Ernesto Antonini, Jacopo Gaspari

# Architectures for Next Generation EU Cities

## Challenges, Key Drivers, and Research Trends

Ricerche di tecnologia dell'architettura
FrancoAngeli

RICERCHE DI TECNOLOGIA DELL'ARCHITETTURA



La collana *Ricerche di tecnologia dell'architettura* tratta prevalentemente i temi della progettazione tecnologica dell'architettura e del design con particolare attenzione alla costruibilità del progetto. In particolare gli strumenti, i metodi e le tecniche per il progetto di architettura alle scale esecutive e quindi le modalità di realizzazione, trasformazione, manutenzione, gestione e recupero dell'ambiente costruito.
I contenuti scientifici comprendono la storia e la cultura tecnologica della progettazione e della costruzione; lo studio delle tecnologie edilizie e dei sistemi costruttivi; lo studio dei materiali naturali e artificiali; la progettazione e la sperimentazione di materiali, elementi, componenti e sistemi costruttivi.
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La collana nasce sotto la direzione di Raffaella Crespi e Guido Nardi nel 1974.
I numerosi volumi pubblicati in questi anni delineano un efficace panorama dello stato e dell'evoluzione della ricerca nel settore della Tecnologia dell'architettura con alcuni testi che sono diventati delle basi fondative della disciplina.
A partire dal 2012 la valutazione delle proposte è stata affidata a un Comitato scientifico, diretto da Giovanni Zannoni, con lo scopo di individuare e selezionare i contributi più interessanti nell'ambito della Tecnologia dell'architettura e proseguire l'importante opera di divulgazione iniziata quarant'anni prima.

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# *Introduction*

Jacopo Gaspari and Ernesto Antonini

The destabilizing challenges that European Countries are increasingly facing at social, political and economic levels are directly or indirectly dependent on the effects of Climate Change, with evident impacts on people living conditions, health and wellbeing. A wider social awareness on these topics has been achieved only in last years, built over an evidence-based scientific demonstration of the correlation between the increase in anthropic generated emissions and the rise of global temperature, with its due consequences on the environment. The extreme and recurrent events experienced by many people in different countries – from flooding to wildfires, from hurricanes to heatwaves – suggest that the urgency to cope with climate change effects can no longer be ignored. In the recent decades, the European Union [EU] has played a leading role in promoting the reduction of $CO_2$ emissions by supporting the transition to clean energy through structured measures in many key sectors, including mobility, construction and industrial processes. Despite the great efforts and resources spent in these directions, the path towards a carbon neutral society is unfortunately still far from being achieved, and the 2030 and 2050 goals would not be achieved unless further measures are taken. The current shortage of energy supplies, the still strong dependence on gas and oil, the uncertain availability of materials to fuel the growth of renewable energies represent key barriers for the transition, as well as a general resistance to overcome the business-as-usual model, which is struggling to find the necessary political consensus.Further possible adverse events – unpredictable though not unlikely – risk worsening the situation even more and require improving the ability to predict their large-scale effects and to guide policies and decisions accordingly. That's why in 2021 a research group from the Department of Architecture of the University of Bologna decided to launch the NEXTBUILT [NB] initiative, right in the midst of the pandemic circumstances that have strongly contributed to soliciting new ways of looking at and approaching the built environment. This initiative is intended as a kind of observatory on the challenges that the evolution of the next generation cities will face, and to explore them in a cross-scale perspective spanning from urban shape to technological solutions, and by an interdisciplinary approach, including social, cultural, economic dimensions.

A large palette of different formats for delivering and spreading the research outputs is embedded within NEXTBUILT: conferences, seminars, workshops, and publications, which all to share a future-oriented vision and the aim of anticipating the debate on tomorrow's built environment. Such vision inspired the title of this book – *Architectures for Next Generation EU Cities. Challenges, Key Drivers, and Research Trends* – which evokes an open and wide research approach on the main elements that will influence the evolution of European urban environments and their needs, while keeping an eye over the possible fallouts on the local policies – within EU and beyond – as well as on key drivers at global level. Four priority topics emerged from the first research activities of the NB observatory, which were then confirmed in the debate promoted within the scientific community.

The first addresses the resilience of the city, the second focuses on the energy demand of cities and buildings, the third aims to explore the future needs of buildings, while the fourth concerns the ability to imagine and evaluate solutions within circular models. Without any ambition to providing definitive answers, the aim of this book is to collect reflections on those topics, from scientists, academic, researchers on whose basis drafting a large picture of the field potentially fuelling further initiatives of the observatory.

Once the four topics were refined in cooperation with NB's scientific committee, a call for contributes was launched and the most promising contributes where selected through a blind peer review process and then organised as chapters clustered in four sections corresponding to the four topics. The final book layout includes therefore the following sections:

Section 1: *Climate resilient cities* - The lack of preparedness and of adequate plans to make cities able to promptly react to extreme conditions is at the core of the challenge being, at the same time, cities major contributors of $CO_2$ emissions causing climate related phenomena. This section focuses on more sustainable and resilient design approaches which represent viable pathways for the near future cities which will most likely focus on regenerative design, adaptation rather than mitigation, and the ability to deal with uncertainty in both acute and chronic ecosystems and communities' status. Chapters from 1 to 4 respectively offer: an overview about the key climate challenges and related implications; a reflection on how to integrate and combine resilient design criteria within the wider and more consolidated framework of sustainable design strategies; a focus on the need to rethink relations and the way cities are shaped and organized considering the insights and the constraints emerged during the lockdowns; a chance to explore how the digital age will influence life in cities and the way people interact within this dimension.

Section 2: *Energy, buildings, users* - Energy represents nowadays a crucial topic whose related decisions in the next few years will affect the future of EU and global relations for decades. The building sector still accounts globally for about 33% of the total primary energy demand, making the achievement of the 2050 planned carbon neutrality very challenging according to the current decarbonization pathway. Both additional technological improvements and more conscious individual behaviours are expected to be integrated in forthcoming design solutions for effectively and timely achieving this goal. Chapters 5 to 8 respectively provide: a picture of the emerging needs in energy demand and of the evolving perspective of Positive Energy Districts in the energy market; a lens on the relation between end-users behaviour and related implication in energy use optimization for energy efficient buildings; a reflection on the factors influencing the social perception and the choice withing the energy retrofitting market; a focus on the trends and perspectives about energy supply with an interesting overview comparing the EU context and Latin America.

Section 3: *Adapting systems and components to Next Generation needs* - While great progresses have been done in fostering the adoption of sustainable design to make buildings increasingly more efficient, the ratio between operational and embodied energy is progressively re-balancing. The service life of building systems and components is rapidly evolving according to a life cycle perspective and much more relevant according to the emerging needs of a new generation of buildings (and users).

Chapters from 9 to 12 are devoted to: reflect on the balance between operational and embodied energy and carbon emissions within renovation processes; explore the role of (embodied) energy in construction processes considering not only the building as a system but also the implication at production stream level; consider the use of alternative, natural-based materials through innovative approaches evolving the traditional know how; suggest how to improve the flexibility of existing buildings towards variabilities of context to optimise the system response.

Section 4: *Predicting, simulating, assessing sustainable features and circular systems* - The complexity of the current socio-economic circumstances calls for multi-level and multi-criteria approaches to effectively predict, simulate, and evaluate the conditions affecting the future of the built environment at the different scales particularly considering the need to revise conventional models towards circular systems. Chapters from 13 to 16 offer: an overview around the concept of circular systems focusing on definitions, limitations and potential outcomes; a focus on the methods and tools to assess circularity in design and construction processes including environmental, social, logistical, technical, and economic issues; a reflection on the influence of climate change on the processes and on the need of more synergic approaches among the involved stakeholders, operators and players.

Overall, the high number of contributions received from twenty-six different countries witnesses that NEXTBUILT has been able to catalyse the interest of a vast international audience and to establish a well-balanced global network of researchers working on challenging cross-cutting issues.

This makes the book not a destination reached, but a promising starting point for future activities that will address challenges, drivers and trends for the next generation cities.

# *Section 1 - Climate resilient cities*

# *1. Resilient urban environment: challenges and mitigation strategies*

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According to the (OECD) Organisation for Economic Co-operation and Development, resilient cities are cities that have the ability to absorb, recover and prepare for future shocks and disasters. Resilient cities promote sustainable development, well-being and inclusive growth. This is often measured by the four main criteria of Economic, Societal, Governance and Environmental Resilience (OECD, 2022). At the same time, the UN SDG 11, Sustainable Cities and Communities, reminds us to make cities inclusive, safe, resilient and sustainable. The SDG 11 targets for 2030 are seven, and they range from sustainable transport and affordable housing for all to green spaces and reduction of pollution and waste, with particular reference to developing countries and the impact that any type of disaster has on the vulnerable in society (UN, 2015). With this premise, this study examines the challenges of contemporary cities in finding resilience and identifies opportunities for mitigation strategies within an interdisciplinary and systemic approach.

## 1.1. Challenges of contemporary and future urban environments

As it has been already documented, overpopulation and urbanisation, change in land use and loss of natural habitats compromise biodiversity and lead to pandemics and pathogens such as viruses and bacteria jumping from animals to humans (Hassell et al., 2017). At present, half of the world's population lives in cities, and it is predicted that by 2050 it will be 68% to do so (UN, 2018). Approximately 90% of this urbanization will happen in developing countries (Henderson and Turner, 2020), where the effect of Climate Change is felt the most through extreme weather events (e.g. floods, droughts, food scarcity, heat-waves and wildfires). However, from recent events, these extreme anomalies are now experienced everywhere and are not exclusively in developing countries (CarbonBrief, 2022).

*Fig. 1.1 – Example of a dense and congested urban environment where there is a poor connection between the indoor and the outdoor.*

*Source: Alexandr Bormotin on Unsplash (Creative Commons).*

According to the World Health Organisation (WHO), the combined effect of ambient and indoor pollution causes 7 million premature deaths every year globally. Nine out of ten people breathe air that exceeds WHO guideline limits, with low- and middle-income countries suffering from the highest pollutants exposures (WHO, 2021).

Noise and light pollution are additionally recognised as factors detrimental to the health of urban citizens. In the world, 120 M people have hearing difficulties due to noise pollution. With the effects on health being stress, sleeping problems, hearing impairment, hypertension, heart disease and concentration problems.

### *1.1.1. An interdisciplinary approach*

In this context, what is the contribution that the environmental design discipline can make and what exactly is Environmental Design (ED)? ED refers specifically to the design of the thermal (including the provision of heating, cooling and ventilation), visual and acoustic environments of buildings and their impact on energy demand reduction.

Traditionally the two mainstream approaches in ED are split between that of environmental engineers promoting low energy and energy efficient active systems, including the provision of renewables for achieving net-zero or whole-house mechanical solutions, and those environmental architects promoting passive design, natural ventilation and bio-climatic strategies with the aim of reducing the building's energy demand to negligible levels.

However, the majority of examples, guidelines and criteria for ED are still too often based on buildings assumed to be in benign settings where passive strategies are assumed to be applicable and mainly deal with the building remit.

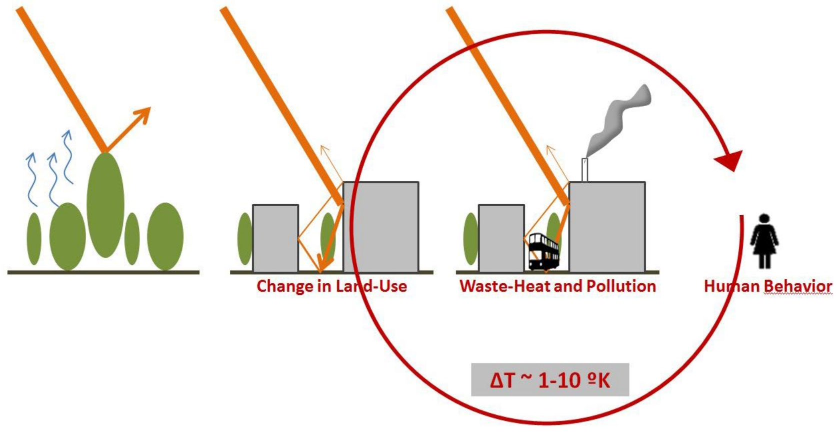
To move forward, we must acknowledge and deal with the non-benign, often unfavourable urban settings in which buildings are placed. And therefore, widen the discipline of ED to the urban context, focusing on the space in between buildings, urban environments and their microclimates. Cities account for between 60 and 80 per cent of energy consumption and generate as much as 70 per cent of human-induced greenhouse gas emissions (UN, 2018). Hence, in order to mitigate and mostly adapt to climate change, we must tackle what happens in cities as a priority.

### 1.1.2. The microclimatic vicious circle

What happens in cities is strictly related to what happens globally and the effects are compounded by moving from global climate change to local climate change (often expressed in the form of UHI) and the microclimatic vicious circle (Fig. 1.2). A vicious circle which takes place when, for example, the outdoor conditions do not allow (due to noise, air pollution or thermal conditions) simple strategies such as natural ventilation, which in turn leads to the adoption of mechanical cooling, which increases the outdoor temperature due to the heat emitted from compressors, then perpetuating such vicious circle. The area of the context of these dynamics and the research focus, can be notionally defined as 'the street section'. The street section is modelled around the street canyon, universally present in all urban contexts and where there is an interface between urban environments and indoor environments. And it is also where the main socio-economic, environmental and infrastructural functions of city life take place.

One of the greatest challenges to tackle in cities is the detachment from the outdoors and the extensive use of mechanical systems to the detriment of passive strategies, reducing the interaction with, and the use and enjoyment of open public spaces so relevant to urban prosperity and economic growth.

*Fig. 1.2 – Microclimatic Vicious Circle and contributing factors.*




*Source: Elaborated by the author and Filippo Weber.*

Global warming and urban microclimatic modifications, added to the standard climatic regions, shift towards warmer conditions and consequently a greater demand for energy for cooling than for heating. This results in:

- increased cooling demand in buildings, which affects the health of the urban population, raises the concentration of specific urban pollutants, increases the ecological footprint of cities, and deteriorates outdoor and indoor thermal comfort levels while it augments the risk to the vulnerable urban population during heatwaves.
- increased urban temperatures which raise the peak electricity demand and induce utility companies to build additional power plants.
- the environmental and economic penalty of the increase in mechanical cooling is substantial, especially if considering the economic losses caused by blackouts due to the extensive use of A/C during heat waves.

Looking in more depth into the consequences of the microclimatic vicious circle, they range far and wide. Reduced quality of life and productivity will be more of an issue in future, especially for the ageing population and vulnerable in society. We will see more long-term health problems among the population, as documented already in a study conducted in Melbourne in 2010, finding that Hospital admissions increase by 38% when the average temperature during two consecutive days is higher than 27 °C (Laughnan et al., 2010). Increased mortality during heatwaves is something to get used to, sadly. Data collected during the heatwaves of 2003 and 2006 showed that mortality increased rapidly at threshold temperatures above 29.4 °C in Mediterranean cities, and above 23.3 °C in Northern and Continental European cities (Kirch et al., 2009). Recent heatwaves in 2021 and 2022 confirm this trend with the total number of excess deaths increasing to 3000 per week in certain European countries (Coi and Weise, 2022). We can also link these issues to increased epidemic and pandemic risks (due to increased density, poor ventilation, etc.). Implying the need for indoor and outdoor antiviral environments, with increased ventilation and often as simple as opening a window, but also with a better understanding of the role that the urban environment can play on health in large cities (Borna et al., 2022). Microclimatic changes in large urban environments modify the pattern of the local weather, intensifying other weather events such as precipitation patterns. Rainfall in Ho Chi Minh City, one of the most flood-prone cities in the world, has been on a steady upward trend for decades and this has been attributed to urban microclimatic changes rather than CC itself (Phi, 2007) (Fig. 1.3).

Risks are much higher for low income and more vulnerable groups of society due to the poorer condition of their housing, the lower affordability of high efficiency goods, and the usually denser and overheated areas of the municipalities where they live – further emphasizing social disparities and energy poverty. And creating a direct relationship between socio-economic vulnerability and environmental vulnerability.

*Fig. 1.3 – Flooding in Ho Chi Minh city, Vietnam.*

*Source: Xuan Huong Ho (Creative Commons).*

### *1.1.3. Barriers and Limitations*

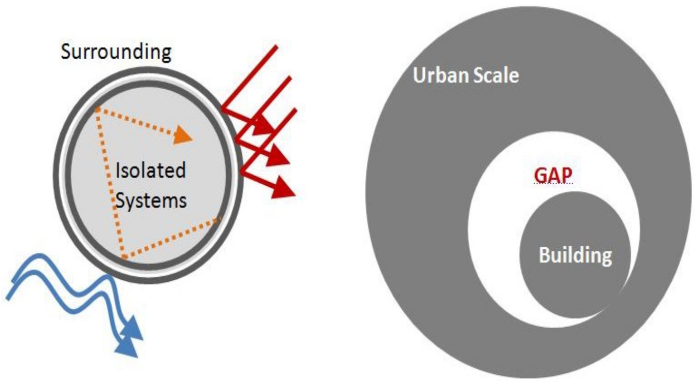
Thinking of the different infrastructures of a city – such as transportation, built environment, green spaces, etc. as separate elements is clearly a limit for their sustainable development.

Research on cities with an extensive portfolio of low-carbon urban innovation projects found that they did not achieve the expected impact because their projects were usually treated separately from each other in a stand-alone project management fashion, which reduced their transformative capacity (Bloomfield, 2014) (Fig. 1.4).

The improvement of the urban microclimate is not fully considered in current planning instruments in many EU countries. Technical strategies to improve conditions at various levels are well known and have been proven by research and case studies.

However, cross disciplinary research and action are not always applied and adequate policies which encourage the design of appropriate microclimates at EU and National and regional level are still lacking.

*Fig. 1.4 – Diagrams visualising the isolation of individual interventions and the gap in planning actions between the urban microclimatic scale and the building scale.*

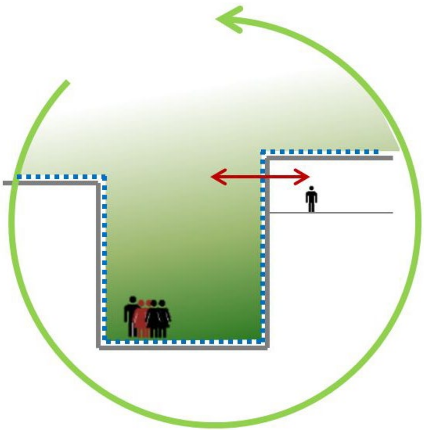



*Source: Elaborated by the author and Filippo Weber.*

## 1.2. Mitigation strategies towards long-term resilience

The main Climate action policies generally refer to Resilience, Mitigation and Adaptation, with a clear separation between Mitigative and Adaptive actions. Mitigation (in the building sector) implies emissions reduction through efficiency in buildings for long-term GHGs reduction. Adaptation implies acceptance and inevitability of immediate consequences of CC, for short-term adjustments. What instead we need is a joint-up approach where mitigation and adaptation happen simultaneously by proposing actions which while adapting to climate change also help to mitigate it in the long run. Many of the actions and strategies, are already known, but need to be applied simultaneously to make urban environments more benign and cities more resilient. The potential for the implementation of the pathways towards what we can call Mitigative Urban Environments, expresses the ability of urban environments to mitigate their microclimate through ameliorating strategies with a strong socio-environmental component. These pathways would be able to simultaneously reduce building energy demand, change human behaviour, improve “urban prosperity” (UN Habitat, 2013) and offer alternative low-tech pathways to efficiency-focused actions. The ameliorating strategies are many and range from those interventions on the physical environment, which address buildings and urban microclimates, and those interventions, which have a more social dimension and aim to promote behavioural shifts in society and reduce climate change induced social disparity.

*Fig. 1.5 – Diagrams visualising a better connection between the urban and building scale in the context of the street section.*



*Source: Elaborated by the author and Filippo Weber.*

The positive impact of microclimatic mitigative strategies (i.e., cool roofs, vegetation, water bodies, cool pavement, etc.) on the urban environmental conditions (i.e. temperatures, air quality, visual environment, etc.) are already documented, but there are no studies of their cumulative applications at a greater urban scale so far.

Amongst them, the use of reflective materials to be applied to the urban and buildings fabric, the use of additional green spaces and green roofs in cities, the use of the ground for heat dissipation and other techniques associated with the use of ambient sinks, seems to be the most developed and technologically advanced (Mihalakakou et al., 1995).

Reflective or cool materials present a high reflectivity in the solar spectrum together with a high emissivity factor (Santamouris et al., 2011). The use of cool materials on the roof of the buildings may decrease the corresponding surface temperature by several degrees and highly contribute to decreasing their cooling needs. Thousands of applications are already performed around the world with significant energy and environmental benefits (Santamouris et al., 2007). In most cases, the surface temperature is reduced by 10-15 K and the cooling load by 20-30 %, depending on the characteristics of the building. In parallel, cool reflective materials are used for urban pavements in order to decrease the surface temperature of the urban fabric (Santamouris, 2013). Hundreds of applications involving cool paving materials have been realized and monitored. Results show that it is possible to reduce the peak and the average summertime temperature of open spaces by several degrees and also improve the global environmental quality of the cities (Santamouris et al., 2012). Increasing the green spaces in a city highly contributes to decreasing its ambient temperature.

Urban green cools cities through evapotranspiration and solar control and is associated with the development of cool islands in and around parks and public green spaces (Skoulika et al., 2014). Cool islands created by urban parks offer improved comfort conditions and lower ambient temperatures around them and to a distance equal to their length. Appropriate spatial distribution of parks and other open green spaces can contribute to significantly decreasing the average surface and ambient air temperature of cities. However, the lack of available open spaces in cities significantly reduces the potential for further integration of urban parks.

The use of green or planted roofs seems to be a very powerful climatic solution. Planted roofs decrease the surface temperature of the buildings and decrease the temperature of the air above them using latent heat processes. Their mitigation potential depends on their characteristics and the local climatic conditions, but they may offer more than 150 W/m2 during the peak cooling period (Kilokotsa et al., 2013).

As for the cool reflective materials, the benefit of the vegetation on sun exposed facades contributes to reducing the energy demand of buildings while significantly reducing ambient temperature and consequently, thermal comfort may improve considerably (Djedjig et al. 2015).

The use of heat sinks that present a lower temperature than that of the cities, presents a high potential for dissipation of the excess urban heat (Santamouris and Kolokotsa, 2013). In particular, the implementation of earth to air heat exchangers to provide cool air in open urban areas has gained significant interest in recent periods. Buried pipes may decrease the temperature of the air flowing through them up to 10 K and thus provide comfort around them. Evaporative techniques like permeable pavements and sprays are also tested and employed in urban areas where the excess of humidity is not a major problem.

Other interesting studies and practices involve the efficiency of public transport in cities and the classification of streets with different priorities. For example, the Road Task Force in London is setting up strategies to redefine streets according to their effective use allowing heavier traffic to be diverted to specific boulevards while leaving local streets for uses different form mobility (Roads Task Force, 2012). These strategies will reduce not only the pollution but also the noise, especially at the local level.

Explorations at the urban block scale in Athens have tried to apply a number of strategies yielding peak summer temperature reduction of up to 4 K but more could be done in large scale projects.

## 1.3. Resilient urban environments

The potential of urban environments to mitigate their microclimate and to adapt to and mitigate Climate Change has so far received minor attention at the technical and policy level, compared to other approaches such as improvements in building efficiency. However, initial studies and experimentations indicate that actions at the urban scale would yield significant immediate mitigative benefits in improving the local microclimate of cities and reduce energy consumption of existing and new buildings. This would consequently reduce GHG emissions of the urban buildings. Hence, considering that the urban physical environment and its activities have a major impact on their microclimate and that the GHG emissions of cities are today the greatest contributors to CC, this underexploited adaptive and mitigative potential requires further investigation. This study shows the necessity of taking the first step towards a new paradigm of the urban environment by bringing a unique perspective on CC actions focusing on the role of urban environments and their microclimates in the sustainable development of cities. This calls for scientists, policymakers and stakeholders working together to produce successful pathways towards improving urban microclimates. The quality of the urban environment is an equally crucial issue for CC actions in developed, emerging and developing countries. Its potential to improve microclimates, to reduce energy demand and GHG emissions, relates also to improvements in the health and social conditions of the urban population, and could unlock new employment and market opportunities. However, this capacity has not been fully recognized yet and, in developed countries, this is proven by the lack of systemic urban policies linked to improvements of urban microclimate. In emerging and developing countries, this is aggravated by the lack of basic energy policies, even for buildings. The current approach translates into fragmented, sectorial and untied strategies which fail to address the CC mitigative and adaptive potential of the urban environment and do not fully involve its key stakeholders. More research is needed to characterize the urban microclimate by analyzing the space in between buildings, its physical boundaries, the related urban activities and the connected behaviour of the main stakeholders. This should be done for different urban and socio-economic contexts in order to establish a clear and wide-ranging definition of a mitigative environment and its potential to drive cities towards prosperity.

Given the fragmented nature of existing technical solutions, small-scale demonstrations and various policies to mitigate the urban environment, there is the need to gather this knowledge further, encompassing good and bad practice examples, in a comprehensive and rationalized manner and to evaluate it under technical, policy and socio-economic dimensions. The gathering of knowledge, practices and initiatives will be crucial to determine the potentials and constraints of existing and prospective strategies and to define the most effective new pathways. Moreover, this exercise will identify the cross-disciplinary framework and cross-stakeholders involvement within which innovative pathways and systemic strategies need to be defined in order to be effectively implemented and economically grounded on a balanced route towards the improvement of urban environments. The systematization of existing knowledge and related case studies, together with their evaluation and proposed improvements should be used to inform decision-making processes of key stakeholders and policymakers at the local level and through international policy channels.

*Fig. 1.6 – Seville is an example of a Mediterranean city, which adopts a range of microclimatic friendly strategies for the benefit of outdoor and indoor comfort.*


*Source: Author's photo archive.*

In order to change the current state-of-the-art and transition to the new paradigm of urban environment offered by Mitigative urban Environments and their Microclimates (MitEM), a collective effort involving all levels of society is required. However, when it comes to transformations in the built environment, our society's aspiration for fast economic growth and short-term returns poses substantial barriers to the implementation of mitigative and adaptive CC actions, which are based on different economic models.

Therefore, in order to overcome these barriers, it is essential to adopt a joined-up approach, which considers many perspectives and interfaces, and involves a plurality of society's stakeholders. Transfer of knowledge, collaborative work and cross-sectorial considerations become fundamental.

Overall, this review shows that not only there is the scientific and cultural maturity to postulate a new concept of Mitigative Environment and that technical advances and experimentations have demonstrated the feasibility of such postulation but that this new proposal fulfils a need and a gap. The need is for a new way to consider and conceive our built environment, which will allow the local and global mitigation and adaptation to Climate Change and the extreme weather events associated with it.

The gap is the universal gap that is currently present at the policy level where there is a lack of specific recognition of the impact of buildings on their urban environment and microclimate. The big open question at this point is that even if at the technical and policy levels there are the condition for the postulation of a new paradigm, can it be sustained at the political and economic level, given the values of our current society?

In other words, would we as a society be prepared to pay the extra cost of a healthier and more benign urban environment?

The answer is in the necessary shift that historically has brought on the change when socio-environmental demand and technical offer converge. The shift from coal-based heating systems polluting the industrial cities of the $19^{th}$ century or from the unsanitary conditions infesting the streets of the $18^{th}$ century. The same shift is now necessary to transform our urban environments from the recipient of noise, waste heat and poor air-quality into positive microclimates which contribute to both the outdoor and indoor comfort of our urban living.

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# 2. Exploring synergies in sustainable, resilient and smart buildings to address new design paradigms in the next generation of architecture

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The accomplishment of the United Nations Sustainable Development Goals (UN SDGs) by 2030 will be largely influenced by the effectiveness level of planning, design, building and management stages in the next years (United Nations, 2015b).

Since the late 1990s, buildings began to be designed according to more sustainable principles and this growth is also driven by the much more demanding current standard; however, due to the current impact of climate change (CC), this is no longer sufficient. At the same time, during the last decade, resilience has assumed an increasingly important role in design to ensure longevity, withstand the extreme weather brought on by CC, and reduce environmental impacts.

The fact that sustainability has been considered more than resilience indicates the necessity to pay closer attention to the latter to reduce building vulnerability rather than responding reactively to a disruptive event. Smart technologies, which rapidly grow with the expansion of the information and communication technology (ICT) domain in the building sector, may reduce energy demands and respond to users' needs while improving the performance of the building as a whole.

The potential intersection of these design domains may reveal synergies, gaps or potentialities at an early stage of the design process for a new generation of buildings clearly aligned with the SDGs.

## 2.1. Introduction

The future generation of buildings will require highly efficient operation levels and the capacity to respond (and even adapt) to varying climate conditions. Currently, more than half of the world's population lives in cities (Chokhachian et al., 2017). This trend, which is expected to continue for quite some time to come, will inadvertently pose threats to the infrastructure, economy and environment of cities (Sharifi et Yamagata, 2016).

It is therefore expected that the challenges associated with resilience in cities will be exacerbated as a result of natural hazards, CC, poverty reduction, and social inclusion (United Nations Department of Economic and Social Affairs, 2018).

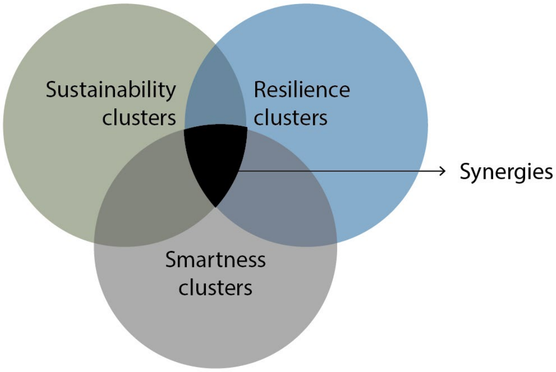
*Fig. 2.1 – Office building Main Point Karlin, Prague (Czechia), designed by DAM Architeki (2012).*

*Source: Author's photo archive.*

Since most contemporary cities were not designed with resilience concepts in mind, this topic becomes more pertinent. The office building Main Point Karlin in Prague (certified LEED 2009 Platinum), for instance, is built below street level despite being very close to the Vltava river, which might flood in the event of heavy rain, as was the case in 2002 (Fig. 2.1).

The 2021 report of the Intergovernmental Panel on Climate Change (IPCC) (Intergovernmental Panel on Climate Change, 2021) reports that emissions of greenhouse gases from human activities are responsible for approximately 1.1°C of warming from 1850-1900 and significantly contribute to the alteration of the local climatic conditions in the built environment (i.e. urban heat islands) (Intergovernmental Panel on Climate Change, 2021) and other climate-related phenomena, such as floods and droughts (Felicioni et al., 2020). The building sector is responsible for approximately 36% of emissions and 40% of energy consumption (Balaras et al., 2007; Bean et al., 2018; Lin et al., 2022), representing a crucial segment in terms of saving potential and, at the same time, one of the most vulnerable affected by CC effects (European Commission, 2020a).

*Fig. 2.2 – Intersection of design clusters.*




*Source: Elaborated by the author.*

The importance of promoting sustainable solutions has increased significantly over the past few years. In this regard, smart and resilient cities, combining technology with CC adaptation strategies, can be used to enhance and ensure the sustainability of urban areas and enhance living conditions for residents. Smart cities are increasingly expected to be supported by ICT, while nature-based solutions will support resilient cities (Lin et al., 2022).

When examining the main objectives outlined in the SDGs, in the European Green Deal (European Commission, 2019), and even the New European Bauhaus (European Commission, 2021), it is clear that there are many potential synergies between resilient planning, technology integration, and CC adaptation which can make a significant contribution to social, economic, and environmental aspects.

In this context, the main challenge is to determine how to interrelate these three building design domains (sustainability, resilience, and smartness) in order to design the next generation of buildings. One possible solution would be to intersect the main clusters of the three domains to demonstrate their commonalities and synergies, which can be applied in buildings (Fig. 2.2).

### *2.1.1. Buildings' contribution to the UN Sustainable Developments Goals and European Green Deal*

Developing the built environment sustainable and resilient to CC is a pressing global need, as outlined by the 2015 Paris Agreement (United Nations, 2015a). The need for effective strategies arises in the 2015 SDGs (United Nations, 2015b), where adequate mitigation and adaptation measures are expected to be introduced by 2030 (Dobie et Schneider, 2017). In particular, the targets of SDG 13 are aimed at increasing resilience from natural hazards, while others, such as SDG 7 or 11, are more focused on sustainability. However, SDGs always share benefits and synergies and are directly connected to sustainability, resilience, and even intelligence for the built environment. This highlights the fact that both resilience and sustainability, and even smart technologies, can have commonalities at the building level, and should be considered during an early design phase to maximise their potential and benefit cities and citizens. By aligning its actions with the UN's SDGs, the building sector can significantly contribute to sustainability and resilience, as recognised by experts in the construction industry and green building rating systems (DGNB, 2020). Focusing on the European context, in 2019, the Green Deal was released (European Commission, 2019). This initiative emphasises the importance of designing and renovating buildings to be more energy efficient in order to achieve the main goal of carbon neutrality by 2050 (e.g. under the Renovation Wave – European Commission, 2020b – that prioritises decarbonisation of heating and cooling). Therefore, even in this situation, simultaneous consideration of sustainable, resilient, and smart principles would be essential to achieving a compelling carbon-neutral and climate-resilient European future.

## 2.2. Three design approaches

### *2.2.1. Sustainability in buildings*

For many years now, fostering sustainable design has been one of the main urban planning challenges in cities (Cariolet et al., 2016). Sustainability has been a trend since the 90's, when the certifications systems started to be developed, such as Leadership in Energy and Environmental Design (LEED) (USGBC, 2021) in the United States, Building Research Establishment Environmental Assessment Method (BREAM) (BREEAM, 2016) in the United Kingdom, or Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) (DGNB, 2020) in Germany.

*Fig. 2.3 – Common clusters for sustainability in buildings.*

| Clusters | Description |
|---|---|
| Energy performance | Increase the adpotion of passive solutions, track the consumption and the use of renewable energy sources in order to reduce the energy demand. |
| Greenhouse gases and air pollutant | Reduce the total GHG emissions associated with a building's life cycle by focusing on operational energy use and embodied energy |
| Connectivity and transport | Ensure the quality of access and transportation. |
| Land use and ecology | Reuse of previously developed land and enhancement of biodiversity. |
| Circularity and efficiency | Reduce significant environmental impacts (embodied and operational) by optimizing the building design and the waste management. |
| Healthy spaces | A comfortable, attractive, and productive building for living and working, ensuring a high standard of living for all. |
| Water consumption | Ensure that water resources are used efficiently by taking measures to minimize the use of water. |
| Adaptation to CC | Protect people's health and comfort by implementing resilience strategies for potential future climate change. |

*Source: Elaborated by the author.*

They have raised awareness of sustainability and environmental concerns using some criteria that highlight possible paths for achieving a higher level of sustainability, such as considering energy performance and water consumption. However, not only environmental sustainability should be taken into account, but even economic and social aspects such as building life cycle costing and design for all – including people with disabilities and the elderly.

Based on the analysis of the most worldwide used manuals and guidelines (BREEAM, 2016; Dodd et al., 2017; DGNB, 2020; USGBC, 2020; SBToolCZ, 2022), eight clusters are highlighted as being common to all sustainable tools (Fig. 2.3). A cluster-based system allows for the definition of a circle in which more subsets can be considered; however, the edges of the circle are blurred as the cluster is eventually described in greater detail, adding new features but without necessarily introducing new clusters/categories that may disrupt the system as a whole.

However, most of these tools chosen for the investigation do not address all three aspects of sustainability equally (i.e. economic, environmental, and social (Felicioni et al., 2020)); indeed, environmental impact is of the utmost importance (Marjaba and Chidiac, 2016).

### *2.2.2. Resilience in buildings*

The current concept of resilience owns a less shared and consolidated understanding compared to sustainability (Nop and Thornton, 2019). Although the precise meaning of building resilience stays indeterminate, many organisations have tried to define this issue. For instance, the Rockefeller Center states city resilience as the 'overall capacity of a city (individuals, communities, institutions, businesses and systems) to survive, adapt and thrive no matter what kinds of chronic stresses or acute shocks they experience' (ARUP, 2016). Moreover, since building resilience in cities needs an understanding of both what contributes to resilience and how it can be measured, ARUP has developed the City Resilience Framework (The Rockefeller Foundation and ARUP, 2015) and the City Resilience Index (ARUP, 2016) with support from the Rockefeller Foundation.

These two tools offer the city's comprehensive and accessible guidelines for assessing and measuring resilience at an urban scale (ARUP, 2018). It is also the responsibility of the European Commission to promote prevention and preparedness initiatives, such as early warning systems and disaster insurance, which enable local communities to deal with disasters that are predictable or unpredictable, such as an earthquake (European Commission, 2016). The European Commission has developed the Smart Mature Resilience project (ICLEI European Secretariat, 2018) with the objective of encouraging more resilient cities by following a European Resilience Management Guideline (Smart Mature Resilience, 2018) to increase public awareness of the resilience and sustainability of cities as well as activate potential stakeholders.

However, resilience assessment tools for buildings are available, such as REDi (Almufti et al., 2014), which mostly focuses on seismic safety, and RELi (USGBC, 2018), which addresses different hazards and follows the same structure as LEED. In general, considering environmental resilience, the most common hazards covered by resilience assessment tools and guidelines are flooding, heatwaves, and severe storms, while other hazards, such as air and water quality, drought, and wildfires, are not as extensively covered (Felicioni et al., 2020). This highlights that the current CC mitigation efforts are directed at facing visible threats or hazards that have caused extensive physical and economic damage, such as floods (or earthquakes – not a direct consequence of the CC).

