

BUILDINGS OF THE FUTURE: CHALLENGES OR OPPORTUNITIES?

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ABSTRACT

The accelerated evolution of technology, the pressures generated by climate change, and global socio-economic transformations have led to a profound reassessment of the way residential buildings are designed and used. This paper analyses the concept of "buildings of the future" from the perspective of residential housing, highlighting both the challenges and opportunities associated with their implementation. Issues related to digitalization, sustainability, innovative materials, social impact, and urban integration are addressed, with the aim of assessing whether these transformations represent real progress or an obstacle to contemporary society.

KEYWORDS: residential buildings, sustainability, smart homes, energy efficiency, urban development

1. Introduction

The rapid transformations of the global environment, the growth of the urban population, digitalization, and climate change are driving a profound reassessment of the way we design and use the built infrastructure. Buildings are no longer just static structures, but dynamic systems integrated into a complex digital and ecological ecosystem.

The concept of the building of the future involves intuitive architecture, capable of meeting the

needs of users through smart technologies, sustainable materials, and adaptive design.

The construction sector plays a key role in economic and social development, while also being one of the largest consumers of natural resources.

According to the United Nations Environment Program (UNEP, 2022), buildings are responsible for about 37% of global carbon dioxide emissions. In this context, residential buildings of the future become a topic of major interest, both for specialists and for the public (Fig. 1) [1].

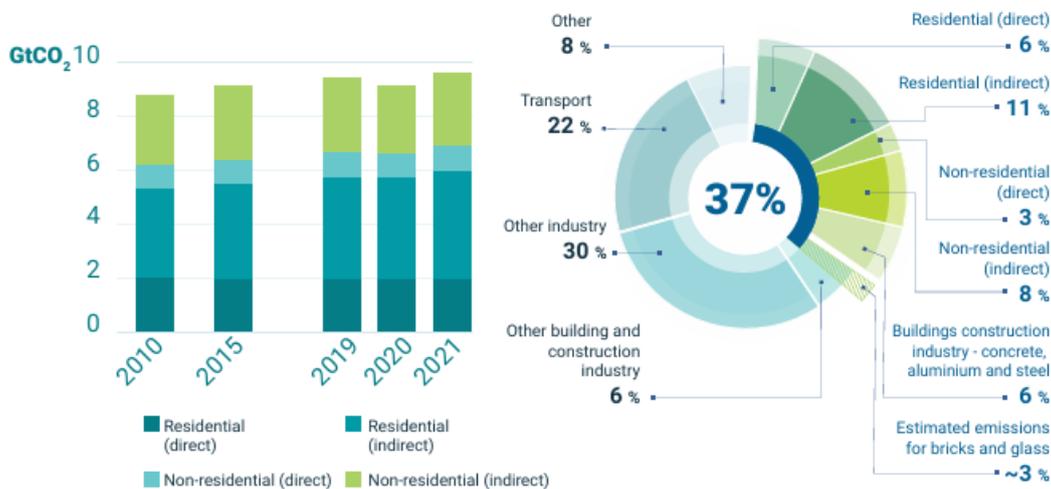


Fig. 1. CO₂ emissions in buildings 2010-2021 (left) and share of buildings in global energy and process emissions in 2021 (right) [1]

The aim of the study is to analyse the current directions of development of residential housing and to assess the extent to which they constitute an opportunity or a challenge for society.

2. The need to transform residential buildings

The existing built stock is largely characterized by low energy efficiency and the use of outdated technologies that no longer meet current sustainability and performance requirements.

According to the European Commission (2020), more than 75% of buildings in Europe were built

before the introduction of modern energy performance standards, and around 85% to 95% of them will still be in use in 2050 (Fig. 2) [2].

This situation highlights the need to intervene in the existing built stock to reduce energy consumption and environmental impact.

A determining factor in the transformation of residential buildings is the increase in energy consumption.

The buildings sector is responsible for around 40% of total energy consumption and around 36% of greenhouse gas emissions in the European Union (Fig. 3) [2, 3].



Fig. 2. Solutions: less energy used, more green energy, less emissions [2]

The lack of adequate thermal insulation, insufficient glazed areas, inefficient windows, and outdated heating systems contribute significantly to energy losses and increased operating costs for users [4].

