MINISTRY OF EDUCATION
AND SCIENCE OF UKRAINE
NATIONAL UNIVERSITY
OF FOOD TECHNOLOGIES
NATIONAL ERASMUS+ OFFICE IN UKRAINE
EUROPEAN STUDIES PLATFORM

Co-funded by
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SELECTED PAPERS

VII INTERNATIONAL CONFERENCE

EUROPEAN DIMENSIONS OF SUSTAINABLE DEVELOPMENT

MAY 5-7, 2025, KYIV

Selected Papers of the VII International Conference on European Dimensions of Sustainable Development, May 5 – 7, 2025. – Kyiv: NUFT, 2025. – 184 p.

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ISBN 978-966-612-388-9

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FROM RECOVERY TO REGENERATION: EMBEDDING CORE SUSTAINABILITY PRINCIPLES INTO UKRAINE'S RECONSTRUCTION EFFORT

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This article focuses on the integration of most important sustainable development elements into Ukraine's post-war reconstruction process, taking into account contemporary challenges such as the climate crisis, resource depletion, and social vulnerability. Central to the discussion is the need to shift from a harm-reduction approach (sustainability) toward a worldview rooted in regenerative design - an approach aimed at generating positive environmental, social, and economic impact.

The authors examine the role of Life-Cycle Assessment (LCA) in accordance with EN 15978 standards, the use of building energy modeling that incorporates future climate scenarios (using modified weather data based on Intergovernmental Panel on Climate Change Representative Concentration Pathway 8.5 (IPCC RCP 8.5) and other projections), and the adoption of measurable, evidence-based performance indicators embedded in international green building certification systems (e.g., Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), etc). These tools support informed design decisions that align with long-term sustainability goals.

Special attention is given to the potential of implementing such solutions during the early stages of the building life cycle, where the cost of change is lowest and the impact on final quality is greatest. The paper outlines practical measures for both new construction and retrofit projects, including the reduction of embodied carbon, the use of renewable energy sources, and strategies for managing indoor air and water quality, along with climate adaptation measures.

Additionally, the article explores the redefinition of fundamental terminology and principles underlying contemporary design thinking, proposing a shift toward an ecologically-centered and multidisciplinary approach that prioritizes the interests of future generations.

Keywords: Sustainability, Regenerative Design, Life-Cycle Assessment (LCA), Building Energy Modeling (BEM)

DOI: 10.24263/EDSD-2025-7-14

Received 26.05.2024
Received in revised form 22.09.2025
Accepted 06.10.2025

Introduction

In the fourth year of the ongoing illegal war against Ukraine, some may argue that discussions around sustainability appear secondary considering urgent humanitarian and infrastructural needs. Such as the provision of affordable housing for internally displaced persons, the transformation of the energy supply sector to enhance resilience against continual attacks, and numerous other pressing environmental, social, and technological challenges. In certain contexts, the temporary deprioritization of sustainability may be considered justifiable (Crawford et al., 2023).

Nevertheless, some institutions jointly established by international partners, donors and the Government of Ukraine have emphasized the importance of integrating sustainability principles into reconstruction efforts. One notable example is the Digital Restoration Ecosystem for Accountable Management (DREAM) platform which outlines core principles for sustainable restoration of Ukrainian infrastructure (DREAM, n.d.). However, the practical implementation and measurement of these sustainability principles remain uncertain.

This paper seeks to explore and evaluate foundational tools and approaches for embedding sustainability into current and forthcoming reconstruction projects in Ukraine. The analysis aims to support the integration of sustainability into the country's both sort-term and long-term recovery efforts.

Life Cycle Assessment and "grand objectives" of sustainability

According to (Graedel T. E. & Allenby B. R., 2010) the "grand objectives" of sustainability encompass the following:

- «Maintaining the existence of the human species
- Maintaining the capacity for sustainable development
- Maintaining the diversity of life
- Maintaining the aesthetic richness of the planet»

As the instrument of quantifying sustainable engineering that could help to reach these objectives the authors analysed in details Life Cycle Assessment (LCA).

It is the instrument which could help the engineers, industrial ecologists and other professionals to measure the impact in equivalent of CO_2 emissions, and after been measured it is possible to optimize it, and to reduce the negative impact.