*Fig. 2.4 – Common clusters for resilience in buildings.*

| Clusters | Description |
|---|---|
| Thermal safety and passive survivability | The indoor building comfort can be moderated both during regular operation and during periods of grid-supplied power and fuel outages, heat waves, and other emergencies when local self-reliance. |
| Back-up energy system and on-site renewable energy | Balance energy demand and availability by using passive solutions, managing energy efficiency, and generating renewable energy on-site. |
| Water management | Efficient water management respects the natural hydrological cycle and maintains a balance between surface water, rain events, and water use. |
| Location and biodiversity | Identify long-term adaptation strategies to cope with the consequences of climate change through shock-resistant design and planning for extreme events. Biodiversity and greenfields must be protected and enhanced. |
| Transportation system protection | Increasing accessibility to alternative transportation options during times of crisis. Social cohesion and knowledge of the local environment are improved as a result. |
| Material effectiveness | Increasing material recycling and reuse, local extraction, and harvesting of all materials used in the project. Using EPD-certified, life-cycle-impact positive and carbon- and energy-efficient products. |
| Passive Lighting and Ventilation | Indoor comfort ensured through passive systems that allow the building to remain operational even in the event of a disruptive event. |
| Community education and training | Resilience can be successfully embedded in buildings and communities through education and capacity building. |

*Source: Elaborated by the author.*

Buildings should be designed to be resilient to extreme events to keep the occupants safe and reduce the environmental impacts associated with post-event adjustments (Welsh-Huggins and Liel, 2018). Other aspects of resilience should be considered, including economic and social aspects such as the recovery time following a disaster and the feeling of safety.

Figure 2.4 shows the common clusters among the most known resilience assessment tools and guidelines. The resilience metrics of these clusters may come in a wide variety of typologies. They can be descriptive or quantitative, as for the local renewable generation or indoor water use reduction; they can be based on interviews, experts' opinions, engineering analyses, or pre-existing datasets, such as the site risks assessment. They can also be presented as an overall score or as a set of separately reported scores across physical, economic, social, and environmental dimensions, as for the hazards-resilient materials. These metrics help assess the current level of resilience of each objective and the potential benefits of actions to improve its resilience.

### *2.2.3. Smartness in buildings*

The built environment is increasingly challenged by the climate emergency. To ensure effective and efficient operations, smart technologies should be integrated into buildings (ARUP, 2022), for example, to reduce energy consumption and improve the sustainability of buildings as well as smart electric grids (Zhuang et al., 2020). According to the Smart Building Readiness Level (VITO, 2017), buildings are expected to "minimise grid power dependence and maximise service efficiency" by integrating components such as sensors, renewable energy sources, and energy management systems (EMS) (Alduailij et al., 2021). Developers can gain insight from this type of building in addition to maximising productivity, improving user health and wellbeing, and establishing a consistent user experience across multiple sites. In the wake of the recent pandemic, buildings equipped with smart technologies have become increasingly significant as they provide effective methods for understanding and managing occupancy, adjusting the conditions in accordance with the needs of the users (for example, acoustics, lighting, space booking, and audio/visual features), as well as weather conditions. Considering that these buildings are already designed to harvest energy and water and use both resources efficiently as a standard operating procedure, they may be planned to be prepared for disruptions in power and water services. Generally, smart buildings can monitor and control the activities within a building and use the information to automate various processes, such as heating, ventilation, air conditioning, security, etc. (Zhuang et al., 2020). As a result, facility management will be streamlined management (Moretti et al., 2021), leading to a higher level of security, both on the physical and cyber fronts (Ciholas et al., 2019). Figure 2.5 illustrates the common clusters of the concept of smart buildings.

*Fig. 2.5 – Common clusters for smartness in buildings.*

| Clusters | Description |
|---|---|
| Ehnanced overall performance | Using IoT sensors, smart appliances are monitored and data are collected; decisions are taken to allocate resources efficiently in response to weather conditions. |
| Energy flexibility | Interaction with smart grids resulting in load reduction, peak shaving and load shifting, and reducing blackouts and brownouts . |
| Building adaptability to users' needs | Increasing of occupants productivity by providing an optimal level of air quality, security, lighting, physical comfort, sanitation, and space availability measures. |
| Networking and communication | All data provided by sensors are stored and accessible for futher studies in preventing the anomalies around the buildings for false detection of data. |
| Facility Management | Integration of systems, processes, technologies and personnel to enhance the management of a building's facilities. |
| Security and safety management | Both physical and cyber security are guaranteed (e.g., intrusion alarm, access control, audio surveillance, and internet remote management and maintenance). |

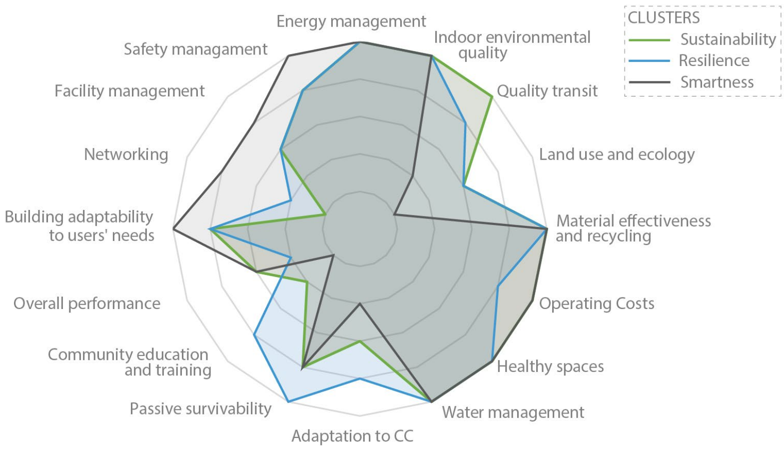
*Source: Elaborated by the author.*

In order to achieve the full potential of smart buildings, a variety of factors must be linked, tracked, analysed, and measured. These factors include water conservation, energy generation, and optimisation of the indoor environment and ICT. As one integrated digital organism, the building must consider water, light, indoor environment, information supply, ICT, resource utilisation, fire and safety, building access, and building safety, which require continuous and interrelated analysis.

## 2.3. Three principles for a sustainable, resilient and smart built environment

In the past decade, society has increasingly embraced digital solutions in almost every aspect of daily life (Malagnino et al., 2021). In the context of a building, sustainability, resilience, and smartness have been considered separately so far. However, these domains are interconnected, and they should be taken into consideration simultaneously since many clusters overlap, so they should be properly balanced throughout the entire design process.

*Fig. 2.6 – Radar chart comparing the three domains in different clusters.*




*Source: Elaborated by the author.*

The first benefit of this integration may be the reduction of water and energy consumption while increasing savings. Sharing synergies between these three domains could therefore enhance the quality of life for building stakeholders as many benefits can be achieved simultaneously, such as the ability to regulate the temperature and turn on/off the lights. The primary target group for any integration effort is the end-users, although they sometimes have limited control over the building system. Despite this, since most residential buildings are multifamily structures, the owners and managers have more power than the building occupants; indeed, they can still influence and take purposeful actions in order to make the building system more sustainable and smart, even in the face of extreme circumstances (Hewitt et al., 2019). The common clusters resulting from the intersection of the three domains can be grouped as follows (Figure 2.7):

- Environment – energy, water and waste management are crucial aspects to consider; a proper selection of materials can enhance the level of sustainability, and correct monitoring of consumption and savings can boost both resilience and smartness.

- Society – considering the actual needs of residents is the key to designing a new generation of buildings, as well as improving their overall comfort.
- Economy – although initial costs may be higher, integrated solutions result in a reduction in energy consumption, improved work efficiency, higher wellbeing and user's satisfaction.

*Fig. 2.7 – Common clusters for sustainable, resilient and smart buildings.*

| ENVIRONMENT | |
|---|---|
| Energy management onsite | Energy-efficient building with passive solutions controlled by sensors for cooling and heating and back-up power for HVAC and boilers. |
| Water efficiency and management | Climate-appropriate landscaping, efficient appliances, and rainwater collection on the roof or in parking areas. |
| Indoor environmental quality | Passive solutions for daylighting and ventilation to maintain the indoor environmental quality also in case of energy disruption. |
| Ease of recovery and recycling | Locally sources materials and a life-cycle approach with a special focus on waste management. |
| **SOCIETY** | |
| Architectural design | Designed for all (aesthetics and functionality), the building ensures a long service life with a minimum of induced changes during usage. |
| Perception of safety | The building should be protected from various threats so as to minimize the possibility of damage. Risk assessment of natural and man-made hazards and potential crime risks. |
| Access to quality transit | Diverse transport options to reach the building (bus stop, bike routes, ferry station, metro) in order to reduce the negative impacts caused by individual car traffic. |
| **ECONOMIC** | |
| Affordability and flexibility | Changing the use over time ensures longer building service life and reduces the financial and environmental burdens. |
| Operating cost | Costs can be forecasted and reduced through facility management and energy and water consumption metering. |
| User comfort | Guaranteed thanks to control-related building occupants behavioral trends and patterns as well as a wide variety of relaxation areas and green spaces. |

*Source: Elaborated by the author.*

The intersection between the three domains allows understanding that many characteristics that describe each domain also exist in others.

Consequently, it would be possible to combine multiple strategies and provide multiple benefits. This would apply not only to the building and the environment but also to the quality of life of the building's occupants.

Smart systems can self-regulate the indoor environment, or the stored energy generated by the photovoltaic system installed on-site can still be used in case of heavy rain and a consequent blackout.

## 2.4. Final reflections and future directions

CC has triggered the emergence of a next generation of buildings that combines sustainability and resilience through an integrated technological system.

Currently, the trend of sustainability, which is more solid and more defined, is evident. Sustainability started to be conceived as an element of the general environmental situation, then it has been scaled to the built environment and, consequently, to buildings as specific targets. There is a successful development of frameworks aimed at measuring sustainability performance, but they still lack in addressing specific questions, such as hazards preparedness and adaptation; this gap should be reduced to allow synergic strategies that connect resilience and sustainability concepts to be incorporated at the design stage of a building, instead of being placed reactively after a shock event.

At present, resilience is perceived as a general target for all the economy and all human activities. Due to the central role that buildings play in all environmental phenomena, something similar to what was observed ten years ago for sustainability is needed, from a general perception to a more detailed and specific one. Nowadays, information technology allows a high level of control capacity in many complex environments and could certainly improve building management and functionalities.

The proposed work highlights the common clusters of three design domains in buildings (sustainability, resilience and smartness). From a design perspective, they may provide valuable guidance if their synergies are considered. Additionally, a number of key indicators should be identified and become indispensable for guiding the design process. Buildings should attain these indicators in order to be sustainable, achieve better overall performance through technological systems, and provide a minimum level of resilience.

Buildings that integrate all three domains allow envisioning what a building of the future could look like. Indeed, as a result of its high level of energy efficiency, the building is not susceptible to shocks caused by grid outages due to potential heavy storms or floods and fluctuations in the price of electricity, whereas the building's users can make informed decisions when interacting with the building through its understanding and exploitation of big data. The embracing of these common clusters would allow a greater opportunity to address the building sector in dealing with the challenges of tomorrow, which are an urgent call for action by all countries (United Nations, 2015b).

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# 3. *Running after pathways: a critical reflection on climate change roadmaps*

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Cities are since several years now at the centre of a growing debate about their role in climate change. Multiple measures, responsibilities and directions have been identified in order to cope with this growing issue. There is a deep reason why cities are at the core of this debate, more than other areas: cities are the places where most people live and where it is expected that the majority of mankind will live in the future.

The availability of services, relational places, support groups, and working spaces has made urban areas the elected environment to live in. More than reversing this trend, the COVID-19 pandemic has somehow increased the need to reshape cities in order to ease and improve life quality in them, with the implementation of new and more significant green and open spaces. Those reflections and interventions usually go also in the direction of improving urban adaptation capabilities to climate events. Green and open spaces are, in fact, some of the most used strategies to make cities more resilient. However, those actions do not seem to be sufficient to improve people's life nor to really support the climate transition.

Some of the last reports on climate change show that even if some measures have been taken, those are still not sufficient to meet the expected goals. This chapter will deepen these points, trying to focus on climate transition roadmaps and pathways.

## 3.1. Recent key facts about the climate change

The Intergovernmental Panel of Climate Change (IPCC) is a key United Nations body for assessing the science related to climate change. Their reports are recognised as the most important current studies about climate change. This is why the release of new reports from this body is seen by the scientific debate and by institutions as a key moment for reflecting on the actions we are taking to fight climate change. The last report has been the Sixth Assessment Report, composed of different relevant focuses titled "Climate Change 2022: Mitigation of Climate Change" which is the contribution of the working group III - WGIII (IPCC, 2022b) and "Climate Change 2022: Impacts, Adaptation and Vulnerability" (IPCC, 2022a), which is the contribution of the working group II - WGII. Both documents are crucial for the understanding of our current climate change status.

The report of WGIII, in particular, shows how, despite the efforts made worldwide, we are not on track to maintain the average surface temperature behind +1.5/2 °C (IPCC, 2022b). The report, in particular, defines in point B1 that *total net anthropogenic GHG emissions have continued to rise during the period 2010-2019, as have cumulative net* $CO_2$ *emissions since 1850. Average annual GHG emissions during 2010-2019. Were higher than in any previous decade but the rate of growth between 2010 and 2019 was lower than that between 2000 and 2009* (IPCC, 2022b). This finding means that some improvements have been made in the last ten years, in comparison with the 2000-2009 decade, but that there is still a significant increase in cumulative $CO_2$ emissions. As the report goes on, it points out that:

- GHG (greenhouse gas) emissions have been 12% higher than in 2010 and 54% than in 1990 (point B1.1);
- the GHG emissions' growth has been present across all major GHG groups, with the largest growth in $CO_2$ from fossil fuels and industry;
- around 17% of historical cumulation of $CO_2$ emissions since 1850 are concentrated between 2010 and 2019 (point B.1.3).

Additionally, the report recalls the role that urban areas have in emissions (point B.2.3), saying that in 2020 urban areas were responsible for 67-72% of the global share and it recognizes the importance and strategic role that policies and laws addressing mitigation are putting in reducing emissions (point B5). If this report focuses mainly on climate mitigation, the Working Group II reported key facts and data on adaptation and climate vulnerability (IPCC, 2022a). After confirming the role that mankind is playing in changing the climate and the biodiversity and in the resulting impacts on health (see, for example, points SPM.B.1 and following) and pointing out that extreme events are expected to increase in the future, especially in urban settings (SPM.B.1.5), this study points out very clearly that climate change impacts and risks are becoming more complex and that we should expect the concurrence of multiple climate hazards at the same time, especially if we fail in maintaining the average surface temperature behind +1.5°C (point SPM.B.5). Moreover, point SPM.C.1 refers that *Progress in adaptation planning and implementation has been observed across all sectors and regions, generating multiple benefits. However, adaptation progress is unevenly distributed with observed adaptation gaps. Many initiatives prioritize immediate and near-term climate risk reduction which reduces the opportunity for transformational adaptation* (IPCC, 2022a).

This is a crucial aspect in order to understand the weaknesses in the current action implementation systems: short-term planning seems to be a key point in this analysis. To sum up, IPCC's last reports are evidencing how the current paths are not meeting the expected results. In particular, it is clear that COP26 goal of maintaining the average surface temperature below 1.5 or 2°C is at risk. In the next paragraph, some considerations about current strategies of adaptation and mitigation are provided.

## 3.2. The mitigation, adaptation and compensation approaches

Three core actions are nowadays commonly used for tackling climate change: mitigation, adaptation and compensation. Mitigation refers mainly to implementing strategies for direct $CO_2$ and GHG emissions reduction, while adaptation refers to strategies improving the built environment (and economy and society) vulnerability to changes that are already present. In particular, adaptation includes the concept of anticipation as a way to prepare in case of adverse events (European Environment Agency). Compensation, also referred to by the terms "carbon compensation" or "carbon offsetting", is different from the first two definitions, as it is more linked with finding compensative actions for damages that already happened as well as for covering emissions that are not possible to reduce in the place where they are produced. This usually involves private individuals (citizens) and other bodies, such as industries, services, institutions, etc. In this last meaning, compensation measures are, for example, financing projects that capture greenhouse gases or planting new trees. Part of the compensation strategies is, for example, the so-called carbon taxes. If the first two methods (mitigation and adaptation) are the ones more investigated in the international debate, compensation remains less considered a "real" action against climate change, especially as some authors argue that compensation can be used as an easier way to avoid facing the problem of emissions overproduction (Hyams and Fawcett, 2013; Anderson and Bernauer, 2016; Zeller, 2019). If mitigation and adaptation both embed the possibility of reducing climate modifications and of lowering their eventual impact as much as possible, compensation mainly refers to a scenario where damages are happening, and no more prevention measures are possible. Other authors (Farber, 2008) refer to compensation in relation to ethics and climate justice, considering how to compensate for the costs of losses due to climate, including life losses.

Some forms of carbon compensation are rising and pursued at the institutional level. This is the case with the carbon taxes that are intended by the European Union as a way to force highly pollutant industries or bodies to implement green actions. There are several forms of environmental taxes and fees, such as real taxes on specific emissions (e.g. from transport, agriculture, waste disposal, etc.), deposit-refund schemes (e.g. allowing people to get refunds while buying a product if they bring back the packaging), tradeable permits schemes (which are quotes for pollution allowed in an area), offsetting schemes (which are proper compensation of emissions through paying equal or greater environmental restoration somewhere else) and finally paying for ecosystem services (European Commission, 2019). These days, a growing concern is regarding forms of carbon compensation by planting trees that are happening in New Zealand at a very high-speed (Driver, 2022). Despite the presence of several contributions highlighting the importance of each of these macro-strategies, and the growing role that compensation measures are taking, this chapter will mainly focus on mitigation and adaptation, as these are usually the most included in climate strategies, climate pathways, roadmaps and scenarios.

## 3.3. The green&smart city as a utopia for the future

It is now several years that cities worldwide have been trying to cope with climate change. Since the first recognition of climate as a key topic for mankind's future, several steps have been taken. Strategies, scientific reports, and several reflections at different societal levels have been proposed during the last decades: from the global and international level to the more site-specific country and city-level strategies. From the end of the previous century, in particular, growing attention has been put to cities' evolution, using several claims: "digital city", "smart city", "green city", "recycling city", until the most recent "15-minute city". Why within not much more than 30 years, there have been so many names and claims assigned to cities? Several years ago I wrote an article (Boulanger, 2015) arguing that this need to find new names to identify a new direction for cities was in line with a utopian thinking approach. Today I confirm this interpretation because utopian thinking and utopia creation are both very linked with ages framed by big transformations, when people have the necessity to put in place strategies and to think differently about the future (Claeys, 2020). According to this interpretation, the proliferation of such types of claims can be seen as the search for an improved future, especially in relation to climate change and social gaps. According to Gregory Claeys (Claeys, 2020), utopias need to be plausible and realizable and can play a positive role in solving real problems and envisioning pathways for transition. He, in fact, says: *Utopia represents a fantasy of escapism, the rejection of unpleasant reality and substitution of an inverted or dream-like opposite, polar set of pleasures, sometimes portrayed realistically [...]. And if we need large-scale [...] social planning to deal with problems of the future, then we also need an image. Of the future that accounts for long-term problems and. Offers long-term solutions on a global scale. This, then, is a utopia in a positive sense* (Claeys, 2020). In this way, the current idealisation of projects such as the "smart city" or the "green city" or the "15-minutes city" can be intended as utopian tensions, at least, claiming the need to make cities evolve into a more aware and responsive form to climate and societal changes. Indeed, all those strategies start from the identification of a current negative starting point, where challenges and weaknesses are more evident than positive aspects. In the case of smart cities, for example, the topic has its premises directly from the experimentations of a more functional architecture made during the last century, meeting the new technological development of the Internet of Things and the subsequent rise of digital instruments and portable devices. The first ideators of the Smart City saw in these potentialities the premises for a world shaped by high-tech services and infrastructures, where people would have been entirely supported by machines able to predict their needs and ease their life. However, the idea of the smart city rises from the observation of the present: inefficient, with multiple services not connected to the other, with several leakages in the grid systems (not only energy grids but also water ones), with multiple steps required from people to do anything (from presenting documents at the municipal offices, to using domestic appliances) (Hall et al., 2000; Nam and Pardo, 2011; Anthopoulos and Vakali, 2012; Batty, 2015; Bertello et al., 2013; Neirotti et al., 2014). The Smart City is presented as a futuristic strategy to solve societal problems and to transit mankind into the future. And in this, its discourses remain strictly linked with this limited vision. The tentative to enlarge the objectives of the Smart City tended to produce new claims, suggesting that the role of technology was not enough and aspiring to a more “resilient” and “green city”. Also, in these approaches, the references start from the current situation toward the identification of a vision of the future, which is again limited. Resilient and green cities are proposed as contexts where the natural element (both green and blue) take a protagonist role (Danish Ministry of Climate, Energy and Buildings, 2012; State of Green, 2018; Berkowitz and Kramer, 2018; Boulanger, 2020). Current cities are mainly covered by asphalt or concrete, with limited capacity to autoregulate temperature and water flows. Frequent heat islands and drought, in summer, and landslides and floods, in winter, call cities to reintroduce trees and green surfaces, while reducing concrete with multiple projects going in the direction of urban reforestation, urban gardens and similar. Then, the inclusion of a more citizen-centred and services-centred approach produced the recent “15-minute city”, in which people should live at no more than 15 minutes of walk or cycles from any activity or service they need, especially the basic ones but also leisure (Allam et al., 2022; Moreno et al., 2021; Pozoukidou and Chatziyiannaki, 2021).

Those approaches have some similarities in their construction and sometimes they cross-fertilize each other, as proposed by Zahir et al. recently, who approached the “15-minute city” through the spread of digital technologies and the 6G (Allam et al., 2022). It is possible to see contribution referring to a composition of those approaches. However, even with some interrelations, it is possible to argue that a predominant vision is always present: a people-centred or services-centred one, or a digital or a green one. If those ideations can have a role in framing visions for the future, the creation of roadmaps following just one of them can be a failure. Urban systems are very complex environments framed by multiple layers of needs and potentialities, thus, the conformation of strategies just to digital infrastructures, or to greenings or mobility or others will not be able to deal with this complexity.

In conclusion, effective pathways and roadmaps can benefit from envisioning a future with very specific characteristics, but they then need to be rooted in the specificities of the different contexts and complexities.

## 3.4. Running after the pathways and “the pathway problem”

As said in the previous paragraph, it is possible to see, in the proliferation of city-related claims, the need of envisioning and designing the city of the future. This is then put into practice through sets of strategies and actions currently going under the name of "pathway" or "roadmap" and sometimes of "scenario". Due to the urgency of taking action against climate change, it is possible to see a proliferation of these instruments. Several levels of roadmaps are available: from the institutional ones to consulting agencies proposing innovative approaches, to design-related instruments, and finally to cross-national networks, rankings and certifications aiming somehow to measure and define the best strategy for the future. The next sections of this chapter will analyze some of these cases, trying to put in evidence their structure, interesting elements and also weaknesses.

According to the Oxford and Collins dictionaries, the definitions of the pathway, roadmap and scenario are multiple, but in general, they align under the followings:

- "A pathway is a path which you can walk along or a route which you can take" and "A pathway is a particular course of action or a way of achieving something" (Pathways);
- "A road map is a map which shows the roads in a particular area in detail"; "A road map of something is a detailed account of it, often intended to help people use or understand it"; "When politicians or journalists speak about a road map to or for peace or democracy, they mean a set of general principles that can be used as a basis for achieving peace or democracy"; "A plan or guide for future actions"; "Any plan or guide to show how something is arranged or can be accomplished" (Roadmap);
- "If you talk about a likely or possible scenario, you are talking about how a situation may develop"; "a predicted sequence of events" (Scenario).

What emerges from these definitions are the following key elements:

- pathways are future-oriented
- they are composed of steps
- they can include alternatives (scenario)
- they should include guidance to support the implementation
- they should have enough details to understand the current position and the direction.

Not all the most important climate pathways include all these elements, but some are recurrent. A long-term goal definition, the identification of intermediate steps, actions that should lead to meeting the goal and the presence of a monitoring phase often appear as common elements, while the comparison of alternative scenarios is less frequently included. The strategic importance of those instruments asks researchers to have a deeper look at them. In particular, an interesting approach is given by Rawls, Gilabert and

Lawford-Smith that in 2012 (Gilabert and Lawford-Smith, 2012; Houston, 2021; Kenehan and Katz, 2021) raised the so-called “pathway problem”. In their works, they strictly link climate pathways to political feasibility.

This model implies that when deciding the steps that have to compose a pathway, political bodies tend to consider both the desirability of the transition and the likelihood, based on probabilities of achievement. This means that, according to Gilabert and Lawford-Smith, when an institution has to decide which actions and steps to take in the climate transition, they usually reflect on how much this transition is desirable but also on how much it will probably happen. The probabilistic approach goes along with the necessity of making these steps for the transition. However, as Houston (Houston, 2021) remembers, the climate is non-predictable, especially in the long term and this implies that even if the Gilabert and Lawford-Smith model seems to be applied by political bodies, in reality, it should be, because there future is non-scientific and, thus, institutions seem more to speculate on it than taking actions with correct information. As an example, we do not know how in reality carbon emissions will go, even with actions undertaken, but mainly more important, we do not know the economic, political and social environment in the future. The COVID pandemic and the Ukraine-Russian conflict are an expression of this uncertainty.

This point is also highlighted by other authors (O’Neill et al., 2014, 2017; Riahi et al., 2017) and recalled by the IPCC, when referring to the Shared Socioeconomic Pathways. These are innovative ways to understand, analyze and forecast future climate scenarios not only according to predicting specific climate-related indicators, such as carbon emission but linking strictly those climate-related indicators with social, economic and political hypotheses. These studies are relevant because they evidence how it is not possible to predict climate change future. After all, it is strictly linked with mankind and our decisions also on other non-climate-related aspects. To say it with Wolfgang Behringer’s words: climate is a cultural history (Behringer, 2019).

An additional element of complexity is again recalled by Houston (Houston, 2021) when saying that it is crucial to take into account the different competing agents involved in the climate crisis (deciding, opposing and dominated). In his theory, deciding agents are those able to make decisions about the climate transition, for example, institutional bodies and government. Also citizens, and civil society can be included here if they are *sensitive to the moral demands of climate justice and enjoy the power to enact political change* (Houston, 2021, p. 199). Dominated agents are those that do not have the power to make those decisions, but somehow they are hit by them. They can be sensitive to the problem but do not have the power to take decisions: poor people are usually inside this category. And, finally, opposing agents, who are agents that have the powers to act and may also be sensitive to the problem but in a negative way, being hostile or insensitive to it. In this category, for example, fall *some fossil-fuel corporations, morally callous politicians beholden to the former's sway, and climate-denying citizens among the global affluent* (Houston, 2021, p. 199)

According to Houston's study, current pathways mainly address the deciding agents and do not consider the others as proper agents of the change, with specific and individual intelligence. And this is one of the main barriers, in his opinion, to the actionability of those action-guidance instruments. Furthermore, he suggests the use of alternative pathways as complementary instruments able to encounter multiple possible futures. Houston's and Gilabert and Lawford-Smith's studies are both interesting in their critical approach to the current structure or pathways and roadmaps. In the following sub-paragraph, I will explore some of them to provide a clearer picture of what is currently ongoing in reality. Several existing climate pathways and roadmaps have been studied and analysed, investigating multiple aspects such as the structure, the goals, the timeframe, the geographical level, the actors involved and the impacts. The following sub-paragraph describes only a few of them, providing some elements of reflections more than complete descriptions (which can be found in the references). The selection has been made qualitatively, trying to identify the most important and strategic climate transition pathways ongoing across different geographical levels.

### *3.4.1. Real case pathways and strategies*

Cross-national pathways are instruments not specifically linked with a precise country. They can be supra-national and still refer to a specific geopolitical dimension (e.g. the European strategy which is referred to European Union), or they can be detached from a proper geopolitical dimension or applicable worldwide. The last one is the case of instruments such as the ones proposed by the Covenant of Mayors or the Green City Accord, or the 100 Resilient Cities. In this broad category, a small selection of the most interesting ones is composed of the 2050 European long-term strategy, the Sustainable Development Goals roadmap, the Covenant of Mayors and the 100 Climate Neutral Cities. Those instruments are very different from one to the other for multiple reasons (scope, extent, relevance, object of application), but they have in common the interest in supporting a high-level transition to more sustainable and resilient territories.

*Fig. 3.1 – Main strategic plans with related targets and key features.*

| | Extention | Targets | Key elements |
|---|---|---|---|
| **2050 EU long-term strategy** | European Union | Singles countries, citizens, industries | Climate neutrality by 2050 / Composed by multiple and theme specific sub-plans / Presence of a vision / Addressed to all actors / Specific requirements to single countries / Presence of a long term strategy |
| **SDGs roadmap** | United Nations (worldwide) | World | 2030-2050 Sustainable Development / 17 goals with specific visions and indicators for each / New Sustainable Development Pathway (2022) |
| **Covenant of Mayors** | Europe / Worlds | Single cities and mayors | 2050 decarbonized territories / Resilience as a core target / Monitoring report / Action plans tailored to the local levels and leveraging local values |
| **Denmark 2050 strategy** | Single country (Denmark) | Denmark territory, citizens, industries. etc | Strong guiding principles / Deep analysis of the state of the art / Milestones for the mid-term and specific actions toward welfare and cost-effectiveness / Attention to true actions without considering shortcuts / Very high commitment |

*Source: Elaborated by the author.*

The first is the 2050 European Strategy. An innovative aspect of this strategy is its structure composed of multiple sub-elements that are, in some cases developing the vision ("A clear planet for all") (European Commission, 2018), in others, the proper long-term strategy (European Commission, 2019) and finally the operationalisation of both the previous European Commission, 2019). Inside this structure, it is evident how the European Commission is focusing on defining a framework with which all countries inside the union should align with. The definition of a precise vision is a key aspect of this pathway as it sets the major themes, values, and aspects that are at the core of the actionable strategies. From the operationalization perspective, the European Green Deal tend to focus more on mitigation actions than on adaptation or compensation. This is also supported by the main claim of the 2050 strategy, which is to become carbon neutral by 2050. Of course, some adaptation measures are still present, especially in some of the more thematic and specific actions included in the European Green Deal. Another interesting aspect is the involvement of actors inside the transition as the European Commission has set two specific complementary tools for this: the New European Bauhaus, which targets citizens, creative people, and single professionals, especially in technical and creative fields; and the European Climate Pact, which also targets communities on a broader level to empower them in taking actions. According to Houston's model (Houston, 2021), it seems that despite the EU efforts in involving civil society and despite the vision of encountering a just transition, mainly deciding agents are targeted here.

There is mainly attention to institutions on the one hand and middle-class citizens on the other. If opposing and dominated agents are included this doesn't seem to be a core objective of this strategy.

The second instrument analysed is the 2030 Agenda for Sustainable Development, also known for its explication of 17 Sustainable Development Goals. This strategy was developed in 2015 by United Nations and other 195 countries, with worldwide attention. The key and most recent interesting points on this strategy are the following. At first, the strategy is explained in 17 thematic goals, each of them having a specific thematic vision, targets and indicators to measure it. Recently the Economic and Social Council of the UN published a report that contains the impact analysis of this strategy, the acknowledgement that not enough progress has been made and the proposition of a new Sustainable Development Pathway toward 2050 (United Nations - Economic and Social Council, 2022). In this pathway, there is a specific proposition of key urgent lines to be implemented, such as the deployment of negative emission technologies and carbon dioxide removal technologies, the focus on "a decent house for all", and others. Also in this strategy, some positive key elements can be recognised, such as the presence of indicators and visions which are tailored to specific themes, the high efforts put into monitoring results and improving the strategy along the way. Again, applying Houston's model, it seems that also this strategy is mainly directed to deciding agents even if there are some specific goals, such as the number 17 that focuses on creating effective partnerships among different actors. Dominated agents seem more like a target group to which provide solutions than a real partner in the transition.

The last strategy analysed is the strategy behind the Covenant of Mayors for Climate and Energy initiative (CoM). This initiative was launched in 2008 by the European Commission to support and engage single mayors in starting a transition pathway in their cities. It has been a very important innovation as it directly targeted local governance structures, completely skipping the national and regional institutional levels. As also recalled in this recent paper (Boulanger and Massari, 2022; Covenant of Mayors), the CoM saw a large diffusion both in Europe and worldwide. Its main target has always been to create a supporting service for cities willing to become more sustainable and resilient. As a difference from the previous ones, the CoM targets not only mitigation measures but also adaptation ones, having included specific adaptation action plans in the years. Even if resilience and adaptation are a core part of the CoM action plan, greater attention is still posed to mitigation actions, especially in how they are monitored. Also, in this case, the agents involved are mainly deciding ones, both institutional actors, citizens and associations, while opposing and dominated ones seem not to be present.

On the national level, an important pathway is the one developed in Denmark. This pathway was presented in 2020 under the Paris Agreements and it can be considered a lighthouse for the development of national strategies (Danish Ministry of Climate, Energy and Utilities, 2020). The relevance of this instrument relies on different elements that compose it, starting from the identification of Guiding Principles conceived as mandatory for the pathway. These principles can be seen as visionary aspects, but in reality, they are very precise and operative.

The first principle, for example, acknowledges that climate challenge is a global issue but that Denmark *must be a leading nation in the international climate effort, a nation that can inspire and influence the rest of the world. Furthermore, Denmark has both a historical and moral responsibility to take the lead* (Danish Ministry of Climate, Energy and Utilities, 2020, p. 9). This is a very strong commitment to the climate challenge that goes beyond the simple taking into account the challenge but targeting to assume full responsibility. Another principle expresses the necessity of the transition of the most cost-effective as possible while ensuring enough welfare and quality standards for all citizens.

The last principle, then, says: *The initiatives to be taken to reduce greenhouse gas emissions must result in real domestic reductions, but it must also be ensured that Danish measures do not simply relocate all of the greenhouse gas emissions outside of Denmark's borders*. Even this aspect of ensuring a real reduction of greenhouse gases without using shortcuts is crucial. Similarly to other strategies, also Denmark defines a 2030 and 2050 vision of decarbonization, but as a difference from many other countries, Denmark is almost maintaining its goals, as in 2018, they reduced by 65% the emissions in the energy sector (target of 70% for 2030). The strategy then assesses quite precisely the current situation in a very critical way, putting in evidence the shadow sides of the implementation of ongoing actions. Finally, this pathway very precisely identifies networks of collaboration, priorities and main aspects to work on.

## 3.5. Conclusions and further works

The analysis presented in this chapter showed how pathways could be a key instrument to achieving the decarbonization objectives. They are very used across countries to identify and set the path toward a more sustainable future. However, several critics can be made of their structure, goal and organization. Some common elements that seem to have positive effects on their concrete realization are the following:

- pathways should be operative instruments to implement short-term actions with a long-term goal. They should have a long-term vision, but they should identify precise short and medium-term milestones;
- the presence of monitoring systems and indicators of performance is crucial to evaluating intermediate steps;
- details and guides for action implementation should be provided, detailing different aspects, such as costs, timeframes, and actors;
- alternative pathways or scenarios are necessary to ensure enough flexibility of the instrument to change along time;
- there is the need to involve all agents, including opposing and dominated ones, at the same time to identify ways to collaborate with all the actors of the society;
- pathways should be aligned with local and specific vocations, needs and necessities.

Far from aspiring to exhaustiveness, this chapter aimed to put in evidence some key criticalities and aspects that are framing the adoption of transition pathways and roadmaps. Further works will encounter a systematic review of all instruments currently available across geographical levels to even detect more elements of success and failure. The different National Recovery Plans will also be included in this work for the parts relevant to climate change.

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# 4. *Citizen's shaping power in the city in the digital age*

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The rapid urbanization and population growth have been transforming the way we live, work and play, and putting immense pressure on cities to grow further.

The emerging city has been creating income inequality, inadequate housing supply and corresponding problems in affordability, and inequitable environmental risks, among others. Increased urban activity and distorted consumption patterns demanded sustainability metrics to gain importance much more than ever.

Given the recent advancements in smart cities and green technologies, the study acknowledges that shortcomings regarding sustainable development do not mainly stem from the lack of technical capabilities but rather from the challenges of "dark matter" of organizational relationships.

When it comes to the smart and sustainable city, the study advocates for an open-minded approach that focuses on the qualities of a hybrid space that prioritizes web of services, how people organize, mobilize, communicate via new tools rather than construction, and asks how can we achieve a system in which we, as citizens, have greater control over the environment in which we live, and how can we use the abundance of digital tools at our disposal to promote design and policy innovations that will result in better and more equitable urban living?

## 4.1. Introduction

We are witnessing a time in which there are major challenges to long-term sustainability. Hundreds of millions of people in cities remain impoverished and robbed of the possibility of living a decent life. Differences are widening both within and between countries. There are significant disparities in terms of access to opportunity, capital, and power. Global health difficulties, increasingly frequent and severe natural disasters, rising unrest, violent extremism, and related humanitarian crises, as well as forced population relocation, are all threatening to undermine much of the progress made in recent decades (United Nations, 2018). Environmental and economic problems do not occur in isolation; they are accompanied by several other issues. As the number of individuals who are denied of a decent human life grows, social sustainability suffers even more. The patterns that shape our living environments are undergoing a paradigm shift. Large-scale automation, climate change, inequality, an ageing and growing population are all driving forces in today's cities. Moreover, with the immense technological developments, the growing "smart city" concept has paved the way for cities that are more efficient, useful, faster, and profitable. It has mostly focused on physical structure improvements, pushing the challenges posed by existing power structures and urban policy concerns, as well as those that have come as a result of these new advances itself, into the background. This corporatist approach to the emerging city has resulted in income disparities, insufficient housing supply and related affordability issues, inequitable environmental concerns, and so on. They have a significant impact on employment and skill development, air quality, service delivery, housing demand, and affordability. However, these difficulties also present a number of opportunities, including new welfare models, mobility, ownership, and planning. We may work to address these issues with a focus on improvements in technology, public policy, and design. The study aspires to reconceptualize the understanding of "smartness" in achieving sustainable development in which the "smartness" is understood as a multi-layered, complex phenomenon that can be channelled through different dynamics; and aims to question the prevailing conversation about smart and sustainable cities, which has resulted in a large-scale, top-down, heavily infrastructural approach that is in the hands of corporations and governments. It claims that in order to achieve equitable urban living, the ways in which smart and sustainable city concepts are implemented in cities must be reconsidered and asks how can we achieve a system in which we, as citizens, have greater control over the environment in which we live, and how can we use the abundance of digital tools at our disposal to promote design and policy innovations that will result in better and more equitable urban living? The study conducts a literature review in order to understand the current discussions within the field of smart and sustainable cities. Through literature review, the main definitions and understandings of the concepts of smart and sustainable cities and how they have evolved are studied. The study offers a qualitative reading of the concept of smart and sustainable cities, how their understandings have shifted and what are the prominent values and guiding principles that have started to dominate the discussions. Certain examples around the world that have goals toward becoming smart and sustainable cities are presented. The aim is to understand the current trends and general dynamics in the field; the main issues that are being addressed, and the scale that is preferred to reflect upon. The particular examples were chosen because they use the means of digital technologies to provide a platform for citizens to have a say in the environment they live in. The examples have a common ground in which a smartphone was considered as an optimal interface to realize the projects and engage with the citizens. However, they differ in the content exemplifying key approaches to include citizens in the ways in which the cities are designed, planned, and governed: establishing an alternative economy to manipulate the activity in such a way to enhance the local economy, providing a platform for various city-related issues such as news, complaints, suggestions, and putting happiness as a priority for a successful city, thus measuring and monitoring people's satisfaction levels. These key approaches exemplify an understanding which does not offer the construction of an infrastructure or a new technology, rather, the aim is to leverage the dark matter of organizational relationships in various ways via an online platform.

