traditional in-situ construction **Core end markets:** SFHs, low-rise civil infrastructure buildings (administrative, educational). Particularly suitable for rapid construction of cottage towns due to the high mobility of robotic equipment	Significant reduction in human labor needs, construction time, construction waste, CO_2 emissions, mobility of equipment

Box 1. Construction waste and debris management and recycling

CWDMR could play an important role in the reconstruction and modernization of construction value chains over the next decade. The ongoing hostilities have left massive quantities of debris scattered across large areas, although unevenly across the country. While there is no official data, the Kyiv School of Economics estimated there were over 18 million tons of debris as of March 2023 from a wide range of buildings, structures and infrastructure (World Bank 2025). Some experts interviewed as part of this study estimate over 100 million tons of the amount of mixed debris, including debris left in the territories temporarily not under GoU control and debris already sent to landfills or otherwise disposed of over the past three years. While systematic removal is a de facto pre-requisite for mass scale new construction at the same sites, it has been prevented by factors including the proximity to active military activity and the presence of explosives and hazardous materials in the debris mix (e.g., asbestos and other substances used in pre-2000 construction). Overall, the RDNA4 estimated the cost of debris demolition and removal at about USD 6 billion as of end-2024. While this represents a serious challenge, it could also create long-term opportunities to improve the circularity and lifecycle environmental footprint of Ukraine's construction sector and to reduce pressures on new material production capacities in the reconstruction phase.

Transporting, sorting and recycling such volumes of debris would be a decade-long challenge even for countries with advanced recycling ecosystems. Ukraine's waste management systems are nascent. As of 2021, only 7 percent of household waste was recycled (compared to 40 percent on average in Europe), while over 90 percent was sent to about 6,000 dumpsites and landfills, many of which were over capacity and/or not meeting environmental standards. [23]The construction waste recycling market lacks a legal framework, supporting infrastructure and funding mechanisms, limiting Ukraine's ability to harness and scale CWDMR opportunities in the short and medium-term. This has also been hampered by the presence of harmful materials, such as asbestos, in construction and the lack of adequate legal mechanism to classify debris as hazardous or nonhazardous, with no capabilities for carrying out the measurement of asbestos in the debris, or for its proper disposal. While reforms in 2022-2023 aligned national waste regulations with EU standards, promoted a circular economy and established safety norms for handling asbestos-containing materials, the debris management framework remains incomplete. Procedures for permitting and licensing disposal sites, especially for asbestos-contaminated debris, are still lacking, and unclear ownership of debris complicates accountability for its proper handling, recycling, and disposal (World Bank 2025).

23 Vox Ukraine (August 2022) Reform Index Focus: Waste Management Reform. What will change in Ukraine?

Ukraine can look to other countries to draw from good practices. Countries with higher rates of construction waste recovery and diversion from landfills have gradually developed more complex systems to implement the "3Rs" (reduce, reuse, recycle) using different mixes of "sticks" (e.g., regulatory mandates for construction and demolition, landfill taxes) and "carrots" (e.g., subsidies for production and use of recycled material, support for R&D and establishing new recycling businesses). Efficient CWDMR at scale requires operational ecosystems closely associating public and private actors to handle the controlled dismantling of structures, in-situ bulk triage, transportation, off-site sorting and filtering (ideally, at least partially automated) and recycling "low-hanging fruit" debris for consequent reuse in non-structural materials. A conducive policy framework including a mix of regulatory standards and mandates, taxes, incentives and green public procurement policy can help attract private investment in the more commercially viable niches of recycling ecosystems.

Recent efforts in the EU and beyond to decarbonize the production of cement and concrete provide new impetus to CWDMR. In addition to switching to low-carbon energy to power production processes, decarbonization pathways for these materials include changing production formulas to include a higher share of low-carbon aggregates, including from recycled CWD. The gradually increased taxation of the carbon embedded in cement and concrete expected over the coming decades should also increase the commercial viability of using recycled aggregates.

CWDMR systems can be developed gradually in Ukraine, over a time horizon beyond short-term clean-up objectives. Given the nascent stage of the market, increasingly complex market models and solutions could be developed in stages until a comprehensive and self-sustainable market system aligned with best international practices and the EU acquis is achieved (see below). Implementing them will require concerted effort over the next 10-15 years by the authorities and the private sector to address key challenges, including the following:

- Develop waste management planning at the national and regional/Hromada/municipal levels.
- Develop technical specifications for recyclable and uncontaminated debris products, including clear practical guidance on determining the feasibility of reusing and recycling various types of debris, as well as different levels of contamination.
- Strengthen the regulatory framework by adopting more detailed procedures for the permitting and licensing of the treatment, processing, and disposal facilities for debris, including debris contaminated with hazardous materials such as asbestos.
- Develop fiscal instruments to facilitate circularity in the construction sector, with financial support for those who are establishing debris recycling facilities and systems.
- Establish a market demand for recycled debris materials in reconstruction works.
- Transform debris management policies into CWDMR waste management policies and regulations aligned with the EU accession goals.
- Establish an effective system of waste management accounting of debris volumes and processing stages.
- Establish quality infrastructure to enable testing and certification of materials produced using recycled debris and construction waste.

A phased approach can be considered to introduce and develop CWDMR and private sector engagement in Ukraine:

Model 1: Situational Disaster Waste Management and Accounting

- What it entails: Emergency-focused model for managing CDW in post-disaster/ conflict zones
- Timeline: Short- to medium-term
- Prerequisites: Government coordination, emergency protocols, basic infrastructure
- Activities: Hazard detection, temporary storage, sorting, public communication, basic training
- Public sector role: Leads all aspects (planning, funding, site provision, regulation)
- Private sector role: Limited, mostly contracted services (e.g., transport, sorting)
- Challenges: Low commercial viability, ad hoc funding, limited scalability

Model 2: Material Recovery Facility (MRF) as a Service

- What it entails: Market-based model using centralized facilities to sort and recycle CDW.
- Timeline: Short- to medium-term.
- Prerequisites: Capital investment, enabling regulation (e.g., landfill taxes), demand for recycled materials.
- Activities: Collection, sorting, hazardous waste treatment, resale of materials.
- Public sector role: Enables market via subsidies, co-financing, and regulation.
- Private sector role: Operates MRFs, provides services, sells recycled outputs.
- Challenges: High CAPEX, dual revenue dependency (service + product), not fully self-sustaining.

Model 3: Regulatory-Driven Material Sourcing

- What it entails: Mandated use of recycled content in construction materials.
- Timeline: Medium- to long-term.
- Prerequisites: Strong regulatory framework, standards for recycled content, compliance mechanisms.
- Activities: Standard setting, compliance monitoring, public procurement alignment.
- Public sector role: Legislates quotas, sets standards, provides incentives.
- Private sector role: Adapts production, ensures compliance, innovates in product development.

Challenges: Higher product costs, enforcement complexity, market adaptation.

Model 4: Integrated CDW Recycling and Product Manufacturing

- What it entails: Full-cycle model integrating CDW recycling into new product manufacturing.
- Timeline: Long-term.
- Prerequisites: Mature market, advanced technology, regulatory alignment, traceability systems.
- Activities: Collection, processing, manufacturing, certification, marketing.
- Public sector role: Sets enabling regulations, supports infrastructure and innovation.
- Private sector role: Leads in design, manufacturing, tech adoption, and traceability.
- Challenges: High-tech requirements, vertical integration complexity, export competitiveness.

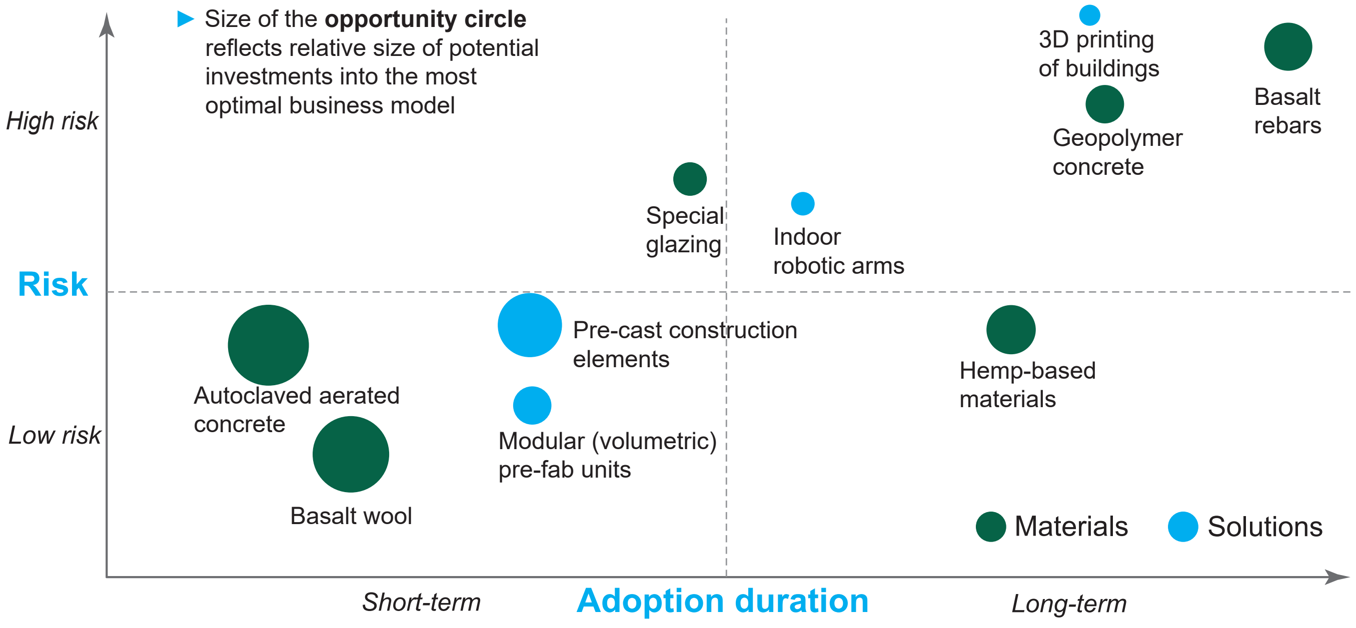
Relevance and viability of materials for Ukraine's reconstruction

Most of the selected materials and solutions share key characteristics which make them particularly suitable to the Ukrainian post-invasion context and build back better agenda. These include superior technical parameters compared to traditional alternatives, relative affordability, local availability of raw materials, higher energy efficiency, lower environmental footprint (including reduction of construction waste), factory standardization of materials leading to higher quality of construction, easier and faster on-site construction cycles, and process automation. These characteristics are well-suited for Ukraine's context to address longstanding issues in the building sector, the specific challenges of the reconstruction period, and the GoU's long-term policy priorities.

Most materials and solutions are known in the market, both local and global, but adoption varies widely. Some of them, such AAC and basalt wool, are widely known in Ukraine and were embraced by the local market long before the invasion, with robust historical demand and large future addressable markets. Others, including precast elements, volumetric units, special glazing and indoor robotic assistance equipment, are at rapid growth stage, carving out their own niches in Ukraine while already quite well-known and developed globally. Others present longer-term development opportunities as they have clear technical and environmental benefits but remain to some extent at the development stage and only have nascent or limited market penetration globally. Most of these, apart from 3D printing of buildings, have been known for years or even decades, but have not garnered necessary attention and funding so far although this could change as sustainable construction practices become more prominent on the global agenda.

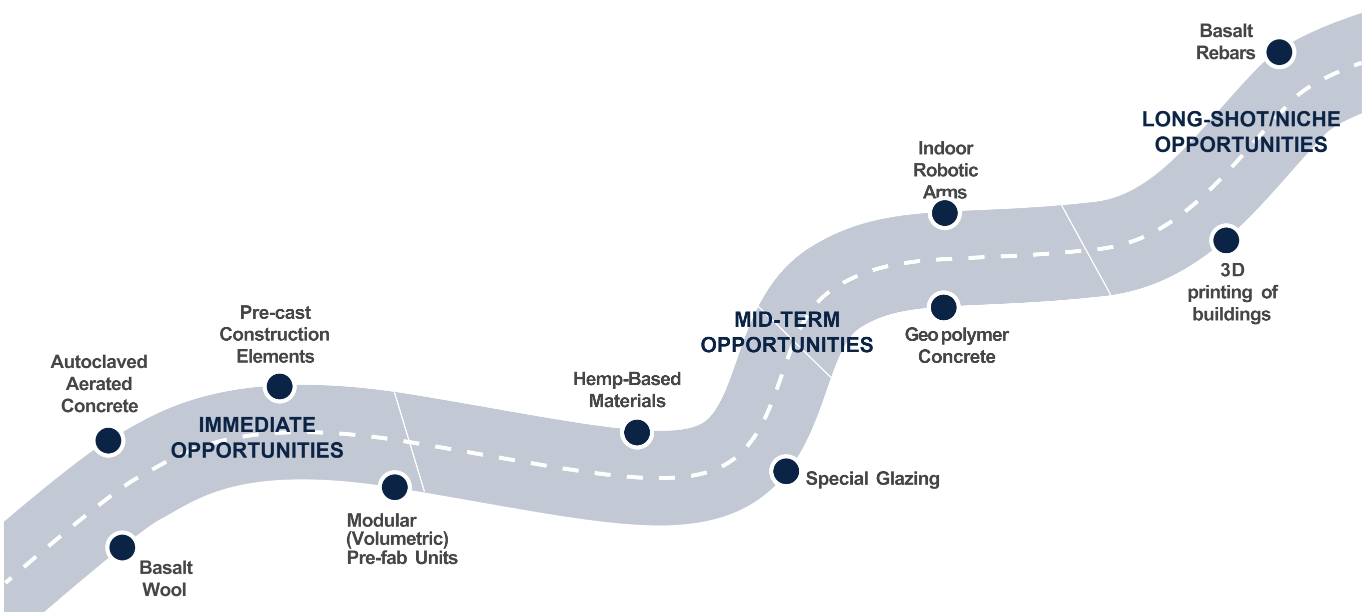
Given the different maturity levels and magnitude of future opportunities, the selected materials and solutions vary in terms of the opportunities they provide to potential investors and their time horizon. Figure 6 provides a visual representation of the assessed range of risk and reward, based on both desk assessment and discussions with market players and experts. *Risk* reflects the relative range of investment failure probability vs reasonable payback period. *Adoption duration* reflects the relative combination of wide market adoption of material/solution and ideation-to-sales period. The size of each opportunity circle represents the relative volume of potential investments required to establish a sizable market presence (no less than 10 percent of the market over the next decade). Drawing on this mapping process, Figure 7 categorizes the selected material and solution into immediate, mid-term (2-5 years) and long-shot/niche opportunities (beyond 5 years).

Figure 5. Selected materials and solutions: reward-risk-adoption opportunity map



Source: IFC estimates

Figure 6. Potential timeline of selected opportunities



3. Private sector opportunities

Market size assessment

To estimate the market potential for innovative construction materials, one needs to consider reconstruction needs and the resumption of regular construction activity. Consistent with the RDNA4, the estimations in this section are based on a 10-year period for the reconstruction phase. While the assessment extrapolates from the best available sources and market expert views, it is important to emphasize that future construction needs and dynamics remain subject to considerable uncertainty in view of the ongoing invasion.

Estimation of reconstruction needs based on damages under this study used some adjustments. Per RDNA4 data and market expert estimates, the total gross floor area (GFA) of residential and civil infrastructure damaged or destroyed from early 2022 to the end of 2024 is in the range of 100-120 million m^2, which may potentially increase by another 10 percent if active hostilities were to phase out by the end of 2025. However, the volumes of residential infrastructure actually requiring significant partial or full reconstruction may be lower if the RDNA4's damage scale is applied.[24] Furthermore, reconstruction needs depend on possible remigration scenarios, with as few as only 30-35 percent of refugees and internally displaced households returning to their areas of original residence in a pessimistic scenario.[25] On the other hand, most of the damages are likely to be of the old Soviet-period buildings with relatively small floor areas per person. Reconstruction according to modern standards (at least those of Ukrainian real estate over the past decade) would likely require premises 30-60 percent more spacious than the original units, although the capacity to do this would be subject to budget availability. On balance, the likely 10-year reconstruction volume range for housing and civil infrastructure is estimated between 20 and 70 million m^2.

Regular construction is expected to rebound from the current 5-6 million m^2 annually to at least pre-invasion levels over a few years, assuming continuous economic recovery. Regular construction is defined as planned housing construction not related to the damage and destruction inflicted by the invasion. With pre-invasion GFA volumes for residential and civil infrastructure construction exceeding 10 million m^2 annually in certain years,[26] the 10-year regular construction volume for housing and civil infrastructure can be estimated between 70 and 100 million m^2.