For building environment LCA involves quantifying two primary sources of greenhouse gas emissions throughout a building's life cycle: embodied carbon and operational carbon. Embodied carbon encompasses the emissions generated during the extraction of raw materials, manufacturing of building components, and construction activities. Operational carbon includes the emissions resulting from the energy consumed during the building's use phase, such as heating, cooling, lighting, and equipment operation.

The foundational concepts for conducting LCA of products and services have been formalized through international standards, particularly (EN ISO 14040, 2006) and (ISO 14044, 2006). The EN 15978 standard (EN 15978, 2011) provides a structured methodology for evaluating the environmental performance of buildings throughout their life cycle. It delineates the following key stages: the product stage (A1–A3**)**, which includes raw material extraction, transportation to manufacturing facility, and manufacturing; the construction stage (A4–A5), covering delivery to site and installation processes; the use stage (B1–B7), which involves operation, maintenance, repair, and renovation activities; and the end-of-life stage (C1–C4), encompassing demolition, transportation, waste treatment, and final disposal.

Ruuska and Häkkinen (2015) showed that the carbon equivalent emissions generated during the operational phase of a typical apartment building are approximately equivalent to the total embodied emissions arising from material production, construction activities, maintenance over the building's lifetime, and eventual demolition. However, as building energy performance improves-driven by regulations such as the new Ukrainian NZEB requirements recently adopted In Ukraine, and harmonization of other Ukrainian energy efficiency standards with EU Energy Performance of

Buildings Directive (EPBD) the relative share of operational carbon is expected to decline. This transition underscores the growing importance of addressing embodied carbon in building design and policy in Ukraine.

While the above listed standards offer clear system boundary definitions for life cycle assessment, it does not address the evaluation of a building's energy performance or the characteristics of its energy sources as also operational water efficiency use which we will discuss further.

Energy Efficiency and Energy Modelling for Existing and New Buildings

Despite recent advancements in building energy efficiency Ukraine's regulatory framework (Kryvosheiev et al., 2024), it partly still relies on DSTU B EN ISO 13790:2011 as the official standard for calculating building energy consumption (Verkhovna Rada of Ukraine, 2018).

DSTU B EN ISO 13790:2011 is no longer aligned with international best practices, contemporary levels of thermal insulation and the modern technologies currently available in the construction market. Consequently, this standard has been replaced in the European Union- and subsequently in Ukraine - by the EN ISO 52000 series. These newer standards account for dynamic thermal processes, including the thermal inertia of building elements, spontaneous heat accumulation effect caused by internal heat gains and solar radiation heat gains, and the influence of changing climatic conditions. The application of energy modelling techniques can significantly simplify the implementation of these new methodologies and standards into design both of new buildings and retrofits, while also offering the following advantages:

- Enables more accurate energy demand and peak loads calculations, allowing for appropriately sized HVAC systems, connection to utilities and reduced operational costs
- Facilitating for Ukraine's professionals and project's ability to engage in the international energy efficiency cooperation and sustainability initiatives.
- It supports the adoption of innovative energy saving technologies by more accurately reflecting the performance potential of modern energy-efficient solutions.

Climate Change

Climate change is expected to lead to increased thermal loads on HVAC&R systems. Application of the dynamic thermal energy simulation (building energy models) with modified weather data files according to different climate change scenarios such as IPCC scenario RCP8.5 or others will allow to estimate future consumption and peak loads and to mitigate the impact already now, at the design stage.

For other climate change challenges, it is proposed to adopt the follow a structured approach focusing on building resilience against extreme weather conditions (Department for Environment, Food & Rural Affairs, 2013, Gething & Puckett, 2013, Graves & Phillipson, 2000):

- **Hazard Identification:** Review relevant data to understand expected impacts from climate change, such as increased extreme weather events, and identify potential hazards.
- **Hazard Assessment:** Evaluate the scale of these identified hazards.
- **Risk Estimation:** Assess the risk to the building, considering factors such as structural stability, material durability, health and safety, and business continuity.

- **Risk Evaluation:** Determine the potential impact of these risks, establish tolerable risk thresholds, and identify unacceptable risks related to health, safety, life cycle, and financial terms.
- **Risk Management:** Develop risk reduction strategies and mitigate identified hazards as much as possible. Adapt the building design to include risk management measures.

This systematic risk assessment will help ensure that the building is resilient to climate change impacts throughout its life cycle.

Water Quality and Efficient Water Management

First priority could be to create all water systems of a building in compliance with international health and safety best practice guides or regulations to minimise the risk of microbial contamination, e.g. legionellosis and to ensure access to drinkable water for all building users.