## 4.2. Smart and sustainable cities

### *4.2.1. The concept of sustainable development*

The World Commission on Environment and Development (WCED) issued a report in 1987, which was titled "Our Common Future". The study was then called the "Brundtland Report" after the Commission's chairwoman, Gro Harlem Brundtland and it created the guiding concepts for modern-day sustainable development and provided its description as *development that meets current needs without jeopardizing future generations' capacity to fulfil their own needs* (World Commission on Environment and Development, 1987). In a broader sense, the strategy for sustainable development aspires to promote peace among people and between society and nature. The concept has undergone a radical rethinking and a more collaborative perspective on the part of global sustainable development, which expands the meaning of "needs of generations" beyond human generations to include the needs of other life forms, as well as the recognition that *nature matters in and for itself* (Imran et al., 2014). As Lambacher points out, a holistic definition of sustainable development that includes the concepts of socio-ecological ethics and ecological responsibility can provide political legitimacy to biodiversity conservation as well as a political context in which ecological and social justice can coexist. Sustainable development will thus be viewed as a method or technique that contributes to the health of ecological systems, resulting in a higher quality of life for all living things (Imran et al., 2014). From an urbanism point of view, Farr provides a reading for sustainable urbanism as *walkable and transit- served urbanism integrated with high performance buildings and high-performance infrastructure* (Hermand and Quesada, 2019). Cities that are well-planned will assist in lifting families out of poverty, eradicating gender inequality, pointing to bright prospects for children and youth, providing comfort and security to senior citizens, and welcoming migrants in search of a better life.

This wide umbrella covers, among other things, the rule of law, property rights, and democratic participation procedures, which enable cities to function efficiently. Unlocking urbanization's social value demands a paradigm shift toward people-centred approaches as well as holistic and integrated urban planning principles. Strong institutions, formal and informal, decent governance, respect for human rights, and appreciation of cultural variety are all intangible aspects of sustainable urbanization (UN-Habitat, 2020).

### *4.2.2. The concept of smart cities*

The Information Age has totally overtaken the entire world. Technology continues to transform economies and communities due to the rapid disruption caused by the possibilities of billions of people connected by mobile devices, with unrivalled computer speed, storage space, and access to information. Artificial intelligence, robotics, the Internet of Things, autonomous cars, 3-D printing, nanotechnology, biotechnology, materials science, energy efficiency, and nanotech are just a few of the emerging technological advancements that could expand these possibilities. Cities are at the heart of these changes, as dense populations and human mobility encourage the concentration of technical and engineering skills. The interplay between technology and creativity has already shaped and will continue to shape urbanization patterns. The image of a "smart city" or "future city" that is widely promoted primarily coincides with the reality of a modern far East Asian metropolis. China and South Korea, in particular, are keen to take the lead in the competition by using improved technologies to construct bigger, higher, and faster structures. Shenzen and Songdo are two examples of cities that promise investors the most modern technologies and gleaming structures. These cities are referred to be "smart" because of the tremendous developments in engineering and infrastructure that they are fostering. Cities are becoming coated with smart sensors, smart lighting, smart waste, power, and water management, smart transportation, and communication systems. "Technology for the sake of technology" is at work here. There is, nevertheless, a fundamental misunderstanding about what constitutes a city. "People" do not exist as people in almost all of the features they represent; instead, they exist as data or classifications. Instead of "why" and "how", the most frequently asked questions are "how many" (Mattern, 2017). It is critical to place "people" at the centre of any discussion on smart cities. Data of people is insufficient since data is subjective. It is incapable of solving any problems or transcending the complexity and dynamism of the social realms it monitors on its own. Mattern puts an emphasis on the need to focus on the human, institutional, and technological creators of data, as well as the curators, preservers, owners, users, hackers, and critics of data (Mattern, 2013).

Smart cities have seen a great shift in the level of thought and discourse as a result of the paradigm shift that has dominated all disciplines. Its theory has evolved from its initial image of an efficient, organized, controlled, and predictable masterplan, as seen in extreme examples in Asian and Middle Eastern cities, to a more holistic understanding that does not prioritize certain technologies and acknowledges that "smartness" is a multi-layered complex phenomenon that can be channelled through different dynamics. A more holistic definition states that *the 'smartness' of a city is a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth* (Zygiaris, 2013). The neoliberal smart city concept combines three future city visions: digital city, entrepreneurial city, and sustainable city (Martin et al., 2018). Taken together, these perspectives illustrate that digital innovation has the potential to connect urban infrastructure systems and increase operational efficiency, all of which help economic development, environmental protection, and social equity. The most essential element of present and future data-based smart city advancements, not ICT, data, or intelligent infrastructure, is creative applications for value production for stakeholders (Lim et al., 2018). *Smart-city solutions must start with* *the "city" not the "smart"*, according to Stratigea et al. (2015), *shifting from a technology-pushed to an application-pulled smart-city planning approach, matching different types of "smartness" with different types of urban functions and contexts*. Advanced technological innovations have brought sustainability discussions to such a place that the notions of "smart city" and "sustainable city" have become almost inseparable.

### *4.2.3. Resmarting the city*

*Revisiting the idea of "right to the city"* - In the late 1960s, radical social and political movements erupted, resulting in a liberal humanism perspective across all fields. The social and humanist concerns such as urban reform, affordable housing and social justice had started to be observed widely. Early modernist architecture and urbanism's highly constructed, systematic, and logical concerns turned to the impact of design on the sociological structure. The issue of the citizen as both a builder and a user began to be widely explored. Aiming for social and geographical justice, the search for an ideal city was on the rise. Under the umbrella of the "right to the city," various perspectives have been developed, arguing from a social, political, or spatial standpoint. Henri Lefebvre saw it as a "cry and a demand" for the right to live in the city (Lefebvre et al., 1996).

According to him, the right, which can be defined as a spatial right, is the embodiment of the urban dweller's presence and ability to act in and through it by having access to and use of the city's utilities, participating in the urban space production process, and avoiding all forms of discrimination and segregation (Lefebvre et al., 1996). His view of the right to the city proposes a set of rights that begins with our basic presence in and use of space, and then extends to the claim of privileged space for everybody. David Harvey, on the other hand, describes the right to the city as a collective right to shape power over urbanization processes (Harvey, 2013). It is a battle for power within and through socio-political structures. The right to the city, according to Harvey, is a communal rather than an individual right, because transforming the city necessitates the exercise of common control over urbanization processes (Harvey, 2013). Therefore, it goes beyond having access to the resources that the city provides, rather, it is about claiming the power that can change the city. While sustainable development aims to foster peace among human beings and between society and nature, we see that understanding has majorly become the discourse of a capitalistic environment. Private businesses occupied themselves with the intention of creating sustainable and smart cities.

With the availability of state-of-the-art technologies, the most efficient of all has become a goal to achieve with a corporatist view. However, if we look at the core understanding of the discussion, there is, in fact, an approach that puts individual and collective wellbeing as well as the preservation and betterment of nature at the very centre. According to the reports of UN Habitat, reducing urban poverty and deprivation, creating a healthy urban climate, improving personal security by minimizing the risk of crime, conflict, traffic collisions, and natural disasters, developing an equitable system of legal defence and government participation, and making cultural and leisure facilities accessible to everyone are all on the agenda (UN-Habitat, 2020). These core understandings can be related to the idea of "right to the city" and seen as an extension of it. Even though the idea of "right to the city" stems from a Marxist point of view, ideally opposing the use of nature just as a source of resource, distancing ourselves from it and monopolizing it for our own advantage (Benton, 2018), reinterpretation of sustainable development with a post-anthropocentric worldview coincides with the values of the idea. The embodiment of the presence of the urban dweller and act in and through it by having access and making use of the utilities of the city, being involved in the production process of urban space and avoiding all forms of discrimination and segregation and claiming right for housing, transportation, health, education, cultural activities, citizenship, voting, participation in decision-making etc., as well as preserving nature, protecting biodiversity and reinforcing environmental assets (UN-Habitat, 2020) corresponds to both the ideas developed by Lefebvre and Harvey and the contemporary understanding of social sustainability, inclusion and equitable urban living. Given the discussions about growing cities and shifts in urbanization processes, one may argue that the problem's conceptualization is evolving from "ideal city" to "future city", which is more creative, more interdisciplinary, more flexible, and more human-centred. The first wave of smart cities lacked an openness to the administration of urban growth and the ethics of urban technology. The second wave prioritizes people's needs over technology (Van den Bosch, 2020). It is safe to say that right to the city in the future smart and sustainable cities will be majorly concerned with the well-being of the citizens; occupied with the provision of a healthy environment, offering a range of services and job opportunities, being safe, walkable, inclusive etc. However, those aspects are no longer considered enough to assume smart and sustainable. The penetration of information technology into cities with a data-rich context has brought many parameters into the discussion. Being able to reach out to the authorities and institutions by digital means, having a platform to get informed about the city news, making your voice heard, and getting your data and privacy protected are some of the parameters that are crucial for a future city.

*Rethinking right to the city in the digital era: emerging examples* - The prevailing discussions within the field are paving the way for creative projects to be produced by the public and private sectors. We are witnessing a growing number of examples that prefer an approach that does not seek answers to each question regarding smart and sustainable cities in construction but rather in establishing networks within the flows of people, goods, information etc. Opening the way for policy and governance innovation with a decentralized approach that can allow for creative public and private initiatives to flourish lies at the centre of the future city. Cities that have a goal of becoming "smart" have started to adopt this understanding, and there emerged various creative projects. Barcelona is one of the pioneer cities to pursue a holistic approach to smart and sustainable city planning. Barcelona's municipal government has been working on numerous programs to promote more sustainable and equitable urban life in conjunction with corporates, academics, and non-profit initiatives. REC (Real Economy Currency), Barcelona's social currency, is an interesting project. It was developed by the Barcelona City Council-led B-MINCOME project, an international collaboration of partners that also included the Young Foundation, UPC, Ivalua, IGOP, and NOVACT (The REC, n.d.). This social currency is intended to supplement, rather than replace, the national currency. It is a citizen exchange mechanism that works in tandem with the euro to make community-wide payments easier for individuals, organizations, and companies who accept it. Moreover, it enables the evaluation of the impact of consumer behaviour on the city. It is a completely digital currency that can be accessed using a smartphone app. The concept is to keep capital in the city with the purpose of expanding the local economy and community bonds, as well as increasing the economic and social viability of the districts. The project acknowledges that economic sustainability is a priority for a thriving city and focuses on local development to achieve that. By using a supplementary digital currency as a tool, the project aims to strengthen the local network of services, and thus revive the local economic activity. The method used for the project that is targeting to enhance the communication and connectivity within local citizens sets an example for the major principles and dynamics of Castells' seminal "network society" understanding, which focuses on the flow and exchange of information and the change in the understanding of network infrastructure within a society. The key dimensions of social organization and social practice here unravel through the concepts of human experience, digital technologies and the characteristics of the information society (Castells, 2010). Another case that exemplifies building an interface between people, businesses and governmental institutions is a mobile application that is called SmartAppCity. The project was first developed in Spain and have been distributed in different countries such as Chile, India and Costa Rica (SmartAppCity, n.d.). It was developed with the goal of creating a fully integrated vision that would show and map all of the city's massive data, including residents, visitors, services, and infrastructure, providing real-time information to the people, improving their quality of life and generating value for the city. While bringing various service platforms together, such as information about transportation, traffic, environment, events, as well as municipal news and notifications; it also allows people to convey their suggestions and complaints regarding the city. This case exemplifies an effective feedback system to determine what works well, what does not and hear the voices of people about what is needed and what matters. The approach of using a data-driven smart mobile application has brought a new perspective to the field of smart and sustainable cities. By providing a common ground for different stakeholders of the city, and thus increasing the communication, focus areas, priorities and efficiency of the interventions are aimed to be brought to a better light. In other words, what the particular example accomplishes is to provide a platform for people to reclaim their power on the city via digital means. The development of pleasure and a sense of satisfaction for inhabitants and visitors is at the heart of Dubai's commitment to smart city initiatives and innovation. While Dubai's commitment to digital city transformation dates back to 1995 (Bishr and Lootah, 2016), the government's response to the MENA region's political challenges and instabilities was to improve public satisfaction through the adoption of policies and visions, including the goal of "becoming the happiest city on earth". The Happiness Meter, for example, is used to provide a city-wide snapshot of people's happiness. Available as a mobile and desktop application, it records real-time city emotions and can be used to generate a happiness map at the city level. The measuring, monitoring, and reporting of people's satisfaction levels can be broken down into several sectors and areas on this application (Kim et al., 2021). Similar to Barcelona's REC project and Spain's SmartAppCity, Dubai also preferred to use the touchscreen as an interface to establish a connecting ground between different actors of the city. By getting feedback from its citizens on how happy and satisfied they are with the environment they live in, authorities of the city are able to focus their attention on specific targets, as in SmartAppCity. The project acknowledges that the road to a smart and sustainable city places the happiness of its citizens at the foundation; and providing a collective platform and increasing communication allows for people to make their voices heard. These cases exemplify some of the prominent understandings in the field of smart and sustainable cities both in terms of the issues to be addressed and the method of project implementation. Although the examples illustrate city scale projects, there are initiatives that have started to emphasize these pressing issues with a shift in the attitude through an overarching framework. The European Green Deal, for instance, establishes a new EU growth strategy. It backs the EU's transition to a more just and prosperous society that addresses the problems posed by climate change and environmental degradation while also increasing the quality of life for current and future generations. Its goal is to protect, conserve, and develop the EU's natural capital, as well as citizens' health and well-being, from environmental risks and hazards. It puts an emphasis on a just and inclusive transition which prioritizes people and pays special attention to those who face the greatest challenges (Fetting, 2020). The New European Bauhaus initiative acknowledges that these concerns regarding a more sustainable future entail a shift in the approach. Its goal is to make the European Green Deal accessible to everyday lives and living spaces of the people and encourages all Europeans to create and develop a future that is both sustainable and inclusive. Its discourse revolves around a creative and transdisciplinary understanding by establishing networks between various disciplines, backgrounds, and individuals while putting sustainability, aesthetics, and inclusion at the centre as the core values of the initiative (European Union, 2021). As Brundtland Report in 1987, both the strategies of The European Green Deal and The New European Bauhaus initiative, as well as the collaboration between them, provides great potential in terms of taking concrete steps towards a sustainable future from the ground up. Bason et al. makes an emphasis on this potential and offer guiding thoughts and principles for a different reading of Bauhaus. They argue that our primary problems are behavioural, cultural, political, and economical in case of implementing any version of the Green Deal.

This approach brings design, architecture and crafts into the discussion for the European Green Deal, in which their cross-disciplinary nature and operational flexibility offer a widespread literacy and toolkit from the design of institutions to the technologies and infrastructure (Bason et al., 2021).

## 4.3. Pressing issues to address

The field of smart and sustainable cities has seen a tremendous shift from a concern with construction to an opposite obsession with use, meaning, behaviour, society, and life. The focus is on city use and rights to the city, rather than "city-making" per se, as indicated by various examples. However, even if the scale and scope of the smart and sustainable city interventions are being reconsidered, there are still challenges to be addressed to achieve more equitable, inclusive, and transparent cities. First of all, without adequate social policy, the current and potentially dramatic changes in jobs and labour that are a result of these modern innovations are likely to exacerbate inequality even more (Schäfer and Westerberg, 2019). According to the report on the study of five Dutch cities, the analysis conducted by Martin, Evans, and Karvonen revealed that without complementary policies smart city programs reinforce the focus on delivering unsustainable types of economic growth and consumerist cultures while ignoring social fairness and environmental preservation (Martin et al., 2018).

This study's primary conclusion is the possibility for inhabitants to be empowered, as it represents the key to unlocking new emancipatory and sustainable sorts of smart urban development. The notion of a smart-sustainable city would be reframed as a radical alternative to current urban production processes, incorporating more innovative approaches to urban design, administration, and operations (Martin et al., 2018). In contrast to overly enthusiastic claims about the benefits of smart cities, policymakers and scholars are increasingly acknowledging that data-driven urban activities raise technological, managerial, normative-ethical, and societal concerns (Bunders and Varró, 2019). The current trends in the field intensify the conversation on smartness, sustainability and right to the city; however, the means to materialize the projects are not yet diversified enough and mostly depend on smart appliances. According to ITU, UN agency for information and communication technologies, 2.9 billion people still lack affordable internet service, which is around 37 percent of the world's population (ITU, 2021). Without accessing those who cannot afford or do not have technological literacy and thus cannot benefit from the services or make their voices heard, we cannot talk about smart and sustainable cities for all. Big data has proven to be a valuable tool for analysing markets, anticipating customer behaviour, discovering trends, and training machine-learning algorithms. Invariably, new information and communication technology bring both benefits and costs to each sector. As a result, the potential hazards linked with big data analytics should be given greater care when it comes to human rights, where the stakes are higher owing to marginalized populations. The use of big data analytics to promote or defend human rights has the potential to violate privacy rights and norms, as well as cause individual harm. Indeed, when it comes to human rights monitoring, data analytics has the same legal ramifications and issues as governmental or corporate surveillance (Latonero, 2018). A recent well-known case sets an example for that aspect in which due to probable privacy and inclusiveness problems as well as a reluctance to involve core neighbourhood partners in the establishment of its data governance system, Alphabet's breakthrough Sidewalk smart city project "Quayside" was cancelled in Toronto (Townsend and Zambrano-Barragán, 2019). On the other hand, the importance of local focus is undeniable; however, if it is ignored on the national level, the consequences could be fatal. Citizens being attracted to specific cities and avoiding some others could result in some serious problems for both parties. Scaling-up the positive impacts on different levels is critical for the long-term sustainability goals.

## 4.4. Conclusion

There are various dimensions of a smart and sustainable city, which can fall under the large umbrella of environmental, economic and social principles. The study aims to change the perspective to look at the ways in which these principles can operate; and asks how can we achieve a system in which we, as citizens, have greater control over the environment in which we live; and how can we use the abundance of digital tools at our disposal to promote design and policy innovations that will result in better and more equitable urban living? Digital technology may benefit citizens by increasing public amenities and working standards. However, if sufficient measures are not in place, the smart city will swiftly become a nightmare of intrusion, dominance, and oppression with intelligence in the hands of a few. Technology is most effective when linked with institutional innovation.

When projects are driven by technology rather than by people, the outcomes of smart city attempts are poor. Developers, architects, and planners may use technology to address the myriad difficulties that communities face today, such as affordability, equality, mobility, and environmental, social and spatial justice. Smart city planning, rather than following a technology-driven, industry-driven strategy, would focus on addressing essential goals like eliminating poverty and enhancing public involvement. When it comes to the smart and sustainable city, the study advocates for an open-minded approach that focuses on the qualities of a hybrid space that prioritizes a web of services, how people organize, mobilize, and communicate via new tools, and the quality of architecture and urban form rather than on implementing technology, designing a master plan, or constructing a building.

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# *Section 2 - Energy, buildings, users*

# 5. *Addressing rising energy needs of EU cities of tomorrow: positive energy districts*

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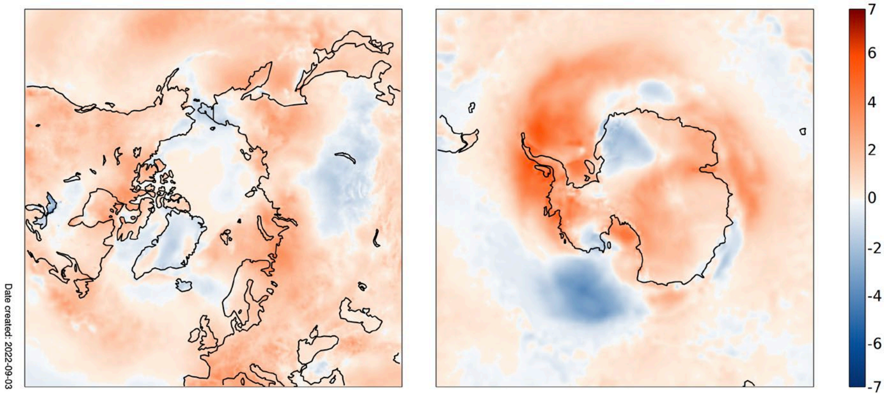
The rise of energy needs in contemporary cities requires considering the energy use and the role of buildings according to a wider scale and perspective, especially in the framework of the current market fluctuation of conventional energy sources. Positive Energy District can be seen as a model for urban energy transition, capable of responding to several challenges involving energy, buildings and people.

## 5.1. Context and challenges

The challenges related to the built environment in cities are huge and mostly well known nowadays. The potential future effects of global climate change include more frequent wildfires in natural areas surrounding cities, longer periods of drought in some regions and an increase in the number, duration and intensity of tropical storms. Global climate change has already had several observable effects on the environment close to urban areas, examples have been observed in almost all types of climate and geographical locations, as some examples it can be referred to wildfire in Australia in 2019 (ScienceNews, 2021) and California in 2020 (The Guardian, 2019), flooding in China or Hurricane Hanna in the Gulf of Mexico (NWS, 2020). Similar events are increasing in frequency and are becoming even closer to cities, with a huge risk for the population requiring adequate plans and measures to prevent (despite the difficulties in adopting reliable models) the possible effects or, at least, try to understand how to mitigate the effects of these catastrophes. This is strictly connected to developing a more resilient approach to forthcoming phenomena and to build effective solutions to keep key infrastructure and services in operation during these events. The collapse of energy infrastructure, for example, represents one of the major obstacles in providing a prompt reaction to the emergencies caused by climate phenomena. More recently, according to World Meteorological Organization and EU's Copernicus Climate Change Service (C3S) (WMO, 2020a), Summer 2022 was the hottest summer in Europe, and August was the hottest month (Figure 5.1). According to the same source, wildfires across Europe this summer caused the highest emissions since 2007.

*Fig. 5.1 – Surface air temperature anomaly for June to August 2022. Reference period: 1991-2020.*




*Source: (WMO, 2020b), data based on ERA5, credit C3S/ECMWF.*

According to Renewables in Cities 2019 Global Status Report (REN21, 2019), cities are directly responsible for around two-thirds of global final energy use as well as for significant indirect consumption of energy that is embodied in materials, products, and other goods. Due largely to this energy use, cities account for an estimated 75% of global carbon dioxide ($CO_2$) emissions. In addition, cities account for 55% of the global population and for more than 80% of the global gross domestic product. Thus, shifting to renewable energy in cities is critical to decarbonising the global energy system. At the same time, cities offer a lever to advance the transition towards renewable energy in all end-use sectors, not only in power but also in heating, cooling and transport. On the one hand, the urgency to cope with Climate Change, and with a massive reduction of the emissions feeding the process, has led to developing during the last decade of several solutions addressing energy efficiency, renewable energy sources integration, energy retrofitting taking into account feasible business model to support the process. On the other hand, urban laboratories, co-creation initiatives, and participatory workshops were launched to reach the widest audience possible and to actively involve citizens in the transition. The scientific and academic community spent huge effort to provide reliable and consistent evidence and data about the effects of Climate Change, pushing the decision makers and the political levels to finally consider carbon emission reduction an urgent priority. However, the results of research activities can influence the contents, the targets, and the ambition of policies and plans but more rarely is able to establish a stable timeline to meet the expected achievement, which is highly influenced by the political level from country to country.

The European Union has developed a strategic long-term vision that strongly relies on a clean energy transition to achieve a net-zero greenhouse gas emissions economy by 2050 (COM 2018 - 773). This objective is at the heart of the European Green Deal (European Commission, 2019) and in line with the EU's commitment to global climate action under the Paris Agreement, especially addressing the Sustainable Development Goal n.11 - Sustainable Cities and Communities (United Nations, 2015). Instead, for what concerns research outcomes, particularly noteworthy are Climate Action in Megacities 3.0 (ARUP and C40, 2015a) and Deadline 2020 (ARUP and C40, 2015b), which are key references in the current trends. In this framework, some years ago, the European Commission launched the so-called SET-PLAN (Strategic Energy Technology Plan), which consists of 10 research and innovation actions aligned to the energy union objectives, thus supporting Energy efficiency first, Sustainable transport, Carbon capture, storage and use, nuclear safety, Smart EU energy, Global leader in renewables.

Accordingly, it can be said that the overall framework is set – at least at EU level – and a faster systemic shift to more sustainable and energy efficient models is expected in the next years. This can even be accelerated by the instability of the gas and oil market following the Russia-Ukraine conflict and the related energy crisis, which is clearly pushing the EU and many Member States to largely rethink energy supply and storage. The key questions deal, therefore, with identifying the needs of cities towards energy transition and with providing adequate tools to support the shift. Some guiding principles could be listed as follows:

- the need to understand urban systems in time and space;

- the need for adopting innovative solutions for energy efficiency, renewable energy integration, energy flexibility (including smart infrastructures, smart energy grids and smart mobility systems);
- the need for new urban services and business models associated with the transition to sustainable energy urban systems;
- the need for societal innovation, social entrepreneurship and citizen participation;
- the need for public innovation governance and challenge driven approaches in practice;
- the need for an index to measure the energy sustainability of cities;
- the need for available data on whose basis effective planning and research could be undertaken.

As previously mentioned, the built environment is responsible for a huge part of energy consumption and related carbon emissions in cities, great effort has been put into increasing their efficiency at different scales: from the building level to the envelope, up to the integration of renewables.

This deals with the concept of Net Zero Energy Buildings (NZEB) that was studied many decades ago with the first MIT Solar House (MIT, 1939) and landed in 2010 with the first directive on NZEB (Directive 2010/31/EU).

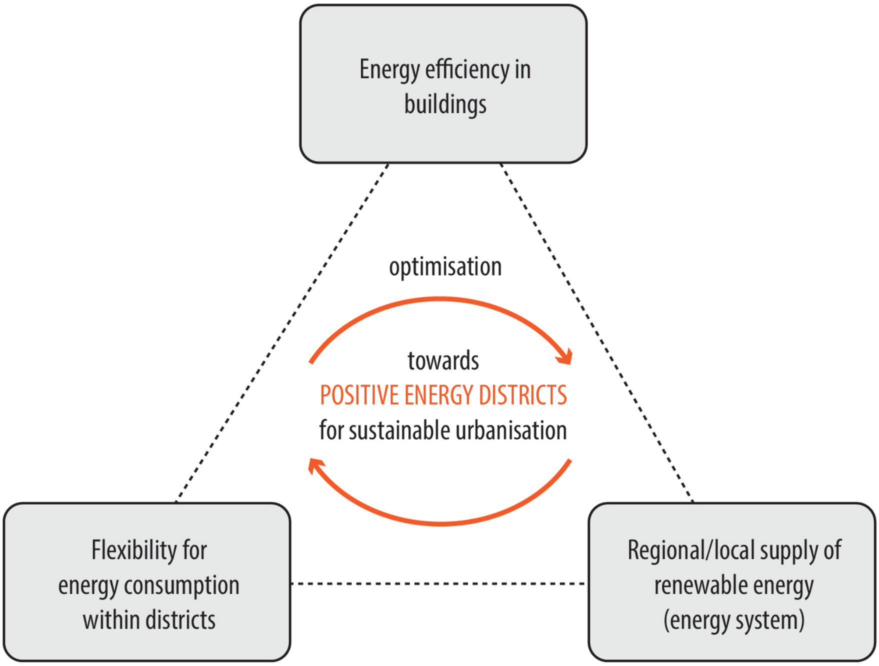
Then solar design and renewable energy building integration have been brought a step forward by enlarging the perspective from building to neighbourhoods which became a preferential field of action during the last decade.

## 5.2. From NZEB to Positive Energy District

The potential of the neighbourhood approach to zero energy lies mainly in the idea of compensating at a larger scale for what cannot be included in specific constructions (for instance, sometimes renewables cannot be installed in a specific building such as monuments or listed ones).

In this regard, the SET Plan Action 3.2 describes a Positive Energy District (PED) as a good compromise between NZEB and a Positive Energy City (SET Plan document, 2018). The action was aimed to "enhance capacities of cities, industry and research to make Europe a global role model and market leader in technology integration for and deployment of Positive Energy Districts taking into account aspects of inclusiveness with the aim by 2025 to have at least 100 successful Positive Energy Districts synergistically connected to the energy system in Europe and with a strong export of related technologies". From the technical point of view, the PED model is based on three pillars, as displayed in Figure 5.2.

*Fig. 5.2 – Definition of Positive Energy Districts according to Set Plan.*




*Source: Elaborated by the authors, based on (SET Plan document, 2018).*

The first pillar is strictly connected with building energy efficiency, which represents the most consolidated part of the optimisation process, considering the knowledge gained during the last twenty years at the building scale. Energy comes first and is one of the most important aspects related to energy in the built environment, as there is an urgent need to diminish the energy demand and improve living conditions. The second pillar is related to the Renewable energy integration in the built environment in order to supply the energy demand using renewable sources. With the publication of the RePower European plan (SWD 2022 - 30 final) and the EU Solar Energy Strategy (SWD 2022 - 148 final), the urban integration of renewable energy will gain more attention and will accelerate the implementation in the near future. The third one regards the energy flexibility aspects related to energy demand and generation. There is a need to properly use the energy so highly depending on the use and consumers' profile, and this puts a lens on the role of citizens and on their behaviour or preferences in shaping the energy demand while suggesting more active participation in the process. On the other hand, the urban infrastructures should be prepared for a high rate of renewable energy generation import, so strategies and solutions for the urban grid and the buildings should be designed. The main drivers identified for the implementation of this model at the EU level are:

- PED Labs, where the model can be demonstrated;
- PED Guide and Tools, which can help the implementation and set of legal and funding framework;
- PED Replication and Mainstreaming, based on the analysis of successful cases and which will become very important no sooner the 100 PEDs will be ready as demonstrators;
- PED Monitoring and Evaluation, where the analysis of the demonstration action is performed and recommendation for further implementation based on Key Performance Indicators is provided.

## 5.3. International initiatives around PEDs

With the publication of the Set Plan Action 3.2 (SET Plan document, 2018), many initiatives have been started working on the topic of PED to support the effective development and implementation of at least 100 PED by 2025. These initiatives adopted different implementation strategies, although many common aspects have been identified and are expected that their results will support the transition process, driving and showcasing pilots across the EU with the purpose of demonstrating the potential outcomes and provide feasible models to be replicated. Between these European initiatives, the following three are working together in a strong collaboration between the teams.

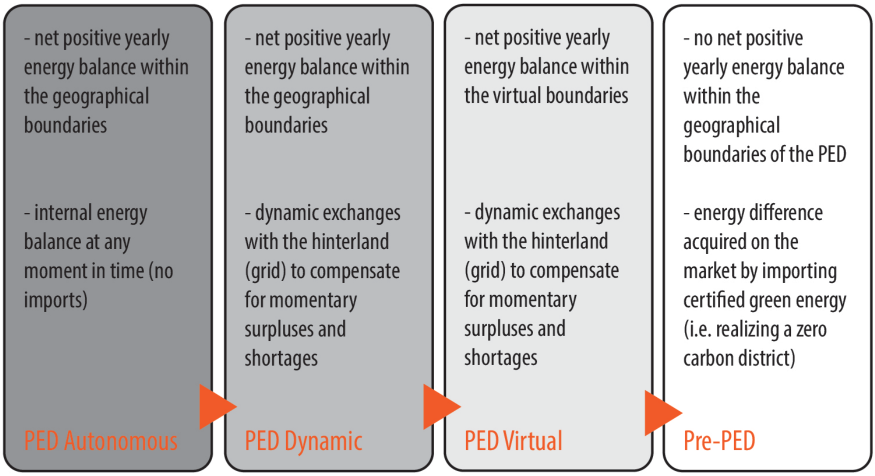
### *5.3.1 EERA JP Smart Cities*

One of the first initiatives on PED was launched by the European Energy Research Alliance (EERA) Joint Programme on Smart Cities (EERAJPSC, 2020). EERA Joint Programme Smart Cities (EERA JPSC) is one of the initiatives (joint programme) of the European Energy Research Alliance. Its mission is to contribute to research and innovation in smart cities – both in the development of fundamental research, innovation and co-creation with city and industry partners and in showcasing the importance of research and innovation in a field that is more and more prone to high-TRL (Technology Readiness Levels) demonstration projects.

Since initiating its activity in 2010, EERA JPSC adapted its work plan according to European Research Needs and Politics regarding energy in cities. Since the publication of the SetPlan Action 3.2, EERA JPSC has adopted its work plan in order to support the development and implementation of PEDs in Europe.

The program proposed by EERA JPSC is structured in five strategic modules as follows: Module 1 Towards European Positive Energy Cities, Module 2 PED Labs, Module 3 PED Guides & Tools, Module 4 PED Replication & Mainstreaming and Module 5 Monitoring and Evaluation. In Module 1, the pool of experts dedicated time to proposing a PED definition framework which can be used in different contexts. As a result, in 2022, they propose four tentative definitions for a different type (or status) of PEDs in order to support their implementation, as illustrated in Figure 5.3.

*Fig. 5.3 – EERA JP SC different definitions of PEDs' types.*




*Source: Elaborated by the authors.*

Module 2 is dedicated to defining a PED Lab methodology, which will play a relevant role in boosting the actual implementation of PEDs. The proposed methodology is based on four key phases:

- Demonstration projects – which are intended as pilot experiences where models and solutions are experimented to achieve the highest efficiency possible;

- Monitoring – which is a systemic and constant activity of data collection regarding the effects of the implemented solutions against pre-defined thresholds or starting conditions to provide evidence of the effectiveness and achieved savings;
- Evaluation – which critically analyse the collected data to provide a practical recommendation, lesson learned and guidelines;
- Exploitation and replication – which are expected to be supported through prototypes in a virtual lab with the purpose of accelerating the adoption of the proposed models and solutions, maximising the impacts at a broader scale.

In addition to the technical aspects and demonstration projects such as buildings, RES integration and storage, electric mobility, and smart grid, non-technical aspects are considered in this integrated PED model, such as for example environmental, social, economic, spatial, and legal aspects are carefully considered according to a multi-disciplinary perspective which represents a crucial challenge in successfully manage the process.

On this basis, the concept of PED Labs grounds on an integrated energy design approach where renewable energy, energy flexibility and energy efficiency work synergistically, taking into consideration social economic, environmental and legal aspects.

Moreover, these labs are carefully characterised, taking into account the level of demonstration, and can take the character of a living lab, a test bed, a field trial, a market pilot, or a testing platform. According to their features, the implementation stage starts with a plan in where every key stakeholder is involved from the beginning. It follows the design, implementation, test, and validation stages, and eventually, the replication once needed flaws have been fixed.

### *5.3.2 EBC IEA ANNEX 83 Positive Energy Districts*

The Energy in Buildings and Communities Programme (EBC) applies a different and somehow complementary approach to EERA. It is more focused on defining a robust methodological backbone which is again articulated in four main research activities:

- Definitions and context, which have been set with EERA, pave the ground for the following phases providing a framework of shared knowledge (not only within the initiative itself but also towards other possible complementary actions);

- Method, tools, and technologies for realising PEDs, which is aimed to provide an organised structure and a set of possible solutions and technologies to meet the positive standards;
- Organising principles and impact assessment, which is of great importance not only to evaluate the effects deriving from the implemented solutions but also to understand how to properly measure them, including economic, environmental, and social implications;
- Demos, implementation, and dissemination, which include the actuation and the communication of the outcomes supporting the replication in other contexts.

### *5.3.3 PED-EU-NET*

The COST ACTION Positive Energy Districts European Network (PED-EU-NET) is a transnational research activity which consists of a pool of experts on the topic from all over Europe aimed to capitalise on the knowledge and stimulate its application.

The project counts the participation of over 180 participants from 40 countries and over 130 organisation across Europe. The working plan is structured into four working groups, each devoted to specific activities, illustrated in Figure 5.4:

- Mapping, characterisation, and learning
- Guides and tools
- Laboratories, monitoring and replication
- Dissemination, outreach, and exploitation

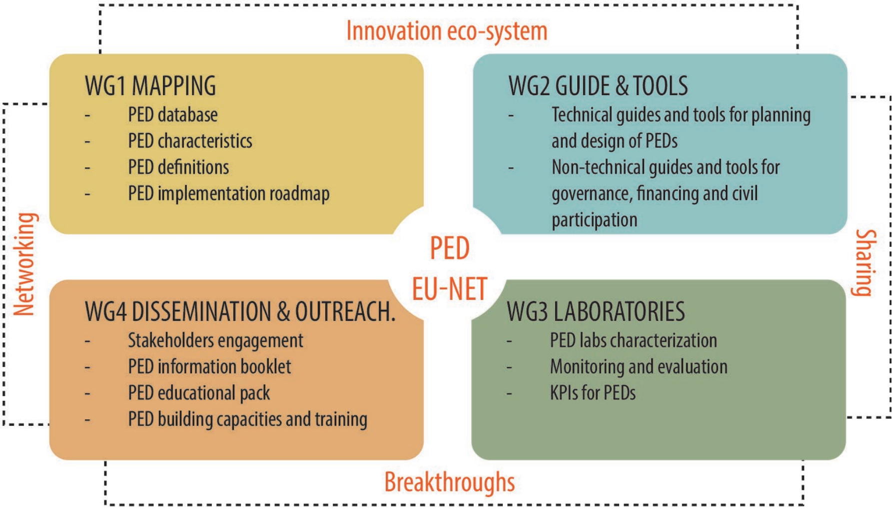
Like the previous initiatives, it aims to create shared knowledge across the involved countries and to provide a set of tools to facilitate experimentation and implementation with the main objective of fostering the development of PED in as many European cities as possible.