Based on these estimations and data on historical construction and damaged units' segmentation between single homes, MFBs and non-residential facilities, Table 4 below presents low and high estimates of the 10-year new construction cumulative Total Addressable Market (TAM) for materials and solutions reviewed in this report.

Table 4. 10-year Total Addressable Market for reviewed materials and solutions

	Scenarios (million m^2)	
	Low	**High**
New construction TAM of which:	90	170
1) Construction type:		
Regular construction	70	100
Reconstruction	20	70
2) Segment:		
SFHs	32	54
MFBs	50	102.5
Non-residential	8	13.5

Source: IFC estimates

Further adjustments were made to estimate the Serviceable Addressable Market (SAM) for the different materials and solutions. Key factors considered include applicability to different construction segments, compatibility with other construction technologies used in projects, and historical market share (if any) in the Ukrainian market. Several potential market upsides are also factored in, including the additional use of the materials and solutions considered in construction segments not covered by this report (primarily industrial and transport infrastructure); for thermo-modernization retrofits of old stock; 'topping up' (adding floors to existing buildings); for re-

[24] The RDNA4 applied a new methodology according to which over half of impacted housing units were categorized as having minor damage (below 10 percent asset damage), just over a quarter had medium damage (10-40 percent asset damage), and the remainder suffered significant damage or was destroyed (above 40 percent asset damage).

[25] This worst-case scenario assumption is consistent with recent survey-based studies of refugees and IPDs (CES 2025, IOM 2025).

[26] It is noteworthy that, despite the steadily declining population since Ukraine's independence, both housing and non-housing construction increased in the period preceding the invasion, due both to income growth and the gradual replacement of increasingly obsolete old real estate stock.

placement rather than new construction; as well as export opportunities. After adjusting for all the above, and factoring in gradual growth to target market shares, the 10-year SAM and estimated quantity of materials required for construction is presented in Table 5.

Table 5. 10-year SAM for reviewed materials and solutions

Materials/solutions*	GFA (mln m²)		Materials/units required**		
	Low	*High*	*Low*	*High*	*Unit*
Basalt wool* **	210	400	4	8	*mln tons*
AAC	45	85	18	34	*mln m³*
Special glazing	50	90	36	65	*mln m²*
Hempcrete	10	20	1.5	3.0	*mln tons*
Geopolymer cement	60	115	30	58	*mln tons*
BFRP rebars	35	65	0.5	0.9	*mln tons*
Pre-cast elements** **	30	60	n/a	n/a	*n/a*
3D printing of buildings	0.5	1	10	50	*gantry systems*
Indoor robotic arms*** **	70	130	n/a	n/a	*n/a*

** Modular (volumetric) units were excluded from estimates, as they are a diverse group of products and solutions, some of which are not directly related to regular and reconstruction volume estimations.*

*** Estimation of materials required is based on average use per m² of construction, using typical project ratios provided by Ukrainian construction companies and reviewing global academic references for materials not yet available in Ukraine. Similar estimations cannot be made for solutions marked n/a.*

**** Basalt wool stands out as the only material with SAM significantly larger than new construction TAM, due to the untapped potential for thermo-modernization retrofit of at least 150-350 million m2 of weakly or non-insulated old residential and non-residential stock and insulation of HVAC and piping systems to improve efficiency of utility networks.*

***** Pre-cast elements are a diverse group (e.g., slabs, pylons, stairs/steps, panels) made of several different types and combinations of materials. Accordingly, an estimate of an aggregate need in units cannot be made.*

****** Indoor robotic arms are a diverse group of construction support machinery. Estimating the need in units is difficult at this stage without analyzing specific sub-categories of machinery and gauging interest by construction companies.*

Source: IFC estimates

To the extent possible, the high-level estimates aim to capture potential export opportunities on top of local market needs. While the markets for construction materials in Europe and beyond are competitive, Ukraine could gradually develop competitive exports for some of the products, particularly those still in early development phase globally. For instance, exports could potentially equal or exceed domestic consumption for low-carbon cement/concrete given the entry into force of CBAM and the EU's long-term decarbonization targets in this sector. Hemp-based construction materials also have potential, as recent reforms made Ukraine's legal framework for these carbon-neutral materials more advanced than in most EU countries, adding to the advantages stemming from Ukraine's large agribusiness sector with scale economies. Basalt polymer rebars and locally designed 3D printing systems could also have their own niches within the EU. Special glazing would benefit indirectly, given the growing export volumes of complete window units to Europe. Of the more traditional materials, AAC has potential, as some were already exported to the EU prior to 2022.

Summary of viable investor entry models and selected opportunities

Domestic and international investors in Ukraine's construction market have historically used mergers and acquisitions (M&A) as the primary entry mode, while purely greenfield investments have been rare. Most existing production assets, especially in traditional construction materials and raw materials, were commissioned during the Soviet period before being modernized and expanded over the past two decades. Post-Soviet facilities are mostly concentrated within the newer generation materials segments, such as AAC and mineral insulation, and were typically financed using a mix of local and international loans and private capital.

Institutional and venture investment in Ukraine is very limited, with only a handful of private equity funds pursuing investments in the construction materials space. Most of the investments come either from domestic or international strategic investors, private business and financiers, and in certain cases from equity and debt co-investments by international financial institutions (IFIs), such as IFC and EBRD. The only publicly known case of private institutional capital investing into the materials sector is the local investment banking and private equity firm Concorde Capital acquiring two cement production and one slag grinding plant from HeidelbergCement, which divested from Ukraine in 2019 due to change of Group strategy and optimization of their asset portfolio.[27]

In the current Ukrainian market context, different market entry models for private investors are likely to be better suited for each material and solution. For each, this depends on several factors, including current market competitiveness, pre-existing conditions, development maturity, investor interest/pledges during the invasion. Based on expert judgement, historical transaction experience in Ukraine and stakeholder interviews, Table 6 presents a high-level assessment of the range of market entry options and their suitability for particular materials and solutions, which are further discussed in the rest of this section. Some (1-5) focus on investment in material production, while others (6-9) are more about the provision of inputs and services.

Table 6. Suitability assessment of potential market entry models in current Ukrainian context

	1. M&A	2. Brown-field	3. Green-field	4. Loans	5. Venture	6. Raw materials	7. R&D	8. Equipment lease	9. Services
AAC	+++	+	+	++	+	+			
Basalt wool	+++	+	+	+++					
Pre-cast elements	++	+++	++	++	+	+	+		
Modular (volumetric) prefab	+	+	+++	++	++				
Hemp-based products	++	+++	+++	+	++	+++	++		
Special glazing		+++	+	+		++			
Geopolymer cement		++	++	+	+++	++	+++		
BFRP	++	++	++	+	++		+++		
Indoor robotics			+	+	+++		+++	+++	++
3D printing of buildings			+	+	+++		+++	+++	+++

+++ (best suited) *++ (average)* *+ (possible but unlikely)*

Source: IFC assessment

[27] See *"HeidelbergCement is leaving Ukraine."* (The New Voice of Ukraine, March 20th, 2019) and *"HeidelbergCement sale now on"* (Global Cement, January 16th, 2019).

MATERIAL PRODUCTION MODELS

Model 1: M&A. Mostly applicable for segments in which enough local producers are operating, including some that are technologically obsolete or chronically underfunded with shareholders looking to exit. Of the materials and solutions reviewed in this report, the obvious best fits for this model are the AAC and insulation sectors, with their highly developed and competitive local markets, with the pre-cast, basalt rebars and industrial hemp segments also exhibiting some M&A potential. Full legal control over the business, as well as full control over operations, market positioning and product quality are the primary advantages. Key risks primarily involve lower than expected market growth, loss of client base due to exit of original shareholders, high investment outlays and full P&L exposure.

Model 2: Brownfield investment/co-investment/joint venture (JV) with local producers. This entry model has variations – a) co-investment with a local producer into a new facility or segment; b) independent investment into production capacity within an industrial park with basic infrastructure already in place – an option actively supported and incentivized by the Ukrainian government; c) investment into a new product line or segment within facilities owned by one of the old technologically obsolete producers. The approach is the best fit for materials and solutions where timeframe for successful wide market adoption is mid- to long-term or unclear, raising their initial investment risk profile – hemp, low-carbon cement/concrete, special glazing, and pre-cast are best examples. Greenfield investment in supporting infrastructure in these cases further increases the required investment outlay and potential losses in case of failure to establish a strong market foothold. Operational control, lower investment outlays and the existence of basic infrastructure which speeds up facility launch are primary advantages. Potential legal challenges to ownership of constructed facilities or supporting infrastructure and different visions of business development between the new investors and incumbents are likely to be the primary risks for the incoming investors.

Model 3: Greenfield. The establishment of a new standalone facility (or network of facilities) in Ukraine is best reserved for early-stage markets or markets with low competitiveness, but with clear potential for short- to mid-term wide product adoption and thus, scaled production. This approach is particularly viable when the incoming investor can provide both funding at scale unattainable by fragmented local producers and/or next-generation product formula or production technology, while not looking to engage in technology transfer. Full legal control over the business, as well as full control over operations, protection of technology, market positioning and product quality are the primary advantages. Similarly to M&As, key risks involve lower than expected market growth, high investment outlays and full P&L exposure.

Model 4: Loans. As the local banking system offers high interest rates and has strict collateral requirements, local producers are often looking to alternative financing sources, including loan or hybrid facilities from IFIs, export financing facilities covering imported equipment, and private direct or quasi-debt – the latter often in the case of start-up investments. Accordingly, this model works primarily as support for local producers focused on scaling local production capacities or for the initial market entry of machinery-focused solutions. Insulation producers, and to a lesser extent AAC, pre-cast and modular segments would likely benefit the most.

Model 5: Venture investments. Market entry by means of venture financing is one of the key models focused on high-risk, low current adoption next-generation solutions in Ukraine. Primarily suitable to materials and solutions with no or minimum current presence in the Ukrainian market, as well as to potential technological spin-offs to already widely adopted solutions (i.e. the DALSICA technology for AAC). Financing and operational flexibility are the core advantages. Venture investments, however, are inherently high-risk, both due to the unpredictability of the future market and potential challenges in cooperating with the local teams responsible for the projects.

INPUT AND SERVICE MODELS

Model 6: Raw materials and intermediate products investment. In certain cases, investment in raw materials and pre-processed inputs required to produce construction materials may be just as or more commercially attractive as investment into the materials themselves, especially when the input market is still low or non-competitive. Across the studied materials, this model may be of particular interest in the cases of a) hemp, where agricultural cultivation of hemp and/or hemp seeds is a commercially attractive business given diverse use of hemp plant elements across numerous end markets; b) special glazing, where float glass – currently still fully imported – is the primary raw material; and c) geopolymer cement/concrete, where the future industry will likely require at least one milling facility of production-grade caliber GGBF slag – a key activation material for geopolymer cement – that will be supplying the milled and lab-tested slag to all geopolymer cement producers. Investment into the supporting ecosystem which will drive the overall segment growth and ability to seize the currently non-competitive niches are some of the primary advantages of the approach. Risks vary case by case, with a common one being incorrectly estimating future demand for raw materials.

Model 7: Stand-alone R&D investments. While investment into production facilities and wide adoption on the local market may be seen as premature or non-feasible due to unknown market size and consumer perception, establishment of local R&D and technology excellence centers focused on supporting global product lines and adoption may be a viable opportunity in some cases, given Ukraine's long-standing academic and technological expertise in some of the materials and solutions and highly educated and motivated workforce. Of the materials and solutions reviewed, this predominantly fits R&D-intensive segments, such as low-carbon cement/concrete, polymer rebars and various robotic machinery support units.

Model 8: Equipment lease. One of the two primary market entry models for machinery-focused solutions is the creation of a local equipment fleet (robotics or otherwise) for leasing to local construction companies, where localized production of such machinery for internal market usage is currently not warranted by the potential market size and low adoption rates. This may be seen as a first stage of market entry, focused on gaining traction with the market and raising client base awareness. Once the minimum critical level of potential demand is achieved, production of machinery may be partially or fully localized. Introduction of high-speed robotics-based construction solutions to the Ukrainian market without overcommitment of capital is the key advantage of the approach. Risks are limited, as the size of the equipment fleet on offer may be scaled to growing demand and machinery may be re-sold to buyers outside of Ukraine in case of business failure/insolvency.

Model 9: Services. The second market entry model for machinery-focused solutions is providing construction services using the equipment fleet rather than just leasing it out to local construction companies. This is particularly suitable for product-making' machinery segments, such as 3D printing of buildings, where responsibility for quality and necessary minimum equipment operation skills is inherently higher. Advantages and risks are similar to the leasing model, but the approach involves additional investments in education and hiring and training skilled professionals.

Key market players: incumbents and potential entrants

Ukraine's construction materials industry has a mix of both large and small local producers across most materials group, interspersed with several global and regional manufacturers and imports from various geographies. Traditional structural materials – steel, bricks, cement and others – and corresponding raw materials required for their production, are likely to remain largely driven by Ukrainian players, such as Metinvest (steel, rebars and steel pre-cast elements), Kovalska Group (sand, granite, limestone, concrete – reinforced and aerated, slabs, dry building mixes and real estate development), Kerameya (clinker bricks), Keraterm (ceramic bricks) and others. Several global construction materials corporations – most notably Saint Gobain, CRH and Kingspan – are also operating extraction and production facilities in Ukraine and expanding even during the invasion period. Apart from steel and clinker bricks, however, no market segment is dominated by a single player (KSE 2024, UkraineInvest 2024).

The situation is more diverse for the studied materials and solutions, with various degree of maturity and penetration in the Ukrainian market. Basalt wool and aerated concrete – materials well-known and used in Ukraine for at least a decade – enjoy a producer structure similar to the traditional materials. The others, however – both materials and machinery-based high-speed construction solutions – do not have as much foothold, if any, in the market, and are more operating in niches.

As of the end of 2024, AAC likely has the most competitive market among the studied materials. The invasion has led to the cessation of operations of several smaller AAC producers, yet the largest remained fully functional. StoneLight – the largest AAC blocks producer in Europe with over 1.4 million m^3 annual production capacity – remains the key player, alongside several smaller ones, but will soon be challenged by AEROC Group, which was nationalized after the invasion and re-privatized in an open auction to Trident Geoinvest Ukraine (a Ukrainian investment group) in December 2024. AEROC's total designed capacity, including a nearly completed third plant in the Lviv region, equals StoneLight's. On top of that, Kovalska Group is building its own AAC facility in Lviv region with a 0.6 million m3 designed capacity, with project financing of EUR 27 million provided by Dutch Invest International. Even at full capacity, however, StoneLight, AEROC and Kovalska are unlikely to be able to satisfy post-invasion demand, providing opportunities for new entrants either through targeting smaller Ukrainian producers for potential M&A or launching small flexible-capacity greenfield plants close to or in the invasion-impacted regions based on alternative cost and environment-friendly AAC technologies, such as DALSICA.

Mineral external insulation is another highly competitive segment, supported by local producers' efforts to raise consumer awareness and government subsidies for energy efficiency retrofits. The mineral wool product group, which the basalt wool belongs to, takes up 60-70 percent of the overall external wall insulation market, with basalt wool moving to a dominant market share of 60-85 percent[28] within the materials group over the past decade. About 80-85 percent of basalt wool is produced locally, with only 15-20 percent covered by imports. Three local producers – Sweetondale (formerly Technonikol, renamed after an acquisition of production of assets by the Czech group Sweetondale in 2018[29]), Obio (TM Izovat) and Novoterm – share over 80 percent of the local product manufacturing market, with the rest dispersed amongst several small producers. Imports are predominantly comprised of global market leaders in external insulation (e.g., Rockwool, Knauf, Isover, Baugut, Kingspan). Kingspan, however, announced a major investment of EUR 280 million to build a construction materials manufacturing campus just outside Lviv, which may contain basalt wool unit production as part of the insulation segment of the campus, and has been granted permission to begin construction in early 2025[30]. Some local players also plan to expand their production after the invasion, in preparation for both the reconstruction phase and renewed demand for retrofitting. Key opportunities for new entrants would likely focus on M&A efforts with some of the smaller producers. Export of basalt wool is unlikely, as key international producers have ample capacity within Central and Eastern Europe.

[28] Data on respective insulation market shares was gained from interviews with local producers who provided varying estimations and insights from their sales departments.

[29] *"Czech company Sweetondale has bought three Ukrainian insulation materials plants from Russia's Technonikol."* (UBN, September 11th, 2018).