Climate change is another major argument for transforming homes.

According to reports by the Intergovernmental Panel on Climate Change (IPCC, 2021), reducing carbon emissions from the buildings sector is essential to achieving the climate goals set by the Paris Agreement - Intergovernmental Panel on Climate Change. (2021) [5].

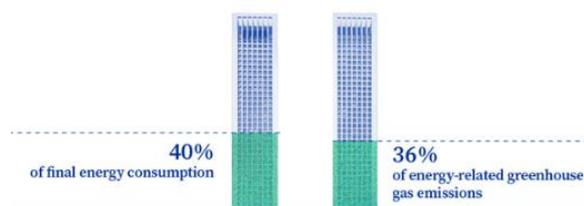


Fig. 3. Buildings in the EU account for [2]

Adapting residential buildings to new climatic conditions, by increasing energy performance and using renewable energy sources, contributes both to

mitigating the effects of climate change and to increasing the resilience of the built environment [6].

Accelerated urbanization is also an important factor requiring the modernization of residential buildings.

According to Eurostat data (2022), more than 75% of the European Union's population lives in urban areas, and this proportion is constantly increasing [7].

The densification of cities and the pressure on existing infrastructure require sustainable solutions that optimize the use of resources and reduce the impact of urban development on the environment.

Studies by the World Health Organization (WHO, 2018) show that homes with low energy performance can have negative effects on health, favouring the development of respiratory problems and thermal discomfort [8].

Through thermal rehabilitation, modernization of installations, and increased structural safety, buildings can provide a healthier, safer, and more adapted living environment that meets current requirements.

The main factors that require the transformation of homes are (Fig. 4):

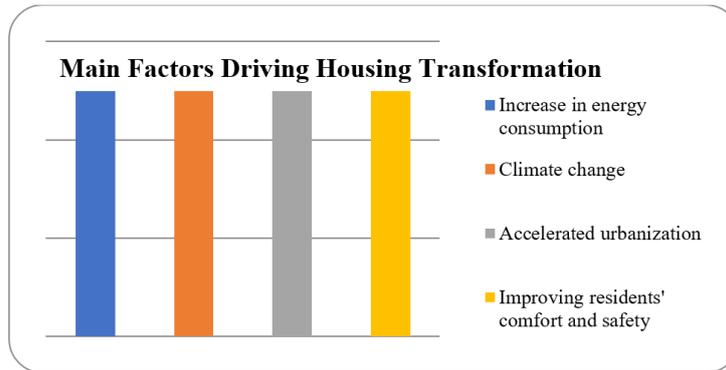


Fig. 4. Main Factors Driving Housing Transformation

The transformation of residential buildings is essential to improve the comfort and safety of beneficiaries.

3. Digitalization and the concept of smart housing

Digitalization is a broad process of transforming society by integrating digital technologies into all areas of daily life, both economic and social. In this context, the smart home appears as a direct result of technological progress, combining automation, connectivity, and artificial intelligence to improve the comfort, safety, and energy efficiency of the living space.

Digitalization is fundamentally changing the way people interact with the environment, and the home becomes an active space, capable of meeting the needs of users [9].

The concept of the smart home is based on the use of devices interconnected through the IoT, which allow the monitoring and control of different systems within the home, such as lighting, heating, security, or household appliances.

The IoT plays a critical role in the development of smart homes, as it enables continuous communication between devices and users, in real time. Thus, the dwelling is no longer a passive space, but an adaptive one, capable of anticipating the preferences of the tenants [10], (Fig. 5), [11].