PED-EU-NET main drivers are:

- The interdisciplinary network of researchers and practitioners working on energy-related fields but with a diversity of expertise (engineering, informatics, economics, business, political science, social, science, humanities and social and economic geography).
- Well-connected participants working in the same field in EERAJPSC and IEA Annex 83, alignment activities are developed.

- Extensive geographic coverage includes countries with advanced development in PEDs as well as less experienced countries where the concept of PED is so developed.

*Fig. 5.4 – Work plan structure, COST Action 19126.*




*Source: Elaborated by the authors, based on COST Action 19126.*

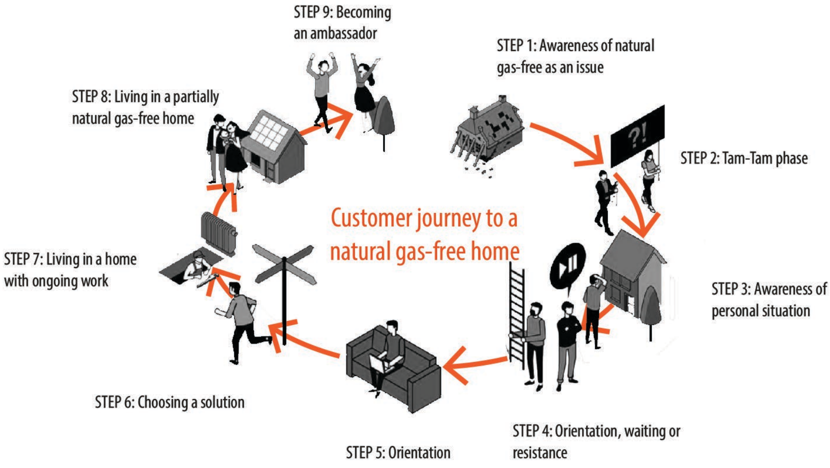
## 5.4. Example of PED initiatives at the EU level

Among the other initiatives, the European Commission proposed specific Calls for PED implementation as lighthouse projects in the context of the Horizon 2020 Framework Programme – Smart Cities and Communities. Between the first funded projects in this context, it is worth mentioning +CityxChange | Positive City ExChange (+CityxChange, 2019) to accelerate the clean energy transition while realising Europe-wide deployment of PEDs by 2050. The project envisioned a prototype of the future in order to accelerate the future happening itself. The model is based on integrated planning and design strategies along with common energy market and social activities matching together.

SPARCS, project (SPARCS, 2019) project funded in the framework of H2020, aims to create a network of sustainable energy positive and zero-carbon communities in lighthouse cities with examples of PEDs and technical implementation, including a focus on a user-centric platform for social engagement in the energy issue. SPARCS largely adopted the PED definition framework developed by EERA JPSC with three types of PEDs, namely, PED-autonomous, PED-dynamic and PED-virtual. Both PED-autonomous and PED-dynamic have clearly defined geographical boundaries. PED-autonomous is completely self-sufficient, with energy demand covered by onsite renewable sources. PED dynamic allows the import of external energy insofar as the annual energy balance is positive. PED-virtual operates within virtual boundaries, which allows the use of renewable energy sources or energy storage outside the geographical boundaries.

POCITYF project (POCITYF, 2019), funded in the framework of H2020, aims to implement and demonstrate innovative solutions at the building and district level that enable the increase of energy self-consumption, energy savings and locally produced renewable energy. The project adopted the PED definition from the Horizon 2020 Framework Programme. The PED concept is achieved through measures such as building-integrated photovoltaics, P2P energy markets, storage solutions, integrated electro-mobility, integrated ICT solutions, and active citizen engagement. The project facilitates the development of PEDs in mixed-use urban districts with a focus on cultural heritage areas (Albert-Seifried *et al.*, 2022).

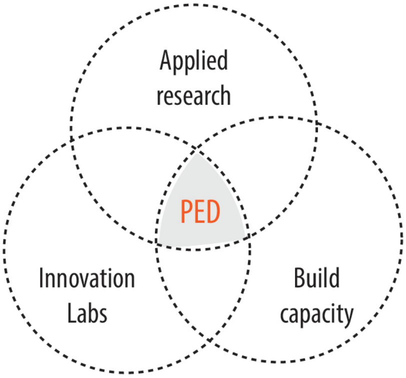
*Fig. 5.5 – Customer journey to a natural gas-free home.*




*Source: elaborated by the authors based on (POCITYF, 2020).*

A slightly different approach was proposed by ERA-NET-PED, which differs from the previous projects for working with applied research and innovation labs matched with capacity building for practitioners and citizens of the future. The ERA-NET PED proposes as main drivers for implementation (Figure 5.6): Applied research, strategic innovation and demonstration projects, transnational innovation labs, innovation platforms and experimental areas for PED and formats to build local capacity and institutional learning in PED.

*Fig. 5.6 – ERA-NET PED model.*




*Source: Elaborated by the authors, based on ERA-NET model.*

Regarding the first pillar (applied research), the following targets are considered:

- Increasing Energy Efficiency of PED by promoting integrated and holistic approaches through optimisation of the energy system in the built environment, innovative building solutions and innovative approaches for interoperability of new and existing technologies.
- Integration of Renewable Energy and transformation technologies to support and optimise storage, concepts such as integration in regional energy systems through flexible and optimised energy consumption within the district, smart interfaces to balance real-time energy supply and promotion of the prosumer concept.
- ICT solutions, supporting integration and development of integrated and smart solutions for sector coupling, mobility, and ICT in a systemic setting.
- Planning, to streamline and align the spatial planning processes and develop digital planning strategies and optimisation tools (e.g., using building/neighbourhood information modelling – BIM).

- Citizen participation, through societal innovation, social entrepreneurship and citizen participation aims to integrate all relevant stakeholders assuring an integrated urban transformation process, where relevant, aspects of gender and diversity, inclusiveness and accessibility.
- Business models for implementing and operating PED on a full scale that consider the whole process of planning, operation and operation.

To this end, the second pillar, open innovation urban laboratories, have been devised to test prototypes, co-create and pilot new concepts and approaches, and enable feasibility studies, field testing and sharing of kwnoledge. The third complementary pillar, building capacity, serve to speed up the technology and service learning curves, and bring city administrators working together with other relevant stakeholders to:

- Build local capacity and institutional learning in PED planning, development, and operation with the aim to replicate and mainstream PED in a local, national and European environment.
- Consider the need to develop new public services and public innovation governance, in particular concerning effective public participation and challenge-driven approaches in practice.
- Enable sharing of experience, adaptation of regulations from the building site to the neighbourhood one, and human capacity building/training, etc.

The effort put into creating a collaborative multi-stakeholder environment put the basis for collectively engaging society in the transition process and educating the new generations from the very beginning about the key elements of the topic being involved from childhood in the discussion about energy transition and urban spaces. Despite this may sound like a long-term strategy, this grounds a new cultural dimension about energy, its value and its use which will be embedded in the citizens of tomorrow.

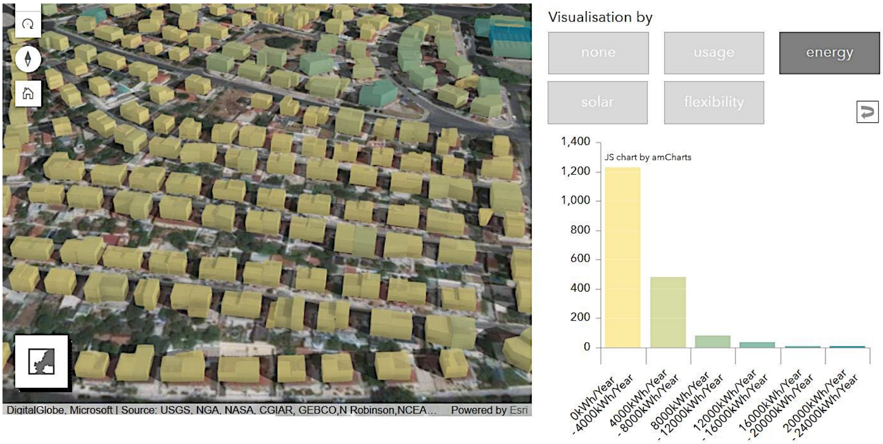
## 5.5. Example of PED initiatives at the national level in Portugal

During the last years, Portugal achieved one of the highest rates of RES energy and carbon emission savings among the EU Member States, due to a stable and committed carbon neutral policy promoted at the governmental level and supported by a massive research activity under the umbrella of national and EU funding schemes to develop exemplary pilot projects in many cities of the country. Among them, SusCity | *Urban data driven models for creative and resourceful urban transitions* (Universidade de Coimbra, 2017) is a project aimed to catalyse the generation and proliferation of scalable urban interventions through the development and deployment of a multi-dimensional Urban systems Simulator and Dashboard (USD). In the context of Portuguese cities, the city dashboard had the objective to:

- Analyse urban interventions
- Evaluate alternative scenarios
- Aid in decision making
- Promote new services and business models
- Promote smart building solutions and refurbishment
- Promote innovative mobility solutions
- Support smart grid-based energy services

While the visualisation and communication of data are essential, urban models provide the ability to envision alternative scenarios and new services and products founded on rigorous urban science. The team proposes to couple a multi-dimensional simulation with physical urban modelling and a data collection machine to serve these objectives. As a follow-up of SusCity, the FIRST project was developed to map the flexibility of urban energy systems. Based on the energy analysis from the former, the project tried to optimise the dashboard with a tool which uses a GPS and a GA4S (in the case of the community approach) to find the operation starting times of the controlled devices that minimise the electricity costs.

*Fig. 5.7 – Flexibility of urban energy system mapping in the FIRST project.*




*Source: (Aelenei et al, 2019) and (IN+, 2018).*

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# 6. *Energy efficient buildings and behavioural implications*

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The ever-increasing frequency of extreme weather events and even more relevant structural alterations of temperature trends, draught periods and heat waves recurrency in many countries have recently showed not only the urgency to cope with Climate Change impacts but also the dependency on energy supply to maintain acceptable indoor comfort levels within the built environment which definitely contributes to increase the energy demand and the related emissions responsible of such changes. Thus, it is evident that the recent claim for action directly involves the built environment and the building sector both in terms of appropriate technical answers and also in terms of more adequate end-users' behaviour.

## 6.1. Context and background in the field of energy efficient buildings

According to the International Energy Agency [IEA], the building sector is responsible for approximately 41% of the energy final consumption and 30% of global greenhouse gas [GHG] emissions (with some small differences depending on the calculation methods and the assumed boundary conditions) across the European Union [EU] (IEA, 2008; Dol and Haffner, 2010) with the residential sector estimated to be the main generator of environmental impacts (62%) corresponding to the 25% of energy demand for operating (IEA, 2020). However, these estimations do not consider the short and long-term effects of the turbulence generated by Russia's invasion of Ukraine on energy markets. On the one hand, oil and natural gas – which are largely used in many EU countries – are receiving much attention because of the price and availability fluctuation, and on the other one, a relevant global coal demand has been registered during the last months returning to its all-time high in 2022 especially in the countries where coal remains a key fuel for electricity generation and a range of industrial processes (IEA, 2022). This is feeding a global concern among the scientific community being coal the largest single source of energy-related carbon dioxide ($CO_2$) emissions and a major contributor to Climate Change.As a reaction, the growth of awareness regarding the impacts of climate change is rapidly leading people to call for a quick and strong change in the policies addressing the energy market and particularly of energy sources in many countries. The energy crisis offers the opportunity to explore alternative solutions and massively support the adoption of renewable energy sources [RES] on a broader scale, particularly in relation to the building and mobility sectors.

*Fig. 6.1 – Example of advanced integrated PV cells on a glazed surface.*

*Source: Author's photo archive.*

That's why the EU and most of its Member States are addressing a remarkable number of resources in this direction within the framework of the recent EU Green Deal (2019) and other national supporting initiatives. Some of them are specifically addressed to fund interventions on the existing stock and particularly residential buildings, which are estimated to account for a share of 26% of energy demand for operating (Eurostat, 2021). This is not a novelty itself, as huge efforts have been spent so far to support renovation and retrofitting actions able to stimulate the regeneration of relevant parts of European cities while achieving significant energy savings.

The process started in the late 90s with some experimental initiatives funded under the umbrella of the EU framework research programmes to explore the saving potential of a very heterogeneous stock, including very different typologies from single family houses to multi-storey housing blocks. Many projects such as "SUREURO - Sustainable Refurbishment Europe" (Eriksson, 2000), "HQE²R - Sustainable Renovation of Building for Sustainable Neighbourhood" (Blum, 2006), "RESTATE - Restructuring Large Housing Estates in European Cities: Good Practices and New Visions for Sustainable Neighbourhoods and Cities" (Musterd, Van Kempen, 2005), "SOLANOVA - Solar-supported, integrated eco-efficient renovation of large residential buildings and heat-supply-systems" (Hermelink, 2007) were developed across the first decade of 2000 and followed by the CONCERTO programme that with its 175 M€ budget and twenty-two actions in twenty-three countries represented one of the widest attempt to drive renovation initiatives its time.

In the following decades, with Horizon programmes, the focus shifted to the district scale and on understanding the potential synergies within a complex interrelated environment.

These experimental initiatives basically demonstrated that energy savings up to 50% could be achieved (Pol and Lippert; 2010), improving the quality and the performance of the existing stock and that the residential sector played (and still plays) a primary role within this challenge compared to commercial, offices and other sectors due to its longevity, diffusion, and demand trends (Eames et al. 2013).

In the last 15 years, several renovation and retrofitting campaigns have been launched to significantly reduce the emissions in the Building and Construction Industry and meet the target of the 2030 and 2050 agenda through the systematic application of the Energy Efficiency Directive 2012/27/EU (EED) and the Energy Performance of Buildings Directive 2018/844/EC (EPDB III) to reduce the 80-95% of new and existing building GHG emissions by 2050 (GlobalABC, 2020).

*Fig. 6.2 – A renovation action within the consolidated urban context of Bruxelles.*

*Source: Author's photo archive.*

## 6.2. Challenges, barriers and trends

Within the current energy crisis, the main challenge is clearly to drastically reduce the energy demand not only to contribute to contrasting the Climate Change speed but largely to prevent the long-term effects of increasing energy costs deriving from the dependency on Russia's gas, of low and middle-income households' expenditure capacity.

These circumstances are accelerating the need for a change in the architectural design paradigms, which are shifting from the energy efficiency standard to Net Zero Energy Buildings [NZEBs] or to Positive Energy Buildings [PEBs], meaning that the key objective is at least to reach a neutral energy balance or to possibly produce energy. Promising design concepts have been developed in the last years to meet such ambitious objectives, with the chance to down energy demand up to 70% compared to conventional constructions. However, if this can be relatively easy to achieve in new buildings, it is very much harder to obtain when renovating existing ones due to several constraints deriving by the original concept and construction choices.

Despite their huge potential, new buildings still represent a very small percentage of the stock, strongly reducing the chance to foster savings due to the very slow turnover rate of existing ones (Levine et al., 2007). Thus, the focus is still on renovation solutions and particularly on how to maximize the deriving benefits.

According to McKinsey & Company (2009), the existing residential stock is estimated to have a 40% saving potential due to the flexibility of the demand for energy and resources, which remains still untapped.

Most of the European cities developed after the Second World War during the 60s, 70s and 80s of 1900 where new residential districts and suburbs were added to the historic city centres (which were also partially rebuilt with modern techniques in some cases), which means a large share of the existing stock is approaching the end of its expected service life and needs to be deeply refurbished or replaced in a quite short range of time.

*Fig. 6.3 – The heterogeneous nature of the urban fabric in contemporary cities requires different renovation approaches depending on the typologies and age of the involved stock.*

*Source: Author's photo archive.*

Additionally, in the next forty years also, more recent buildings erected before energy efficiency standards were introduced will enter this phase, and the majority (90%) of the existing stock will require relevant extraordinary maintenance or retrofitting actions (Economidou, 2011).

The heterogeneity in the age, typologies and distribution of residential stock makes the mapping of the current gaps and performance levels as well as the systematization of the possible renovation approaches harder than simply pursuing individual interventions. However, it is in the understanding of the interrelated complexity within the urban fabric that probably lies the most promising way to maximize the potential benefit of retrofitting. That's why remarkable efforts have been spent by the scientific community to explore these possible synergies and to analyse which could be the most relevant variables influencing the process.

A study conducted in the first decade of 2000 by Buildings Performance Institute Europe [BPIE] (Economidou, 2011) tried to provide a comprehensive picture of the building stock across the EU with the purpose of highlighting differences and common elements useful to address future improvement plans. It must be said that the objective was particularly challenging due to the differences occurring in many countries in collecting statistical data and in the way they are processed. However, although some small errors might affect the process, the study is of great relevance both for its coverage and for its methodological approach, which helps in creating a reliable reference for categorisation. The study grouped the buildings belonging to the residential stock into some homogeneous typological families – with the purpose to consider the differences between multi-family buildings, detached houses and single houses – and into specific age ranges (pre-1960, 1961-1990, 1991-2010, 2011-2020), listing the associated architectural configuration, construction systems, characterising materials and deficits which might influence their energy performance and quality. The study, based on statistical data collected in the different State Members, also considered the geographical differences assuming three main areas (North & West Europe, South Europe, Central & East Europe) to take into account how climatic and context conditions could have influenced the design and construction choices and how this could have been reflected into the energy performance. The geographical areas also helped with considering the cultural and socio-economic backgrounds.

Looking at the obtained picture, the stock built before 1960 requires more specific and tailored approaches for energy improvements to take into account the historical and cultural background, which has been largely influenced by the local construction tradition and the availability of materials.

*Fig. 6.4 – A huge number of energy intensive buildings are approaching the last phase of their expected service life.*

*Source: Author's photo archive.*

Relevant differences can be registered from northern to southern Europe also in terms of typological features making it very hard to suggest common strategies to improve energy performance, especially when looking at historic city centres. Despite some differences occurring, the post-war stock can be instead considered quite homogeneous: the diffusion of concrete-based construction techniques across the different countries allows to identify a limited number of construction systems and configurations whose gaps and limitations can be approached according to common renovation strategies.

One of the most critical outcomes of the study deals with the stock belonging to the period between 1990 and 2010 that includes some recent buildings completed before the introduction of energy standards or the very first generation of sustainable buildings whose performances are no more compliant with the current standards which rapidly evolved during the last decade making them out of date. On the one hand, it is evident that this group is performing under the expected levels and would probably need some updates, but on the other one, the quite limited ageing and the potential effort required to adequate their condition make them unlikely candidates for renovation actions at this stage.

Additionally, it must be reminded that this group, as well as the one including building from 2011 on, represent a small share of the existing stock due to the already mentioned slow turnover rate and therefore, they cannot be addressed as the priority to achieve massive savings.

Not surprisingly, several EU-funded projects and many studies within the scientific literature focused on the stock consisting of buildings dating from the 1960s to the 1990s, and particularly on multifamily and multistorey buildings, to develop renovation and retrofitting solutions to be replicated at a larger scale. Nonetheless, the rate of interventions is still very slow, considering the ambition of the 2030 and 2050 goals.

According to United Nations Environment Programme [UNEP] and IEA (2020), the main detected barriers preventing a higher pace in renovation actions to boost energy efficiency in the housing sector deal with:

- economic and/or financial issues, related, for example, to the high investment cost compared to energy saving return and payback time;
- hidden costs/benefit ratios, which usually generate a misleading perception of cost focusing on the first cost rather than on reduced operational costs, often splitting the economic interest between owners and tenants (who is spending the money is not who directly benefits from the intervention);
- market failures, behavioural and organizational obstacles, low level of awareness due to a lack of information about the energy saving potential;
- administrative/structural constraints, often connected with ownership fragmentation.

This last point, in particular, represents a relevant element influencing the feasibility of the renovation or retrofitting action. In the case of a multifamily housing complex, the property can be associated with a unique (private or public) subject or with different individuals. A mixed condition which produces critical effects in terms of decisional power when the fragmented property is called to take a position on possible interventions (budget, timeline, tender, contracts, etc.) involving the building as a whole and not the single units.

Most of the current renovation trends operate on the building envelope to improve the thermal insulation and on the heating/cooling systems in order to improve energy efficiency while reducing dispersions and this, of course, generally requires a huge budget and the consensus among the owners which represent two of the major barriers to action. Thus, recent research is no more simply focused on providing adequate technical responses but also on developing effective and viable solutions to overcome these constraints.

## 6.3. Methodological approaches

A rough estimation of the average annual demand per unit can be set around 200 kWh/m2 of energy consumption per year with significant variations country by country due to several reasons – climate conditions above all – with a huge gap to bridge for meeting the threshold of 30 kWh/m2 y that usually corresponds to energy efficient new buildings.

Despite the huge saving potential, even without targeting more ambitious positive energy goals, most of the renovation actions are based on quite a few elements: the replacement of windows, integration of thermal insulation, heating system replacement just to mention very basic solutions.

Unfortunately, single actions are usually not effective to contrast thermal dispersion, especially if thermal bridges are not carefully considered (Jelle, 2012; IEA, 2013), and to remarkably increase the energy performance level (Dall'O', 2012).

It must be said that very often the replacement of the building energy systems (HVAC, lighting etc.) is considered an alternative and not a complementary option to reduce energy consumption with the result that even the most performing system is not efficient enough to balance the massive dispersion from external walls without they are appropriately insulated. Furthermore, the fulfilment of the EU Directives imposed the adoption of solutions ensuring the indoor temperature and conditions can be regulated at single unit level, even when a centralized system is installed.

On the one hand, this allows the end-users set indoor conditions according to their comfort preferences while considering the related energy costs, but on the other one, it leaves room for a drastic voluntary reduction of heating hours in the case of low or very low-income occupants with potentially relevant consequences on health and quality of life.

This phenomenon known as energy poverty (EPEE, 2009; Boardman, 2012; BPIE, 2014; Fabbri, 2019) depends on multiple variables and can be highly influenced by the fluctuation of the energy market and can affect a larger amount of people during a period of energy crisis like the present time.

It can be argued that energy poverty is indirectly dependent on the end-user's decision – despite in most of the cases there is no choices, just the consequences of available income – but the building envelope response capacity highly influences the building energy performance level and consequently, the operation time of heating (and cooling) systems to maintain acceptable living conditions.

Thus, something which is frequently considered dependent on the behaviour of inhabitants is instead largely dependent on a technical response capacity. Additionally, it can be noted that a spotted individual reduction in the use of a heating system might lead to unpredictable thermal distribution patterns within the building as a whole, creating different microclimate enclaves that may originate a number of possible building pathologies directly connected with uncontrolled hygro-thermal conditions (Hens, 2012; Peixoto de Freitas, 2013).

Therefore, it is highly recommendable not to consider the system update separately from the building envelope improvement and at least within a comprehensive vision of the potential renovation outcomes.

Conventional approaches are usually driven by budget limitations and by the lack of a comprehensive understanding of the building envelope response in relation to external climate conditions and to end-users' behaviour. Other methodological approaches, considering interrelated factors, are instead based on careful observation of the building configuration and of the original construction system with reference to some key factors (i.e. orientation, exposure to solar radiation, wind direction and ventilation, etc.). In any case, when a renovation action is under planning the decision-making process is frequently influenced by the total investment required, the cumulative value of savings during the building lifetime and the benefit for end-users. These elements are mainly analysed considering the internal rate of return [IRR] (based on the net saving each year); the saving to consumers, which is the difference between the lifetime energy cost savings and the lifetime investment; the net saving to society, including the value of externalities (Hendricks, 1998). Any renovation action should start from a good understanding of the building conditions based on data and information gained during the years. Unfortunately, one of the most relevant problems is not only the availability of data but also their reliability, being the collection methodology quite different and with no fixed references. It is exactly the opposite of the systematic, organized and integrated way of managing information based on advanced Building Information Modeling [BIM] that characterises new contemporary buildings to monitor the performance levels, the ageing and quality levels while tracking the required maintenance actions.

Therefore, having a clear picture of the building conditions requires costly and time-consuming data collection campaigns, instrumental monitoring or software simulations which often discourage the owners from initiating the process. Several tools are currently available on the market to support the definition of renovation scenarios, but they need at least some basic input data, and they are not designed to prioritize interventions, only to evaluate potential options. In order to speed up the process and accelerate the renovation rate from the decision-making stage, some alternative approaches have been explored. An attempt in this direction is offered by a predictive tool aimed to compare the cost-energy benefits ratios of alternative renovation scenarios. It basically needs to determine some homogeneous pieces of information about the current energy behaviour of the buildings within a certain stock (baseline scenario), then it allows to select envisaged interventions among a set of recurrent actions estimating the benefit on the overall energy demand.

The comparative approach allows prioritizing interventions facilitating the decision-making process through a user-friendly visualisation. This iterative process has been validated on a test-bed residential district, and the overall energy efficiency improvements have been explored against the mapped current energy demand (Gaspari et al, 2020; Vodola et al, 2022). It is interesting to note that this study overcomes the recurrent lack of data associating the building characteristics to Tabula WebTool pre-defined categories with the purpose of quickly obtaining a rough energy performance estimation. When Energy Performance Certificates or real data are available – which are certainly preferable – the tool allows to directly process these input data. The precision level depends, of course, on the source, however, at the very initial stage of the process, the possible discrepancies or deviations are negligible considering the performance gap to be bridged and the benefit to facilitate the understanding of phenomena to non-technical actors involved in the process. Once the potential savings and the deriving benefit have been clarified a more systemic approach can be followed, usually including diagnostic activities and data collection (when needed); modelling and simulation of possible solutions according to pre-defined performance thresholds; scenarios creation and possible outcomes; impact evaluation; implementation and monitoring. It must be remarked that the ambition to shift the energy efficiency standards towards NZEB or PEB can only achieved with deep renovation where a massive use of RES is adopted, and the proposed technical solutions are coupled with appropriate end-users' behaviours. That means inhabitants are informed and aware of both the functional principles behind the system operation and of the potential effects of their own decisions (i.e. the decrease of efficiency when windows are left open and mechanical ventilation is operating, day or night use of appliances, etc.). This puts the role of end users at the core of the process, like a skilled driver of a very performing car, suggesting a different design approach in which solutions are thought to support the mutual interaction between man and building: a change in the design paradigm that apparently lies in the use of Information and Communication Technology [ICT] and instead is strictly linked to the understanding of the user's behaviour.

## 6.4. User-centred design and behavioural implications on energy savings and comfort

In the recent years, a user-centred perspective has been adopted in advanced design of new buildings, basically meaning that the user is placed at the core of the design concept considering the related needs, living conditions and preferences as input to which not only the design brief has to adequately respond but also the building as a system must be able to adapt. This is easier to achieve in new construction where the overall building configuration can be totally shaped from the very beginning while it is certainly more challenging in renovation actions where the original characteristics may limit this design approach. These constraints are frequently overcome increasing the technological level of the project introducing several devices aimed to monitor the indoor environment and to optimize the setting of the installed services and equipment. The development of ICT tools and solutions during the last decade certainly contributed to expand the possible solutions and their accessibility to a broader range of users. From the designers' perspective the introduction of sensors and monitoring systems allows to analyse the technical response and the user's preferences in real time to facilitate the optimization of the system as a whole. On the one hand, this is strictly connected with the monitoring of energy demand (and the related savings) and on the other one, it leaves room to a high level of customization which is usually particularly appealing within the market perspective.

*Fig. 6.5 – The adoption of advanced management systems allows the end user to carefully set operating conditions with potential relevant impacts on savings and comfort conditions.*


*Source: Author's photo archive.*

Conventional solutions in this field usually operate with control touch systems enabling to manage most of the installed devices and systems (including sun blinds, lighting, air conditioning, etc.) also via smart devices (tablet, smart phones, etc.) which allow the end-user a remote control in the case some specific actions are required to change a routine scenario (due to individual decisions or unexpected external reasons). Advanced solutions, based on machine learning technologies, are under development at pilot stage with the purpose to track and record the user's preferences or habits and optimize the system response accordingly while possibly suggesting possible alternative energy savings options when preferred conditions are not addressed towards efficiency principles. This approach aims to facilitate the adoption of sustainable behaviours even with not particularly informed (or interested) users. If one can easily share the objective to widen as much as possible the adoption of sustainable habits, it would certainly be much more useful that owners, tenants, and users in general increase their level of awareness and understanding of the connected phenomena. That's why many systems, but also service and energy suppliers, are developing informative apps which are designed to make users more familiar with basic indicators and values that can be easily visualized on their smart mobiles as notes following some specific actions to advise them of the cause-effect relation. It is also very important that the user understands the functional principles behind the design concept and the system configuration, such as the Mechanical Ventilation setting during the daytime and the different seasons or the need to shield glazed surfaces to avoid overheating during summertime, for exploiting its saving potential without reducing optimal comfort levels. New buildings and advanced renovations are evolving the design concept of building envelopes which are thought to become even more relevant in controlling the heat and ventilation exchange between indoor and outdoor environment. Not only the massive integration of thermal insulation, associated to air tightness, ensure to drastically reduce dispersion and maximize the potential energy savings reducing the service operation time, but also the adoption of innovative solutions to control the solar radiation and natural light inflow, especially during summer, allow to protect the glazed surfaces and reduce energy demand for cooling.

The use of climate adaptive building shells is based on the idea that the façade can adapt to variable conditions – such as the amount of incident solar radiation, the temperature or humidity variation etc. – on daily and even seasonal basis shading the glazed elements reacting to an external stimulus. This is preferably to be achieved using passive actuators which do not require energy supply (as typically happens with electro-mechanical solutions) and self-adjust their configuration according to the external conditions. Adaptive solutions operate independently from the user control following the optimisation of the response to variable external condition: if on the one hand this clearly maximize the potential savings and does not require an active contribute of the inhabitants to set it (that means they could not be fully aware of the effects of configuration on indoor conditions) on the other one it is often perceived as something preventing the user to set the configuration according to his own preferences and therefore as a limitation. That's why many adaptive solutions are design to include an override letting the user to force the optimal configuration into the preferred one (i.e. a fully open configuration to maximize views on the landscape instead a shielding configuration preventing overheating).

*Fig. 6.6 – Example of an advanced façade shading system.*

*Source: Author's photo archive.*

This is an extreme example of how the understanding of phenomena and of possible related technical responses of the system by the users is crucial point to establish an effective and informed human-machine interrelation. Much more important, the awareness of the user towards his own decisions is a key point also for addressing more sustainable behavioural patterns without compromising the achievement of comfortable and healthy conditions (which is a contemporary major issue).

Following this approach, the system must be designed to be adaptive – both to external variations and user's preferences – and the decisional capacity of people must be placed at the core of the strategy to let a certain level of freedom in choices and to make these choices responsible and energy saving oriented.

This main objective requires to consider real time monitoring as a tool for analysing both the building response and users' capacity to understand and use it, opening several opportunities to provide more tailored and effective solutions and, at the same time, it clearly requires coping with data protection and ownership which are certainly major issues to manage nowadays.

However, this will not prevent to develop innovative design strategies involving the end-users from the very beginning to facilitate the mind set shift and to accelerate the adoption of more effective behavioural patterns which will be an essential part of the energy transition especially when targeting very high standards like PEBs.

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# 7. *Factors influencing the social perceptions and choices towards circular renovation in the housing sector*

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## 7.1. The role of social sciences in the circular housing sector

The housing sector is one of the major contributors to climate change and resource depletion as one of the major consumers of natural resources (Giljum et al., 2016). Simultaneously, it is a critical sector where building activities are estimated to form around 9% of the European gross domestic product (European Commission, 2016). There is consequently an urgent need for the housing sector to become more resource-efficient by incorporating the CE approach. This implies a pressing requirement to change the decisions and choices taken by the stakeholders in this sector.

Although the construction sector is recognised as having great potential in implementing the CE approach (The Ellen MacArthur Foundation, 2017), it is precisely one of the sectors with the least outreach and experience (Ghisellini et al., 2016; Pomponi and Moncaster, 2017). CE in the construction sector is a focus area that is receiving more and more attention (Norouzi et al., 2021); however, less attention is given to social sciences and humanities. The European Commission, among others, heralded its CE strategy as an opportunity for social integration and cohesion (European Commission, 2019). Therefore, the CE approach needs to promote the participation of and interaction among stakeholders at each stage of construction in a co-creation process. In this way, it will overcome the cultural and social barriers associated with circular management while ensuring the optimal use of resources (Hartley, 2006; Vassileva and Campillo, 2014). The models of circular consumption, such as in the housing sector, inevitably require acceptance by consumers and other stakeholders. However, there is currently a lack of knowledge and familiarity with these models, which is preventing the development and adoption of a CE due to its challenging and multi-disciplinary scope (Atherton, 2015; Muranko et al., 2018). Indeed, there is little research on the intended behavioural change with specific regard to CE (Ellen MacArthur Foundation, 2013; Muranko et al., 2018a ). There is a need to better assess the social impacts of a transition toward circular cities; addressing this gap in research is critical to understanding how transitions towards circular cities can work for a wide range of stakeholders (Vanhuyse et al., 2021). In the housing sector, the usage phase of the buildings is a key area of action (Maslesa et al., 2018) for which the European Commission (EC) has launched an ambitious package of initiatives focused on existing buildings by including the new 'Renovation Wave' strategy (European Commission, 2020). Jiménez-Pulido et al. (2022) emphasised that, in building renovation, there is a need to maintain systemic and out of the box approaches. The same authors note that greater stakeholder engagement focusing on the global sustainability goals would be essential in having a community assessment approach based on the identified needs of households.

Addressing the implementation of circular solutions in the refurbishment of buildings implies that changes would be required in the daily behaviour of the inhabitants, as well as having motivated building owners and investors ready to adopt these changes (Ceschin and Gaziulusoy, 2016). In fact, this change implies new forms of collaboration between agencies; it implies acquiring and incorporating new knowledge and establishing a new culture towards the use of resources. The dimensions that emerge in the literature and which are of relevance to behavioural research on circularity can be divided into: governance, behaviour and cultural conditions, and risk/benefit perception. Within the governance dimension, there is a strong role for governmental organisations, according to Olanipekun et al. (2017), which have the power to implement specific policies for the sustainability of the housing sector. The context of housing is also crucial, as expressed by Caeiro and Ramos (2016); the policies that governments implement in this respect should take into account the characteristics of each geographical region and include the social heterogeneity of the households' needs. In the context of CE, European policies should connect specific dimensions of the CE with the social topics of congruence between citizen and policy understandings to raise public acceptance of this concept (Hernández-Sancho et al., 2015). Motivations and stakeholders' belief structures are strongly connected to specific cultural conditions. Culture generates a set of norms and values and these, at the individual level, can play an important role in pro-environmental behaviour (Horne and Kennedy, 2017). Thus, households' propensity to invest in sustainable solutions is influenced by the cultural expectations of that household (Domènech and Saurí, 2010). In this same study, the authors identified that economic, social and cultural factors play different roles at different stages of the dissemination process of a technology. Thus, it is vital to integrate into policies the lessons learned from pilot studies, and furthermore, to incorporate new policy objectives into adaptive policy instruments (Hamann and April, 2013; Frantzeskaki and Tilie, 2014).

Achieving effective governance for circular housing solutions requires the provision of timely and adequate information. This, in turn, requires that the stakeholders involved have management skills. Without effective communication and information management, it is difficult to implement a fair decision-making process in which outcomes are generated and trust is built in its governance structure and its mechanisms (Hartley, 2006). The lack of awareness can become a problem as it can constitute a barrier to the adoption of new technologies (Barnicoat et al., 2015).

Governance, knowledge and learning also have to be accompanied by an assessment of the social perceptions (Renn et al., 2016). Pro-environmental subjective norms conditioned by risk and benefit perceptions influence citizens' willingness to accept circular solutions (Sharma et al., 2019). Consumer acceptance can be driven by perceived risks and the need to change behaviour, but also through environmental benefits (Poortvliet et al., 2018).

## 7.2. Analysing perceptions and beliefs of stakeholders involved in circular solutions in the renovation of European buildings

This study analyses the social perceptions and beliefs influencing behaviour and choice-making structures of stakeholders involved in circular solutions in the renovation of four European buildings. As part of the European-funded project Houseful (http://houseful.eu), this study aims to gather evidence through consultations to understand factors that would lead stakeholders to support or reject the installation of the proposed circular solutions. Through the four demo-sites (two in Spain and two in Austria), the Houseful project develops an integrated systemic service composed of circular solutions in existing buildings addressing the housing value chain. In this study, we addressed questions such as what the foreseeable changes in the intended behaviour in the adoption of those solutions are, what are the benefits, and risks that are perceived by the relevant players regarding these solutions, and what structures are present in the decision-making process in the housing sector that can be influenced or be mobilised. We, therefore, looked at the various areas of social research to answer these questions.

## 7.3. The qualitative social approach to collect evidence regarding stakeholders' attitudes towards the use of solutions in a circular housing model

### *7.3.1. Data collection using in-depth interviews*

A qualitative social approach was conducted using in depth interviews to collect empirical evidence regarding the factors influencing stakeholders' decisions towards the use of solutions in a circular housing model. The content of the interview was based on gathering information about variables according to the codes in Table 7.1. A total of 44 interviews were held with the selected stakeholders at the four demo-sites, including those from a professional capacity and those with non-certified expertise in the decision-making process of the four demo-site buildings.

### *7.3.2. Data analysis and analytical approach using qualitative content analysis*

The data gathered from the interview transcripts was addressed through a qualitative content analysis approach using MaxQDA2020 through a deductive analysis.

The interview transcriptions were coded according to variables (Table 7.1) of each of the three areas of analysis with the following theoretical approaches. In the first area of analysis, we used an integrated framework of social perception of risks and benefits based on Espluga Trenc et al., (2017). We grouped relevant aspects into the following subsections: economic/market sub-area; health and environmental sub-area; technological sub-area; governance sub-area; and socio-cultural sub-area.