[30] *"Kingspan breaks ground on €280m Building Technology Manufacturing Campus in Ukraine"* (Kingspan, April 2nd, 2025).

The pre-cast segment is enjoying lower competitive intensity for now, with only a handful of producers focusing on specific base materials – primarily concrete and steel – and wide consumer acceptance lagging. The pre-cast construction approach has historically been compromised by the mass construction of standardized low-quality housing during the Soviet era – the infamous 'khruschovki' and similar building models. The last 10-15 years saw the resurgence of the approach, given new much more versatile technologies and much higher quality of the factory-produced elements. Demand was growing prior to the invasion, bolstered by local investment into pre-cast innovations by Metinvest for steel-based prefabricated elements and Kovalska Group for reinforced concrete pre-cast. Demand remains limited, however, due to historical consumer resistance. Several old reinforced concrete pre-cast plants, which were constructed during the Soviet era, remain afloat producing technologically obsolete wall panels and similar elements. Some of them would be prepared to cooperate with investors to turn around their operations and introduce innovations. Several new pre-cast projects have already been announced, with at least one, by Peikko Group Corporation, already officially opened at the Bila Tserkva Industrial Park in late April 2025[31], and a network of housing construction factories (concrete pre-cast) being actively negotiated and developed by Vollert Anlagenbau and supported by European insurance leader Euler Hermes and several European banks since mid-2024[32].

Volumetric or modular pre-cast products, on the other hand, are a niche segment with new local producers joining the market and investing into market awareness and creation of value chains with construction companies. Over 300 companies were registered as operating within the segment in 2023, according to the Prefabricated Buildings Association of Manufacturers[33]. Based on expert data, over 70 percent of the operators offer wood-based prefab products, with the rest operating in steel, concrete and hybrid combinations segments. The modular producer market is currently highly fragmented, with no clear leaders, providing a clear opportunity both for M&A market entry efforts and 'green-field' market penetration.

Industrial hemp processing and its use in construction is still a nascent segment, both locally and globally, but it is seen as having high potential from both an environmental and economic perspective. Ukraine is uniquely positioned to partake in the global segment growth, with strong R&D history in hemp processing remaining from the Soviet era, including proprietary hemp varieties with record fiber content rates and yields, agrarian economic focus and brand-new legislation adopted in 2024 significantly improving the framework for current and potential hemp cultivation and processing operators. While still marginal in monetary terms, the Ukrainian hemp ecosystem is expanding. At least one Ukrainian player, Hempire, specializing in hemp-based construction materials, is well-known within the global hemp processing community. Several other players are gradually increasing their production capacities for raw and downstream processing hemp, including Global Hempiness and K.Tex (who have also invested over $11 million into a full-scale agro-industrial park for hemp processing in 2023-2024). Given the early-stage status of the market, entry opportunities may range from M&A and co-investment with the existing players to 'green-field' entry focused on establishing and expanding previously untapped elements of the budding ecosystem.

Several other materials and solutions are at an even earlier market maturity stage, locally and globally, but have nonetheless attracted growing attention from investors. Alternative cement/concrete formulas designed to decarbonize traditional clinker-based concrete, including geopolymers, other alkali-activated formulas and limestone-calcined clay concrete (LC^3), are being developed and sought after by the majority of global cement and con-

[31] *"Peikko celebrates the opening of its new factory in Bila Tserkva, Ukraine"* (BFT International, April 29th, 2025).

[32] *"Vollert, the German giant, is getting ready to build factories in Ukraine."* (UBN, March 20th, 2025).

[33] https://pragmatika.media/zhytlo-dl-vpo-prefabricated-in-ukraine-struktura-osoblyvosti-ta-perspektyvy-ukrainsko-ho-budivelnoho-prefabu/

crete producers, with companies such as Hoffman Green, Cemex, LafargeHolcim and others driving global R&D and mass adoption (Box 2). Ukraine has only a handful of producers offering low-clinker concrete and several companies, including Kovalska Group seem, based on public statements and expert discourse, to be developing proprietary geopolymer formulas. Basalt FRP rebars have attracted interest globally, primarily from countries with low and/or subsidized energy prices, but also from the United States. In Ukraine, previous attempts to establish production have so far had limited success due to various reasons not directly related to the benefits and challenges of the material itself. Ukraine being well-known globally as both a source of high-grade basalt, and unique R&D expertise for continuous fiber and BRFP production, it may be a destination for systemic international investors into the space.

Box 2. Global PE and venture investments into sustainable cement and concrete

Beyond the focus of global strategic investors, such as Hoffmann Green and Holcim, on cement and concrete decarbonization, numerous low carbon concrete ventures have been successfully funded by institutional investors in recent years. The past two years have been marked by heightened activity in this space, with notable funding rounds including Terra CO_2, a leading US-based low-carbon construction materials company, attracting Series B equity from Generation Investment Management and Breakthrough Energy Ventures[34]; CarbonCure attracting Series F funding from Blue Earth Capital[35]; and Queens Carbon securing a funding round led by Clean Energy Ventures[36] – with large strategic investors like Buzzi joining the rounds to secure access to the new technologies.

Construction robotics, in particular 3D printing of buildings, have seen a surge of global investment over the past decade. Startups, such ICON (US), COBOD (Denmark) and XtreeE (France), are investing heavily to develop proprietary solutions and construction materials, with incumbents like PERI Group (Germany) expanding into the 3D printing space. In Ukraine, despite lack of an adequate legal framework to ensure wide adoption, the startup ecosystem is also gaining vibrancy, with at least one company, UTU, having developed and successfully piloted a proprietary fully locally assembled 3D printer for low-rise residential facilities.

Financing sources and needs

Most investments into the construction materials and solutions sector in Ukraine have historically been from the local private sector, with some segments also driven by inbound FDI. Local private capital was typically supported by project finance facilities provided by local banks or IFIs, though in a limited fashion. While exact numbers for particular segments are unavailable, in general the share of (local and foreign) debt financing of capital investments in Ukraine never exceeded 5-7 percent of total CAPEX, most of which was financed through companies' own balance sheet[37].

FDI in the sector has been through M&A, greenfield investments and representative/sales offices of large global corporates. FDI has originated primarily from Europe, although a certain share has historically come from Russian industrial and investment groups,

34 *"Terra CO2 raises $82m to scale sustainable cement technology"* (Global Cement, February 20th, 2025).

35 *"Blue Earth Capital leads $80m Series F in CarbonCure, leader in low-carbon concrete"* (Blue Earth Capital, July 11, 2023)

36 *"Queens Carbon secures $10M in seed funding for low carbon cement"* (World Cement, May 2nd, 2025).

37 *https://www.ukrstat.gov.ua/operativ/operativ2021/ibd/kin/kin_df_ved/kin_df_ved_24.xls*

either directly or through Ukrainian partners in segments like AAC, raw materials and inputs. New investments have stalled following the invasion and temporary contraction of demand for materials but have gradually resumed since mid-2023.

On the supply side, the volumes of potential investments in new or expanded production capacities vary. Expected CAPEX for new production facility or a product line expansion may range from several million euros for niche and early-stage development products to several hundred million euros for large-scale factories. While exact numbers differ depending on technology used, particular land plots and locations and multiple other factors, recent publicly stated examples include the future float glass plant NovaSklo by local investment group EFI Group currently estimated at EUR 240 million of CAPEX, with an initial planned capacity of 25 million m^2 annually and a special glazing (coated glass) division included in the project[38]; Kingspan Group's future Building Technology Manufacturing Campus near Lviv worth EUR 280 million, which will manufacture advanced insulation, energy efficient construction materials and district heating solutions[39]; local investment vehicle Trident Geoinvest Ukraine paying under EUR 45 million to acquire privatized AEROC[40]; and pre-invasion plans by the Obio Group (TM Izovat, mineral wool insulation) to expand their production capacities by another 90,000 tons per year – a project estimated at 30 million EUR back in 2021.

[38] *Ukraine to Build Its First High-Tech Float Glass Manufacturing Plant | EFI Group*

[39] *Kingspan breaks ground on €280m Building Technology Manufacturing Campus in Ukraine | Kingspan Group*

[40] State Property Fund of Ukraine, Antimonopoly Committee of Ukraine

4. Potential aggregate economic and environmental benefits

Economic benefits

Ukraine's large reconstruction needs and domestic market present significant investment opportunities in the building sector. In particular, estimates of the addressable markets for sustainable structural materials and modern solutions elaborated in the previous section are substantial enough to warrant attention from both global and local players. The realization of this potential would result in direct economic benefits, including capital inflows from investments, new jobs, additional tax revenue and new export opportunities.[41] It could also bring more indirect benefits, including the development of supply linkages with local companies, transfers of technology and know-how, reduced energy consumption from buildings, etc. While most of these benefits are difficult to estimate precisely, particularly given current uncertainties about the scale of reconstruction, this section attempts to give a sense of the potential magnitude of direct economic benefits in terms of CAPEX and job creation.

[41] Cf. the previous section for a brief discussion of potential export opportunities.

Scaling up the production and use of innovative and sustainable materials/solutions could bring EUR 4 billion in CAPEX and contribute to creating over 17 thousand direct and indirect jobs. These estimates are based on the addressable markets calculated for each studied solution, as well as available data on comparable investments into these or similar materials and solutions within Ukraine and abroad (acknowledging the significant uncertainty and range of factors that can influence costs for a particular project in a given context). The analysis suggests that the largest opportunities for CAPEX investments could come from geopolymers and concrete pre-cast, while basalt-based materials could yield more opportunities for jobs. The actual fulfilment of potential economic gains depends on numerous factors and may not happen within the assumed timeframe, but these estimates provide a sensible top-down view of the cumulative opportunity for investments into the studied materials and solutions. Detailed results of the estimations are provided in Table 7. While not estimated here, it is important to note that the gradual development of CWDMR, as previously laid out (Box 1), could generate additional investment and employment opportunities.

Table 7. Potential direct investment CAPEX and new jobs

Material / solution	Unit	Extra capacity needed, mln units*	10-year additional cumulative capacity range**	CAPEX per unit, EUR	CAPEX, mln EUR	Direct jobs	Indirect jobs***
Geopolymers	tons	8	30 – 58	170	1,360	4,000	2,500
Concrete pre-cast	m^2 GFA	6	30 – 60	250	1,500	2,000	1,200
Basalt wool	tons	0.7	2.9 – 6.9	600	420	2,100	1,000
Basalt rebars	tons	0.1	0.5 – 0.9	4,200	420	2,000	1,000
Hempcrete	tons	0.5	1.5 – 3.0	40	20	400	250
AAC	m^3	1	0 – 15	100	100	400	200
3D printing for construction	gantry system + workshop	50	0.5 – 1	1	50	100	100
Special glazing	m^2	8	0 – 8	9	72	60	40
Total					**3,942**	**11,060**	**6,290**

**This refers to capacity needed not covered by known investment plans.*

*** This is calculated as addressable market estimation, minus the 2023 baseline production, multiplied by 10.*

**** Potential indirect jobs refer to jobs created in the construction ecosystem (services, logistics, R&D). They were estimated using a 0.5x-0.6x multiplier range to direct jobs except for 3D printing, which is a special case. This is conservative, as multipliers from recent construction material facilities investments globally have often exceeded 1x-1.5x to direct jobs.*

Source: IFC analysis, based on industry expert interviews, publicly available data on transactions

The estimates of potential investment volumes and jobs rely on several high-level assumptions. First, the calculations are based on a 'greenfield' scenario using comparable numbers from relevant projects globally, and M&A-based investments that may have lower initial capital needs.[42] Second, the CAPEX per unit values used for the estimations were determined through

[42] However, in many cases the need to adapt and modernize existing processes to produce sustainable materials coupled with marketing expenses to effectively penetrate the Ukrainian market may match or exceed the difference between greenfield and M&A-based CAPEX.

discussions with industry experts and with local and international producers operating in Ukraine, as well as through the analysis of publicly announced investments in the respective material and solution. Since each investment project has its own specific starting conditions and technological characteristics, CAPEX benchmarks should be viewed as general averages within each category.

Environmental benefits

Scaling up the use of sustainable materials and solutions could make a decisive contribution to the needed decarbonization of Ukraine's construction sector. This sector is a major source of GHG emissions globally and in Ukraine,[43] and decarbonizing it is essential for Ukraine to meet its international commitments and EU requirements, as well as to remain competitive in export markets. As explained in Box 3, this can be achieved through several pathways. While using clean energy to produce basic materials, such as steel and cement, is an important one, it will take time in Ukraine given the still high reliance of its power system on fossil fuels.[44] Due to their production processes and technical performances, alternative construction materials and solutions are a promising way to reduce energy and raw material consumption across different stages of the construction value chain, which can be leveraged early to decarbonize the sector in parallel with investments in clean energy. Based on the estimated addressable markets and considering GHG savings from production processes and building performance compared to traditional options, high-level estimates suggest that total potential savings could reach up to 79 million tons CO_2e over a decade (Table 8). Assuming emissions grow in line with projected GDP recovery during this period, this would represent around 2.5 percent of Ukraine's total cumulative emissions.

Box 3. Decarbonizing the construction sector

Decarbonizing the construction sector is crucial for climate mitigation. Construction value chains – including the production of materials like cement and steel, building construction, and operations – account for approximately 40 percent of global energy and industrial CO_2 emissions. Emerging markets are responsible for two-thirds of these emissions, driven by rapid urbanization, population growth, and rising incomes. Within the value chain, materials production and building operations both contribute about half of emissions, while construction services only represent 0.3 percent. Without intervention, emissions from construction are projected to rise by 13 percent between 2022 and 2035, undermining global climate goals.

43 The manufacturing of iron and steel, non-ferrous metals (e.g., aluminum, copper, zinc) and non-metal minerals (e.g., cement) accounted for over 80 percent of Ukraine's industrial GHG emission in 2021 (Government of Ukraine 2024).

44 Under the National Energy and Climate Plan adopted in June 2024, GoU's target is to increase the share of renewable energy to 27 percent of total final energy consumption by 2030, up from about 10 percent in 2021.

Decarbonization of construction value chains can be pursued through several pathways. For new construction, reducing emissions in material manufacturing and lowering material use are key. This particularly includes switching to clean energy for materials production, improving energy efficiency in production processes, reducing process emissions through innovative production technologies (e.g. cement, steel), and reducing waste and developing more circular value chains. Operating emissions can be reduced by developing efficient building design to manage energy use and temperature balance inside the building, as well as increasing the use of adequate structural and finishing materials. For existing buildings, decarbonization is primarily dependent on reducing lifetime emissions, mostly related to utilities consumption, including by investing in energy efficient retrofits. Some technologies, such as reflective coatings, district cooling, and smart energy systems, are already commercially viable. In the longer term, innovations such as green hydrogen and carbon capture could further reduce emissions, though they remain costly and not yet widely deployable.

Emerging markets face several barriers to green construction. These include fragmented construction sectors dominated by small firms, limited access to green finance, weak enforcement of building codes, and a lack of skilled labor and technical capacity. Market failures – such as the absence of carbon pricing, information asymmetries, and underdeveloped financial markets – discourage investment in green buildings and materials. As a result, only 10 percent of global green construction finance reaches emerging markets, and most of it is concentrated in a few countries.

To address these challenges, policymakers can combine several interventions, adapted to each local context. These can include (1) adopting and enforcing green building codes and energy efficiency standards; (2) greening public buildings and procurement to stimulate market demand; (3) mobilizing private capital through green bonds, sustainability-linked loans, and green mortgages; (4) implementing carbon pricing and fiscal incentives where feasible; and (5) supporting innovation and capacity building through development finance institutions. Tailoring interventions to country-specific conditions – such as income level, fiscal space, and technological readiness – is essential for a cost-effective and inclusive green transition.