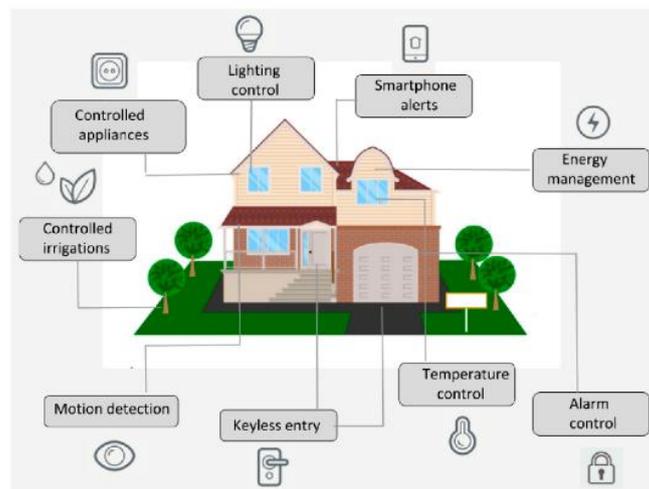


Fig. 5. An IoT-based smart home depicting the use of smart sensing devices for different purposes [11]

One of the main advantages of home digitalization is increased comfort. Through mobile apps or voice assistants, users can control home functions remotely, saving time and effort.

Automating household tasks helps reduce daily stress and improve quality of life. In addition, customized scenarios such as "night mode" or "departure mode" demonstrate how technology can simplify daily routine [12].

In addition to comfort, the smart home makes a significant contribution to energy efficiency and environmental protection. Smart energy management systems can optimize electricity and gas consumption, reducing losses and costs.

According to the International Energy Agency (IEA, 2020), the digitalization of buildings can reduce energy consumption by up to 20%, which highlights the important role of technology in sustainable development [13]. Thus, smart housing becomes an essential tool in the fight against climate change.

The development of smart homes also poses certain challenges, in terms of data security and privacy [14].

Connected devices collect large amounts of information about users, which can create risks if this data is not properly protected.

Therefore, digitalization must be accompanied by appropriate policies and technical solutions to protect users.

4. Integration of residential buildings into the urban environment

The integration of residential buildings of the future into the urban environment is one of the fundamental directions of the sustainable development of contemporary cities.

Today, housing is no longer conceived as an isolated element, but as an integral part of a complex, energy-connected, functional, and social urban system. This principle underpins the smart city concept, which promotes resource efficiency, digitalization of infrastructure, and improved quality of urban life [15].

A first essential aspect of urban integration is the correlation of residential buildings with the city's energy infrastructure. The homes of the future are designed to be connected to smart grids, enabling a two-way exchange of energy.

Buildings equipped with photovoltaic panels and storage systems can function as prosumers, supplying surplus energy to the grid and helping to balance urban consumption [16].

This energy integration reduces dependence on conventional sources and increases the resilience of cities in the face of energy crises.

Another major element is the integration of buildings into sustainable urban mobility systems. Modern urban planning favours the location of housing in the vicinity of public transport, bicycle infrastructure, and pedestrian routes, with the aim of reducing the use of personal cars. Many residential complexes include charging stations for electric vehicles and spaces dedicated to alternative mobility,

supporting the objectives of reducing carbon emissions at the urban level [17].

Integration into the urban environment also involves the relationship between residential buildings and green spaces.

According to recent studies, urban vegetation contributes significantly to reducing the heat island effect, improving air quality, and increasing the psychological comfort of the inhabitants [18].

Green roofs, green façades and communal gardens become central elements of modern residential design, integrating buildings into the urban ecosystem and enhancing local biodiversity [19], (Fig. 6), [20].



Fig. 6. *Stadium Green – Seasons* [20]

The integration of residential buildings into the urban environment depends directly on public policies and urban planning regulations.

Strategies such as the European Union's Renovation Wave aim to modernize the existing built stock and integrate it into the vision of sustainable, energy-efficient, and inclusive cities [21].

The residential buildings of the future will be an active part of smart and green cities. Modern projects emphasize biophilic design such as: the inclusion of green spaces, abundant natural lighting, and the installation of effective ventilation for the health of residents.

In the future, urban plans should include mandatory energy efficiency and environmental criteria, and the smart city network will connect data on housing consumption with transport or energy infrastructure for global optimization.

Through coherent planning and strategic investments, residential buildings of the future can become active drivers of urban regeneration and sustainable development.

5. Sustainable materials and sustainable construction

Innovation in the field of building materials is making a significant contribution to the development of the homes of the future.

Cross-laminated timber (CLT), self-healing concrete, and 3D printing technologies reduce costs and lead times, as well as reducing environmental impact.