The second area of analysis covered the governance aspects of how the different management systems in housing and in the CE can condition engagement actions based on the factors addressed by the following main areas of analysis: roles of the cities, mobilisation of institutional knowledge and the capacity of the housing sector to adapt to future trends.

*Tab. 7.1 – Codified dimensions and variables.*

| Coding Dimension | Codified Variables |
|---|---|
| Risk perception<br><br>Benefit perception | • Health/Environment<br>• Technology<br>• Socio-Cultural<br>• Policy/Governance<br>• Economic/Marke |
| Governance/organisational | • Municipalities role<br>• Future/long term<br>• Institutional Knowledge |
| Cultural | • Capacity to adapt<br>• Subjective Awareness /Beliefs<br>• Economy and market<br>• Community cohesion |
| Behaviour<br><br>Attitudes | • Satisfaction<br>• Performance<br>• Ownership<br>• Ecologic behaviour<br>• Motivation<br>• Power/influence<br>• Awareness<br>• Nature relatedness |

The third area of analysis covered the cultural and behavioural aspects with regard to the experience and daily life of the stakeholders. For this, we drew on the Theory of Planned Behaviour (TPB), as one of the most extensively used behaviour theories to analyse individuals' intentions and the related sustainable behaviour (Zhang et al., 2018; Prouty et al., 2018; Tsoka et al., 2018). We identified the following variables that can help address TPB in the framework of this study:

- *Attitude Towards Circular Behaviour* (ACB) to help predict those behaviours and form interventions with regards to certain circular solutions;
- *Subjective Norms* (SN) that are here conceptualised as the perceived social pressures about the performance of behaviours towards circular practices. Here, SN is differentiated in two aspects: related to cultural beliefs and related to the market and economy;
- *Perceived Behavioural Control* (PBC) that specifies how people perceive the performance of circular behaviours in the housing sector.

### *7.3.3. The four European demonstration buildings*

The study is carried out through the engagement with local and regional stakeholders from the four demonstration buildings, which have different characteristics and social contexts (Medina et al., 2020).

The demo-site 1, located in Sabadell (Spain), is being renovated to be used for social housing in a renting scheme for vulnerable social profiles (large families). A challenge with regards to this building is the high turnover of occupants. The district in which the building is located is characterised as a working-class neighbourhood with substantial challenges, including high rates of immigration.

The Demo-site 2, located in Sant Quirze del Vallès (Spain), is also currently dedicated to social housing, addressing young and vulnerable social profiles in a renting scheme. The inhabitants already know that their involvement is very much needed and valued.

Demo-site 3, located in Fehring (Austria), is a cooperative founded in 2014 named as the Cambium Community Project. This community rented a former military barracks in 2017 and bought the property in 2019 through a direct credit campaign. Since 2019, they have been transforming the building into a suitable living and working area with residential units, co-working spaces, and a seminar facility.

The Cambium community is organised in a horizontal way through a so called "sociocracy", based on a consent decision-making processes.

Demo-site 4, located in Vienna (Austria), is also dedicated to social housing. It is a residential building with apartments and common spaces, a day care centre and a supervised flat-sharing community for young people. The building was finished in 2017 and the inhabitants have a young profile, which leads to a high rate of single households or dwellings of two people.

## 7.4 Results about attitudes, planned behaviour, and perceptions towards circularity in the renovation of buildings

The evidence gathered on the attitudes, planned behaviour, and perceptions towards circularity in the housing sector are presented and classified according to the three analytical dimensions: risk-benefit perception, governance, and planned behaviour.

These results outline the aspects and factors dealt with in each of the respective sections.

### *7.4.1 Perceived risks and benefits with regard to circular solutions in the housing sector*

We attempt to provide an initial answer to the question: how is the implementation of circular solutions in the housing sector perceived as either a risk and/or a benefit? We addressed this question through 5 domains: (i) market and business, (ii) environmental and health, (iii) technological, (iv) policy, and (v) socio-cultural in accordance with the perception dimensions. With regard to the business and market domain, risks were perceived in relation to potential new businesses within the development of new circular services; the cost increases; the need for new public or private investments; and the household costs due to daily consumption (water, waste, energy). In terms of the perceived benefits in the economic and market category, it was seen as a growing and necessary sector that opened new horizons and new markets. This is mainly observed by those stakeholders considered as experts in the circular housing value chain.

The generation of new market opportunities required by the housing sector is valued as something positive. Those stakeholders already addressing the CE perspective perceived that there will be a reduction in costs in the daily use and maintenance of materials and resources. The unique concerns expressed about environmental issues were related to the safety of the materials used and user's comfort level with the use of certain resources, such as reused water. More specifically, there was some concern over the safety of the recycled products and their toxicity. As for the benefits identified, they include the use of construction materials and solutions that solve health problems derived from excessive humidity in buildings. With regard to the technological domain and its circular solutions, most mentions about risks refer to the need for maintenance of the new services, both for the level of training that may be required by the users and the maintenance staff. Inhabitants perceived the risk that they won't be able to maintain complex technologies and that it could imply future maintenance costs. Policymakers stated that trust in the operation and hence in the maintenance of the solutions could be a potential problem. Policymakers (at the social housing demo-sites) were concerned about the quality and functionality of circular products. Questions were raised about how adaptable and flexible the installed solutions are with regards to their location and their aspect. This could be a factor for the implementation of circular solutions. The reuse of grey water is mentioned as a factor which generates certain reproach because of its potential odour and the space that this technology may require in the buildings. As the benefits perceived in the technological domain, it is perceived that circular solutions in the housing sector will provide greater efficiency in the use of resources. It was also stressed that society in general is becoming more visually accustomed to having sustainable solutions in the field of housing. Aesthetically, they are increasingly approved. Within the policy domain, distrust is perceived between society in general and the housing sector, potentially hindering the deployment of new circular solutions in this sector. In general, all stakeholders perceived that there are certain barriers to implementing novel processes because it is perceived this lack of trust from general the general public in the housing sector. It is believed that the interests behind actions, such as those pursued by pro-sustainability approaches, are financially motivated. Moreover, trust in the implementation of technology is slow to develop due to legislative barriers and the need to adapt regulatory structures. Gaining trust in housing managers is seen as a critical point for long-term applicability. At the governance level, more multi-disciplinary and holistic approaches are also required, and interviewees are reluctant to see this happen in the short term, especially in public policies.

In relation to the socio-cultural domain, there were mentions regarding the knowledge required to create the paradigm shift to a CE. It is precisely on this issue that it is perceived by interviewees that the public is not aware of the need for a change and therefore cannot demonstrate an interest and will not feel ready to adopt these solutions.

### *7.4.2 Key governance factors for implementing circular solutions in the housing sector*

The future of the housing sector at the governance level can be broken down into time scales such as the participants in the consultation process have mentioned, i.e., short- and long-term feasibility issues. A similar approach over the four demo-sites is found in the long-term perspective, as many more rehabilitation actions are planned, and they need to follow more circular schemes, and be aligned to Sustainable Development Goals.

There is certain ambivalence with regard to the short-term governance adaptations to CE, in which a need to do much more is identified by participants of this study at a national and regional level. But it is also recognised that fairly good progress towards CE adoption at the local level (municipality or neighbourhood in question) is being addressed. The CE and the housing sector are two areas where the governance is complex, broad, and transversal, requiring mechanisms that operate within this context. In the short term, the participants expressed the need to uncover mechanisms of support, to unite the efforts of similar initiatives, and to genuinely collaborate between institutions.

Participants in this study have emphasised the importance of the role of the municipalities which host the demo-sites. One aspect common to the four demo-sites, is that city councils are active in the local measures. They are keen to showcase the ways by which they are strengthening innovation and promoting local sustainability in their current policies. Establishing collaborative models in the city councils has been mentioned as a successful factor. Priority in the city councils is to promote social housing by mobilising also the private sector. Furthermore, the inclusion of environmental issues in this process is vital. Relevance of circular pilot actions is also crucial, as it raises awareness and creates trust (as mentioned in the previous section), therefore municipalities already acknowledge the need for increasing awareness of those pilots within their municipalities.

### *7.4.3 Behavioural intention towards the implementation of circular solutions for building renovation*

This section is organised according to the TPB configurating behaviour towards the use of circular solutions in the 4 demo-sites.

*Attitude towards circular behaviour (ACB)*- The CE is a familiar concept among the participants in this study, and generally, people recognised that they do “something” for it. We distinguish three profiles: 1) actors whose business is framed by the CE; 2) actors who, although not aligned in their mandate with the CE, already do something for it; and 3) actors whose professional activities are unrelated to the CE but do “something” related to the circular economy in their personal lives. This “something” is usually connected with actions that were already being carried out in the not-too-distant past. CE is not addressed as a new practice, but rather a reconnection with the resource cycle from traditional actions. However, the “need to change behaviour” is a constant demand expressed by the participants in this study. In the three demo-sites with a social housing model, the interviewees mentioned as essential that public institutions are the main drivers of CE practices that will motivate users (dwellers) and generate trust. In the case of demo-site 3 (the cooperative model), the community required a greater visibility of the pilot actions in order to create impetus for change. Once some circular solutions are implemented, this can encourage users to more readily adopt further solutions where they live. And visual materials can be reused at the demo-sites to reassure and gain the trust of those who live in nearby areas.

*Subjective norms related to cultural aspects (SNC)* - Subjective norms can shape behaviour towards circular housing because there is a perceived link between people's houses and their social status. The two Spanish demo-sites are associated with socially vulnerable areas, involving different social profiles. Our consultations found that it is generally assumed by the participants that vulnerable communities "know little" and therefore, it is assumed that they are little prepared to face changes.

The controversy around decentralised solutions proposed by circular approaches versus centralised ones was mentioned. Participants referred to the idea: *if it ain't broken, then don't mend it*, referring to the reason a change is required if the system currently in use is already known and it is widely implemented and works. At the level of the building itself, circular solutions involve sharing spaces and having a degree of community cohesion around the demo-site. The "sharing" concept can be complex and require effort in obtaining residents' agreement and a greater commitment by associated institutions. At demo 3, as a cooperative, this is already intrinsic to the organisational nature, and this effort is already integrated. But a greater effort to achieve social cohesion around shared use is envisaged when dealing with rental systems and social housing.

*Subjective norms related to market aspects (SNE)* - At the market and economic level, some aspects have been identified. With regard to the price of resources (household water and energy consumption), the consulted experts in the sector believed that the public does not perceive what the fair price for water and solid waste should be. If the general awareness or tendency is that the price of water and waste in daily bills is perceived as expensive, the true value is not being attributed to it. Questions such as "Do we have to pay for something extra that is not necessary?", requires greater effort to clarify the need to switch to circular systems. The perceived meaning of "low cost" and "beautiful" in the housing and building sector does influence the aesthetic appeal of circular solutions in terms of user profiles. The housing sector has been greatly affected by the economic crisis; the level of configuration of subjective norms also represents an obvious uncertainty. We must speak in pre- or post- pandemic Covid-19 terms (interviews were carried out before and during the pandemic), where the housing sector was perceived to be in recovery and being able to afford innovation changes towards circular economy models. Already in the interviews held later during the Covid-19 pandemic, this observation has changed completely into a new uncertainty.

*Perceived circular behavioural control (PCBC)* - In the context of housing, one of the factors that influence the sense of control to perform a circular behaviour is how solutions are installed, maintained, and used. The proposed circular solutions do not always require the same level of interaction; indeed, some of these solutions will not practically need interaction from users at all while other solutions could imply a daily involvement from the users. The degree to which we can measure behaviour varies.

A certain amount of controversy arises with regard to the preferable type of solutions to be installed in the demo-sites. Some interviewees (especially those who tend to deal with tenants in social housing on a practical level) believe that solutions should be as passive as possible. On the contrary, in the cooperative demo-site, it was suggested that solutions involving a greater degree of participation would generate more commitment to the processes of CE. The participants generally perceived that they were taking individual or organisational actions towards a CE, but sometimes this can lead to a false sense of control as they confuse issues of CE with sustainability actions.

## 7.5 Discussion about problems, enablers, and needs encountered for addressing circularity in the renovation of buildings

Through studying the users' risk-benefit perception, more clarity has been gathered about the problems, enablers, and needs encountered for addressing circularity in the renovation of buildings. As this is a pilot research intervention, it has provided greater understanding and awareness about the materialisation of the CE approach in the refurbishment of existing buildings by taking the theoretical discussions to real-life settings.

With regard to the implementation and usage of circular technologies, there is concern over the cost structures and how these can impact the daily consumption of the tenants and building owners, which is still not known.
Precisely, tenants, being also consumers, are concerned, above all, about the impact on their energy and water bills, even more notable in the case of tenants living in social housing houses. In the discourse analysis of this issue about costs, issues such as fairness in affording costs from households consumptions is raised. For those stakeholder profiles closer to the development and implementation of CE solutions, costs are not a concern.

The innovative character of refurbishing buildings by implementing circular solutions is an aspect that clearly emerges in the discourse of the interviews.With regard to buildings in social housing scheme, doubt occurs over whether it is feasible for the public sector to be innovative enough to include these circular solutions. Undeniably, there is the perception of certain complexity in the decision-making process related to the social housing sector. This complexity is considered the main factor slowing down the agility of the sector and it is discouraging a quicker process for policy implementation in CE schemes.

This is not the case of the cooperative demo-site, which has a community very committed to the environmental cause, as catalysers to adopt the circular solutions. The factor of complexity in the decision-making is raised for the housing sector and the involvement of different areas of expertise and the typologies of institutions. Municipalities involved are addressing this complexity by creating transversal modes of interaction between different departments that include sustainability and housing aspects. Despite the efforts to address this complexity, there is still a long-term perspective in policy planning towards circular housing.

The trust generated by the institutions, including in the process of managing permits for the installation of circular solutions, is also an important aspect that configures the perception and attitudes of involved stakeholders.

Broader evidence has been gathered in terms of stakeholders' knowledge levels as a key factor in mobilising behaviour towards CE in the housing sector. The typologies of knowledge that we could investigate deeper detail at are the following:

- The knowledge acquired and needed for the solutions applied at each demo-site and the levels of understanding among the different actors.
- The subjective awareness: what society (others) seems to know has been very relevant in the evidence gathered, showing patterns of behaviour influence.
- Mobilisation of the institutional knowledge, especially from the social housing demo-sites, is required to move forward towards effective policy plans and regulatory schemes addressing circular approaches.

A significant aspect that already emerged in the reviewed literature is how priming environmental attitudes emerge as conditioning factors for more sustainable (or circular) planned behaviour. Stakeholder groups that, because of their profession or greater affinity to sustainable behaviour, are more likely to react to aspects that generate uncertainty, such as maintenance or the costs derived from the use of these solutions. In future research, this would be an important aspect to study in more depth through participatory interventions.

Among the other motivators that result in behavioural intentions and identity issues that are seen as important are aesthetics. Circular solutions should be perceived as something nice and pleasing, as a building represents a symbol of identity for society. The singular case of the housing cooperatives is one of the case studies where it comes to the fore.

One last key motivator towards implementing circular solutions is the pre-existing level of social cohesion. Higher levels of the community seem to lead to higher levels of acceptance, especially for those solutions that are to be used within the neighbourhood community. A factor that is clearly more prominent in the housing cooperative case study, and which is very poorly perceived in the social housing cases.

With this study, we conducted an exploratory consultation phase with stakeholders from existing demo-site buildings where renovation works were being implemented in line with circular solutions. This has allowed us to gather initial ideas on attitudes and beliefs in shifting to the circular economy in the housing sector. Given the idiosyncrasies of the 4 demo-sites of the project, naturally, our analysis assumes that results are contextualized around these demo-sites. It is for this reason that our analysis provides evidence around social housing and cooperatives in the housing sector. The discussion generated has remained within the broad context surrounding CE in the housing sector and how the paradigm shift can take place instead of specific information regarding the solutions at each demo-site.

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# 8. Renewable distributed generation evolution: perspectives and new trends for prosumers in Brazil and Italy

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## 8.1. Introduction

The current paradigm for electric power generation systems is still based on large plants located in areas where it is more convenient to build them, usually very far away from consumers. These systems are connected by transmission and distribution power grids to supply the main consumer centres (mainly cities and industrial hubs). Moreover, the construction and expansion of these large transmission infrastructures are complex to plan, expensive and time-consuming, and difficult to implement due to multiple land uses and legal restrictions, especially regarding property rights and environmental aspects. Furthermore, in the last two decades, advances in renewable technologies and batteries are opening up an expansion vector on the generation side, allowing the emergence of a new paradigm based on renewable distributed generation (RDG) implemented directly within the electrical distribution network. This evolution will also imply the need to improve and evolve the power grids. Around the world, users, supported by different incentive schemes, are adopting RDG, simultaneously becoming consumers and producers of electricity (prosumers). This can positively impact local production, increasing user autonomy and savings in terms of electricity costs. In addition, photovoltaic (PV) is the most used source of energy in the RDG modality in the energy transition process. According to International Renewable Energy Agency – IRENA (2022), in this last decade, the costs of

PV technology have fallen significantly, and there has been an improvement in its capacity factor, increasing its competitiveness and attractiveness in several countries. This cost reduction has boosted the expansion of PVDG and directly paved the way for the five main vectors of the energy transition (decarbonization, electrification, digitalization, decentralization and democratization) for consumers. In this context, end-users' role as prosumers presents a promising trend of greater interaction, connectivity, proactivity and reciprocity in terms of the provision of the electricity supply service with distribution companies, contributing to implementing energy efficiency measures and improving sustainability in the urban areas. Thus, this work proposes to comparatively study two countries, being a reference country in Latin America, Brazil, and a reference country in Europe, Italy, as a way to contribute to a better understanding of the subject in question.

## 8.2. Scope, specific objectives and methods

This work analyses the RDG evolution in Brazil and Italy through a comparative perspective from 2000 to 2021. It also discusses socio-political issues and the growth of the RDG model oriented by five main vectors of the energy transition, considering the role of the prosumers and their possible contribution to energy sustainability in cities.

The specific objectives are to (i) analyse the RDG evolution from a comparative perspective in Brazil and Italy; (ii) present scenarios about the trend in the prosumer's role and energy sustainability in cities; (iii) point out legal recommendations for improving the development of RDG.

The present work used multiple research methods (Sovacool et al., 2018), blending systematic literature review (Sorrell, 2007) for data collection and the functional method of comparative law (Michaels, 2006), discourse analysis (Antaki, 2008) and triangulation (Flick, 2004) for data analysis, performing thus qualitative, applied, descriptive and exploratory research. A comparative study was carried out on two cases of DG market in countries on different continents:  Brazil (Latin America) and Italy (Europe).

## 8.3. The electric power system and the challenges to enable the energy transition in Brazil and Italy

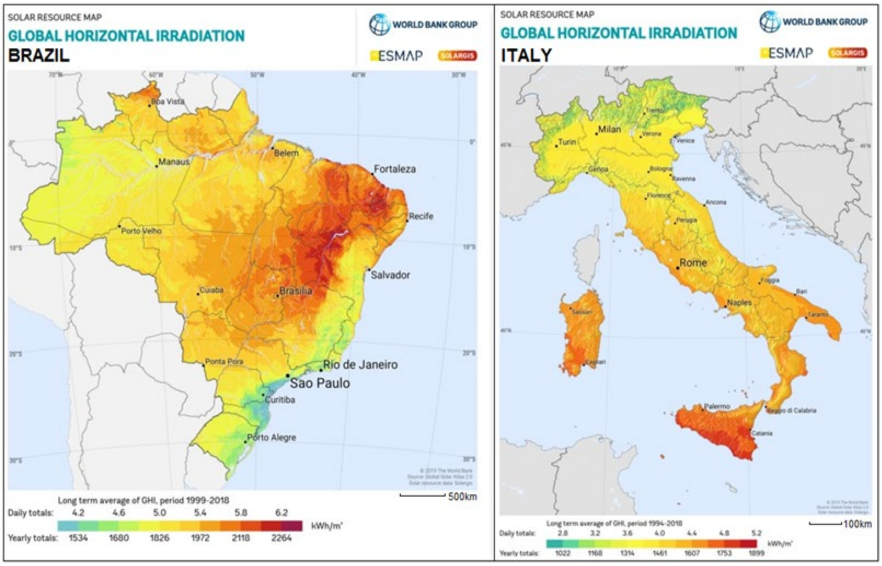
Nowadays, the five main expansion vectors of the energy transition identified in the literature are decarbonization, electrification, digitalization, decentralization and democratization (Dash, 2016; Ghezloun et al., 2017; Di Silvestre et al., 2018; Asif, 2020; Lampropoulos et al., 2020; Wagner and Götz, 2021; Mittelviefhaus et al., 2022). These five vectors can orient the RDG model development toward energy sustainability in cities in Brazil and Italy, the focus of this article.

The term “decarbonization” indicates the declining average carbon intensity of primary energy over time, thanks to the exploitation of new and clean energy sources. Decarbonization targets were set worldwide for the first time at the Conference of the Parties (COP21) in Paris in 2015. COP22 in Marrakech in 2016, called “the COP of the action”, opened the way to the practical implementation of the Paris COP21 agreement (Ghezloun et al., 2017; Di Silvestre et al., 2018;). COP26, held in Glasgow in 2021, and the most recent reports from the Intergovernmental Panel on Climate Change (IPCC, 2022) reaffirm the urgent need to decarbonize the world energy sector to combat global warming and climate change. The war in Ukraine added another dynamic to global investments in energy and even more urgency to the processes of independence from fossil fuels.

Decentralization and electrification are particularly relevant in the urban environment (Lampropoulos et al., 2020; Mittelviefhaus et al., 2022). They have become two major intertwined decarbonization pathways due to the stark technological improvements (incl. digitalization) and growing political support for efficient, electricity-based mobility and stationary energy converters and storage, such as heat pumps and electric vehicles (Steinberg et al., 2017; Di Silvestre et al., 2018; IPCC, 2022). While classical non-renewable electricity generation units can predictably dispatch power on demand in that regard, they face challenges of relatively high emissions due to the commonly used fossil energy carriers. On the contrary, installing renewable energy technologies, such as PV, can reduce the supply’s carbon footprint; however, it brings along with it challenges of seasonality, intermittency, and non-dispatchability. Energy storage systems may alleviate these concerns, adding costs, storage losses, complexity and embodied emissions to the energy system. Whether to implement such supply systems as decentralized energy systems, i.e. via small-scale converters and storage in proximity to the consumer, with relatively high specific investment cost and embodied emissions, or instead to invest in centralized technologies, which profit from economies of scale, but require costly and lossy transmission and distribution infrastructures to supply the end-users, increases the complexity of energy system planning (Mittelviefhaus et al., 2022).

However, the success of electrification is largely dependent on the geographical and temporal availability of affordable, reliable and environmentally-friendly electricity, which is not equally distributed across the globe, as indicated by the Energy Trilemma ranking (World Energy Council, 2020; Mittelviefhaus et al., 2022). Hence, to enable electrification, depending on the geographical location, the existing electricity supply must be upgraded by installing new electricity generation, distribution and storage technologies, and corresponding integration methods (Mittelviefhaus et al. 2022). In these regards, the two selected countries in this study are similar in that they have abundant solar resources located in geographical areas opposite regions of the most significant demand (northeast – southeast in Brazil and south-north in Italy) (Fig. 8.1).

*Fig. 8.1 – Solar radiation comparing Brazil-Italy.*




*Source: Elaborated by the authors, based on SOLARGIS (2022).*

Brazilian PV generation potential is higher than that of Italy due to having more areas and higher solar irradiation levels. However, in both cases, restrictions on the transmission capacity of transferring generations' surpluses are already inhibiting the installations of new renewable energy (RE) centralized generation plants. Accordingly, when planning new complex energy systems, trade-off decisions between centralized and decentralized, renewable and non-renewable, and electrified and non-electrified assets are inevitable. They should ideally simultaneously ensure affordability, sustainability, and energy security (Mittelviefhaus et al., 2022).

Thanks to digitalization, the world is experiencing a fourth industrial revolution (Schwab, 2016; Di Silvestre et al., 2018). According to Gartner's (2022) definition, digitalization is "the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business" (Di Silvestre et al., 2018; Gartner, 2022). The World Economic Forum (Schwab, 2016) and Di Silvestre et al. (2018) indicate three technologies as the most revolutionary in the field of digitalization: the cloud, the Internet of Things (IoT) and the mobile phone. Concerning power systems, decentralization involves generating and managing electricity close to the load centres by using distributed generators connected to the LV and the MV grids. The concept is closely linked to decarbonization and digitalization since most generation units are RES-based plants that must be coordinated to achieve security and efficiency (Di Silvestre et al., 2018). The democratization of the energy industry covers a vast field. This includes the possibility of many individuals becoming prosumers (Brown et al., 2020; Wagner and Götz, 2021) with the desire for social participation in energy issues (Yildiz et al., 2015; Wagner and Götz, 2021) and the fight against energy poverty. The founding of numerous public utilities, the re-municipalization of many electricity distribution networks (Wagner and Berlo, 2017; Wagner and Götz, 2021), the establishment of hundreds of energy cooperatives (Kahla et al., 2017; Wagner and Götz, 2021) and the great interest in bio-energy villages, energy-autonomous municipalities, etc. are an expression of a change in social awareness (Debor, 2014; Wagner and Götz, 2021). It is also an expression of a growing distrust of large energy supply companies and a system for providing services of general interest predominantly based on shareholder value (Wagner and Götz, 2021).

## 8.4. Brazil and Italy in a comparative perspective

The geographic and socioeconomic realities between Brazil and Italy are quite different, as shown in Table 8.1. Brazil is located in South America and covers an area of 8,515,767 $km^2$; it has a population density of 25/$km^2$ and a human development index (HDI) of 0.765 in 2019. Italy is located in Europe, with an area of 301,230 km2, a population density of 201.3/$km^2$ and an HDI of 0.892 in 2019. Brazil is part of the Global South, while Italy is part of the

South of Europe, with similar relative positions in the global and European contexts, respectively.

*Tab. 8.1 – Comparison of some Brazil-Italy socioeconomic indicators.*

| Nº | Indicators | Brazil | Italy |
|---|---|---|---|
| 1 | **Population in 2020** | 212,559,409 | 59,729,081 |
| 2 | **Life expectancy at birth in 2019** | 75.9 years | 83.2 years |
| 3 | **GDP total in 2020** | US$ 1,445 Trillions | US$ 1,889 Trillio |
| 4 | **GNI per capita in 2020** | US$ 7,850 | US$ 32,290 |
| 5 | **$CO_2$ emissions (metric tons per capita) in 2018** | 2.042 | 5.376 |

*Source: Elaborated by the authors, based on he World Bank (2022).*

### *8.4.1. Renewable distributed generation evolution in Brazil and Italy: period 2000-2021*

RDG, especially PV, in Brazil has attracted much attention and has become relevant since 2012 (Jannuzzi and Melo, 2013; EPE, 2014; Santos et al., 2021), as observed in Table 2. According to Energy National Electric Agency – ANEEL (2022) and Energy Research Company – EPE (2022), from normative resolution N. 482/2012 (ANEEL, 2012), the growth in the Brazilian DG has become exponential as the number of RDG systems connected to the electricity grid reached almost 830 thousand and installed capacity reached around 9.2 GW in 2021 (Table 8.2).

In Italy, RDG, also mostly PV, has attracted consumers' attention and has become increasingly relevant from 2005 on (Table 2) with a Feed-in Tariff incentive called *Conto Energia* that finished in 2013 after five years. According to Gestore Servizi Energetici – GSE (2021) and TERNA (2021) (Table 2), between the third and fifth year, the growth in Italian RDG was exponential and became almost flat in the following years. In 2021, the number of RDG systems connected to the electricity grid exceeded 1 million and installed capacity reached 25.5 GW.

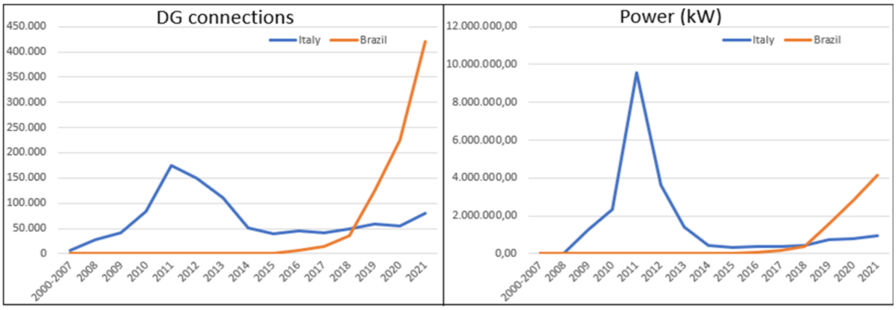
When comparing the evolution of RDG in Brazil and Italy from 2000-2021 (Fig. 8.2), the differences in the growth curves are noticeable. Brazil has an exponential growth curve, while Italy has an elevation curve until 2011 and then there is a reduction in the pace of implementation of new DG systems. A discreet surge in annual growth was observed in recent years.

*Tab. 8.2 – Distributed generation development in Brazil and Italy: 2000-2021.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| BRAZIL | Year | 2000-2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| | DG connections | 0 | 1 | 2 | 6 | 7 | 6 | 58 | 305 |
| | Power (kW) | 0 | 25.00 | 23.00 | 40.02 | 101.00 | 467.22 | 1,493.46 | 2,795.68 |
| | Year | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | TOTAL |
| | DG connections | 1,458 | 6,717 | 13,945 | 35,958 | 124,076 | 224,140 | 420,780 | **827,074** |
| | Power (kW) | 17,032.60 | 65,467.97 | 162,382.54 | 401,547.43 | 1,581,620.14 | 2,828,945.32 | 4,152,058.04 | **9,213,999.42** |
| ITALY | Year | 2000/2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| | DG connections | 7.647,00 | 27.158,00 | 41.788,00 | 84.343,00 | 174.422,00 | 150.048,00 | 110.949,00 | 51.841,00 |
| | Power (kW) | 87 | 344,00 | 1.263.569,00 | 2.328.000,00 | 9.539.000,00 | 3.654.000,00 | 1.400.000,00 | 409.000,00 |
| | Year | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | TOTAL |
| | DG connections | 39.563,00 | 44.294,00 | 41.961,00 | 48.287,00 | 57.789,00 | 55.748,00 | 79.401,00 | **1.015.239,00** |
| | Power (kW) | 307.000,00 | 382.000,00 | 399.000,00 | 426.000,00 | 757.000,00 | 785.000,00 | 937.000,00 | **22.587.000,00** |

*Source: Elaborated by the authors based on ANEEL (2022), TernA (2021), GSe (2021).*

*Fig. 8.2 – Comparison of DG development Brazil-Italy: growth by year from 2000 to 2021.*




*Source: Elaborated by the authors.*

## *8.4.2. Legal structure of electricity markets in EU/Italy and Brazil*

The structure of the electricity market has been widely discussed in recent years at the European level (Europe Commission Communication, 2018, EU, 2022). This sector has increased the share of renewable energy generation up to 37.48% in 2020 (Eurostat, 2022).

However, the EU also suffers from a rise in emissions, high levels of unscheduled and reverse flows and an increase in redispatch costs, which are partly due to the suboptimal geographical zone configuration of the electricity market and distribution of the RE resources available (Europe Commission Communication, 2018; Koirala et al., 2018).

This is a situation currently worsened by the global impacts of the Covid pandemic and the Russia -Ukraine war. Despite the commitments announced and the intention to become the first carbon-neutral continent, the EU is still one of the most prominent greenhouse gas (GHG) emitters, and its commitments are not yet aligned with the goals of the Paris Agreement (CAT, 2022a; 2022b).

Furthermore, the increasing penetration of variable RE generation will increase the challenges of balancing and controlling energy flows. To pursue energy transition in Europe, the most recent plan released by the European Commission is the REPowerEU: *affordable, secure and sustainable energy for Europe*. This plan defines a Clean Energy Package (CEP) that aims to make Europe independent from Russian fossil fuels well before 2030, in light of Russia's invasion of Ukraine.

Nevertheless, in the CEP, by 2030, the share of solar and wind-generated electricity in the total renewable electricity estimated percentage in the grid will be of: 21% at 41% in the reference scenario and at 29% at 50% of the total in the high ambition scenario (REmap scenario), as mentioned by Couture et al. (2019). Thus, the energy transition challenge will be even greater now. In fact, the variable characteristic of generation from modern renewable energy sources and the less-than-optimal integration and coordination of the European electric system (policy, market and geographic aspects) together are becoming limiting factors for the efficiency of the integration process of the electricity market (Europe Commission Communication, 2018; Pérez-Arriaga et al., 2019; Lilliestam et al., 2019; Barroco Fontes Cunha et al., 2021), problems that Europe is trying to solve with successive legal reforms.

In December 2021, six months after the original deadline, Italy promulgated the national law for the transposition of the Renewable Energy Directive with the Legislative Decree 199/2021 (EU, 2021a) and with more than a year's delay, the Directive on the Internal Electricity Market was transposed with the Legislative Decree 210/2021 (EU, 2021b). Both Directives belong to the CEP. The laws, when fully applicable (only after September 30, 2022, with the normative acts from the ARERA), should unblock investment in RE to accomplish the objectives established in the Italian Integrated National Energy and Climate Plan (PNIEC), which foresees a total of 51 GW of PV generation by 2030 due to a 30 GW capacity increase in this next decade (Ministry of Economic Development et al., 2019). This target should be updated to follow the REPowerEU package, leapfrogging the Fit for 55% package approved in 2021 (EU, 2022b).

To date, several aspects regarding RDG foreseen in the new laws, especially involving collective self-consumption and renewable energy communities, are dealt with in Law n. 8/2020, which implemented an experimental phase design to collect data and valuable elements for the final implementation of the Directives.

The main way in which to incentivize the RDG established by the CEP is implemented by four different concepts of collective energy self-consumption, namely: renewable energy communities (RECs), citizen energy communities (CECs), renewables self-consumers and active consumers (EU, 2018; EU, 2019). CEP introduced the concept of shared energy within the scheme members, which is equal to the minimum between the electricity produced by the community generation facility and the electricity withdrawn by all the associated members. The energy is considered shared by the members for instantaneous self-consumption also if stored through storage systems (Gazzetta Ufficiale, 2020; ARERA, 2020).

These new schemes bring a paradigm shift to the energy markets by promoting new ways of engaging citizens and the private sector in the production and consumption of RDGs by giving them the possibility to play an active role in energy markets.

It is worth noticing that before CEP, the incentives to the private sector to participate in the generation of RE around the world could be classified into two central schemes: the *feed-in tariff* (FIT) or the compensation by *net metering*.

In both cases, little attention is required for active consumption, since it was implemented in the passive logic of "feed and forget" (Kubli et al., 2018; Dubois et al., 2019; Barroco Fontes Cunha et al., 2021).

However, the collective models proposed by CEP established the need to match energy production and consumption, thus requiring more user awareness in relation to the production process and even more regarding their own consumption profile. Domotics, smart mobility and energy efficiency also play a significant role due to increasing digitalization and electrification of final uses.

These aspects are implemented aiming to stimulate virtuous behaviours, promote flexibility in consumption and to favour a more significant insertion of variable renewable sources, mainly solar and wind (Kubli et al., 2018; Dubois et al., 2019; Barroco Fontes Cunha et al., 2021).

In Brazil, electricity sector regulation is fragmented in several normative documents, and the current legal framework for RDG is the result of the last reform implemented by Law N. 14.300/2022 (DG New Legal Framework) (Government of Brazil, 2022). This law perpetuated the compensation system (Net Metering) original implemented by the normative resolution 482/2012 (ANEEL, 2012).

It defines the electric energy compensation system, the concept of shared generation and enterprise with multiple consumer units, among other measures. Under the current regulation, individual properties, condominiums, cooperatives and consortia can be included in micro and mini modalities, participating in the energy market through the net metering scheme (Luna et al., 2020; Barroco Fontes Cunha et al., 2020).

In the Ten-Year Energy Plan 2029 (PDE 2029), Brazilian EPE estimates that Brazil will have 1.3 million micro and mini-energy facilities distributed by 2029, equivalent to 11.4 GW of installed capacity (MME and Energy Research Company, 2020). There is, however, no official concern or incentive that focuses specifically on ECs in Brazil. EPE (2014) estimates that by 2050 only 13% of total residential demand will be supplied via distributed generation.

This hampers RDG because large-centralized ventures enjoy many benefits, such as special financing conditions (funding provided by public development bank with long-term repayment and low-interest rates) and long-term energy sales contracts with Distribution System Operators (DSO), in addition to gains of scale, creating utility-scale lock-in technology for PV in the country (Lacchini and Rüther, 2015; Silva et al., 2016; Vazquez and Hallack, 2018).

The official estimate of RDG growth in Brazil by 2050, prepared by EPE (2014), is relatively modest given the growth potential of PVDG in the national market. This might be due to a previous concern about the impact that robust growth of RDG would entail on the income of DSOs and energy trading companies and tax revenues from electricity.

The Federal and State Governments will probably collect less tax. However, the impact of lower electricity costs could be compensated for with part of the savings going to more consumption in the economy, more competitive prices for industrial production and more significant business investment in production, starting a growth cycle in the economy (Lacchini and Rüther, 2015; Cunha et al., 2020).

## 8.5. Perspectives and trends for prosumers in the energy markets in Brazil and Italy

Good policies provide a strong foundation for action on energy efficiency and RDGs growth, which can improve electrification, replace fossil fuels with renewable energy, boost energy savings and participation towards climate goals. Enabling a smooth switch from fossil fuels to renewables is necessary to build the energy transition pathway by lowering the carbon content of electricity (g/kWh) and emissions on a timescale with objectives and goals across the next decade.

Considering the current Russia-Ukraine war, it is also a good investment to consider now for energy security and independence. However, much work remains to be done to modernize traditional utility business models to encourage energy efficiency. These include revenue decoupling and implementing performance incentive mechanisms to limit the carbon content of electricity (g/kWh) and GHGs emissions.