Once this implemented to reduce the consumption of water for sanitary use in new buildings from all sources through the use of water-efficient components, water recycling systems, water leak detection and ensure that water consumption can be monitored and managed. Install rain water systems that are specified and installed in compliance with the national best practice standard.

For example, according to BREEAM Standard (https://breeam.com/standards) the following water consumption could be recommended:

For wash, basins, a mixer tap with an aerator should be used to ensure low water consumption (maximum 3 L/min) under dynamic pressure conditions for low-pressure systems at the mixer outlet of 0.1-0.02 bar (0.01-0.002 MPa), in accordance with EN 200:2008 and EN 1112:2008. Water efficiency should be enhanced by installing high-performance sanitary equipment:

1) Flush tanks/installations with a flush volume of 3.33 liters (dual flush - 2 and 4 L);
2) Washroom taps (aerators) - 3 L/min;
3) Showers - 3.5 L/min;
4) Urinals (for two or more units) - 0.75 L/flush;
5) Kitchen tap - 5 L/min;
6) Restaurant kitchen tap (for pre-rinsing only) - 6 L/min;
7) Domestic dishwasher - 10 L/cycle;
8) Industrial dishwasher - 3 L/rack;
9) Industrial washing machine - 4.5 L/kg;
10) Domestic washing machine - 30 L/load.

Indoor Air Quality

As common practice developers in Ukraine often use finishing materials in buildings without an ecolabel or defined emission criteria by product type that classifies installation materials and building products based on their emission behaviour in compliance with DIN EN ISO 16000-1, CEN/TS 16516 etc. The uncontrolled on VOCs and formaldehydes finishing materials such as paintings, coatings, different floor coverings, sealing materials could be source of the danger for the health of future residents.

Therefore, Indoor Air Quality (IAQ) is a critically important factor for the health and comfort of residents in residential buildings. The issue of IAQ is particularly relevant for social and affordable housing, where economic constraints often lead to the use of materials with high levels of harmful emissions, while ventilation systems remain insufficiently effective.

Key Quantifiable Indicators

Based on above we identify the following as critical quantifiable indicators and tools for evaluating sustainable reconstruction initiatives and projects which are listed in Table 1.

Table 1. Key Quantifiable Indicators, tool or means

Indicator	Tool or by means	Meaning
Embodied Carbon, kg CO_2e	Life-Cycle Assessment	Integration of the whole-building LCA into design process in Ukraine to quantify material-related carbon emissions (kg CO_2e) and its reduction during early design phases
Operational Energy, kWh **and Operational Carbon** kg CO_2e	Use dynamic thermal energy simulation (building energy models) and digital twins	To predict and minimize operational energy use (kWh) and CO_2e emissions.
Potable Water Supply & Water Consumption Efficiency, litter per minute or similar	Selection water efficient fixture at the design stage	Ensure drinking water quality (meeting European regulatory contaminant limits) and minimize use via efficiency metrics and selection of water-consuming components.
VOCs/Formaldehyde levels in internal air	Indoor Air Quality	Maintain low indoor pollutant levels by design and careful selection of finishing materials both for new buildings and retrofits
Operational Energy kWh **and Carbon** kg CO_2e **in conditions** of 2050 temperatures	Use dynamic thermal energy simulation (building energy models) with modified weather data file according to different climate change scenarios such as IPCC scenario RCP8.5 or others	Climate-Responsive Design. to predict and minimize operational energy use (kWh) and CO_2e emissions in conditions of 2050 temperatures
Integration of Evidence-Based Performance Metrics	DGNB, LEED, BREEAM, etc	Adopt evidence-based targets from green rating systems which specify measurable performance thresholds to measure sustainability of this or that project.

Early Design Decisions for Cost-Effective Sustainability Integration

The implementation of sustainable practices requires experienced experts who can oversee and support the creation of a building at all stages of design and construction. This ensures adherence to high standards from the conceptual phase through to the building’s commissioning.

Figure 1 clearly illustrates the core logic behind planning sustainable projects: the earlier design decisions are made, the greater their potential to influence the quality, cost, and sustainability of the building - and the lower the cost of implementing changes. This was extensively analyzed by different authors from early publications refereeing to so-called "MacLeamy curve" (MacLeamy, 2004) to Integrated Design Approach in recent studies (Landgren et al., 2019), (Kamari, 2023).