Sources: (IFC 2023)

Table 8. Potential CO_2 emissions reduction over 10 years

Material / solution	Traditional option	Unit	Average CO2 emissions per unit, kg (Diff. vs conventional option)	Max. estimated additional 10-year cum. demand*, mln units	10-year CO_2 emission savings	
					Kg per m2 GFA	Mln tons (embodied)
Alternative materials						
Geopolymer cement	**Ordinary Portland cement**	ton	300 to 800 (-100 to -600)	58	Up to 300	Up to 35
BFRP rebars	**Steel rebars**	linear meter	0.55 (-0.3 to -0.5)	9	Up to 70	Up to 4.5
Hempcrete	**Clay bricks**	m^3	-100** (-360)	2	Up to 36	Up to 0.7
Concrete precast elements	**In-situ concrete casting**	m^2 GFA***	80 to 150 (-10 to -30)	60	Up to 30	Up to 1.8
AAC	**Clay bricks**	m^3	160 (-100)	13	Up to 40	Up to 1.5
3D printing of buildings	**In-situ concrete casting**	m^2 GFA***	70 to 90 (-20 to -90)	1	Up to 90	Up to 0.09
					Total	**Up to 44**
“Energy efficiency enhancement” materials					**Mln tons (EEI)**	**Mln tons (embodied)**
Basalt wool******	**No thermal insulation; plastic polymer-based options (PUR/PIR/XPS)**	m^2 GFA	EEE: -8 to -16 annually vs. non-insulated; comparable to polymer options Embodied CO_2: -5 to -20 vs. polymer options	340	Up to 27 vs. non-insulated	Up to 7 vs. polymer options
Low-E glazing (as part of triple-glazed window)********	**Old sheet glazing; non-coated double glazing**	m^2 GFA	EEE: -3.5 to -7 annually vs. single-pane non-coated windows Embodied CO_2: only 2% higher than non-coated glass	15	Up to 0.5 vs. single-pane non-coated windows	Negligible
				Total	**Up to 28**	**+ Up to 7**

Source: IFC analysis based on industry expert data obtained through the study (specific sources used available upon request)

Potential GHG savings are sizeable and could play a pivotal role in meeting Ukraine's decarbonization commitments. The estimated savings are equivalent to permanently taking over 1.6 million gasoline-fueled passenger cars off the roads, or about 20-25 percent of the pre-invasion car fleet.[45] They could contribute to achieving the target Ukraine committed to under the Paris Agreement and reflected in the NECP approved in 2024, i.e. to reduce national GHG emissions by 65 percent by 2030 (compared to the 1990 level) to 321 million tons CO_2e. Due to gradual reduction in the carbon-intensity of the economy since the 1990s and successive economic shocks in recent decades, emissions had already decreased to 328 million tons CO_2e by 2021. The invasion's dire impact on GDP resulted in further reduction, to an estimated 223 million tons CO_2e in 2022 according to the latest national GHG inventory (Government of Ukraine 2024). On the other hand, the invasion resulted in an estimated 230 million tons CO_2e in additional emissions over three years (Initiative on GHG accounting of war 2025).[46] On balance, assuming that emissions recover and stay around their 2021 level over the decade following the end of active hostilities as the economy rebounds, further reductions of 7-8 million tons CO_2e per year would be needed for Ukraine to meet its current commitments, roughly corresponding to the estimated savings from construction materials and solutions. Even if GHG emissions grow in line with accelerated GDP growth over the first post-invasion decade, those estimated savings could still account for 15-25 percent of the needed decarbonization effort.

While approximative due to data limitations and uncertainties about Ukraine's medium-term prospects, these estimates highlight the environmental and energy gains that can be achieved through innovative construction methods. These gains, which stem from different technical characteristics (Table 9) and can be obtained for broader product groups:

- **Geopolymer cement**, the largest potential source of construction value chain decarbonization, illustrates gains achievable with various low-carbon / non-clinker cement and concrete solutions currently being developed globally.
- **Basalt (BFRP) rebars** represent potential gains achievable from switching to non-steel, polymer-based concrete reinforcement, with several existing other solutions.
- **Hempcrete** is a prime example of the potential that organic, carbon-neutral or negative inputs derived from advanced agriculture can play in sustainable construction.
- **Concrete pre-cast, AAC and modular/volumetric units** (though not included in the estimations above due to their diversity) show gains achievable by using factory-controlled standardized pre-cast and prefabricated solutions that improve quality, minimize production and construction site waste, and reduce energy consumption during production.
- **3D printing of buildings** shows what alternative approaches may exist to in-situ construction technologies of single homes and low-rise real estate – a category including other solutions, such as structural building system blocks, non-removable formworks that become part of the building envelope, flat slab method that removes the need for horizontal beams (reducing concrete consumption), etc.
- **Basalt (stone) wool**, while a best-in-class external insulation option for mid- and high-rise buildings and retrofit of old real estate stock due to its fire safety performance, is more generally representative of the significant energy and GHG savings that can come from thermal insulation retrofits of old buildings.

45 Based on a benchmark of 4.6 tons annual emissions per car (US EPA 2025).

46 This is mainly due to direct warfare-related emissions (e.g., fossil fuel use, fortification construction), landscape fires, reconstruction of damaged buildings and infrastructure, etc.

Table 9. Primary drivers of CO_2 emissions reduction

Material / solution	Traditional option	Primary CO_2 reduction drivers compared to traditional options
Geopolymer / low-carbon cement	*Ordinary Portland Cement*	• Absence or minimization of clinker • Lighter weight of resulting concrete • Recycling of industrial by-products • Potentially much longer life • End-of-life recycling pathways
BFRP rebars	*Steel rebars*[47]	• 2-3x lower energy usage in production phase compared to steel rebars, and lower production emissions • 3-4x lighter than steel rebars leading to a reduction in transport and handling-related emissions • Does not require welding, removing related in-situ emissions • Up to 30 percent less concrete cover required compared to steel rebars • Raw materials mix does not include coking coal and iron ore
Hempcrete	*Clay bricks*	• Carbon negative – carbon sequestration during cultivation phase of hemp overcompensates for any emissions made during hempcrete production phase (which are 2-3x lower than for concrete and bricks)
Concrete pre-cast elements	*In-situ concrete casting*	• Cement use is up to 30 percent lower due to effective compaction process in the factory • Less steel usage due to factory pre-stressing • Up to 20 percent of wastewater may be added back to new concrete mix as slurry via a closed material loop • Higher quality of materials leads to better energy efficiency and correspondingly, lifetime reductions in energy-related emissions
AAC	*Clay bricks*	• Lightweight • Energy consumption is about 75 percent lower for ACC production than for clay brick (210 vs. 880 kWh/m^3) • Closed loop production with no waste or pollution
3D printing of buildings	*In-situ concrete casting*	• Minimization of material consumption (up to 30-40 percent) and reduction of waste due to precision of construction • Lower in-situ energy consumption • Lower emissions from transportation of materials and workers • Concurrent creation of envelope elements for different internal building systems (e.g., sewage system, electric and ventilation tunnels/socket openings), reducing the needs for post-construction internal works

[47] Accounting for different material properties (e.g., much higher tensile strength than steel rebars), in general, a ton of BFRP rebars replaces 3.5-4 tons of steel rebars at comparable diameter.

Material / solution	Traditional option	Primary CO_2 reduction drivers compared to traditional options
Basalt (stone) wool	***No thermal insulation; plastic polymer-based options like PUR/PIR/XPS***	• Lower energy consumption and utility costs of insulated buildings compared to no insulation scenario; similar or better thermal conductivity than polymer-based options at comparable thickness • 20-80 percent lower lifetime embodied CO_2e per m^2 of material compared to polymer-based options • Dimensionally stable: does not settle under severe temperature and humidity conditions • Remains effective when penetrated by moisture • Potentially infinitely recyclable into new wool • Made of abundant non-organic raw material
Special (low-E) glazing	***Old sheet glass;*** ***non-coated float glass***	• Lower energy consumption and utility costs of buildings with low-E glazing compared to standard glazing scenario • Longer useful life compared to non-coated glazing, leading to reduced waste and replacement needs

5. Obstacles to private investment and needed reforms or interventions

Policies, Regulations and Standards

The modernization of Ukraine's outdated construction legislation gradually gained momentum over the past decade, intensifying in recent years. For two decades after Ukraine's independence in 1991, the legal framework on construction and building materials saw only insignificant updates to Soviet-era legislation, becoming increasingly outdated, limiting the adoption of modern materials and technologies, and eroding building quality. The first significant step came in 2011 when GoU allowed parallel application of national and EU building standards. Reforms accelerated with the signature of the EU-Ukraine Association Agreement in 2014 which, along with growing interest in EU market access by Ukrainian companies and evolving consumer expectations, drove efforts to align with EU standards. Reforms have intensified since 2022, focusing on harmonization, streamlined procedures, and attracting investment for reconstruction and local production.

Despite progress, implementation of Ukraine's construction legislation reforms and alignment with EU standards have lagged. The transition period for parallel implementation of national and EU standards has not been concluded. While Law #850-IX On Provision of Construction Products to the Market transposing EU Regulation 305/2011 took effect in January 2023, its implementation has been slow amid the ongoing invasion (Box 4). As of early 2025, while several newer production facilities already align with some requirements of Regulation 305/2011, both government and industry stakeholders acknowledge that significant implementation gaps remain, notably regarding requirements related to the sustainability of materials (KBU 2025). Moreover, in November 2024 the EU replaced this regulation with Regulation 2024/3110 strengthening sustainability requirements, which could further slow the pace of Ukraine's alignment. In parallel, Ukraine has made progress to update and digitalize several important State Building Norms ("DBNs")[48] in line with EU standards.

Box 4. Key provisions of EU Regulation 305/2011 and its successor Regulation 2024/3110

Construction Products Regulation (CPR) (EU) 305/2011,[49] adopted in March 2011, specifies requirements that must be satisfied by all construction works in several key dimensions (mechanical resistance and stability; fire safety; hygiene, health and the environment; safety and accessibility in use; protection against noise; energy economy and heat retention; sustainable use of natural resources). To achieve this, it determines harmonized rules and obligations of different categories of market participants (e.g., manufacturers, importers, distributors) related to product technical specifications, conformity assessment for each product family, and the CE marking of products. It also stipulates that construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following: (a) reuse or recyclability of the construction works, their materials and parts after demolition; (b) durability of the construction works; (c) use of environmentally compatible raw and secondary materials in the construction works.

Regulation (EU) 2024/3110,[50] adopted in November 2024 in replacement of Regulation 305/2011, with most provisions applicable from January 8, 2026. This regulation updates sustainability requirements and introduces several innovations:

- Encouragement of **sustainable practices and digitalization** in construction, aiming to reduce the environmental impact of products and promote energy efficiency.
- Introduction of a **digital passport** for construction products, facilitating access to detailed information about their characteristics, performance, and compliance.
- Focus on **reuse and remanufacturing** of construction products, fostering a circular economy and reducing waste in the sector.
- Allowing public entities to use **sustainability criteria in public procurement** procedures to select suppliers.

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48 One example is DBN V.2.6-31:2021 *("Thermal Insulation and Energy Efficiency of Buildings")*.

49 Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products.

50 Regulation (EU) 2024/3110 of the European Parliament and of the Council of 27 November 2024 laying down harmonised rules for the marketing of construction products and repealing Regulation (EU) No 305/2011.

In parallel with the update of building materials regulations, recent reforms have aimed to facilitate reconstruction by streamlining procedures governing construction activities. In April 2023, nearly 100 state building codes were digitized and made accessible through the Unified State Electronic System in the Construction Sector, improving transparency and efficiency. Law No. 3563-IX, adopted in February 2024, introduces simplified electronic procedures for changing land designations, particularly for energy and industrial construction projects. It allows land use changes without the need for urban planning and land management documentation, provided that local urban planning documentation is absent. These provisions are effective for five years from the termination of martial law or in a given locality. Furthermore, in August 2024, GoU introduced amendments allowing foreign construction companies to obtain construction permits for projects of "medium and significant" classes through a simplified declaration procedure, either electronically via the Diia Portal or in paper form.

The need to modernize construction materials regulations, particularly regarding sustainability norms, goes beyond future EU accession requirements. Building material regulations must extend beyond energy efficiency to set mandatory values for carbon intensity or recycled content for key materials such as concrete and steel, as is increasingly the case in Europe, the United States, China, India, etc. Failing to adopt and demonstrate compliance with such norms will significantly undermine access to the EU market for producers located in Ukraine. Moreover, the scale of financing required for reconstruction and return to regular construction volumes will require tapping larger funding sources. Green finance can be such a source, but attracting such funds requires implementing strong sustainability standards.[51] In this regard, voluntary green building standards and certification can complement mandatory energy efficiency regulations as key building blocks to develop green mortgages and other sustainability-linked financing support for real estate buyers (Box 5), which can scale up long-term demand for residential real estate.

Box 5. The role of building energy efficiency regulations and voluntary sustainability standards

Mandatory building energy codes (BECs) are among the most effective policy tools to increase the sector's sustainability (World Bank 2025)**.** BECs are requirements that establish minimum performance standards. They can achieve substantial energy savings and emissions reductions, as well as drive innovation in construction practices, develop local supply chains for efficient building materials, and create skilled employment opportunities. A recent analysis of BECs in 88 countries showed that many regions experiencing rapid urbanization still lack basic regulatory and enforcement frameworks, and that many existing BECs had critical gaps in scope and stringency, particularly for existing buildings and fossil fuel phaseout. In addition to adopting sound regulations, effective implementation requires stronger verification systems and targeted support mechanisms to bridge the gap between policy and practice. This study found that Ukraine's standards matched high-income European peers on some dimensions (e.g., roof and wall performance) but were weak on others (e.g. air conditioning efficiency) and lacked some elements, including practical implementation guidance and technical support mechanisms.

[51] For instance, The EU Green Bond Standard (Regulation 2023/2631) – the first EU wide rulebook to define a single green-bond label ("European green bond" or EuGB) embeds stringent performance thresholds for carbon-intensive materials, such as cement and steel.

Voluntary green building standards and certifications complement regulations by promoting best practices and market transformation. Standards such as EDGE,[52] BREEAM (United Kingdom)[53], and LEED (United States)[54] provide measurable benchmarks for energy, water, and material efficiency that often exceed minimum code requirements. Other tools, such as IFC's BRI can be helpful as well.[55] These standards and tools can help drive innovation, attract green finance, and build consumer trust. In emerging markets, they can serve as steppingstones toward more stringent regulatory frameworks, while in advanced economies they support continuous improvement and differentiation in the real estate market. In Ukraine, their use can help embed sustainability and resilience in the reconstruction strategy, but it remains limited. As of 2025, fewer than 20 buildings nationwide have been certified under one of the main international standards previously cited, mostly office buildings, shopping malls, and residential complexes in Kyiv or Lviv. This low uptake reflects both market immaturity and the absence of strong policy incentives. Encouragingly, the Ukrainian Green Building Council (UGBC) was established in 2023 to promote the use of standards and help build the domestic pool of qualified experts and practitioners.[56] On April 1st, 2025, Ukraine adopted a voluntary standard for "nearly zero energy buildings" applying to new construction and retrofits (SAEE 2025). Combining regulatory reform with voluntary certification can accelerate Ukraine's transition to a low-carbon built environment. Drawing on international examples, such as Singapore's Green Mark, Korea's GBCC, and France's climate-adaptive building codes, Ukraine can adopt a phased certification framework that incentivizes high-performance design while remaining sensitive to local capacity and economic constraints. This could leverage the existing ecosystem of private property management and technical appraisal firms that could provide sustainable construction certification services.

Clarifying reconstruction plans when conditions allow will be key to improving visibility for material producers and investors. The rapidly evolving context and high level of uncertainty have made it hard to prepare detailed plans about reconstruction needs, including the locations, type and segment of buildings needed, as well as financing sources. This has limited the private sector's capacity to properly assess future market size, production capacity locations and associated logistics costs, long-term stability of demand, and multiple other market entry considerations. When conditions allow, detailed assessment of needs and reconstruction plans based on consultative processes, including a strong focus on sustainability, inclusion, efficiency and resilience (consistently with relevant GoU plans such as the NECP), will help manufacturers and investors make informed decisions.

Further progress is needed to strengthen implementation of the policy framework on energy efficiency of buildings and its enforcement. While the adoption of the NECP and of the 2050 Strategy for Thermal Modernization of Buildings were positive steps, the lack of mandatory requirements and enforcement mechanisms is likely to undermine their implementation. It will disincentivize property owners (e.g., municipalities, hromadas, homeowners' as-

[52] Developed by IFC, EDGE (Excellence in Design for Greater Efficiencies) is a green building certification system tailored for emerging markets. It enables developers to quantify and verify reductions in energy, water, and embodied carbon, making it easier to access green finance and meet international disclosure standards (see: https://edgebuildings.com).

[53] See: https://breeam.com/

[54] See: https://www.usgbc.org/leed

[55] The Building Resilience Index (BRI) also developed by IFC, complements EDGE by providing a standardized framework to assess and certify the climate resilience of buildings. It evaluates exposure to hazards, structural robustness, and adaptive capacity, helping investors and governments prioritize risk-informed construction (see: *https://www.resilienceindex.org*).