The Brazilian Electric Sector (BES) is a world reference regarding low carbon intensity and the possibility of storing energy in reservoirs of hydropower plants. According to the National Energy Balance 2022 (Energy Research Company, 2022), carbon emissions from Brazilian electricity generation were 118.5 Kg $CO_2$-eq/MWh in 2021 and 104.1 Kg $CO_2$-eq/MWh in 2019, while in the EU, they were 285.0 Kg $CO_2$-eq/MWh in 2019. Nevertheless, Brazil runs the risk of increasing the amount of $CO_2$ due to the operation of very old thermal plants and the implementation of new thermal plants.

The insertion of REs (wind, solar PV, biomass, etc.) will help to maintain and increase the decarbonization of the BES. In this context, PVDG is particularly relevant. According to Balance Energy National 2022 (Energy Research Company, 2022), the Brazilian Electricity Sector emitted 118.5 kg $CO_2$-eq/MWh in 2021. In terms of decarbonization, Italy reduced its GHG emissions by 19% between 1990 and 2020.

Nevertheless, in 2020, 57% of Italian electricity was still generated by fossil fuels and 50% by gas (European Environment Agency, 2022). In 2020 average emissions were 342 Kg $CO_2$-eq/MWh for Italy (NowTricity, 2022). Both countries have shown progress in terms of decarbonization and the expansion of modern sources of RE (solar and wind).

However, the Brazilian energy scenario is in a better situation than the Italian one. The former's load base is provided by hydropower (in many cases with several reservoirs in a basin), which can provide more flexible, cheap and emission-free generation and better storage. Italy's load base, on the other hand, is based on gas, electrochemical or power-to-gas storage options. Brazil still has electrification deficits in its more isolated regions (i.e. in the Amazon region) but in cities, electrification is universal. Nevertheless, the poor population in Brazil usually live on the outskirts of cities or in slums (*favelas*), with lower quality or even precarious and illegal access to electricity (Pilo', 2021). In many cases, the inhabitants of the Brazilian favelas resort to power theft (popularly known as "gatos").

Important initiatives to change this situation has been a programme called Luz para Todos (Lights for everyone) and community projects to alleviate energy poverty, albeit incipient (Barroco Fontes Cunha et al., 2021). In terms of electrification, access in Italy is provided to virtually the entire population. Both countries have progress yet to make in terms of electrification. However, the Italian situation is better than the Brazilian one because the latter does not have areas without electrification. It is worth noting that electricity tariffs have increased significantly in recent years in both countries, and the less favoured layers of the population are suffering to pay their bills. Additionally, future increases in demand from electric vehicles and smart cities will add to this in both countries and this will require the adapting of electric distribution grids. Italy already 99% of users fitted with smart metering devices of the second generation.

Conversely, Brazil has less than 5% of consumers with two-way meters for net metering (first generation of prosumers). The number of electric vehicles in Brazil is still insignificant compared to all vehicles and there are only pilot projects for smart cities.

BES as a whole (Generation, Transmission, Distribution and Commercialization) is still relatively little digitized (Junior, 2020), despite the centralized system, coordinated by the Brazilian Electricity System Operator (ONS, 2022), having a robust operation to command and control of the main generations and consumption units in the country. In generation, companies currently implement infrastructures with a high degree of digitalization (automation, control and telecommunication) but the transmission and distribution sectors are much less digitized.

The Brazilian Electricity System Operator (ONS) and the Italian National Electricity System Operator (TERNA) concentrates on the activities of digitalized supervision and coordination of electricity transmission. As a rule, no IoT and Blockchain are still not full available to the final consumer. DG has helped in the digitalization process of the distribution network due to the need to implement bidirectional meters (first smart metering generation). However, only prosumers (less than 4% of consumers) have bidirectional meters. The Italian situation is better than Brazilian since almost 98% of the meters are bidirectional and digital, even from the first generation. In both countries, the electrical network needs significant investments to expand to cope with the new RE centralized generation and to absorb new technologies such as sensors and automatic controls, improving its digitalized tools. The Brazilian and Italian Electricity Sectors are still relatively centralized with large generating plants predominating and probably continuing like this for many decades.

However, the wave of RDG expansion gained traction in Brazil and is turning back in Italy, since the growth in the installed capacity of RDG should increase in the next period. Both countries have progress yet to make in terms of decentralization. Nevertheless, Italy is implementing an incentive system based upon matching local production and consumption with the collective energy schemes. The definitive legal framework is not yet totally clear and operative in 2022 (GECO, 2022). Brazil, on the other hand, has renewed the net metering system, implemented in 2012, in the RDG through federal law 14,300/2022 (Government of Brazil, 2022).

The net metering system made RDG gain prominence in the last decade because it proved to be economically and environmentally advantageous for prosumers.

However, in the medium and long term, distribution companies will need to invest in improvements to their power distribution networks to support the increase in DG systems with the necessary energy quality. In terms of democratization of the energy supply, even with both small and large consumers adopting DG in the analysed countries, both still have much to develop in terms of RDG since this still represents an adhesion of less than 5% of the total population (Energy Research Company, 2022; ANEEL, 2022). In addition, the RDG systems are concentrated in the most favoured regions and social classes. They are therefore failing to reduce energy poverty or promote social sustainability in urban areas and generate a burden on the grid at critical times, such as sunny holiday periods, extreme weather events or Covid lockdowns. Some suggestions for RDG evolution promotion schemes common to Italy and Brazil are:

- ensuring access to relevant information and data, which are indispensable for the planning and constitution of RDG, especially regarding collective energy coordination and sharing;
- integrating existing generation systems and storage (also from electric mobility) in the energy market schemes
- a more significant consideration to the provision of flexibility and ancillary services, incentivizing storage deployment and aggregated and coordinated use;
- promoting awareness by the inclusion of mandatory customized feedback to users on energy savings and energy retrofits to promote carbon intensity reduction;
- enabling users to respond to price signals, promoting behavioural changes, building retrofits and helping to increase the resilience of the electricity grid in the near future.

Local coordination is key to our shared energy future, even if energy markets present a greater degree of complexity and bid data and AI will be disrupted when effectively implemented in the digitalization trend.

Community energy is also a key to citizenship action on the climate crisis. These initiatives are also essential to empower people, boost local economies and reinvigorate communities, holistically creating greener and more positive energy districts.

## 8.6. Conclusions

The information and results point to the trend of RDG growing in Brazil and Italy as relevant and likely to be leveraged through adequate regulations. In both countries, recent legislative processes aim to change the legal landscape regarding the RDG, even if much of the work to reform the energy market in a broader perspective to allow the energy transition is still to happen. Implementing collective schemes by regulators, especially in Italy, remains lacking, causing legal insecurity and preventing investments in new systems.

In Brazil, the Law 14.300/2022 created satisfactory legal security for the RDG. Furthermore, Brazil and Italy are still very new to digitization, decentralization and democratization, in particular, in their respective national electricity sectors.

In both cases, the expansion of RDG helps to advance these three aspects because: (i) it requires the use of bidirectional digital meters and improvements in the command and control of the electrical network, especially at the distribution level; (ii) it enables greater autonomy of consumers to centralized generation, especially if there is associated storage; (iii) with the reduction in costs and the popularization of the RDG, more and more consumers will adhere to its use and, if there are public policies for the poor population, its expansion will be even greater. In Brazil, net metering compensation, confirmed for 2022-2035 in the current legal framework, benefits the wealthier share of the Brazilian population, taking up resources from the sector that could be destined for the most fragile and vulnerable layers of society or reducing energy bills.

In Italy, CEP still needs to be fully authorized and complied with by the sector authorities, and other energy packages are coming fast, such as REPowerEU plan. In terms of electrification, Italy has a higher level of electrification than Brazil, especially in its rural areas.

The differences in HDI and territorial dimensions strongly influence this aspect. Finally, while having an electrical matrix with a large share of renewable energies (hydro, wind, biomass and solar), Brazil is currently decarbonized, but can further expand the use of RE through the RDG.

Italy is still very dependent on fossil fuels in its electricity matrix, and RDG is an interesting opportunity to reduce this dependence and help decarbonise. Thus, in general, RDG can contribute significantly to the 5 main vectors (decarbonization, electrification, digitalization, decentralization and democratization) in the electricity sectors in both countries for energy security and to reduce current energy prices.

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# *Section 3 - Adapting systems and components to Next Generation needs*

# 9. Balancing operational and embodied energy and embodied emissions of greenhouse gases in renovation projects

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With the continuous improvement of the energy efficiency standards for buildings in the European Union (EU) (European Commission, 2018), their operational impacts on the environment get reduced. The newly built or deeply renovated buildings consume much less energy than it was common before and the remaining energy that still needs to be used for the building stock becomes less environmentally harmful to the environment due to cleaner electricity and cleaner sources of energy heat. The energy grids across the EU countries are becoming more and more decarbonized due to increased use of renewable energy systems and gradual phasing out of inefficient coal-based power plants (European Environment Agency, 2022).

There are new initiatives that aim at reducing the climatic impacts of the gas that is so far widely used for heating buildings – we will see the shift from natural gas to synthetic gases, biogas, and hydrogen (European Commission, 2021). Also, the operators of the local heat distribution systems are trying to reduce their environmental impacts by improving the efficiency of heat production and using more renewable energy from solar devices, biomass, and heat pumps.On the other hand, the reduction of the operational energy demand is not for free. It is enabled only by investing more efforts in building design and management, but also by using more and more materials and advanced technologies. In a recent paper, Röck et al. analysed a sample of 650 case studies of life cycle assessments of buildings (Röck et al., 2020) and identified that in standard buildings, the embodied emissions of greenhouse gases account for approximately 20-25 % of the total life cycle emissions, whereas in highly energy-efficient buildings the share of embodied emissions rises to 45-50 %, and in extreme cases even up to 90 %. Therefore, it is necessary to seek various possible ways to reduce the embodied impacts of the life cycle of buildings.

## 9.1. Design strategies for buildings with embodied energy and greenhouse gases

The design strategies for reducing buildings' embodied energy and embodied greenhouse gas emissions were investigated and formulated within the project Annex 57 of the International Energy Agency (Malmqvist et al., 2018) and the efforts continue in the Annex 72 (IEA EBC, 2019). The design strategies comprise four areas (Lupíšek et al., 2016):

- Reduction of the overall consumption of materials throughout the entire life cycle;
- Substitution of traditional materials for alternatives with lower environmental impacts;
- Reduction of construction stage impact;
- Design for the low impact of the end-of-life stage.

## 9.2. Extension of the service lives of the existing buildings and significant reduction of the operational energy demand

Reduction of the need for new construction materials can be achieved by prioritizing the reuse and adaptation of the existing buildings over new construction. The re-use of existing buildings is often challenging, especially in historic city centres with a high concentration of protected heritage buildings. However, in the EU, there is a significant proportion of the existing residential building stock that has been built after WWII, does not carry any special features of cultural heritage and is now due for a major renovation (Economidou et al., 2011). These buildings can easily be transformed to zero energy levels with a low environmental footprint of the used materials. In the past years, there have been carried out various projects showing that such transformation of the building stock is achievable on a large scale with the help of advanced prefabrication techniques (D'Oca et al., 2018; Rovers et al., 2018). Five projects that illustrate such approaches are presented in the following paragraphs.

## 9.3. Examples of extensions of the service lives of the existing buildings and significant reduction of the operational energy demand using prefabricated modules

The first example of a research experiment on a real scale is located in Parallelweg, Mellick, the Netherlands. In this case, an energy rehabilitation of four houses from one row (two ends and two inners, see Fig. 9.1) was carried out. Although all of the houses were originally built at the same time in the same style of coursed brickwork, each of the houses has been treated architecturally slightly differently. The first of the houses, although visually respecting the original facade articulation into individual bricks, is now in dark blue.

*Fig. 9.1 – Parallelweg project: on the right, four houses renovated to zero-energy standard with different architectural designs of the facades, on the left, for comparison of the buildings in their original state (except for new windows).*

*Source: Author's photo archive.*

The second house has a traditional look by local standards, with a reviving element of the balustrade on the first-floor window and a new vestibule. The third house is finished in a deep red render and the fourth house is again visually in brick, in this case, black (Fig. 9.2).

In all cases, the deep energy renovation led to zero energy standards, which was achieved through a combination of savings and the installation of new sources of electricity and heat.

The walls of the houses were insulated using wood-framed insulation panels with 180 mm thick PIR insulation with integrated new triple-glazed windows.

By removing the roof sheathing and replacing it with new panels with integrated photovoltaics, the heat leakage through the roof structure was reduced, and a new source of renewable energy was created.

A further reduction in consumption was achieved by installing mechanical ventilation with heat recovery and air-to-water heat pumps, which are located in the new attachments to the front entrance of each house.

*Fig. 9.2 – Parallelweg project: view of the new facades of the insulated houses. The new vestibules conceal heat pumps and air handling units.*


*Source: Author's photo archive.*

The second example is a project of an energy renovation of 109 terraced houses in Soersterberg (Fig. 9.3).

*Fig. 9.3 – Project Soersterberg: façade timber-based renovation panels off-loaded from the truck in steel stands are being lifted to their final location.*

*Source: Author's photo archive.*

The builder was BAM Wonen, which achieved zero-energy standard through a combination of external insulation with prefabricated modules, replacement of the roof structure with prefabricated thermal insulation panels with photovoltaic roofing, the introduction of mechanical ventilation with heat recovery and installation of heat pumps. BAM Wonen, which owns the houses, took advantage of new legislation in the implementation of the project, which makes it possible to merge the rent and rebilled energy bills into one item and work with it to finance energy-saving measures. Thus, tenants continue to pay the same amount, but part of it is used to pay off the energy rehabilitation investment.

The following photos show the construction works at various stages of development. The entire renovation of one house is planned for one week of work. The project starts with clearing the ground around the house and digging a shallow trench along the foundation into which the foundation insulation boards are installed. The tenants remove their furniture from the perimeter walls. Scaffolding is then erected around a group of houses, a gap is left between the façade and the wall.

The facades are cleaned and the window joints are exposed. Steel hooks are fitted for hanging the insulation panels. Then arrive trucks with the prefabricated panels. These are transported in steel stands so that they can be quickly unloaded from trucks by crane. The panels have a load-bearing timber frame consisting of a column structure filled with thermal insulation, with stiffening plates on both sides. On the outside, there is an external thermal insulation composite system, imitation brick strips made of aggregate and elastic binder are used as the facing layer (so there is no risk of cracking or other damage during transport and handling). The panels are fitted with new windows with triple glazing.

*Fig. 9.4 – Project Soersterberg: façade timber-based renovation panels off-loaded from the truck in steel stands are being lifted to their final location.*

*Source: Author's photo archive.*

The panels are lowered between the house and the scaffolding (Fig. 9.4) where they are guided into place by three workers who install them on prepared steel anchors.

Compression strips level out the unevenness between the insulated wall and the panel. Once the wall panels are in place, the old roof tiles are removed and on the existing rafters is added a layer of additional thermal insulation, new roof flashing, and a new photovoltaic system.

The project also includes new additions that house air handling units with heat recovery, heat pumps (either air-to-water or ground-to-water depending on the location), and a hot water storage tank. They are delivered as a completed 3D-prefabricated unit and just stand on a prepared lightweight foundation (Fig. 9.5a/b).

The heat pump is connected to the pipes of the heating system and the ventilation and exhaust air pipes pass through the wall on the ground floor ceiling level.

*Fig. 9.5a/b – Project Soersterberg: Left: façade timber-based renovation panels fixed on the existing wall. Right: 3D-prefabricated technical unit containing air handling units with heat recovery, heat pumps, and a hot water storage tank. The heat pump is connected to the pipes of the heating system of the house and the ventilation and exhaust air pipes pass through the wall at ground floor ceiling level.*

*Source: Author's photo archive.*

*Fig. 9.6 – Project Soersterberg: A fully renovated house to zero energy level (right) compared to one that did not undergo any renovation upgrades (left).*

*Source: Author's photo archive.*

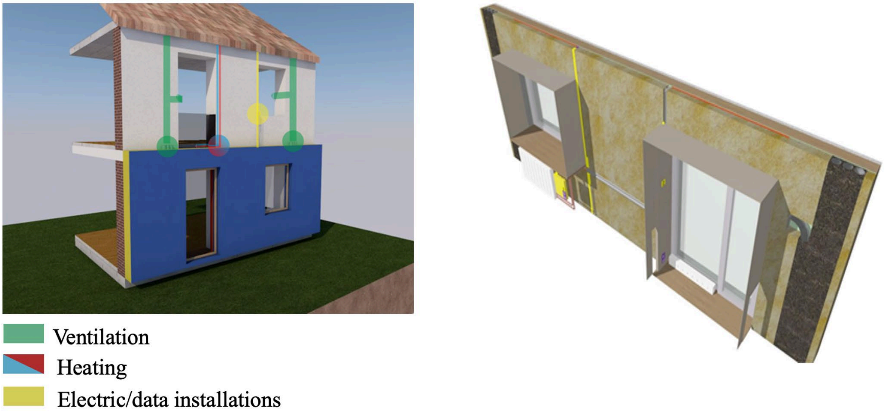
A photo of a block of buildings after finishing renovation to zero energy standards is in Fig. 9.6.

The third example of a modular renovation package is the modular retrofitting package for Central-European multifamily residential buildings with integrated HVAC systems and renewable energy sources developed in the MORE-CONNECT project (Hejtmánek et al., 2017).

The renovation package consists of integrated, prefabricated timber-framed add-on modules for façades, roofs ones, and an engine room with necessary energy sources (Fig. 9.7a, left). The usual wall module consists of one layer of soft, fibral thermal insulation, a secondary main thermal insulation layer in between the main timber frame, and a tertiary layer in the façade thermal insulation.

This diverse layering allows variation of different total thicknesses or U-values of a complete system. Besides the provision of thermal protection, the modules provide several other functions: ventilation piping, hydronic heating plumbing, electric-driven shading, and internet and TV wiring (Fig 9.7b, right).

*Fig. 9.7a/b – MORE-CONNECT: Timber-based modular retrofitting system for central-European multifamily residential buildings. Left: Basic principle of add-on wall panels with integrated ventilation, heating, and electric installations. Right: Visualisation of a typical wall panel.*




*Source: MORE-CONNECT project visualisations.*

Detailed composition and system description was published in the project's Deliverable 2.2 (Volf et al., 2019). The system was tested on a pilot building in Fig. 9.8a/b/c.

*Fig. 9.8a/b/c – MORE-CONNECT*
*a: Prefabrication of the timber-based modules in a production factory RD Rýmařov.*

*Source: Author's photo archive.*

*b: Installation of modules onto a pilot building.*

*c: Finished pilot installation.*

*Source: Author's photo archive.*

The system was developed with low embodied impacts in mind – there was made a comprehensive analysis of the life cycle impacts of various compositions, and they were compared with the competing building solutions used for deep energy retrofits. The analysis comprised life cycle costs related to life cycle energy consumption and life cycle greenhouse gas emissions. The documentation of the whole study is available in an open-access paper (Sojkova et al., 2019).

The fifth example is a prefabricated curtain walling system envelope for a wide range of building types with a significantly reduced carbon footprint made from natural materials. The innovative system was developed by the University Centre for Energy Efficient Buildings of the Czech Technical University in Prague (UCEEB) to significantly reduce the embodied energy and greenhouse gas curtain walls.

*Fig. 9.9 – Envilop: composition of a typical wall module of the curtain walling system based on natural materials.*


*Source: Official envilop brochure.*

Its modules consist of a structural system made of laminated veneer lumber (LVL), which is a more robust and stable alternative to natural spruce timber.

It uses thermal insulation made of wood fibre and features special windows in the passive house standard. Detailing around the external Venetian blinds is made of cork, and the typical external cladding is made of Thermowood (see composition in Fig. 9.9). Example of a look of a real installation is in Fig. 9.10.

Detailed information on the development of the system, including its technical parameters and environmental impacts, is available in the paper entitled Application of building design strategies to create an environmentally friendly building envelope for nearly zero-energy buildings in the central European climate (Volf et al., 2018).

*Fig. 9.10 – Envilop: Experimental assembly on the southern façade of the University Centre for Energy Efficient Buildings of the Czech Technical University in Prague.*

*Source: Author's photo archive.*

## 9.4. Conclusion

Modular retrofitting systems based on prefabricated panels made of timber-based building components with integrated renewable energy systems and highly efficient HVAC technologies represent a viable solution for deep energy renovations of buildings with a balanced ratio between operational and embodied energy and emissions of greenhouse gases.

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# *10. Embodied Energy in building's environmental impact balance*

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About half of non-renewable resources depleted across the planet are used in the construction industry (Doan et al., 2017), which is also responsible for almost 50% of the global emissions of greenhouse gas (Edwards, 2014). Buildings generate significant impacts on the environment during their entire life cycle, from construction to disposal, albeit with different intensity and dynamics at each stage (Cabeza et al., 2014).

Among these impacts, the production and use of energy are acknowledged as the main – although not the only- responsible for environmental endangerment, as building energy supply is stills relies mostly on fossil fuel combustion, which strongly contributes to GHG emissions and derived impacts (Röck et al., 2020).

In the EU, buildings account for 37.5% of total final consumption (TFC) of energy, especially due to space and water heating, which are the two largest uses, together representing 80% of buildings' final energy consumption (Eurostat, 2022).

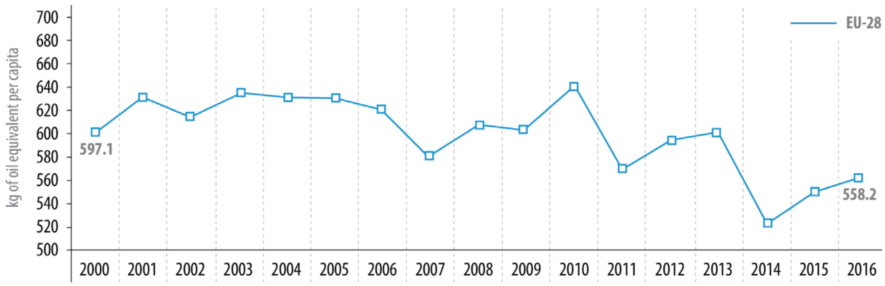
## 10.1. Targeting on downing Operational Energy

Since the energy demand for the building functioning had been identified as – and often continues to be – the predominant component of the building's overall energy balance (IPCC, 2007; Verbeeck and Hens, 2010; Anderson and Thornback, 2012), increasingly stringent energy standards have adopted worldwide, and especially in EU in last two decades, targeting to reduce it. Such policies aim at downing the energy demand which is required for maintaining indoor comfort conditions and supplying ordinary maintenance of the buildings during their long life cycle.

This share of energy is defined as Operational Energy (OE) and mainly includes energy for HVAC (heating, ventilation and air conditioning), domestic hot water, lighting, and running appliances of buildings (Dixit et al., 2010; Cabeza et al., 2014). Indeed, all the more advanced regulations, like the 2010/31 European Directive on Energy Performance of Buildings (Directive 2010/31/EU) and the following Directive 2018/844 (European Commission, 2018), address in reducing the building's OE, as well as fueling it with renewable sources.

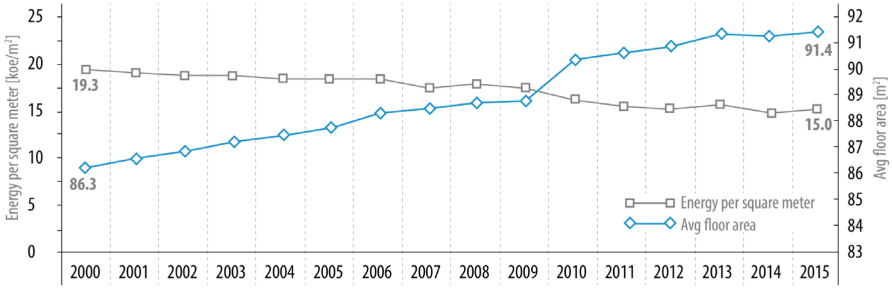
Thanks to these measures, the energy consumption and related emissions of new and refurbished buildings have been shorted within the European context in the last 20 years (Wittstock et al., 2012). Although the recorded rate of reduction is slower than would be desirable, the available data for the EU confirm this trend, as shown in Figures 10.1, 10.2 and 10.3.

*Fig. 10.1 – Final residential energy consumption per capita in the EU-28, 2000–2016.*



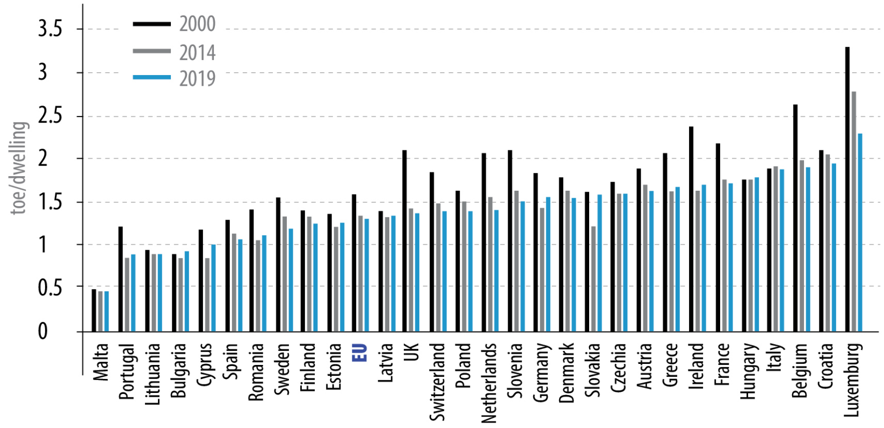

*Source: Elaborated by the author, based on Eurostat data (2022).*

*Fig. 10.2 – Final Energy Consumption (FEC) per capita in the residential sector by EU-28 member state, in 2005, 2010, and 2016.*




*Source: Elaborated by the author, based on Eurostat data (2022).*

*Fig. 10.3 – Average final energy per unit of area and average floor area in the EU-28, 2000–2015.*




*Source: Elaborated by the author, based on Odyssee Database.*

## 10.2. The increasing relevance of Embodied Energy share in buildings

However, several studies highlight that the more stringent energy standards lead to enhancing the energy performance and reducing the impacts of the building operational phase, while raising instead those relating to materials and components which are required to allow the buildings to achieve those benefits. The envelope insulation and airtightness – as well as the adoption and possibly integration of both mechanical ventilation systems (CMV) and devices allowing the exploitation of renewable energy sources (RES) – play indeed a crucial role among the design strategies that can be applied to reduce the building in-use energy demand (Stephan et al., 2013).

This means that the less energy the building requires to function, the greater the quantity of high-performance materials and equipment it must be equipped with. This leads to an increase in Embodied Energy (EE), which is the energy demand due to the production, supply, maintenance and disposal of those elements. Although some differences emerge in the literature about the EE definition (Dixit et al., 2010; Cabeza et al., 2013), all the scholars converge in considering EE as the share of energy "hidden" within the materials and technical installations needed by the building process, which are crucial in providing the on-duty behaviour of the building itself.

Much evidence can be found in the literature regarding the growing relevance of EE in relation to OE reduction, especially when OE levels are significantly lowered, like in high-energy-efficient buildings (Azari and Abbasabadi, 2018).

Among others, Optis and Wild (2010) studied a set of high-energy-performance buildings found in 20 journal articles, observing that the EE varies between 2% and 51% of the Total Life Cycle Energy, while OE varies between 98% and 49%. Based on a deep survey they carried on 60 LCAs of buildings from 9 countries, Sartori and Hestnes (2007) have shown that the EE of low-energy buildings spanned from 9 to 46% of the Total Energy demand, while it ranged between 2 and 38% in traditional ones.

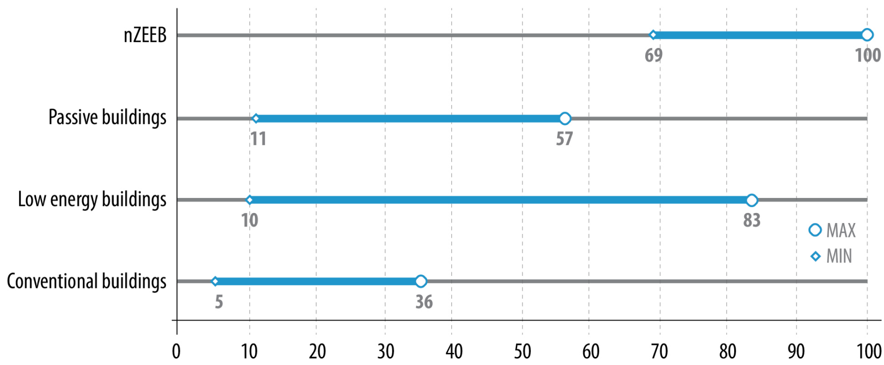
Further evidence of the EE/OE dependencies is also documented by Thormark (2002) and reiterated by Chastas et al. (2017) on the basis of their study on the total life cycle energy of 90 residential buildings from around the world (Europe, North America, Oceania, Asia) with a time horizon ranging between 1997 and 2016 and including conventional, passive, low-energy and nearly zero energy residential buildings (nZEB).

Among this large set, they proved that the portion of Embodied Energy in the total life cycle energy of the case studies ranges between 5% and 100% characterised as follows: in conventional buildings, it ranges between 5% and 36%; in low energy buildings, this percentage varies between 10% and 83% (or between 23% and 58% when excluding particular case studies); in the passive case studies, it ranges between 11% and 57% while the nZEB share of embodied energy varies between 69% and 100%. Fig. 10.4 below shows the study outcomes.

Asdrubali et al. (2013) confirm the trend according to the outcomes of LCA they performed on different conventional Italian buildings.

Again, Azari and Abbasabadi (2018) provide additional evidence showing that EE represents 10 to 12% of the life cycle energy consumption for conventional buildings, while it reaches 31 to 46% in those with enhanced envelope insulation. Based on this evidence, they argue that further increases in the EE/EO ratio could thus be expected by 2050, as a direct effect of the more intense adoption of measures for building OE reduction.

*Fig. 10.4 – Embodied energy share [%] in different types of buildings.*




*Source: Elaborated by the author, based on Chastas et al., 2017.*

If buildings are more performing in terms of OE down significantly their energy demand, nevertheless it has been shown that those benefits are less than it appears when the sole on-duty-efficiency is considered. This is because of the energy required to make the building soberer. Therefore, further measures must be taken to prevent the impacts inherent in the upstream and downstream stages of the building processes (Ding, 2014; Campioli et al., 2018).

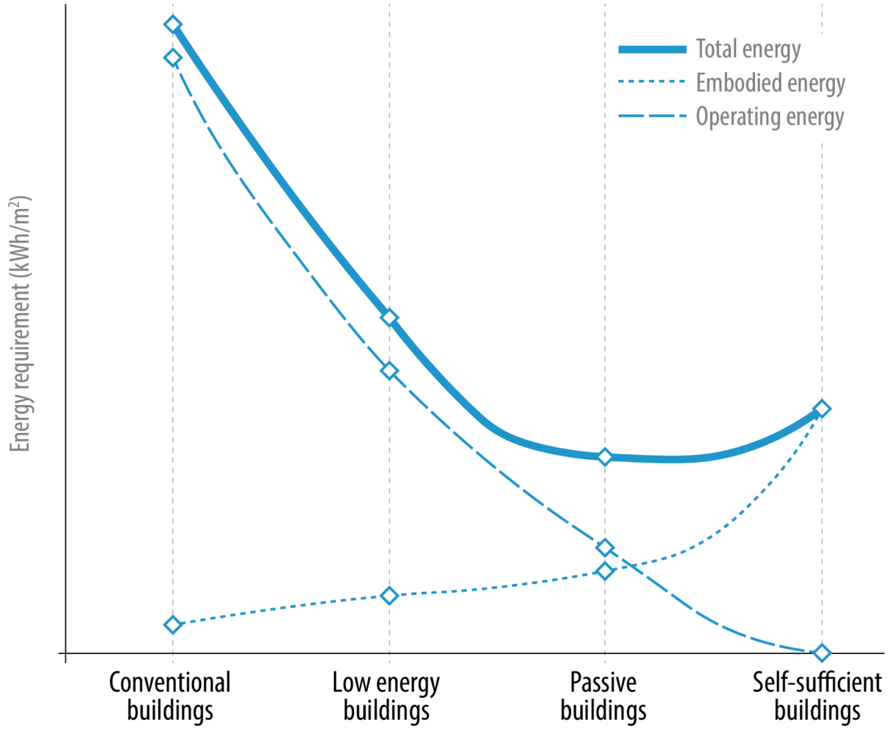
## 10.3. Remedy the underestimation of the Embodied Energy share: why and how

Although a reliable reference value for OE/EE ratio cannot be derived so far due to the lack of standardised assessment methods allowing global surveys, the literature outcomes confirm that the OE reduction always increases the EE, as well as other environmental impact indexes.

Two main consequences can be derived from this widely documented and shared finding. Firstly, a building energy balance focusing on just OE leads to some relevant elements being underestimated, significantly affecting the perception of the environmental impact of the process, especially when effective measures have been adopted to reduce the building OE. Secondly, the challenge to reduce the building-in-use energy demand till the achievement of a "near-zero-energy" standard seems to lead to a substantial increase in the building EE, which can equal and even exceed that related to its OE (Chastas et al., 2016).

This risks triggering a boomerang effect whose ultimate outcome is to intensify the overall building energy consumption rather than decrease it. (Sartori and Hestnes, 2007; Chastas et. al, 2017).

*Fig. 10.5 – Comparison of operational energy and embodied energy for different types of buildings.*




*Source: Elaborated by the author, based on Copiello, 2017.*

When observing this short circuit, some scholars evoque the "Jevons paradox" (Palumbo and Politi, 2018) and suggest that an optimal level of OE must be identified (Copiello, 2017), corresponding to that which is capable of paying off the larger amount of EE which is needed to achieve lower consumption during the building life service cycle (Palumbo et al., 2019) (Figure 10.5).

### *10.3.1. The building whole environmental balance*

Since it is the underestimation of the EE share that mainly perturbs the correct perception of the building energy balance, effective means are needed to be deployed able to quantify not only the building in-use needs, but also the hidden energy that the building has required to be made operational.

This especially concerns the energy embodied within the materials and devices equipping the building itself. According to several scholars, the most appropriate tool for gauging this energy content is LCA (Proietti et al. 2013), as the method is able to provide an analytical, reliable and life-cycle-spanning quantification of the direct and indirect environmental impacts of a production process, using recognised metrics and indicators (Sartori and Hestnes, 2007).

> *Life-cycle assessment (LCA) is a process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities. It can be used to study the environmental impact of either a product or the function the product is designed to perform. LCA is commonly referred to as a "cradle-to-grave" analysis.*
>
> *LCA's key elements are: (1) identify and quantify the environmental loads involved; e.g. the energy and raw materials consumed, the emissions and wastes generated; (2) evaluate the potential environmental impacts of these loads; and (3) assess the options available for reducing these environmental impacts.* (EEA, 2017)

LCA is an internationally standardised methodology concerning both the procedure to conduct the assessments (regulated by the ISO 14040 series) and specific standards for implementing it (among others: ISO 14067:2012 Carbon Footprint of Product; ISO 14064: 2016 GHG Organisations; ISO

14046:2014 Water footprint products; ISO 21930:2017: EPD (Environmental Product Declaration) for the building construction) (Lavagna, 2022).

Standard methodologies for the assessment of the cycle of life impact of both products and organisations have been developed in the EU too. The EN 15804 and EN 15978 standards provide a methodological framework for LCA and establish guidelines for carrying out the assessment stages and communicating their outcomes (Soust-Verdaguer et al., 2016), while EN 15643:2010 defines how to evaluate the sustainability of buildings, EN 15978:2011 provides the calculation method for evaluating the environmental performance of buildings, and EN 15804: 2012 regulates the EPD environmental declarations for construction products (Ganassali et al., 2016).

Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) are the two parts in which the LCA process is structured. LCI is the collection and analysis of all the data concerning the environmental profile of a product, from the extraction of the raw materials it includes to its final disposal at the end of its operational life.

This data includes the emissions to air and water, waste generation and resource consumption which are associated with the product all along its life cycle. LCIA is the calculation of the environmental impact of the product, performed by using suitable indicators (e.g. climate change, summer smog, resource depletion, acidification, human health effects).

### *10.3.2. Issues in performing LCA of a building product*

While the EO can be estimated by simulating the energy behaviour of the building based on thermodynamic principles (as is done, for example, by using an EPBD-compliant dynamic simulation software), specific knowledge and caution are required to perform an LCA analysis for EE calculation.

Despite the LCA approach has been progressively structured in the last decades, and it is now equipped with a robust methodological framework, several Authors identified indeed some barriers affecting the application of LCA in the building sector, especially when the analysis is targeting materials (Rønnin and Brekke, 2014).

These issues affect both the inventory stage and the data interpretation stage of the assessment process (Politi et al., 2018).

The difficulty in collecting all the significant data needed and the scarcity of harmonisation on how to compare the retrieved information are the troubles that mostly affect the LCI stage.

The main issue concerns the strong dependence of the outcomes on the availability and reliability of robust data sources, as well as the quality of the provided data, as they strictly depend on the production geographic location, process, and plants (Ding, 2014). Thus, the sources from which the products and processes emission values are taken strongly affect LCA outcomes, besides being influenced by climatic conditions, context features and building characteristics (Optis and Wild, 2010).

While the LCIA n stage mainly suffers from the margins of arbitrariness that are still influencing the results, the lack of cooperation by product manufacturers, and the difficulties in understanding LCA results (Bribián et al., 2009). Additionally, adopting a life cycle approach requires a complex prevision of the service life of building materials, which depends on many variables, such as the users' life patterns, the maintenance cycle, the climatic conditions and the workmanships performed during design and construction.

The typical wide life-cycle span of the buildings, as well as the huge number of processes and players involved within the building process, can seriously jeopardise the consistency and reliability of these elements, thus the assessment effectiveness.

This means that the assessment can suffer from inaccuracy and unreliability of the methodologies, as well as from the great variations and lack of homogeneity in EE available databases (Dixit et al., 2010).

In addition, the insufficient documentation used to quantify the EE could make ineffective the data obtained by the LCA in order to compare different scenarios (Optis and Wild, 2010).

This complexity and uncertainty lead to the most frequent criticisms addressed to the LCA, which stress the complicated calculation and high cost required to perform the assessment.

## 10.4. Filling the gaps

In order to mitigate the relevant negative effects on the environment arising from the building processes, reliable measures of all the related impacts are needed.