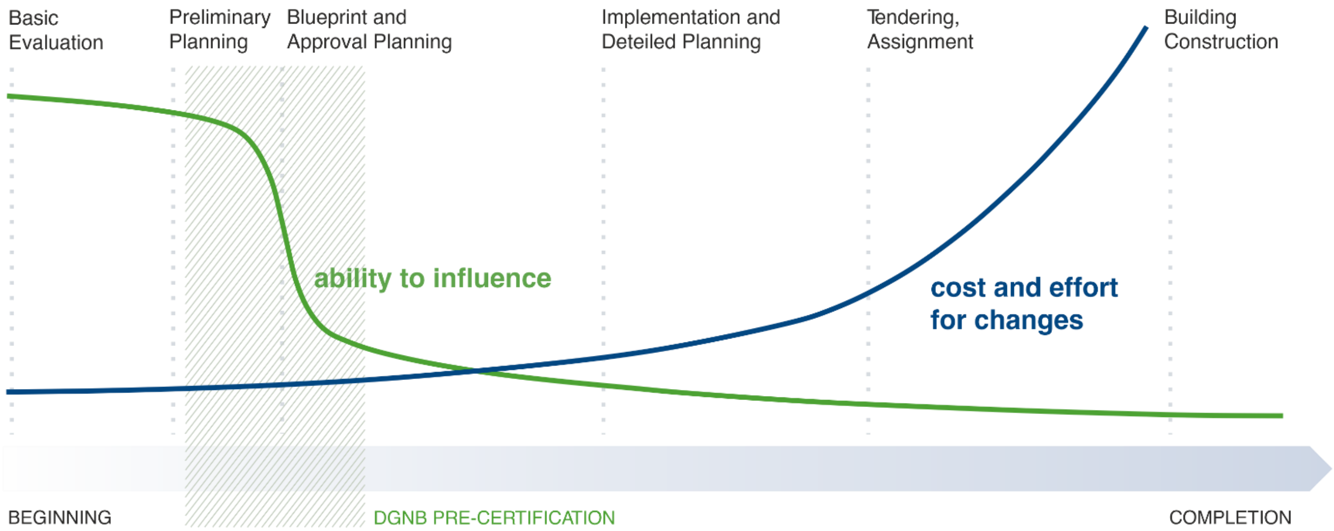

Figure 1. Integrated Design Approach (IDA) for Cost-Effective Sustainability Integration

The green curve (ability to influence) drops sharply after the completion of the initial planning stage (shaded in green). This stage lays the foundation for the building's performance and the integration of sustainable construction principles, enabling maximum quality with minimal expenditure. The DGNB Pre-Certification, positioned in this area of greatest impact, reinforces this logic. It establishes a framework for holistic planning and informed decision-making aligned with sustainability criteria.

The blue curve (cost and effort for changes) shows an exponential increase during the later stages of the project, especially after the "Implementation and Detailed Planning" phase. In other words, the later the need for change is identified, the more expensive and complex it becomes to implement - both technically and organizationally.

Therefore, integrating certification system requirements and sustainability goals at the earliest possible stage not only enhances the overall quality of the project but also significantly reduces long-term costs.

From Sustainability to Regenerative Approach

The next step in the profound shift of mindset- from sustainability to regenerative - is illustrated in Figure 2. This is not merely an evolution of terminology or a trend of "new buzzwords"; it represents a fundamental transformation in how we think, design, and act.

On the left side of the graph lies the zone that illustrates the transition from conventional practices and standard design approaches toward reducing harm and minimizing environmental impact. Sustainability focuses on making projects "less bad" - reducing energy consumption, lowering emissions, and managing waste. However, this approach does not aim to change the system itself or fundamentally rethink the role of architecture, design, and construction within the planet's ecosystems.