[56] See: https://ugbc.com.ua/

sociations) to implement energy efficiency upgrades, limiting the retrofit market potential for insulation and glazing materials. Another positive development was the November 2024 launch of the National Buildings Database (NBD) platform, which aims to collect, monitor and disseminate information on technical and energy consumption characteristics of all buildings in Ukraine. Property owners are responsible for filling in the database, with phased obligations on information provision between end-2025 and mid-2026. However, data collection could remain largely voluntary in practice due to the absence of clear enforcement provisions.

On top of cross-cutting regulatory and policy issues, most of the studied materials face specific legal and regulatory barriers that will hinder their scaling up if unaddressed. This notably includes the following types of issues:

- *Lack of construction standards:* Such standards are still lacking for several materials and solutions not or minimally present in Ukraine, such as hemp-based construction materials and 3D printing of buildings. This prevents mass adoption of these materials and solutions, as buildings constructed using them cannot be certified as safe and commissioned for use. The development and approval of such standards is a relatively cumbersome procedure, requiring laboratory testing and modern quality control equipment. The ecosystem required to facilitate those processes is lacking and requires investments into supporting infrastructure, skills and equipment.

- *Lack of legal clarity:* The absence of clear rules about allowable use conditions for new generation technologies can undermine their use. For instance, the lack of clarity in labor laws concerning the use of robotic arms and assistants alongside human labor may lead to potential legal disputes about worker displacement and safety.

- *Unclear implementation frameworks for legal and regulatory reforms:* For example, the industrial hemp law adopted in Ukraine in August 2024 was a significant step forward for the sector, including for hemp-based construction materials, but it faced several early implementation challenges that limited its immediate impact. A lack of clarity in the accompanying by-laws – particularly around licensing and regulatory procedures – created uncertainty for farmers, delaying their ability to start or expand cultivation. To address these issues, the Ministry of Agrarian Policy launched the eKonopli (eHemp) digital platform in March 2025 to streamline registration and monitor industrial hemp cultivation by integrating with key state registers. The system remains in a pilot phase and its effectiveness is yet to be seen.

Policymakers could also seek to address barriers related to the perception of innovative and sustainable materials by market participants. This includes the following:

- *Lack of standardized terminology:* For instance, the term ‘mineral wool’ is used inconsistently by industry players and tends to be misunderstood by the public. It typically includes both basalt wool, stone wool (mix of basalt, bauxite, diabase and slag raw materials in different quantities) and glass wool – all of which have different mechanical properties and lifecycle eco-footprints. This restricts perception of basalt wool as a best-in-class external insulation material. Basalt rebars face a similar issue, as the term “Composite”, which is used in the current standards covering BFRP, is too generic in covering various types of technologically different products. Fixing this issue would require both the development of adequate standards and awareness raising.

- *Lack of information and misperceptions:* Combined with general resistance to change, this can undermine interest in specific materials by industry players and the public, requiring awareness raising and pilot/demonstration projects. For instance, the public generally lacks clear evidence and financial literacy to balance the cost and benefits of materials that can be used for energy efficiency retrofits (e.g., mineral wool, low-E glazing). Likewise, pre-cast-based construction remains widely associated with low-quality Soviet-era panel housing, while the safety and durability of houses built using new-generation technologies such as 3D printing may be questioned. Reluctance by construction industry operators may stem from different factors, including lack of know-how and concerns about upfront investment costs and operational disruptions associated with new technologies.

Access to financing

FINANCING SUPPLY

Access to long-term finance is one of the key constraints that can hold back greenfield or brownfield investment in the supply of construction materials in Ukraine. Banks, which dominate the domestic financial sector, have historically provided limited project financing loan facilities, leaving many firms to finance investments out of their own balance sheet. Banks further tightened conditions for project finance loans since 2022, as they have limited lending to the real sector and favored safe assets, even though conditions have started improving since 2024. Despite the provision of subsidized loans for SMEs through the government's "5-7-9" program, high interest rates for Hryvnia-denominated loans have made local currency project financing non-feasible in most cases. M&A financing is even rarer, with local banks wary of supporting leveraged acquisition unless heavily collateralized by very liquid assets. Capital markets, another important source of debt and equity financing in developed markets, remain nascent in Ukraine despite plans to support their development. Financing via securities is only open to the largest domestic market players, which can tap into foreign public markets via their international subsidiaries and special purpose companies.

Access to external financing for investment projects is difficult for most firms. As of mid-2025, this possibility remains limited by several factors, including the high country risk premium and limited availability of adequate insurance products, and restrictions on capital outflows limiting the ability of companies to both pay dividends internationally and pay interest to external lenders. One of the main sources of reasonably priced investment funding, both for initial market entries and capacity scaling, has been lending by IFIs, generally using blended donor finance for derisking. However, the conditions and financing threshold set by these institutions tend to be difficult to meet for small domestic investors.

GoU has introduced several programs to stimulate private investment, which can benefit projects in the construction materials sector. This includes the "Investment Nanny" program for "significant" projects (above EUR 12 million). Specific support measures can include exemption from VAT and import duties for new imported equipment and components, compensation for built engineering and transport infrastructure, lease of state or communal land plots for construction of new facilities without auctions, land tax reductions or exemptions, and several other measures – with a total investment equivalent ceiling of up to 30 percent of planned CAPEX. Investing through the industrial parks program is another option, which can provide investors with a 10-year corporate income tax exemption and several compensations and tax reductions similar to the 'significant investments' projects.

Developing green finance could benefit the production of sustainable construction materials. Globally, corporate and government-issued sustainability-linked bonds with terms linked to achieving certain targets or green bonds have been rapidly growing instruments to channel funds to sustainable projects. These instruments are not yet well developed in Ukraine in the absence of sufficiently mature regulatory and institutional frameworks, and they remain underutilized in the construction sector. Adapting and mobilizing these tools could significantly expand access to capital for both new and ongoing investments, while also accelerating the sustainability-driven transformation of Ukraine's real estate and manufacturing base. For instance, GoU and IFIs could explore options to jointly issue such bonds on global markets and channel proceeds to eligible investment projects in the construction sector through local banks.

FINANCING DEMAND

On the demand side, support will likely be required at least initially to make sustainable construction more affordable and attractive to end-users. While supply-side investments are important, they will not scale without clear demand signals. A critical challenge is bridging the affordability gap associated with many innovative and sustainable materials, which often carry an initial price premium even if they can lead to energy and financial savings over the building lifecycle. This is especially the case for materials with less mature market penetration levels, such as geopolymer and low-carbon cement/concrete, basalt FRP rebars, hemp-based materials, and special glazing. Green mortgages and demand-incentivizing programs can stimulate their interest in sustainable buildings and help bridge this gap. To build a strong foundation for green mortgages, it is essential to address systemic gaps in housing finance and improve efficiency of the current mortgage system. Leveraging public investment can also help develop the initial market demand, reach economies of scale in production and bring prices down. Such efforts could be supported by developing the use of voluntary green building standards discussed earlier (Box 5).

Ukraine could build on existing initiatives to stimulate demand for sustainable housing and energy-efficient retrofitting. Recent World Bank analysis shows that well-designed incentive programs, when used to complement rather than substitute enforcement, can help accelerate market transformation and improve compliance with mandatory Building Energy Codes (World Bank 2025). In Ukraine, the EU-funded Energy Efficiency Fund offers co-financing for thermal modernization of multi-apartment buildings, including insulation, heating upgrades, and window replacement. To address affordability gap in homeownership, the government launched the eOselya affordable mortgage program for eligible groups, but this program has not featured sustainability dimensions prominently. As it continues to develop the mortgage market, Ukraine could seek to emulate other countries' initiatives in Europe and elsewhere to develop green mortgages, through which lenders can offer better terms to real estate buyers (both residential and non-residential) for buildings with certified efficiency and sustainability performances.[57]

Embedding sustainability criteria in the selection of public investment projects could help stimulate demand for innovative and sustainable construction materials. Public investment will be a major driver of Ukraine's reconstruction, and the ongoing modernization of Ukraine's public investment management framework is an opportunity to foster sustainable construction. Many projects submitted through the DREAM platform[58] remain of relatively low technical quality. Architects and developers are often unfamiliar with innovative and sustainable construction materials and solutions, while public authorities behind projects tend to lack incentives to prioritize sustainability and resilience. It is important to improve project quality from the design stage, notably for the many relatively simple and generic project types. Increasing the weight given to energy efficiency, resilience and sustainability/circularity in the competitive selection of projects to be financed could shift incentives and motivate municipalities to prepare better projects. This could be supported by a Center of Competence under the DREAM ecosystem, offering hands-on advisory services to project initiators and contracting architectural firms to assist with design. Establishing a help desk on green materials and technologies would be a practical first step, enabling early-stage guidance and coordination with manufacturers – who would benefit from visibility into emerging demand trends. This integrated approach would help align public investment with Ukraine's long-term sustainability goals while building market confidence in new materials.

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[57] See for instance the Energy Efficient Mortgage Initiative in the EU (*https://energyefficientmortgages.eu/*)

[58] Ukraine's DREAM platform – short for the Digital Restoration Ecosystem for Accountable Management – is a centralized digital system designed to manage and monitor public investment projects for reconstruction. It notably provides information about projects included in the government's "single project pipeline" (SPP). (see: *https://dream.gov.ua/en*)

Other constraints

While regulatory, financing and affordability constraints are core barriers, several other issues can undermine the uptake of new materials and solutions in the Ukrainian construction market. Based on expert consultations, this section and Table 10 summarize several important issues, which apply to either to the market as a whole or to particular product/solution categories, and suggest potential interventions to address them.

The barrier of public perception and market readiness to accept specific materials and construction solutions is an inherent feature of a relatively conservative Ukrainian market. In some instances, like retrofits to ensure better energy efficiency and utilities cost reductions – mineral wool and low-E glazing being prime illustrations – the public tends to lack clear evidence-based awareness of benefits and financial literacy to assess lifecycle cost vs. benefit. Pre-cast-based construction is often seen as a continuation of the low-quality standardized panel housing of the Soviet era. In the absence of sufficient experience, both households and industry professionals are likely to question the safety and durability of construction built using new generation technologies, such as building 3D printing. Awareness raising and evidence-based trust building targeting both the supply and demand sides of the industry are critical to ensure market entry and scaling success.

Resistance to technological change by construction sector stakeholders is another facet of the same problem, exacerbated by volatile economic conditions. The construction sector labor force, both unskilled and skilled, are concerned that the industrialization of construction will reduce the quantity of available jobs. Construction companies are often reluctant to invest in automation due to the costs and risks associated with equipment acquisition and reskilling. Both groups typically exhibit a conservative approach to experimenting with new solutions, due to lack of awareness about benefits and information on why new solutions should be seen as opportunities rather than threats.

Lack of skilled workforce and practical material/solution expertise is a significant risk when attempting to introduce new or lesser-known materials and solutions. Reskilling and upskilling costs should be treated as "sunk costs", invested prior to creating and scaling local demand for the new products and solutions. In some cases, on the job training of workers in material manufacturing and construction can be sufficient, but more advanced/complex materials and solutions can require labor to be specifically trained. Educating architects, designers, procurement specialists and other relevant stakeholders to properly introduce new materials and solutions in their project decision-making is another critical challenge. The vocational education system has not yet caught up with current needs and should be upgraded to help bridge the skills gaps.

Scaling up the use of innovative materials is made more difficult by constraints related to shortcomings in the quality infrastructure and lack of guidance about circularity. First, the lack of testing equipment, certification and traceability systems makes it difficult to certify compliance with standards and can undermine trust in claims about material content, performance, or origin (especially for recycled materials). This can also increase the time and cost burden on manufacturers seeking certifications, such as CE marking required for export to the EU. Second, the absence of clear regulatory guidance on and enforcement of end-of-life recycling creates uncertainty around circularity, including unclear cost forecasts and low preparedness for future reforms to foster material recycling.

Table 10. Other constraints and potential interventions

Constraint	Issue	Effects	Material / solution affected
Public perception and market acceptance	• Concerns about safety, durability • Lack of awareness about immediate and long-term benefits • Misunderstanding of effect on total construction costs	• Slower market penetration • Higher marketing expenses • Higher proof-of-concept expenses	• Basalt FRP rebars • Geopolymer/low-carbon cement/concrete • Hemp-based products • Triplex glazing • Basalt wool for retrofit purposes • Pre-cast elements • 3D printing
Resistance to technological change	Reluctance by the construction sector (companies and labor force) to industrialization of construction: • automated construction solutions • pre-cast/prefab solutions • alternative construction protocols	• Limited capacity to introduce sustainable construction solutions • Higher costs of construction • Longer construction project duration • Lower quality construction works • Slower market penetration • Higher marketing expenses	• Robotic arms • 3D printing • Pre-cast elements • Modular construction • Basalt FRP rebars
Local expertise deficit	Lack of skilled labor force (engineers, designers, architects, construction specialists, etc.) able to work with new materials/solutions Disconnect between TVET curriculum/offer and market needs	• Slower market penetration • Higher upskilling and re-skilling expenses • Construction sector ecosystem resistance to new products/solutions • Failed/imperfect construction works/ pilots using new products/solutions	• All
Quality infrastructure	Lack of quality infrastructure, including testing equipment, certification traceability and systems, certified laboratories	• Difficulty to certify material compliance with applicable standards • Lack of trust in claims about material content, performance or origin (incl. recycling) • Time and cost burden of certification falling manufacturers (e.g. CE marking)	• All
Circularity	Lack of clarity and regulatory guidance on end-of-life recycling of materials	• Incomplete national policy/regulation of the waste/debris management system • Low capacity of local governments • Unclear end-of-life cost forecasts • Low preparedness for future sustainability-related construction waste management	• Special glazing • Geopolymer / low-carbon cement / concrete • AAC • Basalt FRP rebars • Hempcrete (due to mix of hemp and special cement formulas)

	Potential interventions	Stakeholders involved
	• Awareness campaigns and demonstration projects for the public, developers, construction companies, designers and architects, public sector • Development of transparent and comprehensive evidence-based material behavior databases Development of comparative construction guidance protocols • Evidence-based awareness campaigns for the construction sector emphasizing construction costs savings because of technical characteristics of alternative materials and solutions	• Private sector • Academia • Professional and industry associations • Consumer associations Homeowners' associations • Public sector (central and local)
	• Awareness campaigns emphasizing that robotic solutions complement rather than replace human labor • Implementation of pilot programs to demonstrate the effectiveness and benefits of industrialization in construction to the sector • Encouragement of participative management where employees are involved in the planning and integration of new technologies	• Private sector • Professional and industry associations • Real estate developers
	• Development of specialized upskilling, reskilling, product/solution awareness, proper use/application, benefit maximization training programs for the construction sector • Add these educations programs to existing EdTech platforms • Encourage private sector participation in developing and offering on-the-job training • Development of specialized vocational and dual-education programs at mid- and higher-education level institutions	• Public sector • TVET institutions • Private sector • Professional and industry associations
	• Enhancement the regulatory framework governing Ukraine's national quality infrastructure in line with EU requirements. Fill gaps in standards and testing protocols for innovative materials • Investment in accredited testing laboratories, including public, private and public-private modalities. Develop shared testing facilities accessible for SMEs	• Public sector (central and local) • Professional and industry associations
	• Develop relevant procedures, plans (at national and local level) and introduce measures to account for, assess and manage construction/ debris waste • Allow private sector participation in waste management (remove regulatory obstacles) • Build capacity of local governments • Development of independent (not producer-ordered) LCA assessments for affected materials • Development, testing and standardization of optimal end-of-life recycling pathways • Prioritization of waste minimization and backfill minimization pathways based on global best practice recycling solutions developed by corresponding production leaders	• Public sector (central and local) • Private sector • Non-governmental institutions • Professional and industry associations

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Annexes

A. Potential supply-demand gaps for construction materials

Material	Annual production capacity (June 2024) [59]	Announced annual additional capacity (June 2024) [60]	Annual consumption (2021)	Annual consumption (2023)	Estimated annual demand during reconstruction phase[61], 10-year running	Potential 10-year demand-supply gap
Cement	13.6 mln tons	n/a	10.5 mln tons	6.2 mln tons	5.5 – 11 mln tons	~
Concrete	21.0 mln tons	n/a	19.7 mln tons	16.0 mln tons	3.0 – 6.0 mln tons	+
Steel	11 mln tons	n/a	5.1 mln tons	3.5 mln tons	0.8 – 1.5 mln tons	+
Bricks	¬ 800 mln pcs	n/a	760 mln pcs	428 mln pcs	300 – 600 mln pcs	+
Aerated concrete	4.0 mln m^3	1.5-2.1 mln m^3	4.5 mln m^3	2.1 mln m^3	2.3 – 7.2 mln m^3	~
Ceramics	61 mln m^2	n/a	46.3 mln m^2	34.4 mln m^2	3.5 – 7.0 mln m^2	+
Dry building mixes	2.6 mln tons	> 0.23 mln tons	1.6 mln	0.664 mln tons	0.2 – 0.4 mln tons	+
Mineral wool	0.21 mln tons	0.02-0.2 mln tons	0.234 mln tons	0.114 mln tons	0.25 – 0.5 mln tons	~
PVC profiles	0.075 mln tons	n/a	0.065 mln tons	0.045 mln tons	0.015 – 0.03 mln tons	~
Float glass	0	47 mln m^2	27 mln m^2	18 mln m^2	6 – 12 mln m^2	–

+ Capacity close to or below estimated total demand
~ Capacity significantly exceeding estimated total demand
– Capacity non-existent or significantly below estimated total

Source: EY (2024) and IFC research

59 Existing production capacity is nominal, and the actual capacity can be lower and require investment in maintenance/upgrading to close the gap.