Most of these impacts are still depending on the energy that the building process requires in all its stages, especially due to the high share of fossil fuels used for this purpose, with the relevant amount of GHG emissions their combustion generates. Also, thanks to the strong regulatory pressure in this direction, the energy required to operate the buildings during their on-duty stage (OE) is downing, and further reductions are expected in the next future, especially in the EU, whose entire building stock will have to comply with the “zero energy” standard by 2050 (Global Alliance for Buildings and Construction, 2020), according to the ambitious goals the Union have set to reach in this field.

Although the current downing rate of the OE in European building stock cannot assure the target will fully reach, these policies will certainly reduce the environmental impact the building cause. However, several scholars demonstrated that the decrease in OE leads to an increase in energy required to make the materials, components, and devices by which the building is equipped for the purpose of downing its energy demand in operating. By becoming part of the building, indeed, these elements carry in it the energy content they embody (EE).

The underestimation of this hidden component of the building energy balance risks disrupting the quantification of the real size of the impacts that the building process causes on the environment, therefore of hinder its effective zeroing. The development of effective methods for determining the EE of buildings is thus crucial and urgent.

The Life Cycle Assessment (LCA) is recognised as the more effective approach that can be adopted to estimate the building EE, based on measuring the energy required by the production process of each element the building is supplied with.

Unfortunately, applying this method still presents some difficulties, especially in the building, mainly to the lack of the data needed to fuel the impact calculation of the huge number of different products supplying the construction processes.

Therefore, the definition of the environmental profile of a product through the execution of an LCA requires considerable amounts of time and work, which, however, sometimes leave some uncertainty regarding the reliability of the result and its applicability as an effective criterion for evaluating competing products.

Despite this, the number and variety of EPD-equipped construction products are increasing, and this could improve the situation, even if the process is proceeding very slowly, mainly due to the above-mentioned uncertainties on the modalities and indicators to be used for environmental declarations, with consequent delays on the part of the manufacturers to release EPDs.

As a result, there are still very few construction products with EPD available on the market, which prevents building energy balances that include all components and not just the OE. However, the significant and growing weight (especially for high-energy performance buildings) of the contribution of EE to the environmental balance of the building remains difficult to determine, mainly due to the lack of both reliable data on the environmental profile of building materials and components and common protocols to calculate them (Din and Brotas, 2016).

This requires intervening on LCA protocols to make them both more reliable in results and less time-consuming, and less expensive to implement. To support this action, a more convincing contribution from the manufacturers is decisive.

First of all, to support study and research activities aimed at improving the effectiveness and applicability of the procedures with which to determine the environmental profiles of products. Secondly, to develop products and increase the supply of lower impact construction products equipped with EPD widely recognised by all the actors of the building process.

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# *11. Bamboo utilisation as a sustainable approach in shaping the diverse built environment: key values and challenges for Vietnam*

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*Green bamboo, ever green?*
*Once upon a time… there was a green bamboo bank*
*Slender body, fragile leaves*
*How have you brought cities to life?*

## 11.1. Introduction

This poetic excerpt is named *Tre Viet Nam* (Vietnam's Bamboo), which is one of the most popular poems in Vietnamese literature. It is taught in every primary school, and almost every child in the country grows up reciting it. There are three important things in the poem that the personified bamboo is associated with, which serve as the raison d'être for this work: the utilitarian longevity of bamboo in Vietnam's history; the culturally connotative value of bamboo properties; and the significance of bamboo materials in founding the country's ancient built forms – citadels, fortresses and their defence walls. Not only does bamboo appear in poetic literature, but it is also found in scientific investigations (such as in Tran Viet, 2010; Tran Van, 2021; Vuong et al., 2021). This resource is historically and culturally significant to Vietnamese people. The use of bamboo in the construction of the basic built forms has been essential to the survival of the local community since ancient times.

To date, bamboo in Vietnam, however, has gradually lost its ubiquity due to the advanced development in building and material technology as well as the changes in human preference towards the built environment. Here, the built environment is used in a broader sense, which is defined as any physical alteration of the natural environment by humans through construction

(Lawrence and Low, 1990). Many industries, including interior design, civil engineering, architecture and garden/park design, have been established as a result of this physical alteration. Within these industries, there has been a surge in the use of modern materials and elements such as glass, metals and other composite materials. These materials are preferred and widely commercialised due to their advanced qualities regarding endurance and convenience, which are often considered to keep pace with and fitting well the discourse and image of modernisation and industrialisation (Snoeck and Belie, 2015; Naser, 2019).

As a consequence, bamboo utilisation in Vietnam has been devalued, poorly recorded in scientific literature, and bamboo has lost its significant contribution in the built environment. It is a common trend in a developing process, mostly in rural areas, that when the income of a household increases, bamboo will be the least favourable option for housing construction, interior furniture or fencing.

There are considerably fewer houses built with bamboo materials and bamboo-based structures, which once were popular in rural areas, only now can be found in the house of some minority ethnic groups (Dinh Thi and Hai Ha Thi, 2017; Vuong et al., 2021). Furthermore, nearly 70% of bamboo products used in construction have low value (Tran Van, 2021), despite the fact that approximately 50% of rural houses rely on bamboo material and about 50% of harvested bamboo components are used for construction activities in Vietnam (Tran Viet, 2010). Other applications of bamboo in furniture design and garden/park landscaping have stayed under the academic radar, mostly mentioned in newspapers (Nguyen, 2018), architectural collection or commercial websites.

However, recently bamboo is innovatively used for industrial development in Vietnam, including the construction of commercial buildings, for international architectural competitions and for exhibition-related purposes. These innovative ways of utilising bamboo are highly valued in terms of aesthetic satisfaction, cultural significance and environmental friendliness. The proponents of bamboo usage in this manner clearly approach their work in line with the perspectives of sustainable development and climate change, which emphasises the use of environmentally friendly, economical and culturally significant materials. Interestingly, it can be seen that there are two confused associations in evaluating the value of bamboo resources.

On the one hand, bamboo materials and elements are associated with the poor as being traditionally considered as "the poor man's timber". On the other hand, they are being utilised to boost the optimal values of the built forms associated with sustainability and modernity. The purpose of this work, therefore, is twofold: firstly, to scholarly examine the promising values of bamboo resources in order to have a better understanding of the nature of the two opposite trends and then introduce the innovative applications of bamboo materials and elements in interior design, construction, architecture and garden/park design in Vietnam from a sustainability perspective in order to have a clearer picture on how these values are cherished in these fields; and secondly, to identify main shortcomings hampering the promotion of bamboo uses in these industries, thereby calling for more scientific investigations into these challenges as well as offering some prospects for future utilisation of bamboo with a more sustainable orientation.

## 11.2. Bamboo's ecological background in Vietnam

### *11.2.1. Location and biodiversity of bamboo plants*

Bamboo literally can grow everywhere in Vietnam with diverse species. This is due to climatic conditions characterised by a generous solar radiator, moisture and different latitude and topography. Different species of bamboo plants grow in natural forests, mixed forests, and plantations, or they can splinter around or inside villages. There are about 1.4 million hectares of bamboo area in Vietnam, of which approximately 1.1 million hectares are mixed forests, around 245,073 hectares are natural bamboo forests and the rest are bamboo plantations (IMBAR, 2019; MARD, 2020). This names the country the top four countries in the world owning a large bamboo area amongst China, India, Myanmar, Indonesia and Thailand (Tran Van, 2021). These numbers record bamboo forests and plantations, while other splintered bamboo areas in some flat delta regions often stayed unmeasured. In terms of bamboo biodiversity, nearly 200 species of bamboo belonging to around 20 genera have been found in all regions across the country (IMBAR, 2019).

### *11.2.2. Biological properties of bamboo for the built environment*

All bamboo species are the fastest-growing grass-woody plants on the planet. Within a matter of two to four months, most bamboo species reach their full height and diameter, and some species can give wood with high quality in only 5 years compared to that of 20 to 50 years of other woody trees (Ben-zhi et al., 2005). As such, it is arguable that bamboo could be the highest yielding renewable and sustainable resource, regarding their ability to constantly provide new plants and raw materials, and their capacity to rapidly reduce heat, and moisture as well as absorb and store $CO_2$ (Ben-zhi et al., 2005; Faisal and Kinasih, 2010). Bamboo characteristics highlighted in the system of joints and culms which come in different shapes and sizes are sustainably beneficial. This system provides bamboo with a wide range of properties, including strength, smoothness, straightness, lightness, hardness and the facility and regularity with which they can be split to change shapes and sizes. It also makes bamboo stronger than other materials such as wood or timber in terms of tension and compression, as well as two times stronger than steel regarding tensile strength (Faisal and Kinasih, 2010). Bamboo is also considered to be able to strongly resist earthquake and wind forces owing to its pipe-shape and elastic fibre (López, 2003). At the same time, bamboo is biodegradable since it is vulnerable to damage from biotic sources such as fungi, termites or worms, which makes it environmentally friendly regarding disposing of used and redundant bamboo materials. Additionally, differences in height, diameter, shapes and sizes of culms, branches, and leaves of all bamboo species are highly potential for versatility of usage. This regards to improving the visual preference and qualities of the built environment, including aesthetic pleasantness, mystery, excitement, and restoration of various places (Nasar, 1995). Also, being evergreen in colour is another property that makes bamboo materials and elements perfect for "green" development or environmental friendliness connotation and association.

## 11.3 Promising values of bamboo in sustainably shaping the built environment

There has been an extensive amount of research conducted worldwide on bamboo utilisation in the built environment from the perspective of sustainability. Most research agrees that the benefits and value of bamboo can be evaluated on its cultural, environmental, economic, psychological, and aesthetic contributions, all of which are discussed as follows.

### *11.3.1. Environmental value*

Environmentally, bamboo's contributing value in the built environment is examined as a living plant and as a material. As a living plant, bamboo's fastest ability to grow and mature is the greatest attribute to benefit the natural environment, solve environmental problems and improve micro-climate in any built forms. Except for saline soil, bamboo can grow in other types of soil and adapt extremely well to different climatic conditions. It was the last plant that survived the radiation of the nuclear bomb, and the first plant grew back from the ruins of Hiroshima in Japan (López, 2003; Yu, 2007; Faisal and Kinasih, 2010). These abilities accompanied by its high adaptability and multiple capacities, such as strong land holding, fast water absorption, fast carbon sequestration and fast oxygen release, make bamboo highly valuable when being grown in various human-made spaces like parks, gardens and outdoor spaces.

As a material, bamboo is often assessed by using Life Circle Analysis (LCA) – the leading tool providing a framework for assessing the environmental impact of products and services. Within the LCA framework, the lifecycle phases of bamboo materials and products, including harvesting, transporting, processing, storage and usages are assessed against environmental sustainability performance. Collectively, many studies confirm that bamboo materials are highly environmentally valuable in terms of having low impact to the environment in all lifecycle phases (Escamilla and Habert, 2014; Vu and Nguyen, 2020) and requiring less energy and emitting less carbon dioxide in manufacturing, designing and constructing process (Manandhar et al., 2011).

### *11.3.2. Cultural value*

Bamboo has a significant contribution to the development of Vietnamese culture as well as that of many other countries whose development involved utilising bamboo materials and elements. This is due to its long and versatile usage in everyday life, its culturally representative medium and its cultural connotation in poetic literature, paintings and philosophy (Yu, 2007). It is its representative cultural roles and cultural connotation that fundamentally make this resource as a motive for its utilisation in the built environment and as a criterion of cultural significance in this domain from a sustainability's point of view. Cultural research on bamboo has used the term "bamboo culture" to represent many countries in Southeast Asia, especially China and Japan (Jiayan, 2014; Mulyono et al., 2017; Nirala et al., 2017; Song and Zhou, 2019). In China, bamboo culture has been developed and evolved as an integral part of Chinese civilisation. Bamboo has a strong ethical and moral association with Chinese people, symbolising perseverance, modesty and a style of a gentleman (Nirala et al., 2017). These associations have penetrated into multiple aspects of material and spiritual life of the Chinese, which is what people in the country have a great sense of pride about

(Yuming and Chaomao, 2010). As being strongly influenced by Chinese culture, bamboo is also culturally significant to Japanese and Vietnamese people. In addition to its materially extensive usage in these two countries, bamboo at the same time represent and symbolise prosperity, purity and nation's idea of advocating nature in Japan while carrying symbolic meanings of straightforwardness, hard-workingness, optimism, unity or brotherhood in martial art in Vietnam.

### *11.3.3. Aesthetic and psychological value*

Dialectically related to cultural value – as an intangible or non-visual dimension of aesthetic value – bamboo's visual contribution to creating a sense of place and enhancing the positive psychological development of humans in place making is also worth of acknowledgement. From a place-making viewpoint, bamboo, bestowed with a wide range of biological characteristics, has a huge potential to improve the physical dimension of a place and invoking human feelings and arousal, thereby improving place attractiveness. Different bamboo plants with distinctive heights, shapes, colours, patterns of culms and so forth can be used as hedges, live fences, windbreaks and bonsai plants in parks, gardens and other open spaces between buildings to improve the visual quality (Roxas et al., 2000). Bamboos in this sense, can be seen as a valuable ornamental element in architectural landscaping, which can be flexibly combined with other elements such as rocks, water and other plants (Dong, 2010; Jiayan, 2014). Furthermore, bamboo culms' flexibility and elastic quality are highly useful in furniture design as various products and objects that are aesthetically intriguing can be manufactured.

In psychological terms, recent studies have found that bamboo used as an ornamental element has positive effects on human psychology. Wang et al. (2021) meticulous work on bamboo visual characteristics, including the shapes, sizes and colours of different types of bamboos shows that viewing different ornamental compositions of different bamboos can reduce high blood pressure and alleviate the negative mood. This finding is supported by Hassan et al. (2017) experimental study on the psychophysiological impacts of bamboos on adults. By using a special device examining human brainwaves, the research concluded that contact with bamboo plants enhances the level of relaxation and attention, thereby improving an individual's work performance (Hassan et al., 2017). In light of these findings, utilising bamboo innovatively and creatively in various built environments would create more positive places, improving human psychological processes and also physiological functions.

### *11.3.4. Economic value*

Bamboo's rapid growth and high adaptability allow it to have a sustainably economical value. This value generated through two mechanisms, which are the cost of the material and the opportunities for income generation for local people. The former is more relevant to the scope of this study, focusing on the built industries. The fact that bamboo is locally available in almost every region in Vietnam, as well as many other countries in the Global South, makes it a cheap raw material for the local communities with limited sources of income (Nurdiah, 2016). For industrial development, locally grown bamboo also provides raw materials and processed materials with a lower price compared to other materials such as wood or metal. This is due to the reduced costs in harvesting, processing and transporting (Lugt et al., 2006). In addition, the construction of simple bamboo-based structures in architecture or civil engineering is economically beneficial since bamboo naturally lightweight, elastic and easy to assemble, which results in time reduction and low labour costs (Manandhar et al., 2019).

## 11.4. Value manifestations of bamboo in the built environment

The chapter, this far, has discussed the potentiality of bamboo regarding its nationwide distribution in Vietnam, and its dynamic biological characteristics resulting in its sustainable values contributing to the built environment worldwide. Academic studies have extensively examined how these values are manifested in the built environment industries in many countries, such as in China (Yuming and Chaomao, 2010; Jiao and Tang, 2019), India (Kithan, 2014; Das and Sarkar, 2018), Indonesia (Mulyono et al., 2017), Malaysia (Idris et al. , 2014) and African countries (Fikirie et al., 2017; Dalbiso and Nuramo, 2021; Borowski et al., 2022).

This section will introduce the utilitarian manifestation of the aforementioned values in interior design, architecture, construction and garden/park design to reveal how these values are embraced and fostered in the built environment in Vietnam.

### *11.4.1. Bamboo utilisation in interior design*

The practical use of bamboo as materials and elements in interior design in Vietnam includes floor-wall-ceiling installation, furniture design and interior decoration. Each use reflects distinctive values, which depend on how bamboo is used, either in processed (engineered) or unprocessed (with round culms) ways.

*Bamboo floor-wall-ceiling*

Although not being developed a decade ago, bamboo flooring, walling and ceiling have been popularly commercialised by many local bamboo enterprises such as Bamboobuild (https://bambubuild.com), Bambooali (https://bambooali.com), Trelife (https://trelife.vn) or Vinatre (https://vinatre.vn). These applications are considered stylish, upstream and have a strong sense of social and environmental responsibility (Nguyen, 2018). The internal envelope made with a bamboo wall, floor, and ceiling is also highly suitable for humid climatic conditions in Vietnam, more economical as being cheaper than wood or granite-installed floor and also is considered to bring good health to the residents.

*Furniture design*

A wide range of products has been used inside the house and apartment of many Vietnamese people, either in a traditional or modern lifestyle. These products are both creatively hand-made and manufactured using bamboo culms and laminated bamboo. Bamboo furniture includes partitions, tables, chairs, sofas, beds, kitchen cabinets and many others, all of which have been innovatively designed to suit well a modern taste and to be labelled as the most environmentally friendly furniture (Nguyen, 2018). Not only are these products being used domestically, they are also being exported globally. In fact, these furniture products have positioned Vietnam as one of the leading countries exporting quality bamboo products in the international furniture market, thereby generating huge revenue for the nation as well as for the local enterprises (Tang, 2013).

*Bamboo decoration*

In addition to flooring, walling, ceiling and furniture, bamboo is also utilised as ornamental elements or handicraft objects to create aesthetic value either tangibly or intangibly. The uses are creative and more of the personal preference as it depends on the requirement of "tastemakers" and customers to decide which uses suit their taste and their status, and what kind of place ambience they want to stimulate. Interestingly, this utilisation is of significant and powerful in place making when it comes to creating the uniqueness of a place which expresses a traditional, cultural and aesthetic value.

### *11.4.2. Bamboo in civil engineering as structural frame materials*

According to Habibi (2019) and Das and Sarkar (2018), bamboo can be utilised as structural frame materials for bearing buildings' loads and improving structural performance regarding building reinforcement, durability and elasticity. This is in accordance with the approach of the present study to examine the innovative ways of employing bamboo as a material to support the construction of a wide range of building forms. In this light, the research has found that there are various traditional and contemporary techniques utilising bamboo to meet this objective. Traditional techniques such as trussing or binding using rattan strings and dowels are used widely in the construction of traditional houses and other simple built forms such as warehouses, farmhouses, barns or bridges mostly in rural areas or within minority ethnic groups. The structure of these buildings is composed of fundamental components including columns and beams, which often use straight and large bamboo culms. Bamboo culms with smaller diameters are used for purlins, while split bamboo is suitable for rafters and laths. These uses of bamboo have long been with Vietnamese people and often taken for granted (Norrie et al., 2018).

However, according to Nguyen Dinh Thi and Pham Thi Hai Ha (2017), these uses are economically, environmentally and culturally valuable as these techniques of using bamboo are simple, cheap and harmonious to the indigenous culture, native environment and climatic patterns. As the authors pointed out, these techniques are highly flexible and can be innovatively combined with other modern techniques to not only enhance the structural performance of the buildings but also promote the continuity of traditional value in a sustainable manner.

In modern structures, bamboo has been innovatively utilised in combination with other materials such as wood, brick, concrete, steel and composite materials to improve the capability of carrying more loads of the structures and general construction performance of different types of modern buildings. This innovative utilisation is also found globally elsewhere in China, India and many other countries (Das and Sarkar, 2018; Jiao and Tang, 2019). The traditional ways of using bamboo, such as trussing and binding, are now being used creatively with steel strings and steel bolts. In this sense, beams, columns and especially arches are more capable of bearing more weight and being curved into different desired bamboo frames such as scaffolding, portals, grids and hybrid structures as bamboo canes can be tightened into bundles supported by steel, wooden or composite poles, beams and frames.

### *11.4.3. Bamboo contribution to various forms and styles of architecture*

In architecture, bamboo has been used widely due to the availability and versatility of the aforementioned bamboo-based structures. This section examines the value of bamboo contribution to an architecture based on a wide range of building types with different architectural styles erected functionally, aesthetically and environmentally. Following that, bamboo used in Vietnam's architecture can be grouped as vernacular housing style and organic style, often featured in regular shapes. The formers are more traditional and local community-oriented with the continuity of traditional, simple and light forms of building shaped in a square or rectangular box (Norrie et al., 2018). This vernacular style employs traditional techniques of trussing, binding and weaving bamboo culms and split stems while creatively combining them with other locally available materials such as brick, laterite soil and rattan to make the building more engaged with and harmonious to native cultures and climatic conditions (Nguyen et al., 2011). This style is often manifested in buildings such as a private house, community house or dormitory. The organic style, on the other hand, is more aesthetically satisfactory in nature in which building forms are often erected to express the idea of an iconic impression. These building forms often include pavilions, restaurants, cafés and resorts. Bamboo used in these buildings is artfully crafted into bundles, employing traditional and high-tech techniques of trussing and binding to shape rectangular, circular or dynamic forms with regular and irregular patterns.

### *11.4.4. Bamboo in garden and park design*

Bamboo plants utilised for garden landscaping as ornamental elements and as plants to generate ecological benefits are found in many countries, especially in China and Japan (Woo-Jin, 2015; Xiaonan, 2020; Zhou and Zhao, 2018; Borowski et al., 2022). Bamboo as an ornamental element has long contributed to improving the spiritual, cultural and visually aesthetic value of not only classical Chinese gardens but also courtyards, folk dwellings, green spaces of urban plazas, residential quarters and urban roads (Juan and Shunkang, 2012). Juan and Shunkang (2012) additionally found that bamboo plants can be applied in urban parks as ground cover, green hedgerow and pathway creation, while Woo-Jin (2015) revealed how bamboo are used as screening, fencing and combined with water to convey special cultural ideology in traditional gardens in China. By the same token, Xiaonan (2020) proposes that bamboo can be grown creatively to form different configurations to divide up spaces, shape different landscapes, stimulate cultural, spiritual and emotional sense of place, create an optical illusion, mix with other landscaping elements like water, rocks and other plants in garden design.

Such research in Vietnam context is literally missing even though the potential of bamboo used in this field is paramount as nearly 200 bamboo species coming with all sizes and shapes found across the country. The use of bamboo in garden and park landscaping is only recorded in online newspapers or commercial websites. However, the present study has collectively gathered multiple practical applications of bamboo in this field. Firstly, bamboo conservation parks as being found in Phu An Bamboo Conservation Village and Son Tra Tinh Vien park. Both places are spacious parks which are home to many bamboo plants artfully grown and arranged to generate cultural, environmental, aesthetical and economic values sustainably. Secondly, bamboo has been used variously as decorating plants, potted plants and as artful objects in courtyards, private gardens within houses or apartment buildings and in public gardens or in cultural villages. As a decorating plant, bamboo is normally used as a green screen or as dividing fences and walls in order to render the space more spacious, to divide spaces, to create channels or to soften tactic built elements. Exotic bamboo plants with unique shapes, sizes and colours of stalks or leaves can be potted not only to beautify physical spaces but also to symbolise "wood" element amongst the other four: metal, water, earth and fire in Feng Shui ideology, which is often considered bringing luck, happiness and positive energy for the inhabitants. Bamboo species used in this way often include Yellow-striped Bamboo (Bambusa vulgaris), Buddha Belly Bamboo (Bambusa ventricosa) and Hedge Bamboo (Bambusa multiplex).

Finally, yet importantly, bamboo is crafted into various artful objects composed with other landscaping elements such as water, rock, sand and other plants to express different values, but mostly to evoke memories or a sense of traditional lifestyle affiliation. This way of using bamboo is often spontaneous and personal.

## 11.5. The shortcomings of current bamboo utilisation in the built environment in Vietnam

### *11.5.1. Decrease in the authentic utilisation of bamboo*

As the study has revealed, bamboo has been utilised in a wide range of industries shaping the built environment; however, some of these industries have experienced a decline in the authentic uses of bamboo. Housing construction, for example, has seen the loss of traditional methods of utilising bamboo in constructing vernacular houses since these houses are mostly constructed by local people, who often abandon bamboo materials once their financial status is improved. This leads to the fact that traditional, vernacular bamboo houses are disappearing from rural life (VNS, 2020). Fewer of these houses are being built and used by the local community, while at the same time modern bamboo houses mixed with modern materials are commercially utilised by tourists as homestay, mimicking the so-called traditional living lifestyles of native people. Architecture also sees the same trend, as many types of buildings are becoming commodified products. Some of these architectural products serve as a marketing narrative for resort development (Norrie et al., 2018), which mostly endorsed by and benefit a certain group of architects not for the sake of authentic bamboo development. In a similar vein, bamboo served as landscaping plants and objects are going through the process of unauthentic commodification to appear as a purely beautified commodity without carrying much cultural meaning.

### *11.5.2. Lack of cultural connotations of bamboo*

The commodification of bamboo materials, elements and products in the built environment industries in Vietnam often see bamboo as an additional decorating or a purely aesthetical creating material. However, the cultural connotation of bamboo culminated in literature, poems, paintings and songs is rarely integrated into interior design, architecture or garden and park landscaping. In fact, there is a lack of interdisciplinary investigation into finding out the connotative meanings of bamboo culture or how bamboo as a material and as a group of landscaping plants have been culturally utilised in different parts of Vietnam. At present, the connotative meanings of using bamboo mostly appear incrementally on advertising websites or online newspapers, which do not comprehensively give a whole picture of the matter. The research subsequently needs to find how to integrate these cultural connotations into each industry in order to create an authentic and culturally stronger sense of place rather than simply adding bamboo elements in the place making process.

### *11.5.3. Lack of skilled/experienced craftsmen*

In increasing bamboo authentic utilisation, searching and preserving bamboo culture connotation, it is crucial to engage with local craftsmen whose inherited skills and experience with bamboo craftsmanship are highly valuable to each built-environment industry. Most of these craftsmen have learned traditional techniques of trussing, binding and crafting bamboo in an effective and environmentally-friendly manner through longitudinal and meticulous observations and trials, passing down from generation to generation (VNS, 2020). Nevertheless, their engagement has dwindled or sank into oblivion. This is because those skilful local craftsmen are rare and often in an older generation, while at the same time, commitment from government, local authorities and bamboo enterprises to fostering and augmenting bamboo craftsmanship have not been demonstrated (Tran Van, 2021).

Additionally, there is a gap between local craftsmen and the younger generation in adopting technology to their work. Local craftsmen manually producing bamboo specialities and handicrafts, taking up a significant amount of labour and time, are often lagged behind technological adoption, while the younger generation involved in the sector relies on modern machines with lack of patience for learning traditional techniques of crafting bamboo (VNS, 2020). This is arguably one of the damaging consequences of unsustainable industrialization and globalisation, which is not an easy challenge to deal with at present (Hue, 2016; Vinh, 2019). While it is necessary to adopt technology in bamboo craftsmanship, it does not mean replacing traditional techniques with modern machines. Certain levels of manual involvement need to be kept intact to make bamboo furniture, decorating products, architecture and landscaping designed plans one of a kind.

## 11.6. Conclusion and future prospects of sustainable utilisation of bamboo in the built environment

The presented research has revealed that the values generated through the innovative and sustainable utilisation of bamboo are paramount. The review of current uses of bamboo in Vietnam has demonstrated that bamboo as a cultural material and element growingly gain its traction within each industry of the built environment by designers, architects and consumers. However, the study also reveals some negative signs of unsustainable development in this utilisation concerning unauthentic applications, deficiencies in cultural connotation and skilful craftsmen. If left untreated, these negative signs will certainly cause more precarious damages. Therefore, considerations need to be taken for a brighter future of sustainable bamboo development in Vietnam. This future prospects for bamboo being utilised widely and authentically in the built environment are foreseeable and secured only if:

### *11.6.1. More authentic applications of bamboo in the built environment*

The impact of industrialisation and globalisation is inevitable and not always positive. One of the negative consequences is the unauthentic applications of bamboo in furniture, architecture or construction as discussed previously. The future usage of bamboo needs to take this current consequence into serious consideration. Clearly, bamboo is different from concrete, steel, glass or composite materials. Its striking difference is not so much about its biological, physical or chemical properties but about its cultural connotation. In this sense, not only Vietnam has a long historical use of bamboo, but many other countries in the Global South to have the same status. If being applied unauthentically only for economic gains or the benefits of a certain affluent group, bamboo will lose its culturally distinctive value in the built industries, assimilating bamboo furniture, structure, architectural forms and garden landscaping with those of other countries. The current development in bamboo utilisation, on the other hand, is showing a positive sign of how certain generations of furniture designers, bamboo craftsmen and especially architects find a way to make bamboo visible in the built environment on a national and international scale. Some of them have made their name internationally recognised, such as Vo Trong Nghia (see his profile on https://vtnarchitects.net/en), even though their bamboo utilisation does not always reflect the cultural and historical value of bamboo and is not in line with human-scale narrative.

However, this is just the tip of the iceberg. Many local bamboo practitioners and communities preserving the authentic spirit in their traditional practices with bamboo might have not been discovered and valued. To increase the authentic applications of bamboo in modern time, it is crucial to bring these practices to the fore, to allow more innovative and creative integration of bamboo utilisation, which values traditional culture, morals and customs while keeping pace with the modern pulse.

### *11.6.2. More innovative integrations of bamboo in different sectors of the built environment*

Due to its dynamic, highly flexible properties and characteristics, bamboo can combine well with other materials and elements to express multiple values. It can coordinate with the indoor and outdoor environment, in accordance with green, environmental protection and sustainable development narrative (Song and Zhou, 2019). Being long utilised before modern time in combination with laterite soil, mud and straw, bamboo has proved its capacity to support the harmonious interaction between the human-made environment and the natural world. In modern times, bamboo continuously demonstrates this capacity by being integrated in many built forms with concrete, metal, glass and composite materials. Thus, it is important for designers, architects and engineers to find more innovative ways to establish formulas colliding and merging traditional with modern materials to achieve more cultural, functional, environmental and economic aims. These innovative ways must coordinate with technological advancement in manoeuvring and processing bamboo.

### *11.6.3. More innovative ways to manifest bamboo cultural connotations combined with local characteristics in different built forms*

Amongst the aforementioned values, the cultural value of bamboo is the most important one, defining the uniqueness and authenticity of physical places. Finding out the cultural connotations of bamboo is crucial to capture this value, and this is a great challenge for future applications of bamboo. The next step is to learn about local characteristics manifested in multiple cultural forms, including intangible things such as language, poems, proverbs, music, mores and customs, and tangle things such as colours, textures, paintings and clothes. If done meticulously and wholeheartedly, future manifestations of bamboo in each built industry must embody and reflect the circle of how bamboo originates from culture and then integrating back into culture. While, engaging with local craftsmen and communities is the key for bamboo practitioners to achieve this goal, other measures need to be adopted, including financial support from the government and local authorities to local communities, as well as more sustainable promotional and educational programs for and about bamboo-based products.

### *11.6.4. Bamboo is legitimised as an eco-friendly material*

Even though the narrative about bamboo as the green gold, or the most environmentally-friendly material worldwide, its legal recognition in Vietnam in the built environment has not been validated.

Despite the initiatives undertaken to conserve bamboo forests and for better management of bamboo plantations, there is no legal standard manifested in laws or regulations on bamboo as a material compared to other industrial materials such as metal, brick or cement. Even the standard price for bamboo material is not included in the national announcement for the annual price of constructing materials. This need to be considered in the future as soon as possible, especially narrative about environmental deterioration, deforestation, and climate change exerts heavy pressure on exploring and applying eco-friendly material in the built environment. Bamboo has all properties and characteristics to deserve to be legitimately praised as an eco-friendly material as a means of environmental protection and climate change mitigation.

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# 12. A multiscalar approach to renovate the building stock towards a resilient and adaptive built environment

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As most of the built environment consists of low-performing buildings, to achieve the European twin transition, it is essential to improve the *flexibility of existing buildings* towards variabilities of context in order to optimise the performance in terms of sustainability (minimising consumption and maximising efficiency) and resilience (enhancing preparedness against unexpected events). The definition of a comparative approach to assess the adaptability of the existing stock allows to foresee the extent and feasibility of the renovation and to predict its expected impact. Through the integration of multiple scales, ranging from urban characters to construction materials, the proposed *multiscalar approach* can identify strengths and constraints of the existing for the deployment of compensation strategies aimed towards the accomplishment of the overall desirable level of resilience. This conceptual framework, structured as a comparative matrix, is conceived to orient and guide the regeneration of the existing building stock according to innovative and adaptive solutions.

## 12.1. Introduction

In the urgency to drive cities towards a more sustainable and resilient future, multiple compelling reasons prompt to believe it is essential to take action to improve the performance and efficiency of the existing building stock. Most of the operating buildings are old and need upgrading: over 85% of the EU building stock was built before 2001 (EU, 2020a), whereas in Italy, there are over 1.504.711 buildings which date as far back as prior to 1991, accounting for 78% of the overall stock (SIAPE, 2021).

Such a large number of unqualified buildings has led, in the past few years, to a rising interest towards the renovation of the existing stock, promoted on the one hand by the European and national directives and, at the same time, embraced by the construction sector through increasing investments (CRESME, 2021).

As for now, the communitarian and national issued policies and actions have addressed the primary environmental consequences of the old building provision, as most of it is scarcely efficient and highly demanding, resulting in the 40% of EU energy consumed by the building sector and 36% of energy-related GHG emissions (EU, 2020a). However, the major share of the existing building stock has also shown to be obsolete, inadequate and unsuitable to respond to the specific functional and spatial requirements defined by their intended use (Bellomo and Pone, 2011), especially under the circumstances of the latest pandemic emergency.

The most recent trends show an increasing need for "temporary" spaces, available for short-term functions, accelerating the obsolescence and shortening the lifespan of buildings and technologies (Lavagna et al., 2020). On these grounds, the reversibility level of the existing building stock plays a significant role in ensuring the possibility to adapt and readjust according to unsteady and unpredictable circumstances. In the thus outlined scenario, it becomes essential to consider that the latest investment programs for the renovation of the existing building stock should be taken as a great opportunity to improve and optimize the building performance not only in terms of sustainability, minimising consumption and maximising efficiency, but also to optimise the resilience of the built environment, meaning the possibility to adapt to the variability of context and demands, while enhancing preparedness against unexpected events.

Therefore, this contribution aims at providing a *conceptual framework* for the further development of *a multi-criteria support tool*, suitable to assess the adaptability of the existing building stock to be renovated towards a more flexible and adaptive built environment.

The following sections intend to build a brief state-of-the-art concerning traditional and current approaches towards renovation and to convey the conceptual framework for the decision-making support method through the introduction of a *comparative matrix*, conceived to orient and guide the regeneration of the existing building stock, according to innovative and adaptive solutions. Further discussion concerns the future development of the proposed multiscalar approach.

## 12.2. European and national renovation trends

### *12.2.1. European and Italian regulatory context*

As already stated, the latest trends driving European policies towards urban regeneration take into great consideration the renovation of existing buildings (Serrano-Jiménez et al., 2020). EU directives on this matter, so as Italian national legislations, follow a common path: they aim at achieving better building energy performance through specific renovation actions (STREPIN, 2020), as energy efficiency is essential to reach the European targets, set for 55% emission reduction by 2030 compared to 1990, thus 60% buildings' GHG emission reduction and 14% final energy consumption decrease (Climate Target Plan 2030) (EU, 2020a).

The so-called Renovation Wave has been introduced to meet this ambition, recently leading to the activation of policies and actions directed towards reducing the environmental impact of the building sector. This generalized approach operates for the upgrade of the regulatory framework, introducing new and more appropriate funding instruments to drive sustainable development at different scales.

Just to mention a few, the EU's Recovery and Resilience Facility, known as the NextGenerationEU, allocates an unprecedented amount of resources to accelerate the renovation process and is complemented by the Cohesion Policy and other support funding sources, while strengthened by the implementation of attractive private financing thanks to the Renewed Sustainable Finance Strategy (EU, 2020).

At the local level, European states are requested to comply with the Community directives by defining the National Recovery and Resilience Plans (NRRPs). Some of these funding instruments are dedicated to the housing stock, while others mainly target public and less energy-efficient buildings, as "the objective is to at least double the annual energy renovation rate of residential and non-residential buildings by 2030 and to foster deep energy renovations" (EU Renovation Wave, 2020b, p. 3).

In general, in Italy, the National Energy Strategy 2017 sets specific goals, that are much closer to achieve for the residential sector: the expected achievement of such objectives in 2020 was 172,5% – in contrast with the

66,6% for the non-residential sector (ENEA, 2021) – hence driving the expected renovation increase for the residential sector in the next decades to get lower than the non-residential.

### *12.2.2. Current renovation approaches*

At the European level, the latest discussion on the building stock involves "deep renovation". Although this topic is soaring in the European research agenda, this term still needs to be fully legally defined (BPIE, 2021), as in the past decades, it has been interpreted in various ways.

Through this definition, the EU generally describes renovations attaining a significant (over 60%) energy efficiency improvement (EU, 2013), thus ascribing deep renovation to substantial climate-mitigating interventions. Nowadays, the average of what is considered the EU deep renovation rate is as low as 0.2% – just a small proportion of the overall occurring retrofits (BPIE, 2021) – as the effort undertaken to its application is remarkable in terms of costs, time and resources (Fawcett and Topouzi, 2019).

What the EU Commission does define is "major renovation", set by the Energy Performance of Buildings Directive as "the renovation of a building where: (a) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25% of the value of the building, excluding the value of the land upon which the building is situated; or (b) more than 25% of the surface of the building envelope undergoes renovation" (EU, 2010, Article 2). As highlighted by this definition, the indexes to identify the different types of renovations are set to be the percentage of building envelope and technical systems involved by the intervention, hence exclusively considering energy efficiency parameters. Consequently, other levels of renovation can be defined through the amount of Primary Energy (PE) savings (EU, 2019):

- medium = PE savings from 30% ≤ 60%;
- light = PE savings from 3% ≤ 30%;
- below threshold = PE savings <3%.

In line with these criteria, the Italian legislation articulates the definition of the intervention types according to the energy efficiency of thermal appliances and the percentage of the implicated building surface area: exceeding the 25% of the building envelope involved in the retrofit leads to second level major renovation, while overstepping the 50% results in a first level major renovation action. [*Ministerial Decree 26/06/2015 "Requisiti Minimi", Annex 1. The intervention types are classified as follows: 1) new buildings* *(including demolition and new construction and significant extensions); 2) major renovations: 2a) first level = involves over 50% building surface area and thermal appliances re-placement/improvement; 2b) second level = involves over 25% building sur-face area and might entail thermal appliances replacement/improvement; 3) energy upgrading = involves up to 25% building surface area and might entail thermal appliances replacement/improvement.*]. On these grounds, what comes to light is that the definition of the renovation "level" is always energy-centred and set according to the extent of the environmental impact reduction.