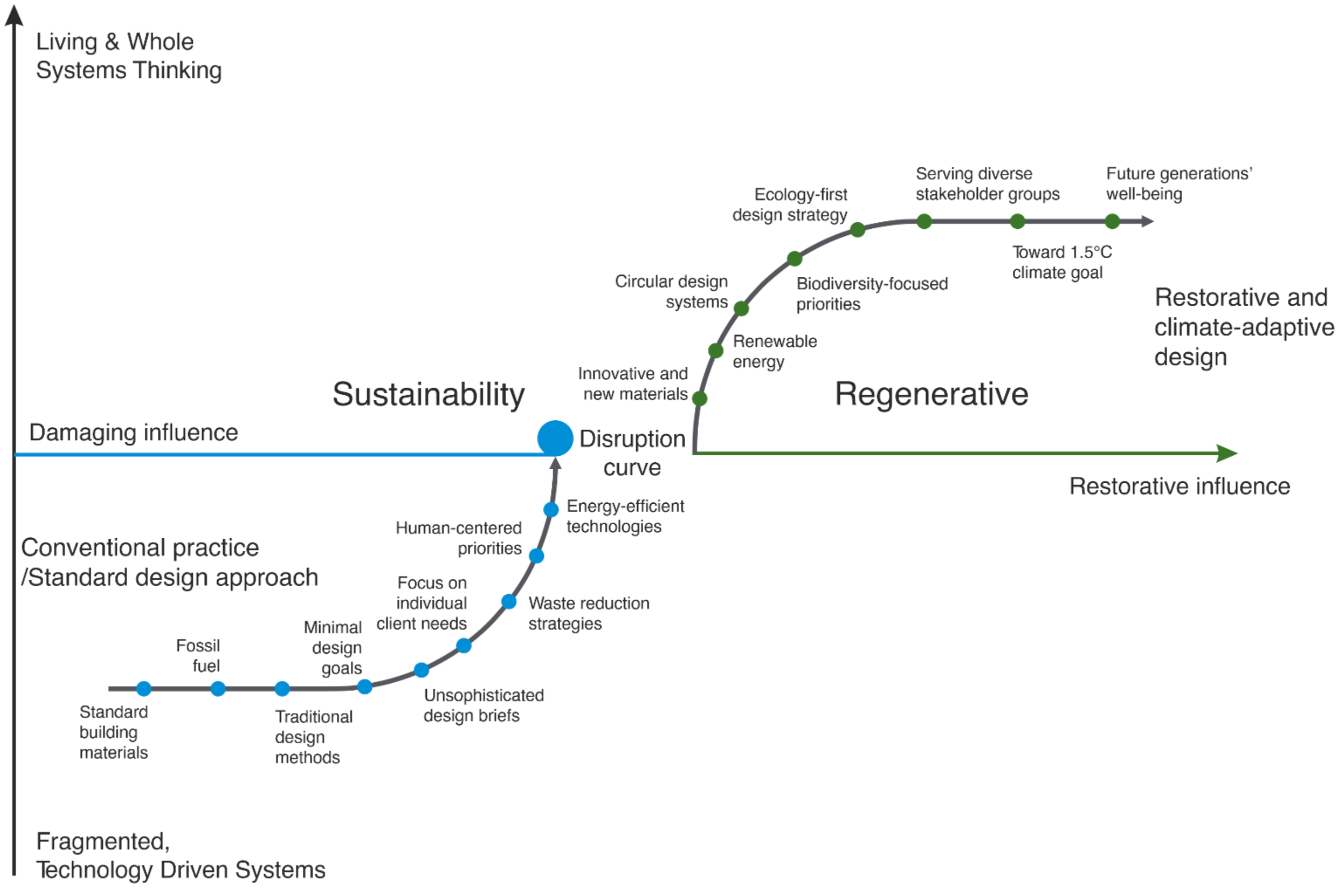

Figure 2 Evolution from common practices to regenerative approach (Inspired by (Soren Brondum et al., 2024)

To address today's global challenges - climate crisis, social inequality, ecosystem degradation we must move beyond the philosophy of "doing less harm" to a philosophy of "doing more good," known as the regenerative approach. This marks a critical shift in perspective, represented in the graph by a break in the X-axis and identified as a Disruption Curve - a point of rupture that signals the emergence of a new frame of reference.

The regenerative approach is a radically new paradigm that goes far beyond sustainability. Its goal is not merely to minimize harm but to restore ecosystems, strengthen social fabric, and operate in symbiosis with nature. It is an active commitment to improving the environment and enhancing life for all forms of existence - including future generations.

The right side of the graph does not reflect technical improvement, but a worldview transformation: a shift from asking "how do we reduce our impact?" to "how can we create a positive contribution?" - from Damaging influence to Restorative influence.

Embracing the regenerative approach introduces an entirely new ethic and vision for the design phase, where the central aim is not simply to avoid harm, but to restore the planet, communities, and the full potential of life.

Conflict of interest

The authors state no conflict of interest.

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