60 Estimates based on public information. Most notable capacity additions include (i) the successful reprivatization in December 2024 of AEROC, the largest AAC production group in Ukraine, which may restart and expand operations throughout 2025-2026, and (ii) Kovalska Group's investment into a new AAC plant in the Lviv region in 2023. Float glass capacity plans are still at early development stage based on the press releases by project developers. The rest are mostly local players' expansion plans, with the notable exception of major Kingspan reinvestment plans, which are likely to proceed at pace.

61 Covers new construction only, i.e. regular construction plus reconstruction needs for residential and non-residential civil infrastructure, as there is a lack of reliable data on secondary market demand (e.g., maintenance, old stock retrofit, private non-licensed construction purposes).

B. Snapshots of studied efficient and sustainable construction materials

AUTOCLAVED AERATED CONCRETE

Main characteristics and usage:

- Autoclaved Aerated Concrete (AAC) is produced by pouring a mixture of sand, lime, cement, water and aluminum powder into molds and curing it in an autoclave under high pressure and temperature.
- It is used in the construction of housing (SFHs and MFBs), commercial buildings (e.g., high-rise structures for offices or hotels, retail stores, warehouses); and industrial facilities (e.g., power plants, factories). AAC comes in two main forms, (i) non-reinforced blocks, mostly used in non-load bearing applications for large buildings (e.g. partition wall, firewall) but can be load bearing in SFHs, and (ii) reinforced panels, a high-performance building element mostly used in more mature markets that can also be used both as partition wall, a non-load bearing outer wall and as a load bearing material.
- AAC is a near century old pre-cast building material offering several advantages over traditional materials, such as clay bricks and concrete. Technically, it is lightweight (as air accounts for 60-85 percent of its volume), durable, has excellent thermal insulation properties and is fire-resistant. Economically, it improves logistics/construction costs as it is light, creating less load on the foundation, and requires much less mortar and additional insulation compared to clay bricks, and is well-suited for rapid construction requiring limited skilled labor and equipment. Environmentally, AAC has a lower carbon footprint as it uses the least amount of energy per functional unit during production of all non-organic wall materials and can be recycled. In Ukraine's context, AAC's lightweight and rapid installation are crucial for addressing labor shortages and the urgent need for reconstruction. Its thermal efficiency is also beneficial for improving building energy performance amidst energy shortages.
- AAC's drawbacks include lower compressive strength compared to traditional concrete, as well as poor acoustic insulation.

Global market:

- Globally, AAC has high penetration in markets such as Europe, North America, and Asia-Pacific. In Europe, AAC is widely used in residential, commercial, and industrial construction, with significant market shares in countries such as Hungary and Poland. The AAC global market is projected to grow significantly, driven by the demand for eco-friendly and energy-efficient building materials. The market is expected to reach $28 billion by 2030, with a compound annual growth rate (CAGR) of 9.1 percent. This growth is fueled by urbanization, population growth, and the increasing focus on reducing the environmental impact of construction.

Relevance for Ukraine:

- In Ukraine, AAC has a high market penetration, particularly in the construction of private houses and cottages. This is helped by the local availability of most raw materials, such as sand and limestone. Opportunities for AAC in Ukraine are significant, especially in the context of post-invasion reconstruction. The demand for affordable housing and the need for rapid construction present a substantial market for AAC, a decline in demand for individual housing due to demographic trends would undermine this.

Investment opportunities:

- The landscape of AAC producers in Ukraine includes several major players, such as StoneLight, GazoBet, UDK, and Kovalska. These producers have the capacity to meet current demand but are underutilized due to the invasion. Investment opportunities in Ukraine's AAC market are promising, particularly through the acquisition of existing producers or greenfield investments focused on reconstruction. Viable business models include acquiring operational players with established supply chains or investing in small-scale flexible factories in post-conflict zones. The potential for high demand due to reconstruction efforts makes AAC a commercially viable investment, provided there is sufficient scale and market access.

Bottlenecks:

- Several constraints hinder the scaling up of AAC use in Ukraine, including potential deficit of cement, corresponding price volatility, and logistical restrictions (commercially viable AAC delivery radius is within 300 km). Coupled with raw materials (lime and sand) supply unevenly spread, effective coverage of eastern and southern regions of Ukraine is limited. Financial barriers also exist, as AAC production requires significant initial investment.

BASALT (ROCK) WOOL

Main characteristics and usage:

- Basalt wool, also known as stone or rock wool, is an insulation material from the mineral wool group produced by melting basalt rock (often mixed with dolomite, bauxite and/or slag) and then spinning the mass in a special centrifuge with a powerful airstream to obtain so-called staple fibers (5 to 8 mcm in diameter) – a process somewhat similar to making cotton candy – which are then pressed together and 'glued' with a phenol or bio-based binder.
- Basalt wool is typically produced in two primary forms: flexible rolls and rigid slabs (or "batts"). Rolled wool is thinner and may be used as insulation for asymmetric and non-flat surfaces (pipes, roof cavities, attic spaces, etc.), while rigid slabs are much thicker and denser and are used as external wall, roof and floor insulation.
- Depending on the form, basalt wool is used in insulation of building envelopes and piping/HVAC networks in housing (SFHs and MFBs), commercial buildings (e.g., high-rise structures for offices or hotels, retail stores, warehouses), social infrastructure, civil defense facilities, and industrial facilities (e.g., power plants, factories). Additionally, it may be used as a very effective pest, fungi and bacteria-resistant plant bed in hydroponic facilities and has several industrial facility applications, including acoustic dampener, solar thermal collector insulation, fire door component and more.
- Initially conceived in the mid-1800s, the mineral wool concept has undergone multiple technological changes and advancements, with proper commercialization starting in the mid-1900s. Mineral wool is a category name, comprising fiber-based insulation materials made of volcanic rock, silica (glass), and other inputs. Of those, stone or basalt wool has the best fire resistance performance, withstanding temperatures of over 1000 C, compared to only 600 C for glass wool. Beyond non-combustibility and best-in-class fire resistance, basalt wool offers other advantages over other insulation materials. Technically, it is water repellent and "permeable", allowing water vapor to escape; has mechanical memory, returning to original form and insulation values, if it gets wet; efficiently blocks rot, corrosion, fungi and mold growth; and is an effective acoustic dampener due to its sound-absorbent structure.
- From an environmental perspective, basalt wool provides best-in-class energy efficiency at a relatively affordable price, reducing operational CO_2 emissions. Furthermore, following recent technological advancements, modern basalt wool is now considered recyclable – able to be re-melted and re-spun into new wool, or just reused effectively in new insulations after controlled removal from buildings. Based on multiple LCA assessments, basalt wool has one of the lowest lifecycle CO_2 emission parameters across the full range of inorganic, organic and bio-based insulation materials. Coupled with best-in-class fire safety, this makes it a primary choice for retrofits of pre-1991 residential and social infrastructure. One current environmental issue is the ongoing use of phenol as a binder – a toxic material being gradually phased out in EU –, although major insulation producers are now developing bio-based binders.

Global market:

- Historically, basalt wool has been most represented in Europe and North America; however, the material has been gradually adopted by Asian and Latin America countries, as their share of mid- and high-rise buildings requiring dense inorganic insulation is growing. Globally, the market is growing at over 4 percent annually and is expected to exceed USD 7 billion within the next 3-4 years. Residential end markets consume just over half of the total production. Within the overall insulation market, basalt wool takes up a 20 percent share, with the relatively cheaper glass wool and polymer-based insulations (XPS, EPS and others) collectively comprising another 70-75 percent, and the remainder covered by specialized and bio-based (cellulose mostly) insulation materials.

Relevance for Ukraine:

- In Ukraine, basalt wool has gradually become the external insulation material of choice, after first gaining a foothold a decade and a half ago. The material has squeezed out consumption of glass wool and reduced reliance on cheaper polymer-based insulation. This has been partly driven by local abundance and cheap access to basalt.
- Opportunities for basalt wool market growth in Ukraine are significant, especially in the context of the need to retrofit old real estate stock to improve energy efficiency and reduce pressure on the domestic energy system. Existing and planned basalt wool production capacities will likely suffice to cover post-invasion regular construction and reconstruction needs; however, the scale of future retrofits will require significant additional capacity.

Investment opportunities:

- The landscape of basalt wool producers in Ukraine is comprised of several large and mid-sized players, such as Sweetondale, Obio (TM Izovat) and Novotherm. These producers have the capacity to meet current demand but have operated below capacity during the invasion. Investment opportunities in Ukraine's basalt wool market are promising, particularly through the acquisition of existing producers or greenfield investments focused on future retrofit demand and reconstruction objectives. Viable business models include acquiring operational players with established supply chains. The potential for high demand due to future retrofit demand and reconstruction efforts makes basalt wool a commercially viable investment, provided there is sufficient scale and market access.

Bottlenecks:

- A key issue is the relative affordability gap between basalt wool and polymer-based insulation. While basalt wool is superior technically and in terms of fire safety, cash-strapped property owners (primarily homeowners' associations) currently often choose cheaper options for retrofits. Without efforts to bridge that gap, the obtainable retrofit-focused market size may be restricted in the medium to long-term.

BASALT FIBER-REINFORCED POLYMER REBARS

Main characteristics and usage:

- Basalt Fiber Reinforced Polymer (BFRP) rebars are produced out of Continuous Basalt Fiber (CBF) mixed with epoxy resin via a complex pultrusion, formation and curing process. CBF, in turn, is made in various diameters from basalt rock – a naturally abundant rock of volcanic origin – which is crushed, melted at 1500 C, extruded through small nozzles (dies) made of platinum or rhodium, and then undergoing a process called roving to create CBF bundles.
- CBF, depending on diameter, has its own commercial value as a semi-finished input in multiple industries, including construction, automotive, defense and others.
- BFRP rebars are seen as an alternative to traditional steel rebars. Like steel rebars, they may be used as concrete reinforcement in construction of foundations, walls, beams and slabs in a wide range of building types, as well as in transport infrastructure – railway beds, bridges, highway beds, marine environment constructions – and in reconstruction of historical buildings and monuments.

- BFRP rebars (and mesh) are a relatively new advanced manufacturing product group, based on the manufacturing of CBF, which was ideated a century ago, and developed primarily ub the former Soviet Union during the Cold War. The first commercial BFRP rebar production facility emerged in Ukraine in 1985 and the technology was later picked up in other countries, including the United States and China.
- BFRP rebars offer several major technological advantages over traditional steel rebars. Technically, they are extremely lightweight (about 4 times lighter than steel), fully anti-corrosive and resistant to alkalis and acids, UV resistant, non-magnetic and non-conductive, have "mechanical memory" and anti-seismic features, have 2.5x more tensile strength compared to steel rebars, and do not require welding. As a result, they have an average lifespan 3 times longer than conventional steel rebars and require up to 30 percent less concrete cover when reinforcing concrete. This feature mix makes them particularly suitable to use in construction of specialized buildings with sensitive electric equipment – data centers, equipment-intensive diagnostic clinics and hospitals, and more – and provides significant construction phase and lifecycle maintenance cost savings.
- From an environmental perspective, based on known independent LCA data, BFRP rebars outperform all key conventional and competitor rebar materials on most key environmental impact indicators – global warming potential of 6 mm BFRP bars, measured in $kgCO_2eq$, excluding transport, is 74 percent lower than that of steel, 22 percent lower than steel with 100 percent recycled content, 49 percent lower than galvanized steel, 88 percent lower than stainless steel, and 44 percent lower than GFRP (glass polymer rebars).
- BFRP rebar drawbacks primarily stem from a distinctly different technological approach to construction compared to steel rebars, which requires significant re-education of the whole construction sector value chain, from architects to in-situ construction teams. Additionally, BFRP rebars are comparatively more expensive than steel rebars, if lifecycle construction costs are not accounted for, reducing construction companies' willingness to consider BFRP as a viable alternative when direct material cost is prioritized over lifecycle calculations.

Global market:

- Globally, the BFRP rebars and mesh market is still nascent, being the smallest of the three primary composite rebar material segments (glass, carbon and basalt). The total composite rebars market is expected to exceed $800 million by 2027, with BFRP making up just 10 percent of the market, at current growth rates. This growth, however, may be significantly boosted over the next decade due to growing demand for "green" alternatives to steel in construction and abundance of basalt rock as a base raw material. Further growth may also be fueled by an increasing number of successful use cases with proven cost and environmental gains.

Relevance for Ukraine:

- Practical BFRP rebar development originated in Ukraine, driven by a mix of strong R&D capabilities and availability of some of the largest basalt deposits in the world, which due to their chemical composition are generally considered to be best-in-class for stable CBF production. Russia, as the long-time CBF/BFRP global leader, has been using both Ukraine's basalt deposits and Ukraine's technological know-how in products and production facility design in its operations before the invasion. Accordingly, given current restrictions on imports from Russia, Ukraine is well positioned to establish and scale its own CBF/BFRP business, both for internal and export objectives.
- Internal demand is currently nearly non-existent, and the market and construction value chain must be educated about the materials lifecycle benefits; however, the opportunities are significant, considering both transport and social infrastructure reconstruction needs and growing steel production capacity deficit due to the invasion.
- Primary threats include 1) significant share (over half) of energy in production cost of CBF and the need to secure uninterrupted rock melting and extrusion process, which may be jeopardized by invasion-induced energy outages, requiring investments into autonomous energy sources; and 2) supply chain risks for CBF production due to use of precious metals like rhodium and platinum, which have volatile price dynamics.

Investment opportunities:

- Ukraine currently has no active construction-oriented CBF and BFRP rebars/mesh producers, though there were several attempts to set up operations by local investors over the past two decades. The R&D and production facility design experts, however, are available, as are capacities of the previous operations (currently dormant). Accordingly, investments may be directed into several operational models between CBF production, BFRP production, R&D hubs/centers of excellence and supply/value chain JVs with international producers (primarily Europe and Middle East) – focused on both internal market needs and global market expansion.

Bottlenecks:

- Several constraints hinder introduction and scaling of BFRP materials in Ukraine, including very limited product awareness, lack of understanding of the technological changes to construction required for efficient employment of BFRP in concrete reinforcement, and perceived affordability gap. Regulatory challenges are practically absent as local investors driving previous attempts have successfully introduced comprehensive product and building codes covering BFRP use into the Ukrainian construction legislation. Financial barriers also exist, as CBF/BFRP production making use of economies of scale requires very significant initial capital investments. Marketing and value chain re-education costs may also prove to be very sizable.

GEOPOLYMER CEMENT/CONCRETE

Main characteristics and usage:

- Geopolymer cement is a sub-class of alkali-activated cements – low-clinker or clinker-free alternatives OPC. These cements use a binder composed of industrial by-products that are high in silica and alumina, such as fly ash and GGBFS (ground granulated blast furnace slag), which are chemically activated using alkaline – sodium/potassium hydroxide and sodium silicate.
- Geopolymer cement is a direct replacement for OPC covering all the use cases of traditional clinker-based cement. Final products, just as with OPC, may be used for pre-cast concrete elements, in-situ concrete casting, dry mixes and special mixes for 3D printing of buildings.
- Development of geopolymer cement materials originated in Ukraine in the late 1950s when Ukrainian scientist Glukhovsky first discovered the possibility of producing synthesized binders using aluminosilicates (clays, rocks, slags) and solutions of alkali metal. While multiple buildings have been constructed over the next several decades, proper commercialization of the technology did not begin until the last decade, as efforts increased to decarbonize the cement industry.
- Modern geopolymer cement formulas are diverse and resulting products differ significantly in their performance parameters. However, from a technical perspective, all geopolymer cements are superior to OPC in a number of ways: they generally have much stronger anti-corrosion properties, protecting the steel bars used for concrete reinforcement; they are resistant to sea water making them particularly suitable for coastal civil and industrial built environment and transport infrastructure; they reach full compressive strengths much quicker than OPC and are less prone to cracking. Put together, those properties ensure enhanced durability of geopolymer cements, leading to lifecycle cost savings on repairs and maintenance and construction phase costs due to more rapid setting of concrete.
- From an environmental perspective, geopolymer cement is one of the key replacement options for clinker cement. They can reduce lifecycle CO_2 emissions by more than half compared to OPC, depending on the binder used. Moreover, environmental benefits also accrue from the reuse of industrial by-products, such as slag and fly ash. By nature of the formula mixes, geopolymers also use less ‘virgin’ extracted raw materials than OPC, leading to resource conservation. Finally, the absence of clinker provides significant energy savings, as high-temperature processing is not required.