Future residential buildings will use materials with a low environmental footprint. For example, there are new cements with 40–50% fewer carbon emissions than traditional cement [22].

Locally, advanced residential projects such as EvoHouse, the first certified passive dwelling in Romania, are built from cross-laminated timber (CLT), a renewable material that replaces concrete over large surfaces (Fig. 7), [23].



Fig. 7. EvoHouse, the first certified passive home in Romania [23]

Prefabricated modular construction uses eco-friendly panels and super-insulated windows to reduce waste and construction time.

The reuse of existing structures instead of massive demolition is encouraged to avoid the unnecessary generation of construction waste [24].

Resource savings are underpinned by the principles of the circular economy: the focus is on recyclable and reusable materials [25].

All of this is a first step toward creating buildings that can replenish their own resources, integrating solar panels on the roof and rainwater collection systems.

This type of approach reduces both environmental impact and long-term costs.

6. Socio-economic impact

Although buildings of the future offer significant benefits, they can accentuate social inequalities if access is limited by high costs.

Risks:

- increasing inequalities;
- social exclusion;
- urban gentrification.

Opportunities:

- reduction of maintenance costs;
- energy-efficient social housing;
- increased quality of life.

Public policies and support programs, such as the "Renovation Wave", are key to ensuring equitable access to energy-efficient housing.

The transition to the homes of the future also significantly influences socio-economic planning.

Initially, new Nearly Zero-Energy Building (NZEB) standards and smart technologies translate into higher construction costs due to advanced materials and complex installations [26]. Developers are feeling the pressure of these costs and the need for technical know-how.

However, the long-term economic benefits are obvious: energy-efficient buildings have much lower operating costs and command higher prices, making them more attractive to environmentally conscious buyers [27].

In Romania, the government and the EU offer generous subsidies to balance these costs: programs such as "Casa Verde Plus" grant incentives for the thermal efficiency of homes. Through this program, any citizen of the European Union residing in Romania can submit an application for financing in the form of an energy efficiency premium [28].

This makes renovation and sustainable construction more affordable from a financial point of view.

Socially, these changes create new jobs for designers, specialized builders, and IT technicians, but they can also generate inequalities if they are not well managed. There is a risk that only high-income families will immediately access new technologies, while others remain in traditional homes.

Buildings of the future will have a major socio-economic impact: they will stimulate the economy, improve the quality of life, and protect the environment, even if the transition brings some financial and technical challenges [29].

However, to maximize these benefits, strategic planning, coherent public policies, and technological education are essential.

7. Conclusions, Challenges or opportunities?

The analysis of residential buildings of the future highlights the fact that they cannot be

classified exclusively as challenges or opportunities; rather, they represent a complex reality at the intersection of technological innovation, ecological responsibility, and social transformation.

From the perspective of opportunities, homes of the future offer concrete solutions to reduce energy consumption and carbon emissions, contributing to the achievement of the climate goals established at the European and global level. The integration of renewable sources, the digitalization of consumption management, and the use of sustainable materials lead to increased energy efficiency and an improved quality of life for residents.

On the other hand, the process of transitioning to these housing models involves significant challenges. High upfront costs, the need to adapt the legislative framework, the shortage of specialists, and the risks associated with digitalization (such as data security) can slow large-scale deployment. At the social level, there is a risk of increasing inequality if access to energy-efficient and smart housing remains limited to certain socio-economic categories [30].

However, the balance tips, in the medium and long term, in favour of opportunities. Investments in sustainable buildings generate operational savings, increase property values, and stimulate the development of innovative industries. Moreover, in the context of the climate and energy crisis, the modernization of the residential stock is no longer an option, but a strategic necessity.

Therefore, buildings of the future should not be seen merely as a simple technological evolution, but as part of a structural transformation of the way society understands housing, environmental responsibility, and the relationship with urban space. To the extent that they are supported by coherent public policies, education, and fair investment, they predominantly represent major opportunities for the sustainable development of contemporary society.

In conclusion, if approached with proper planning and support, these homes of the future will serve as an opportunity to create resilient and comfortable communities rather than just a burden.

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