- As geopolymer cements are a material group with a wide range of potential formulas and usable inputs/precursors, the largest technical bottleneck for new facilities is ensuring factory-grade stability and property uniformity of the final product. Different shipments of slag and/or fly ash, being by-products rather than factory calibrated inputs, may have different chemical compositions, introducing variability into geopolymer products. Accordingly, each facility must have a lab checking each input shipment and course-correcting the alkali-activation process to allow for that chemical variability.

Global market:

- Global market structure for geopolymer cement/concrete is not easy to determine, due to lack of clarity in the definition of what constitutes a geopolymer cement product as opposed to other types of low-clinker/clinker-free cements, and overall early maturity stage and regular innovations in the segment. Various industry assessment reports, however, provide segment CAGR estimates of 20-30 percent until 2028-2030. EU decarbonization policies provide a key growth impetus; however, access to slag and fly ash in the EU is a major bottleneck, as Europe is gradually moving away from coal-fired heat generation facilities (source of fly ash) and coking coal-based blast furnace metallurgy (source of GGBF slag). The Asia-Pacific region enjoys better access to those inputs, thus leading production and demand.

Relevance for Ukraine:

- Ukraine is one of the few remaining countries in wider Europe that is still actively using older heat generation and metallurgical facilities, resulting in much better access to slag and fly ash. Accordingly, this serves a unique opportunity for any major alternative cement manufacturer looking to secure scaled access to those precursors.
- Because geopolymers were originally developed in Ukraine during the Soviet era, it still has some of the best academic knowledge on the material group.
- Given the scale of post-invasion reconstruction and regular construction in Ukraine, the fact that some cement production facilities are located in temporarily occupied locations in the eastern and southern regions of Ukraine, and cement decarbonization policies being gradually introduced by the EU, the growth of the clinker-free cement segment is of particular importance to Ukraine. In addition to the domestic market needs, geopolymer cements may be a commercially attractive export niche to the EU, given much better access to slag and fly ash.

Investment opportunities:

- There are no active producers of geopolymer cements in Ukraine, although several local construction material producers have been working on their own versions of the material. The market, though, would be best served by market entry of some of the large global players in the segment, who could combine their own and local R&D capabilities, financial support and production know-how to boost 'green cement' growth in the country. Primary entry models are either a 'greenfield' geopolymer cement production facility, acquisition of existing cement facilities and subsequent switch to geopolymer production, and/or investments into domestic production of factory-grade inputs – calibrated slag and alkaline.

Bottlenecks:

- The significant affordability gap compared to OPC is the primary significant constraint to domestic segment growth. The other important bottlenecks are very limited product awareness, lack of sufficient number of successful project cases to prove lifecycle economic and environmental benefits, and terms and conditions of access to the domestic industrial by-product precursors and imported alkaline that are currently not produced in Ukraine. Financial barriers also exist, as geopolymer cement production facilities require very significant initial investment.

HEMPCRETE

Main characteristics and usage:

- Hempcrete is a carbon-negative wall construction material made of a mix of processed and pressed hemp shives (also known as hurds) – woody inner core particles of a hemp stalk – and a binder made of lime and various pozzolans. It can be produced using two different approaches: prefabricated standardized blocks and in-situ wall 'casting', similar to the in-situ concrete casting process. Hempcrete may be used for both structural load-bearing wall construction and non-load bearing building envelope creation.
- Hempcrete is seen as an alternative to traditional lightweight wall construction materials, such as AAC, clay and silicate bricks, steel and timber hybrids. Like AAC and bricks, it may be used in a wide range of cases: SFHs, low-rise MFBs, low-rise social infrastructure (administrative buildings, schools, kindergartens, general purpose clinics). In addition, hempcrete may also be used for retrofits of historical timber frame-based buildings as replacement for old infill panels. Beyond these, global successful use cases, also include a 12-story high 'Hemp Hotel' in Cape Town (South Africa), reconstruction of a town hall in Voorst (Netherlands) and multiple mid-rise (5+ floors) residential complexes across the EU.
- While the use of hemp in construction dates back at least as early as the 5-6th century AD, modern revival is attributed to France and the Soviet Union in the 1970s-80s. Initially designed to improve thermal performance in historic buildings and provide a cheaper alternative for construction of rural housing, hempcrete gained traction worldwide over the past two decades as a versatile wall material.
- Hempcrete offers numerous technological benefits over AAC and bricks. While comparably lightweight and fire resistant, it has superior thermal and acoustic insulation characteristics, better permeability, is non-toxic, pest resistant and has anti-fungal and anti-bacterial properties. It has a longer potential life span than AAC, estimated at over 100 years, and it is made of mostly renewable inputs. Its inherent thermal insulation properties remove the need for additional insulation, normally required by AAC and brick walls.
- From an environmental perspective, hemp is "carbon-negative", i.e. more CO_2 is sequestered during cultivation phase than generated across its cultivation and processing cycle. It is bio-degradable, recyclable and provides significant additional emissions savings due to its energy efficiency.
- Hempcrete's key drawback is its relatively low density, limiting load-bearing use. However, AAC and bricks share the same issue, making them comparable and competitive. Additionally, the in-situ casting version of hempcrete depends on weather conditions during the curing and drying phase, making construction length and quality somewhat less predictable. Prefabricated hempcrete blocks do not have this issue and are thus considered a superior approach.

Global market:

- Globally, the hempcrete market is still at a nascent stage, with a large share of the market still confined to rural DIY construction. New producers emerge regularly, however, and key players are now attempting to scale prefabricated production, with companies like Belgium-based IsoHemp launching industrial-scale factories (4 million hempcrete blocks annually) to satisfy growing demand. While exact forecasts are difficult to obtain, industry experts expect the global hempcrete market to potentially reach up to USD 2 billion by 2030, driven by intensifying efforts to decarbonize the cement/concrete industry and correspondingly, building envelopes, and hempcrete's carbon-negative feature.

Relevance for Ukraine:

- A substantial share of Ukrainian residential buildings – and an even higher share of such those destroyed or damaged by the invasion – is comprised of SFHs. Hempcrete, given its technological properties, is one of the most effective organic construction materials for such housing given Ukraine's continental climate.
- Ukraine has a strong agricultural sector, with millions of hectares of arable land, mostly used for cultivation of low-margin commodity crops. Scaling of a higher-margin industrial crop such as hemp may be of particular interest to farmers provided sufficient financing, securing the inputs for downstream processing into hempcrete. Industrial hemp is an extremely efficient value-added crop, with nearly every plant element (stem, flowers, leaves, seeds) usable for downstream processing besides construction materials – pharmaceuticals, edible oil, industrial textiles, paper, clothing, food additives, personal hygiene and industrial products, are some of the other end market options. Considering this, industrial hemp and the processing ecosystem may be an important pathway to improve livelihoods of the entrepreneurs and workforce operating in the Ukrainian agricultural sector.
- Ukraine has a decades-long history of industrial hemp R&D, ranging from seeds/varieties selection (currently developed Ukrainian hemp varieties are considered globally to be some of the best by quality and harvest mass) to downstream processing technologies. Coupled with a new law on cultivation of industrial hemp passed in August 2024, this provides strong impetus to local players to expand their operations. The Ukrainian hemp sector is well-known and respected by the international industrial hemp business community.
- Internal demand for hempcrete is currently minimal due to lack of product awareness, lack of production capacities, as-yet unregulated nature of hempcrete as a construction material and a significant affordability gap between hempcrete and more traditional wall materials. The affordability gap, however, may be bridged naturally by gradual expansion of both the cultivation areas and the processing ecosystem, leading to economies of scale on production costs.
- Main threat for growth of hempcrete is very intensive competition in the wall materials market in Ukraine, prioritizing unit price over long-term economic savings and environmental/quality of life concerns.

Investment opportunities:

- Ukraine has a growing cultivation and processing ecosystem, with recent investments and market activity by mostly locally founded companies: Hempire, Global Hempiness, Ma'Rijanni Hemp Industrial Park and several others. No large international players are currently present, providing diverse 'greenfield' and JV market entry opportunities into a nascent but rapidly developing industry. Entry models may focus either on downstream processing/hempcrete production only, or create more vertically-integrated operations, either controlling or supporting hemp cultivation and further R&D efforts.

Bottlenecks:

- Rapid growth of demand for hempcrete is currently restricted by lack of consumer awareness of the material and its benefits; common perception by authorities and public that industrial hemp is related to cannabis; and, most importantly, absence of corresponding product and building codes in the Ukrainian construction legislation, currently limiting demand to experimental DIY-style constructions in rural areas.

SPECIAL GLAZING

Main characteristics and usage:

- Special glazing is a colloquial category name for several types of architectural glass and glass products with specialized energy efficiency and safety properties. Within the framework of this Report, the focus was made on two primary products: low-emissions glass (Low-E) and architectural laminated (triplex or safety) glass.
- Low-E glass is a coated type of glass where the coating imbues additional energy efficiency properties, by reflecting heat from sunlight during summers and blocking heat from escaping the property during winters. It is produced by applying special coating to float glass either 1) by means of sputter coating process, where metal or metal oxide targets are bombarded with ions in a vacuum chamber, causing atoms to be ejected and deposited onto the glass surface in thin layers; or by means of chemical vapor deposition, where reactive gases are introduced into the process chamber, and when they come into contact with the hot glass surface, they react to form a thin Low-E coating.
- Laminated glass is a coated type of glass product that combines energy efficiency and breakage resistance properties. Upon impact, the glass does not shatter into freely-flying shards but remains stuck to a special interlayer, protecting the interior of the property from damage, minimizing impact waste and reducing petty theft attempts. It is produced by 'sandwiching' together two sheets of float glass and a film-type interlayer (polyvinyl, ethylene-vinyl and polyurethane being main options), pre-pressing them, then subjecting the 'sandwich' to autoclave processing to firmly bond glass sheets and the interlayer and subsequently cooling them down to room temperature.
- Low-E glass is typically used as part of double- or triple-glazing window units and façade glazing units and is suitable for glazing in any application. Laminated glass, on the other hand, is a self-contained product, installable as a window or glass door unit.
- Low-E glass has been commercialized in the 1970s-80s, and achieved widespread adoption and standardization in the 1990s, becoming a game-changer for building energy efficiency enhancement efforts, with continuous technological advancements further improving performance and suitability to different climatic zones and scenarios. Laminated glass, a much more niche product, is a century-old technology, significantly improved in the past three decades by emergence of advanced interlayer films with superior properties.
- From a technical perspective, beyond their primary functions, both Low-E and laminated glass share several additional advantages: they are UV radiation resistant, protecting inhabitants and property interiors from harmful sunlight exposure, they increase acoustic insulation, and they are generally more durable than non-coated glass products. From an environmental perspective, their interior climate control properties result in significant utility consumption savings (up to 30-40 percent in certain scenarios), replacement costs/waste minimization due to better durability and repair and maintenance savings due to UV radiation protection. Both products can be recycled with their respective coatings in a controlled demolition scenario.
- There are no significant technical drawbacks with Low-E glass. Laminated glass, as a niche product, has several potential 'quality-of-life' weaknesses. By its nature, it may somewhat reduce window
- transparency/increase haziness, which may limit residential
- consumer demand; Additionally, studies have shown that laminated glass may partially restrict/limit mobile telecommunication transfers inside buildings. The latter issue is allegedly minimized when 4G telecom and high-frequency Wi-Fi bands are used but may be a restrictive issue in weak network locations.

Global market:

- Low-E glass dominates the global coated glass market with share of up to 80 percent. Global demand has been consistently growing over the past decade, with a forecasted CAGR of 6-7 percent for the 2020-2028 period and a market size of over $40 billion in 2023. Demand is primarily driven by energy efficiency objectives in residential and commercial buildings, including gradually increasing demand for retrofits of the ever-older residential stock in Europe.
- Laminated glass is a major global market of its own, courtesy of growing usage in the automotive and solar panel industries, with an estimated global market size of over $20 billion in 2024. Architectural laminated glass has a significant share in the overall product segment, being increasingly used not just in window and door units, but also for railings glazing, skylights and other building elements. Demand for architectural laminated glass is driven by increased safety considerations coupled with superior UV rays blocking and acoustic dampening properties improving overall safety and quality of life in built environment – particularly in commercial real estate.
- Affordability of special glazing remains a challenge on a global level. While Low-E glass is gradually converging with non-coated glass pricing, providing a clear consumer investment case given its long-term advantages, architectural laminated glass has a much more significant price gap, which coupled with certain technical drawbacks, creates a less compelling case and restricts global market growth.

Relevance for Ukraine:

- All float glass, both non-coated and coated, is currently imported. Laminated glass can be manufactured locally – there are several smaller firms offering the product – but the film interlayers are still imported.
- Current import quantities cover demand, but post-invasion demand may put significant additional pressure on import supply chains. Several investment groups, both local and international, have announced plans to construct float glass plants in the country, which would replace the bulk of imports, but implementation is highly sensitive to availability of significant funding. Planned capacities will likely have Low-E glass production lines as part of the manufacturing facility complexes, but their total future capacity is unknown.
- Given Ukraine's extreme continental climate and widespread damage to the energy generation system, Low-E glass is a critical element of energy efficiency efforts. Potential market size is very significant due to the scale of the addressable retrofit market. Furthermore, while not producing its own non-coated and coated glass, Ukraine has an advanced window units manufacturing ecosystem, with a growing share of exports, which provide an additional potential sales channel for future domestic glass producers.
- Architectural laminated glass is also of relevance to Ukrainian building sector, due to its protection from blast impacts – a regular occurrence during the invasion period and a long-term risk considered by consumers for the post-invasion period.

Investment opportunities:

- Due to absence of any active float glass production facilities or ones nearing completion, primary entry model is a 'greenfield' facility investment into float glass, with special glazing production lines as part of the manufacturing facility. In the mid-term, should several float glass plants be already commissioned, investment in stand-alone Low-E and laminated glass production facilities may become viable, potentially in a 'brownfield' scenario, as part of construction materials-focused industrial parks.

Bottlenecks:

- Local affordability of special glazing is the primary bottleneck, alongside limited consumer awareness of long-term benefits and advantages of such glazing options.

C. Presentation of selected high-speed construction solutions

PRE-CAST CONCRETE ELEMENTS

Main characteristics and usage:

- Pre-cast construction elements are a form of construction based on manufacturing structural elements of a building in a factory environment, as opposed to directly at construction site, and transporting them to the site for assembly. While pre-fabrication may involve several different basic materials, including steel, wood, polymers and more, the term 'pre-cast' specifically refers to manufacturing structural elements out of concrete. At the factory, concrete is cast into a reusable mold and then cured in a controlled factory floor environment, then delivered to the construction site for assembly as a finished product.
- The spectrum of concrete pre-cast elements encompasses, but is not limited to, walls, facades, floor slabs, staircases, beams, foundation piles, roadway slabs, and fencing structures. They may be produced and delivered in different states of finishing: simply finished (basic reinforced concrete walls, slabs, staircases, and sandwich wall panels, which include a layer of thermal insulation sandwiched between two layers of concrete); semi-finished (those elements come pre-equipped with utility conduits and cabling, further reducing construction time); and fully finished (elements, primarily walls, which come with full interior and exterior furnishing).
- The concept of pre-cast concrete has been known as long as concrete itself, but modern mass production has been pioneered at the beginning of the 20th century and used extensively in the aftermath of World War II to deliver new housing and other infrastructure on a scale and in the timeframe that would be difficult to meet with traditional in-situ construction methods. Since then, the technology has significantly advanced, offering much better quality, resource management and numerous other benefits to construction companies responsible for standardized linear built environment.
- From a technical perspective, when such standardized construction is expected and project needs favor speed and GFA quantity over creative custom-made building designs, pre-cast concrete elements offer very significant construction time savings over in-situ concrete casting, as there is no wait period for curing; minimization of labor force needs, as there is no need for a separate team installing in-situ formworks and operating casting and curing processes; and standardized quality and dimensions of the delivered elements, which exclude risks of human error inherently present during in-situ concrete casting.
- Economically, while the pre-cast elements may cost more than the equivalent quantity of concrete used in in-situ casting, total construction phase costs are typically much lower, due to reductions in labor force needs, material waste, transportation and management of in-situ casting machinery and formworks and overall reduction of construction time.
- From an environmental perspective, factory-based manufacturing of complete structural elements delivers up to 30 percent material and energy savings due to several processes: effective compaction process for cement in factory settings, less steel usage due to factory pre-stressing, effective wastewater management, minimization of material waste and reduced energy consumption due to economies of scale at factory floor. Overall reduction of CO_2 emissions between in-situ casting and using pre-cast elements is usually estimated at 10-20 percent in developed markets but may significantly exceed those numbers when developing markets with poor in-situ construction practices are considered.
- Modern pre-cast factory technologies mitigated most of the technical drawbacks associated with pre-cast elements back in the 20th century. The only systemic drawback is the overall limitation of use to standardized building designs, making social and comfort-class housing and administrative infrastructure the most likely end markets.

Global market:

- Estimates of the global precast concrete market differ substantially between different data analytics providers, but they generally expect the market to grow at a CAGR of 5-7 percent at least until 2030-2035, growing from an estimated $130-150 billion in 2024 to $200-250 billion by 2035.
- Global demand is driven by growing needs in mass-produced affordable housing and quicker building delivery. Continued development of the technology, allowing for better element design flexibility, combination of different materials in semi and fully finished products and element design methods allowing for quicker in-situ installation and interconnection of elements (structural building system blocks) provide further boosts to global market adoption.

Relevance for Ukraine:

- Of the currently existing and affordable high-speed construction solutions, the pre-cast construction method provides the best fit to Ukraine's post-invasion reconstruction needs. If quantity and speed of construction are prioritized in the post-invasion country revitalization strategy, no other solution can deliver at the scale expected, while prioritizing speed and overall affordability. Furthermore, given Ukraine's labor supply challenges, mass adoption of pre-cast solutions can be particularly relevant.
- Of special note is the fact that pre-cast products can be combined with several other materials and solutions– most notably, basalt wool and basalt rebars, geopolymer cement/concrete and robotic arms. If combined, both potential economic and environmental gains from introduction and mass adoption will be multiplied, as positive technical spill-over effects are expected from the product/solution combinations.
- The Ukrainian pre-cast concrete market was growing prior to the invasion, with many incumbent old technology factories having order backlogs for months. While the general public tends to be suspicious of the solution due to the poor quality of Soviet Union panel-based housing, the perception has been progressively improving. There are several sizable pre-cast concrete producers, such as Kovalska Group, Oberbeton, DBK-3, and ZZBK Etalon, which could scale up production.

Investment opportunities:

- With an ecosystem already in place, primary market entry models would be either an M&A or a JV with the incumbent producers, 'greenfield' investments into new facilities fully conforming to EU manufacturing standards, or 'brownfield' set-up of new facilities within construction materials-focused industrial parks with special tax and investment incentive regimes.

Bottlenecks:

- Consumer perception of the solution, limited flexibility for design purposes and commercial suitability predominantly to large, standardized construction projects (pre-cast elements are less suitable for small-scale projects, as the weight of finished elements requires handling by heavy machinery at construction site, often too expensive or unavailable to small low-rise projects) remain the key bottlenecks for scaling the solution.

PREFABRICATED MODULAR VOLUMETRIC UNITS

Main characteristics and usage:

- Modular, also known as volumetric, units are an advanced construction method involving the production of three-dimensional, fully-finished modules within a controlled factory environment, which are subsequently transported and assembled on-site to create a complete structure. Like pre-fabrication of structural elements, manufacturing of volumetric modules may involve a number of different basic materials, including steel, wood, polymers and more. In the case of volumetric modules, the choice of material represents a separate market. For illustration purposes within this Report, one of the most popular materials, steel, was chosen, representing the markets of 1) container-type modules, used for temporary housing and construction site lodging for the workers, 2) stand-alone lightweight modules, used as kiosks, mobile offices, portable classrooms and emergency micro-housing, and 3) finished functional blocks for installation in multi-story buildings, i.e. bathroom and kitchen pods, safety rooms, etc.
- Similar to pre-cast elements, volumetric modules may be produced and delivered in different states of finishing: simply finished (basic modules commonly used for straightforward applications, providing essential structural components and minimal finishes); semi-finished (partially finished and require additional on-site work to complete features such as interior finishing); and fully finished (fully completed modules that are ready for immediate use upon installation, incorporating all necessary fixtures, fittings, and finishes).
- Despite the term 'modular' being of relatively modern origin, the concept of finished prefabricated buildings has a long history and was popularized for commercial purposes in the first half of the 19^{th} century. Technological advancements over the past two centuries have significantly improved quality, resource management, design options and optimized fabrication processes, significantly improving environmental footprint of the prefab products.
- From a technical perspective, modular construction can reduce project timelines by at least half compared to traditional (in-situ) construction methods. This is due to concurrent modular manufacturing (independent of weather-related delays) and on-site preparation. Like pre-cast elements, modular construction significantly reduces labor force needs and offers standardized quality and dimensions. Additionally, however, installation of stand-alone modules minimizes adverse effects on the community and surroundings, as most of the traditional construction works involving noise, daily transportation and more, are absent from the installation site.
- Another strong advantage of volumetric units is their potential interconnectivity, allowing the so-called 'stacked blocks' concept. Separate volumetric units (effectively rooms) can be stacked next to and on top of each other and connected to quickly form a much larger integrated space, similar to a multi-room house or apartment.
- Economically, in most applicable use cases, volumetric units turn out significantly cheaper in terms of total construction phase costs.
- From an environmental perspective, modular construction may deliver CO_2 emission savings by up to 45 percent compared to traditional in-situ construction methods, depending on specific material and functional purpose of particular unit.

Global market:

- Estimates of the global modular construction market differ substantially between different data analytics providers, but most expect the market to grow at a CAGR of 4-6 percent at least until 2030-2035, growing from an estimated $80-90 billion in 2023 to $120-150 billion by 2030-2035.
- Volumetric units accounted for less than 2 percent of the global construction market prior to 2022, but have since witnessed substantial market growth, driven by the rising demand for swift, dependable, cost-efficient and eco-friendly construction solutions.

Relevance for Ukraine:

- While a less adopted product in Ukraine compared to pre-cast elements, volumetric units have nonetheless their own niches, and demand for them is growing rapidly enough to have induced launch of multiple domestic manufacturers of different unit products. Given Ukraine's labor supply challenges and need for quick solutions, especially for regions closer to the frontline, modular units are highly relevant.

Investment opportunities:

- With a manufacturing and supporting ecosystem in active development, primary market entry models would be either an M&A or a JV with the incumbent producers, 'greenfield' investments into new facilities fully conforming to EU manufacturing standards, or 'brownfield' set-up of new facilities within construction materials-focused industrial parks with special tax and investment incentive regimes.

Bottlenecks:

- There are no obvious bottlenecks to expansion and scaling of the volumetric units' market in Ukraine.

INDOOR ROBOTIC ARMS

Main characteristics and usage:

- Indoor robotic arms for construction are programmable machines designed to automate tasks typically done by humans in building construction, such as welding, painting, material handling, demolition, bricklaying, assembly of prefabricated elements, palletizing and many others.
- Originally conceived in the 1960s, multiple variations of the technology have been developed since. Global adoption for construction purposes came with the advent of specialized construction software (Building Information Modelling and other types). As robotic arms became integrated with modern software capabilities, they increasingly turned from a curious novelty to highly efficient construction site and factory floor support. Variations in technology and size of robotic arms provide versatility to the solution and allow usage at virtually any type of construction.
- From a technical and economic perspective, indoor robotic arms have several advantages: 1) depending on the particular task, completion time may be significantly reduced compared to human labor; 2) material waste is reduced; 3) task performance quality is maximized due to fully automated process, enhancing accuracy and consistency and avoiding risk of human error; 4) need for on-site labor force is minimized, improving in-situ safety and reducing labor costs.
- From an environmental perspective, robotic arms may reduce construction phase CO_2 emissions via reduction in quantity of material waste, reduction in human labor-sourced emissions and energy consumption savings in tasks where they replace other traditional machinery. Tasks typically completed by manual human labor only, like wall painting and tile laying, may benefit from an increase in quality, precision and speed of performance, but will consume much more energy when robotics arms are used. The net environmental footprint, thus, therefore differs on a case-by-case basis.
- While the technical advantages of indoor robotic arms are numerous, their integration into a traditional manual labor construction process requires significant modification of construction practices and protocols. Replacement of menial tasks by robotic equipment, based on discussions with industry experts, is rarely a simple 'plug-and-play' effort, especially in complex architectural environments, and is currently best suited to standardized linear built environments, like pre-cast/prefabricated buildings.

Global market:

- The global robotics arms market, including robotic arms used in construction and pre-fabrication of construction elements, is expected to grow by 2 or 3 times within the next decade, potentially reaching a size of $40-50 billion by 2032. The Asia-Pacific region is a global leader in both production and usage of robotic arms, while Europe is estimated to hold a 15-20 percent global market share. Robotic arms have been used increasingly and heavily in multiple manufacturing industries; construction usage has lagged but is picking up pace with the introduction of better flexibility, additional safety features, better collaboration protocols with human workers, and, most importantly, gradual reduction in equipment cost, making them accessible to small- and medium-sized construction companies.
- Beyond the affordability of equipment and modification of construction practices, robotic arms replacing in-situ manual labor work can also create legal challenges in countries with strong labor protection laws. These are being addressed as the industry develops but remain an issue for adoption of the solution on a global scale.

Relevance for Ukraine:

- Given Ukraine's current labor supply challenges, adoption of robotic solutions minimizing manual labor involvement both at construction sites and factory floors is highly relevant, especially given the potential scale of post-invasion reconstruction and regular construction.
- Robotic arms are of relevance, if standardized linear designed housing and social infrastructure prevail in reconstruction efforts, as that is where they most enhance the efficiency of construction processes.
- There are no local robotic arms producers in Ukraine, but several global suppliers are working with Ukraine to gradually introduce their equipment into Ukrainian construction practices.

Investment opportunities:

- Given limited product/solution awareness and general cautiousness of the Ukrainian market, local market size is preliminary assessed as limited. Accordingly, the most cost-effective market entry model at this early market maturity stage, like 3D printing solutions, would likely involve the creation of a local fleet of indoor robotic arms designated for different tasks (likely all imported) and operation of a service model, either via providing robotic arm services to real estate developers or authorities, or leasing out the arms to construction companies.
- Investment into domestic production of robotic arms may become viable either in case there are clear export opportunities, or the domestic market embraces the solutions at a scale beyond current preliminary estimations.

Bottlenecks:

- Affordability of the equipment and cautiousness in integrating it into traditional manual-labor based construction practices remain the key adoption challenges in Ukraine, especially when combined with relatively low labor costs and limited awareness of long-term advantages of such robotic equipment.

3D PRINTING OF BUILDINGS

Main characteristics and usage:

- 3D printing for construction is an innovative robotics-assisted process allowing layer-by-layer creation of building envelopes and their components from digital blueprints. 3D printing uses specially designed mixes of traditional construction materials – cement/concrete, mortar, polymers, plastic and more – to deposit quickly drying layers of material using either a construction-scale framed printer system known as a gantry system, or a specialized 360-degree flexible 3D printing robotic arm, which allows the creation of more complex construction designs. Multiple different layering technologies have been designed, providing different advantages and suitable for different use cases.
- Additive manufacturing has originally been conceived and practically tested in the 1980s; however, active development began in the early 2010s, with the first fully 3D-printed residential building complex (10 small-scale houses) constructed in China in 2014. Several auxiliary systems are used in parallel to the gantry: a material delivery system that includes pumps, hoppers and nozzles; software/control system relaying commands to the gantry based on the 3D CAD designs; sensors and monitoring equipment; and, in case of concrete printing, a mixing unit preparing the concrete mixture for supply to the gantry and extrusion.
- Applications and use cases for the technology are still being developed around the world. However, proven use cases include single dwellings, low-rise (1-2 floors) social infrastructure, research centers. 3D printing of building elements – beams, columns, custom-designed facades and decorative elements – is already being used in mid-rise built environment. Small-scale transport infrastructure – i.e. minor bridges – is also a developing end market.
- From a technical and economic perspective, 3D printing has several clear advantages compared to traditional construction methods: 1) construction time is reduced significantly, with a 100-150 m^2 single dwelling building envelope being fully printed within 24-48 hours; 2) material waste is minimized as well due to precision of the layer-by-layer additive method; 3) when built using a hybrid approach with rebar reinforcement, resulting envelope may exceed durability, load-bearing capacity and seismic resistance of traditional reinforced concrete; 4) construction quality is maximized due to fully automated layering process, enhancing accuracy and consistency and avoiding risk of human error; 5) implementation of complex architectural designs is much easier due to absence of dependence on standardized architectural element geometry; 6) need for on-site labor force is minimized, improving in-situ safety and reducing labor costs.
- From an environmental perspective, 3D printed houses have been proven to reduce embedded CO_2 emissions by up to half due to minimization of material quantity (by up to 30 percent) and waste (by up to 70 percent), more energy efficient architectural designs and geospatial energy balance, minimization of transportation-related emissions and other factors.
- There are no clear technical drawbacks of the solutions; however, different printing equipment types are differently suited to particular construction objectives and are tailor-made to use different specific material inputs, providing equipment-specific technical challenges, in case availability of material inputs, design objectives and equipment type are mismatched.

Global market:

- While the market is evolving quickly, most experts agree the global market for 3D printing in construction will exceed $1.5-2 billion by 2030-2032, as demand for next-generation sustainable construction with potential for significant construction time and cost reduction is growing in the wake of global industry decarbonization and energy efficiency efforts. There are 8-10 globally known printing equipment manufacturers providing printing systems for most of 3D constructions globally, with numerous startups also regularly entering the space with proprietary hardware and software solutions.
- On a global scale, two issues currently restrict rapid scaling of the solution: hardware costs and absence of globally standardized approach to building and performance codes for the solution, leading to legal issues in approving exploitation of 3D printing constructed buildings in many countries.

Relevance for Ukraine:

- Single dwellings and low-rise social infrastructure buildings comprise a significant share of the total real estate stock in Ukraine and consumer demand for single dwellings has historically been quite high. Furthermore, single dwellings also comprise a significant share of the damaged and destroyed buildings.
- Given the construction speed and quality offered by 3D printing solutions, coupled with minimal labor force needs, 3D printed single dwellings and social infrastructure buildings like kindergartens, schools and general clinics, as well as administrative buildings, could be one of best high-speed construction solutions. Additionally, emergency 'temporary' housing for IDPs could also be constructed in record time, with minimum equipment mobilization time and offering more comfortable living conditions than refurbished barracks or container housing typically used for refugee accommodation.
- Importantly, there are several startup companies in Ukraine designing proprietary 3D printing systems; at least one of them, UTU, has successfully designed, manufactured domestically and tested one such printer and is prepared to advance to industrial-scale manufacturing provided there's proven demand. While domestic demand may be limited given novelty of the solution and corresponding limited product/solution awareness by the B2B and B2C consumers, even limited scaling in Ukraine could establish sufficient proof of performance to consider exporting their printer system to the EU and beyond.

Investment opportunities:

- Given limited product/solution awareness and general cautiousness of the Ukrainian market, local market size is preliminary assessed as very limited, with likely no more than 30-50 3D printers required for simultaneous operation across the country over the next decade.
- Accordingly, the most cost-effective market entry model at this early market maturity stage would likely involve the creation of a local fleet of 3D printers (either domestically produced or imported) and operation of a service model, either providing 3D printing construction services to real estate developers or authorities, or leasing out the printers to construction companies. Given an average global price per integrated building-scale printing system and maintenance workshops of close to $1 million, even a fleet-based service model may require up to $50 million in investments across several years.
- Investment into domestic production of 3D printers may become viable either in case there are clear export opportunities, or the domestic market embraces the solutions at a scale beyond current preliminary estimations.

Bottlenecks:

- Affordability of printing equipment, availability of specially developed material mixes (concrete, polymers etc.) and absence of 3D printing for construction in Ukraine's legislative framework are key bottlenecks for rapid product/solution acceptance. Of those, the latter is arguably the main challenge for rapid solution scaling.

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