## 12.3. The conceptual framework for the multi-criteria support tool

Besides this vision, which traces back to the definition of the European goals of the Green Deal, a new awareness has arisen within the pandemic context, bringing into sharper focus the need to dispose of flexible and adaptable spaces for swiftly changing functions. Both the public domain, particularly referring to healthcare facilities and crowded public spaces, and the residential sector have proven to be functionally unprepared to unexpected demands.

To ensure an effective response to such considerations, it appears then necessary to improve the systemic adaptability of the building stock, according to the emerging need for flexible and resilient operational spaces. Considering the great potential given by future renovation pathways, but also the new and challenging tasks, it is of utmost importance to reckon that the improvement of energy efficiency within building performance is just one of the various issues to be tackled with renovation: designers, indeed, are challenged to look upon more holistic approaches, considering functional adaptability and performance indexes alike.

The current financial circumstances offer a unique opportunity to reconsider and rethink the role of design in the renovation, not only as a way to reduce the environmental impact of the building industry, but also to upgrade and modernise the building stock to meet future needs (EU, 2020b). In the past decade, literature on this matter has registered extensive discussion on support methods for decision-makers interested in renovating the existing (Nielsen et al., 2016).

The analysis of those methods highlights that much has been said about sustainable approaches to renovation and that the debate has almost always targeted the environmental impact factors, climate mitigation and carbon neutrality goals of the action. Some research studies have tackled the topic through multi-criteria methods, including investigation parameters on accessibility, behavioural analysis, thermal comfort or structural and fire safety (Serrano-Jiménez et al., 2020). However, the literature review underlines that the so far conceived tools need to be implemented in order to additionally involve more substantial discussion on the multidisciplinary variables that will be the design focus in the next few years, especially because of the great diversity of each project, which demands precise response to how the requirements can be implemented in the design (Konstantinou, 2015).

Thus, current research about renovation should not underestimate other significant elements: to actually fulfil the paradigm shift towards a considerably more resilient built environment, it is necessary to fully leverage the potential of a renovation wave in terms of co-benefits, namely, it is required to endorse an integrated approach (EU, 2020b), capable of merging energy performance, functional, spatial and fruition factors, while exploring social, accessibility and safety aspects, including also digital and smart technologies. In addition, these comprehensive tools should be developed through simplified models, in order to be flexible and meet the potentially changing needs without resulting outdated (Nielsen et al., 2016); these tools should specifically target architects, as the decisions concerning the upgrading of existing buildings are normally set in the pre-design phase; instead, architects are often reluctant in adopting them, assuming that such tools are non-user-friendly (Konstantinou, 2015).

## 12.4. A multiscalar approach to renovation for a more flexible built environment

To tackle the issue of renovation through the implementation of resilient design strategies, a possible solution could envision a multiscalar and multi-criteria approach to assess the adaptability of the existing building stock, to be refurbished through flexible solutions, thus providing useful information in the decision-making and early-design phases. As a preliminary support tool, such comparative approach could serve the purpose, on the one hand, to evaluate the feasibility of the renovation actions, while predicting desirable design solutions and, on the other hand, to foresee the expected impact of the project in providing high levels of flexibility. Both complementary parameters, when analysed in combination, could offer a perspective on the success of the visualised interventions, informing and guiding decision-makers towards the most effective and appropriate choices.

### *12.4.1. Proposed methodology*

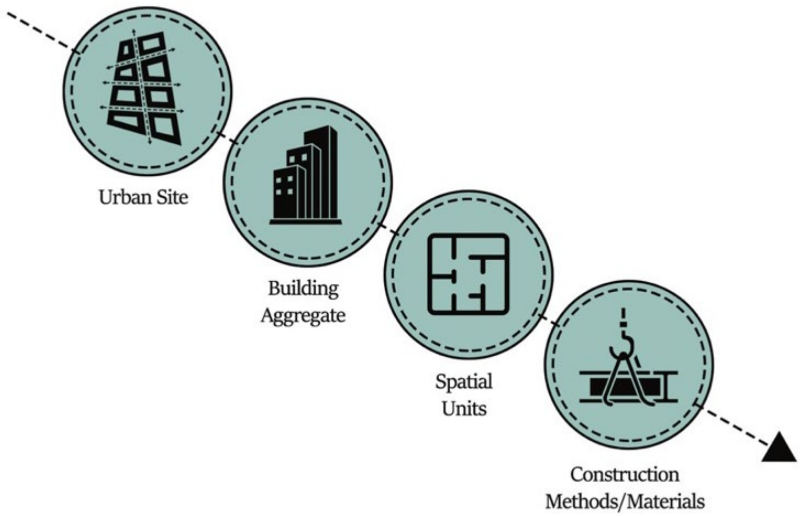
The proposed approach takes into account multiple criteria and scales, in order to convey a complete inspection across the big picture of the renovation actions. Gaining experience from previous research activities [*conducted within the Department of Architecture of the University of Ferrara, focused on the evaluation of the adaptability of the building stock to be converted, especially in relation to territorial healthcare facilities*] the investigation is carried out through the following scales (Fig. 12.1):

- Urban site. The building sustainable and resilient behaviour is deeply affected by the urban context, intended as the geographical and climatic region, along with environmental and urban factors (such as urban presence of greenery, urban fabric, urban density) and social, cultural and historical values;
- Building aggregate. The flexibility outcome of the planned renovation intervention is closely related to the building typology, distribution scheme, structural system, that have to be thoroughly analysed at a global scale;
- Spatial units. At this scale, the environmental (lighting, thermal, hygrometric and acoustic) characters are reviewed, addressing the overall users' comfort; in addition, considering dimensional and spatial factors is essential to evaluate the suitability of the existing distribution to generate internal spatial reconfigurations and correspondingly achieve the flexibility expected rates;
- Construction methods and materials. Deepening the focus, this analysis is aimed at identifying the range of possible interventions allowed at the executive scale, to be operated on the existing.

Given the compelling challenges involved when operating on the existing building stock, the proposed multiscalar approach allows for the accurate identification of strengths, weaknesses and constraints of the existing at different levels.

This building diagnosis is relevant to understand at which scale the assets and the major criticalities are, in order to establish where to direct the renovation actions to maximise their efficiency (avoiding fields with potential limitations) and how to undertake the deployment of compensation strategies aimed towards the achievement of an optimised and balanced outcome, ensuring the accomplishment of the overall desirable level of resilience. In other words, once the drawbacks and advantages of each project-site are exposed, it becomes possible to mitigate the first by leveraging the latter, addressing the most "elastic" scale accordingly, to attain the desired building performance. For instance, if operating on a protected building with extremely restrictive constraints on the façade layout (building scale), actions intended to rearrange the inner layout would be a more viable option (spatial units scale). Once the feasibility and potential of a specific site have been assessed and the most "ductile" scales have been selected, the following steps move towards the definition of a *comparative matrix* – a diagram that can incorporate, combine and manage sets of complex data – providing information about the actions to be operated on the buildings, through specific technical solutions, in order to meet the initial goals.

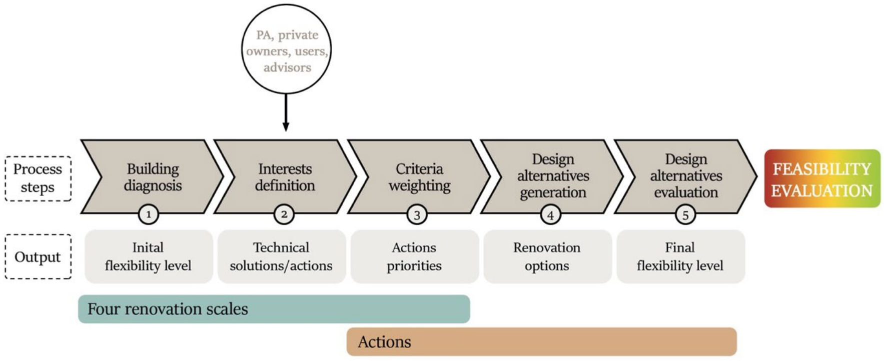
*Fig. 12.1 – Four different scales to be investigated through the proposed approach.*




*Source: Elaborated by the authors.*

For each of the predefined working scales, the matrix could propose a specific list of applicable and congruent actions, suggesting the most feasible intervention options. Examples of such actions could comprise windows replacement, roof renovation, electric installations, addition of vertical connections and installation of shading systems. These specific actions could be sourced by categorising the existing building stock on the base of equivalent parameters; for instance, these categories could refer to the geographical location, extent of damage, new intended use, construction method/materials and building typology and, more in general, can be established in relation to the subjective interests of the involved actors, users or decision-makers, should they be architects of professionals within the building industry, public administrations or private owners. Once the main interests have been defined, the respective actions should be analysed at the different scales to understand if any of them, and which of them, should be prioritised. Should this be the case, the criteria weighting process could set preferences according to the more favourable working scale by associating quantitative and objective criteria to measurable values (such as numbers or symbols) (Fig. 12.2).

*Fig. 12.2 – The proposed process steps towards the feasibility evaluation of the renovation options.*




*Source: Elaborated by the authors.*

Moreover, the applicable actions should be grouped into different types, ranging from the most extensive (generating the optimal flexible/reversible outcome) to the least extensive (adapting the existing to the current needs/codes without compromising the existing with major interventions), through four different intervention "intensities": minor, moderate, significant, major. As a consequence of this scheme evaluating the intensity of each action, in addition to the preferable working scale and the possible solutions – based on the subjective selected parameters – the proposed tool can offer feedback information about the predictable final level of flexibility: according to predefined weighting criteria, each "action intensity group" could be linked to a specific value that would add up to the final score, informing the decision-maker about the potential outcome of the renovation, referring to pre-set flexibility goal thresholds.

If the overall score does not exceed the minimum predefined standards, the identified actions are not sufficient to achieve a satisfactory reversible intervention, and are eventually to be considered unfeasible or barely feasible. The user should therefore step back to the initial stage and reconsider the selection of more extensive renovation actions.

## 12.5. Conclusions

The present contribution aims at building a theoretical framework for the development of a multiscalar approach to the renovation of the building stock, towards a resilient and adaptive built environment. Too often, indeed, the poor compatibility between plans and changing context leads to the demolition and replacement of buildings, instead of pursuing the attempt to flexibly rearrange them. On the contrary, it occurs that a building still in use after 50 years, albeit for a different purpose from the original, stands next to one 30 years younger, that has to be demolished because this happens to be cheaper than adapting it to the new demands. Noticeably, something is going wrong in harmonising design with programmatic constraints.

Because of the natural inclination towards efficiency – in the limited sense of doing the minimum to comply with the brief – the match between design and programme may become too perfect, leaving no margin for changing either, so that it is necessary to completely demolish and rebuild the existing (van Hinte et al., 2003). The proposed tool indeed, laying the foundation for its further implementation, provides useful information that could support the decision-making of renovation strategies through the creation of what-if scenarios.

These alternatives would allow, on the one hand, the organization of existing measures according to the state of the object of intervention, and on the other, their comparison and qualification in relation to the final goal.

The systematic compilation of renovation actions, through their organisation within a matrix, can help to acknowledge the available options and support choosing or rejecting them, according to the different application scale and involved parameters. In this way, the beneficiaries of this tool are provided with practical information in the early stages of design, rather than after most decisions have already been made, which is often the case in the current practice. However, it has to be said that the proposed approach is neither to generate ready-made answers nor to suggest complying solutions, especially if considering the uniqueness of each project.

Rather it aims at providing a holistic approach contemplating different application scales, and the related parameters, that can influence the "resilience level" of a building, combining actions and variables to facilitate and support design interventions during the whole decision process.

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# *Section 4 - Predicting, simulating, assessing sustainable features and circular systems*

# *13. Circular economy in the built environment*

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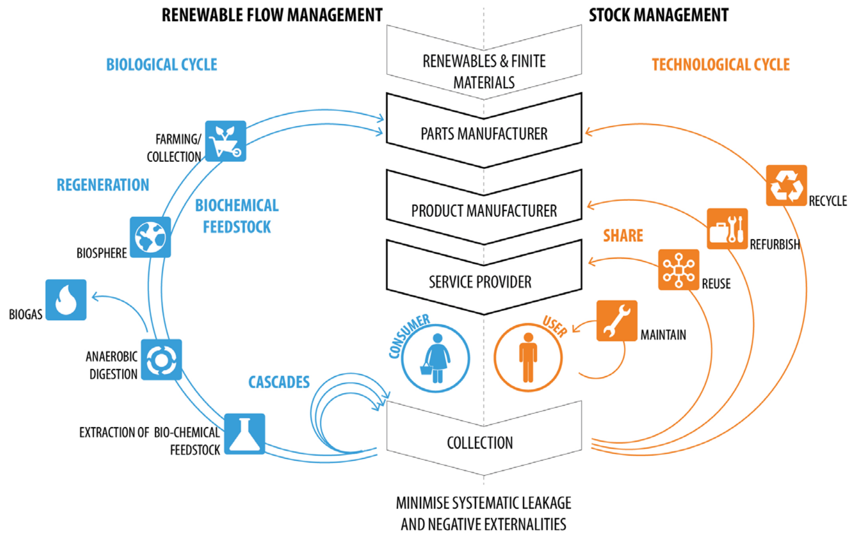
The circular economy is as much an attitude as a program. The circular economy (CE) is an action plan which identifies a series of goals and associated outcomes. It is a comprehensive response to the impact of the industrial revolution and the linear economy model which was the economic basis of the industrial revolution. This manuscript discusses the philosophy and strategies of the circular economy and the role that the built environment has in implementing this philosophy.

## 13.1. Introduction: what is the circular economy?

The circular economy is as much an attitude as a program which establishes a series of goals and associated outcomes. Its overall goal is to create a comprehensive approach to the management of global resources and to correct the negative results of the industrial revolution. Circular economy goals are global, and they define a series of criteria which address the shortcomings of the linear economy model. It is a philosophy based upon the awareness and cooperation of various stakeholders who bear responsibilities in the areas which impact the state of the Earth's environmental health. It is a response to the methodology and practices which are represented by the linear economy model created in the industrial revolution. The circular economy is not a systematic system of review and response rather, it is a philosophy which acknowledges the need for greater cooperation between the numerous stakeholders involved in society. Those stakeholders represent industry, government, and the society that it serves. The fundamental change in thinking or philosophy represented by the circular economy is that we are taking responsibility for the future. We acknowledge that the work and products that we create now not only impact the time that we live in but dramatically alter the future. And that we acknowledge that behaviour that we employ from this point forward can create a better world for those people who live in it and that we can undo the harm that we have created by utilizing a short term and selfish approach to development. The circular economy establishes goals to restore balance to the environment and seeks the cooperation of all the stakeholders. The Ellen Macarthur Foundation (EMF, 2013) is dedicated to the concept of the circular economy. In the private sector, EMF has identified seven concepts or disciplines that are being used to build the circular economy idea, which are: industrial ecology, cradle-to-cradle, biomimicry, performance economy, blue economy, regenerative design and permaculture. *By rethinking the way we design our built environment, using new technologies and innovative business models, we can realize more value from existing assets, keep resources and building materials in the economy, and stop them from becoming waste.*

*Fig. 13.1 – Resource management in the circular economy.*




*Source: Elaborated by the author, based on EMF (2013).*

The Ellen Macarthur Foundation suggests that the circular economy is based on three principles, driven by design:

- Eliminate waste and pollution: in a CE system, there are no waste products, and no system or product produces any pollution.
- Circulate products and materials (at their highest value): products and their materials are always recycled.
- Regenerate nature: the CE works to restore natural systems and make them productive, applying global environmental ethics.

Figure 1, originally elaborated by the United States Environmental Protection Agency (EPA, n.d.), illustrates the concept of resource management by perpetually recycling materials. *It is underpinned by a transition to renewable energy and materials. A circular economy decouples economic activity from the consumption of finite resources. It is a resilient system that is good for business, people, and the environment. The circular economy is a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution.*

## 13.2. Background

The technological advancements, wealth and quality of life which are associated with today's society have origins in the sources of the industrial revolution. The industrial revolution started in England in the mid-18th century. This period is highlighted by the significant economic, social, and political transformation, which was powered by the industrialization of manufacturing.  Hand tooled manufacturing and agricultural society as replaced by industrialized urban society.

### *13.2.1. Linear economy*

The linear economy production methodology is the production model which characterizes the industrial revolution. This production model called for materials to be collected and transformed into products and then discarded when product became obsolete. There is no concern in this model for resource management and ecological impact. The primary focus is for speed of production and maximizing profits. It is based upon the assumption that raw materials are infinitely available and there is no concern for recycling the discarded material or the impact on global resources. This philosophy is often described as a "take make dispose" or a "cradle-to-grave" process.

*Linear economy/impact* - With the passage of time, the negative impacts of the linear economy have been recognized. Their effects have created long term global damage, including among the others:

- Climate Change: A by-product of the linear economy industrial process is the creation of significant amounts of carbon dioxide gas which is the cause of global warming. CO2 is a direct by-product of the use of fossil fuel to create energy for the manufacturing and processing of materials as well as energy to power systems to support various mechanical systems. Since the start of the industrial revolution, the level of CO2 in the atmosphere has risen 50%. Science has concluded that the excessive amounts of CO2 released into the atmosphere changed the equilibrium of the atmosphere resulting in the condition of climate change/global warming.
- Waste: The linear economy encourages the undisciplined consumption of resources. The negative environmental impact is created by the undisciplined collection of raw materials and the disposal of used products as waste. The result is an environmental crisis in resource, waste, and environmental management.
- Natural System Destruction: Because of its undisciplined search for and mining of raw materials, the industrial revolution has place excess pressure and stress on many natural systems which society depends on such as water, air, agriculture, oceans, and wetlands. The circular economy promotes the goal of regenerating natural systems, creating a closed loop system that actively promotes the development of the natural environment.

This global crisis has been recognized by the international community. Coming out of this awareness is the need for a more comprehensive concept of conduct and stewardship, which could address not only the issues of global warming but also recommend concepts and behavioural patterns which would address the future requirements of civilization in managing material resources and restoring the environment.

This call for action cuts across all areas of human endeavour, recognizing the impact on the issues such as food production, water environmental systems protection, as well as climate change and resource management.

The circular economy evolved as a broad philosophy which capitalized on existing concepts establishing a larger agenda for world management. It is an umbrella concept.

Critical to the success of this philosophy is the knowledge that the process must engage the various stakeholders who hold economic responsibilities and that they all understand that it is in their own economic interest and that of society to embrace the overriding goals and principles of a circular economy and then incorporate them within their own sphere of influence.

Cost is a key element for the development of all the choices to be made, at various time scales, starting from the first stage of the building process up to its conclusion in the life cycle perspective. In project sustainability evaluation, the costs are fundamental to the construction, management and building life cycle process.

International scientific studies dedicate extensive discussions on theories and methods for dealing with cost components, as demonstrated in the literature and the more recent norms. These involve engineering, architecture, and specific disciplines such as: building production, architectural technology, materials science and technology, building physics, architectonic and urban design, economic-managerial engineering, real estate appraisal and economic evaluation of projects.

## 13.3. Implementation of circular economy

### *13.3.1. Acceptance of CE philosophy*

The philosophy and concept of the circular economy have been broadly discussed and have been accepted by key stakeholders' global institutions and national and local governments. The United Nations Economic Commission for Europe focused its 69th Session in April 2021 on "Promoting Circular Economy and Sustainable Use of Natural Resources in the UNECE Region" (UNECE, 2021).

The United States Environmental Protection Agency is developing strategies for building the circular economy including planning for the implementation of a national recycling program (EPA, 2021). The stakeholders including international entities and individual governments have embraced the concept. They have stated their support for the adoption of means and methods to achieve the concept of a global economic system which supports the principles of the circular economy.

Private industry such as private builders and real estate industry manufacturers have broadly accepted this philosophy and they acknowledge the economic benefits that they offer to their constituents. The key element to the success of this philosophy is the need for stakeholders to see its merit and actively transition their operations to support broad goals of the circular economy while pursuing their individual economic interests.

### *13.3.2. CE global ethics*

In a July 2022 New York Times interview, Herman Daly, former senior economist for the World Bank, discussed principles related to the circular economy and the importance of global ethics as business enterprises measure their performance and limited resources. He offered that *the wealthy part of the world has to make ecological room for the poor to catch up to an acceptable standard of living.* Mr Daly illustrated some of the key issues that are represented by the circular economy and global ethics as they impact business enterprises. Mr Daly commented on the impact that linear economy has had on the mismanagement of resources and the resulting impact: *What I call the empty world was full of natural resources that had not been exploited. What I call the full world is now full of people that exploit those resources, and it is empty of the resources that have been depleted and the spaces that have been polluted. So, it's a question of empty of what and full of what. Is it empty of benefits and full of cost? Or full of benefits and empty of cost? That gets to that point of paying attention to the costs of growth.*

Mr Daly goes on to suggest a change of perspective is needed that acknowledges the finite resources that are available. His comments regarding steady state economy/earth embrace the goals of the circular economy and our ethical responsibilities: *Earth is not expanding. We don't get new materials, and we don't export stuff to space. So, you have a steady-state Earth, and if you don't recognize that, well, there's an education problem. But again, there's this heroic ethic and economic ethic. Maybe the heroic ethic is the right one, but religion's counsel is to pay attention to the cost. Don't make people worse off* (Marchese, 2022).

## 13.4. Global agreement

Below is a sample from various global stakeholders demonstrating acceptance and encouragement of the principles outlined to address the global threat of climate change and the associated mismanagement of resources and the environment. United Nations Deputy Secretary-General's remarks at the World Circular Economy Forum + Climate Event 15 April 2021 (World Circular Economy Forum, 2021): *The world's production and consumption patterns are unsustainable and are at the root of today's triple planetary crisis of climate change, biodiversity loss and pollution. Against this backdrop, we need far more concerted steps to build a circular economy to put us on track to achieve the 2030 Agenda and net-zero emissions by 2050.*

Closing the loop - An EU action plan for the Circular Economy 2 December 2015 (European Commission, 2015): *This action plan sets out a concrete and ambitious EU mandate to support the transition towards a circular economy. A continued, broader commitment from all levels of government, in Member States, regions and cities and all stakeholders concerned will also be necessary.*

United States Environmental Protection Agency (EPA, n.d.): *A circular economy approach under the SMM umbrella demonstrates continuity in our emphasis on reducing lifecycle impacts of materials, including climate impacts, reducing the use of harmful materials, and decoupling materials use from economic growth*

Paris Circular Economy Plan 2017 (Mairie de Paris, 2017): *A circular economy could reduce global CO2 emissions from building materials by 38% in 2050, by reducing demand for steel, aluminium, cement, and plastic. It could also make the sector more resilient to supply chain disruptions and price volatility of raw materials.*

McKinsey Quarterly "Mapping the Benefits of a Circular Economy" (McKinsey & Company, 2017): *Companies that focus on environmental and social performance may reap profit opportunities their competitors miss.* The consulting firm McKinsey & Company, a global management company, is a significant voice in planning on behalf of industry. In their publications they advocate for adoption of the circular economy, they discuss the transition that would be needed to move from the linear economy into a circular economy, the benefits that it would provide industry in guaranteeing control of issues such as materials and processes and that it would be in tune with the greater global agenda of climate change and resource management. They explain that the circular economy represents the future and a path for increased profits and participation in the world marketplace.

## 13.5. Impact of the built environment: progressive solutions

The built environment is responsible for up to 40% of the annual production of CO2. It is a major consumer of resources and contributes significantly to the creation of discarded materials which then are not recycled and create a further burden on the environment. Sophie Rosso, the deputy CEO of Redman, a real estate management firm in France, states that *the construction industry is responsible for over 30 percent of the extraction of raw materials worldwide and at least 25 percent of waste in the world. Various sources estimate at the end of a building's lifetime, only 40 percent of materials are* *re-cycled or reused* (Roberts, 2021). With the growing awareness of the negative environmental impact caused by the linear economy model when used in the built environment/real estate sector. The response by built environment stakeholders was a series of action plans by which reflected the growing concern and understanding of the global crisis.

### *13.5.1 Energy conservation*

Industry's initial response was to reduce the use of fossil fuels, consequently reducing the amount of CO2 that was released into the atmosphere and it was of economic benefit given various energy crises in distribution and cost of petroleum during the 1970s. Local governments modified building codes to require better energy performance. Manufacturers developed energy efficient devices. The reduced use of fossil fuels directly related to savings associated with energy conservation-lower fossil fuel consumption reduced production of unwanted $CO_2$.

With time a greater understanding of the impact of climate change on all the aspects of building construction developed and new and broader approaches and solutions were adopted under the umbrella of sustainable and resilient design. Stakeholders expanded remedies to improve performance in the construction and operations of buildings. Industry design and product production solutions manifested themselves in more efficient building systems and building envelope and façade designs creating energy efficient buildings. Innovations that have been applied include:

- The introduction of alternate renewal power sources such as solar and wind and greater utilization of hydroelectric power has reduced the reliance of fossil fuel systems.
- Utilization of efficient and innovative building systems such as geothermal and the use of new technologies for controlling building systems and application of conservation/energy saving practices.
- Employing better building envelope design-discarding the modernist façade approach of glass curtain wall construction to dynamic façade design providing orientation-based design, green facades, renewable materials such as wood, smart materials, double-skin facades, and facades as energy generators.

These sustainable/resilient design remedies focused on building design elements and technology used within the perimeter of the building such as material selection, building orientation and more efficient mechanical systems. The result was the design and construction of efficient new buildings, which consumed less energy during their operation. This approach was formalized in the building certification systems such as LEED and BREEAM. The development of solutions based on the concept of sustainable design evolved and expanded into the net zero carbon operation goal or desired outcome of a net zero energy-efficient building where, on a source energy basis, the actual annual consumed energy is less than or equal to the on-site renewable generated energy. The concept can be up scaled to address the energy performance of an entire community.

## 13.6. Environmental management waste and resource management

Concepts and recommended solutions associated with building energy management and sustainable/resilient design advanced the agenda of the circular economy. But they only addressed part of the global environmental issue. With the realization that undisciplined development and exploitation of natural resources promoted systems and processes which were wasteful and contributed directly to the increasing amount of $CO_2$, stakeholders became aware that the industrial revolution and its linear economy had done significant harm to the natural environment and the supply of resources that would be needed in the future.

### *13.6.1 Waste elimination*

We now recognize the undisciplined production and poor waste management by the linear economy philosophy of short-term profitability and exploitation of environmental resources as contributing factors to the global climate crisis. The United States Environmental Protection Agency estimated that 600 million tons of construction and demolition debris were generated in the United States in 2018, which is more than twice the amount of generated municipal solid waste (EPA, 2021). This is an area which has not had the level of research and formal action plans as other problem areas. It has been identified as a critical matter and action is required. Another negative result of excess waste is that often the waste material is dumped in landfills, which impacts proper land use. The location of these landfills often perpetuates economic and social inequality. To rectify these conditions, plans and methodologies were needed to create a closed loop management of materials to eliminate waste, to reduce the production of $CO_2$ and to restore natural ecological systems. Solutions are needed which incentivize practices such as source reduction, salvaging, recycling, and reusing existing materials. The European Parliament, the only directly elected institution of the European Union, has recognized that regarding waste: *This is a departure from the traditional, linear economic model, which is based on a take-make-consume-throw away pattern. This model relies on large quantities of cheap, easily accessible materials and energy* (European Parliament, 2022).

### *13.6.2 Recycling*

A secondary and equally destructive result of the industrial revolution was the exploitation and undisciplined consumption of natural resources leading to the realization that these resources were not in infinite supply. The linear economy had put in motion a system that was exhausting the supply of these materials and if continued these materials and resources would not be available to future generations. Evaluation of existing sources of materials/resources and rate of consumption concluded that industry was consuming materials and that by not returning them for recycling the supplies would be exhausted. Economic models predict the end of resources such as aluminium and copper as well as other rare metals soon. A plan for recycling material and managing and restoring natural ecological systems was called for.

## 13.7. Built environment and the circular economy expanding agenda

The philosophy of the circular economy has expanded the boundaries of concern beyond the management of buildings and their consumption. The circular economy challenged the design and real estate industry to plan not only for the building life cycle but the pre and post-occupancy of the building. While much has been discussed regarding energy conservation and material selection to achieve sustainability, less has been researched on the goal of ongoing management of building materials past the anticipated lifespan of the project and how that material can be successfully recycled to eliminate any waste. The circular economy also deals with the shortcomings of past financial models, which defined the economic incentives of the linear economy. The circular economy seeks strategies which provide financial incentives to support the principles of the circular economy, specifically waste management, and adaptive reuse of materials. The circular economy is an umbrella concept incorporating the previous goals such as the reduction of hot house gases and sustainable design, expands the built environment agenda to deal with the issues of materials management and environmental impact and encourages stakeholders to dismiss the principles of the linear economy and choose and adopt its environmental ethics. The circular economy seeks to incentivize stakeholders associated with the construction industry and encourage their participation in the process. The key to this success is acknowledging and satisfying the stakeholders' economic concerns and that it is in their economic interest to change business models from a linear economy to one that embraces the goals and proposed outcome of the circular economy. Below is a list of targeted stakeholders as defined by the European Commission and the areas and objectives that they can impact (COM 2019 - 640 final).

*Fig. 13.2 – List of targeted stakeholders by the European Green Deal.*

| | OBJECTIVE | | |
|---|---|---|---|
| TARGET GROUP | DURABILITY | ADAPTABILITY | REDUCE WASTE |
| BUILDING USERS, FACILITY MANAGERS AND OWNERS | ✓ | ✓ | ✓ |
| DESIGN TEAMS | ✓ | ✓ | ☐ |
| CONTRACTORS AND BUILDERS | ✓ | ✓ | ☐ |
| MANUFACTURERS (of construction products) | ✓ | ✓ | ☐ |
| DECONSTRUCTION AND DEMOLITION TEAMS | ☐ | ☐ | ✓ |
| INVESTORS, DEVELOPERS AND INSURANCE PROVIDERS | ✓ | ✓ | ✓ |
| GOVERNMENT/REGULATORS/LOCAL AUTHORITIES | ✓ | ✓ | ✓ |

*Source: Elaborated by the author based on COM 2019 - 640 final.*

The Circular Economy Action Plan adopted in March 2020 by the European Commission is one of many action plans that has been generated by various federations of nations, individual countries, and local governments COM, 2020 - 98 final). Each works with the common concept of an umbrella strategy incorporating past work and criteria but focuses on the global goal of managing pollution, eliminating waste and restoring natural systems. The philosophy of the circular economy is to encourage the various stakeholders to embrace these goals and work towards the common good while advancing their own economic agenda.

## 13.8. Built environment: next steps

Significant progress and efforts have been made in the areas of sustainable design and energy management, energy management and net zero $CO_2$ emissions with clear performance goals outlined in such criteria as developed by LEED, other scoring systems, and revised building codes. Efforts focused on the individual building during the process of the design construction and post-construction operation.

This addressed the criteria of pollution reduction, construction waste management, and energy conservation. The circular Economy expands the built environment sector agenda in materials management and the restoration of natural systems.

### *13.8.1 Materials management*

The first area is long-term responsible materials management. Failures of the linear economy model have resulted in waste of non-renewal materials and destruction of the natural environment. The circular economy looks to implement a long-term materials management policy. The goal of perpetual material management is that materials, once created are continually used or recycled with the goal of no waste and the reduction or elimination of the need to seek new raw materials, together with developing materials and production systems using renewal materials and energy resources.

### *13.8.2 Restoration of natural systems*

The second area is the implementation of policies and design which support the regenerate natural systems. Creating design and processes which call for restoration of natural systems and creation of new environments. There was also an awareness that the industrial revolution had changed topography and land use in such a dramatic fashion that many of the natural systems that have supported the planet regarding food production, clean water and air had now been disrupted.

Examples of this are loss of natural forest areas, impact on biodiversity, loss of water systems and rising sea level impacting coastal ecology. This goal when incorporated into the program and development of projects, will encourage and restore natural resources. It is these areas which call for action plans to be developed.

### *13.8.3 Built environment design goals*

The list below of design goals is suggested by the Ellen Macarthur Foundation (EMF, 2013) to identify areas of investigation associated with the advancement of the circular economy in the built environment:

- Circular Building Design: Building design and operation which utilize the principles of the circular economy.
- Circular Building Materials & Manufacturing: Building sector is one of the largest consumers of raw materials and producers of waste in the United States. Production of building materials accounts for a significant portion of the 25% of total energy and 75% of raw materials consumed by the U.S. manufacturing industry. Developing means and methods in the manufacturing process for building materials to make significant gains in efficiency, waste reduction, and decarbonization.
- Construction: The Circular Economy construction model is a process that keeps non-recyclable waste out of landfills or incinerators. It also reduces the need for further mining of construction aggregates, which are a finite resource and require enormous energy expenditures to mine and transport.
- Building Use & Operations: Using principles of the CE to maximize the efficiency of building operation, and eliminate waste in operation.
- Deconstruction & Resource Recovery: Deconstruction is the process of carefully dismantling buildings to salvage components for reuse and recycling.
- Reverse Logistics: Reverse logistics is the set of activities that is conducted after the sale of a product to recapture value and end the product's lifecycle. It typically involves returning a product to the manufacturer or distributor or forwarding it on for servicing, refurbishment, or recycling.
- Improved environmental performance of the office building when designed for disassembly.

Three Dimensions of Transformation: Reversible Buildings: The Ellen MacArthur Foundation suggests that architects design buildings with an eye to the future, embracing flexibility and design methodology, which embrace preparation for future uses-buildings designed to be flexible, thereby accommodating the change.

- Spatial flexibility of the building.
- Technical flexibility of systems and products.

- Flexibility that can make a transition from a linear to the circular economy building.
- The Enabling Ecosystem: Promote a policy and regulatory environment that supports the creation and growth of natural systems. Design buildings and master plans which support regenerating natural systems, protecting the natural environment, and creating a closed loop system that actively feeds natural resources back into the planet.

## 13.9. Barriers to implementation

The adoption of a circular economy philosophy represents an enormous change in approach and goals. The circular economy calls for adjustments in political, social, economic and planning. It requires a high level of cooperation and coordination between the member stakeholders.

The CE requires that stakeholders create an economically feasible system that works to achieve the goals of CE. *Delivering the circular economy requires a lot of collaboration and that's quite challenging. We need a system where every part is accruing value and that needs more trust between different partners through collaboration. We need economies of scale to make this work – it can't just be one company moving on their own.*

### *13.9.1. Barriers to implementation of CE*

Barriers to the implementation of CE can be subdivided into 5 categories: economic, sociological, political, organizational, technological, and environmental. Below is a brief summary of barriers to the implementation of CE that the stakeholders may need to address.

*Economic barriers*

- Stakeholders need to stop using methods that use linear economy practices and create business relationships which are profitable and achieve the goals of CE.
- Stakeholders need to overcome scepticism and resistance, such as the fear of that there are additional costs for better waste management. Stakeholders need to adopt an economic plan which satisfies their own vested interest while implementing the goals of

the circular economy: eliminating waste and pollution, recirculating material, and regenerating nature.
- Reinventing and creating businesses which support CE goals.

*Sociological barriers*
- Governments and regulatory agencies need to draft and enact legislation which creates responsible practices for governing environmental, such as requiring 100% of building materials and waste to be recycled.
- Governments should make political decisions which prioritize the needs of environmental management over short-term goals. Stakeholders should not succumb to traditional beliefs that waste is inevitable, or the disbelief in the potential utility of a constructability program
- Acknowledge the occurrences of social and economic inequality that has been the outcome of the linear economy and work to correct that structure of injustice. Create legislation and codes which manage existing real estate inventories of cultural and historical value. Applying the circular economy principles to guarantee the existence of those structures while adhering and benefiting from the circular economy philosophies of waste management and economic incentive.

*Organizational barriers*

The success of the circular economy relies on communications and agreement between the various stakeholders and the need to develop or strategy which is built on consensus.

The creation of continuity of management of the built environment from one stakeholder to another and the responsibility of custodial care for materials is key to the success of eliminating waste and having perpetual management of environmental systems.

The need for cooperation and discussion between stakeholders establishing the goals and a business model which will allow continuous management is key.

There needs to be organizational discussions at an institutional level and a governmental level with an agreement to establish various paths and responsibility routes to conduct continuous management and surveillance over materials to avoid past mistakes which occur in the linear economy where the cradle-to-grave philosophy is dominant.

*Technological barriers*

The technological barriers are specific to architects, manufacturers, and contractors. New technologies, processes and business models are needed to address changes in material management and waste elimination. Designing buildings which can be recycled and deconstructed and recycled to support a viable business model. Stakeholders associated with the built environment are challenged to create systems and solutions which go beyond their normal areas of responsibility or traditional goals.

Examples of these challenges are:

- The creation of a closed cycle resource management approach/methodology where no waste is created and all materials are recycled for future use. For architects and engineers, this requires them to think beyond the lifespan of their building. They are being asked to consider design buildings which are adaptable to change and can be deconstructed in an effective way which facilitates recycling and resource recovery.
- Creating solutions which address real estate that is completed and in place. What alterations and planning solutions are needed to provide continuity in building material management as well as the issues of sustainability.
- Expanding expertise and technological solutions which address restoration of natural systems is a new agenda for these professionals.

*Environmental barriers*

One of the key CE principles is promoting the development and restoration of natural systems, which can contribute to the renewal of materials and non-polluting energy sources. The goal of restoring natural systems and biodiversity was not part of the traditional goals and objectives of most building projects. The design team and the other stakeholders are now asked to assume this responsibility. This includes restoring landscape and environments to match the historic natural land use and environmental systems to restore natural environments and promote biodiversity, which was disrupted by linear economy cradle-to-grave economic philosophy.

*Unexpected factors*

Will there be a commitment to the circular economy in the face of unexpected challenges and barriers that may be created by political instability and issues such as the global pandemic, political conflict, and war?

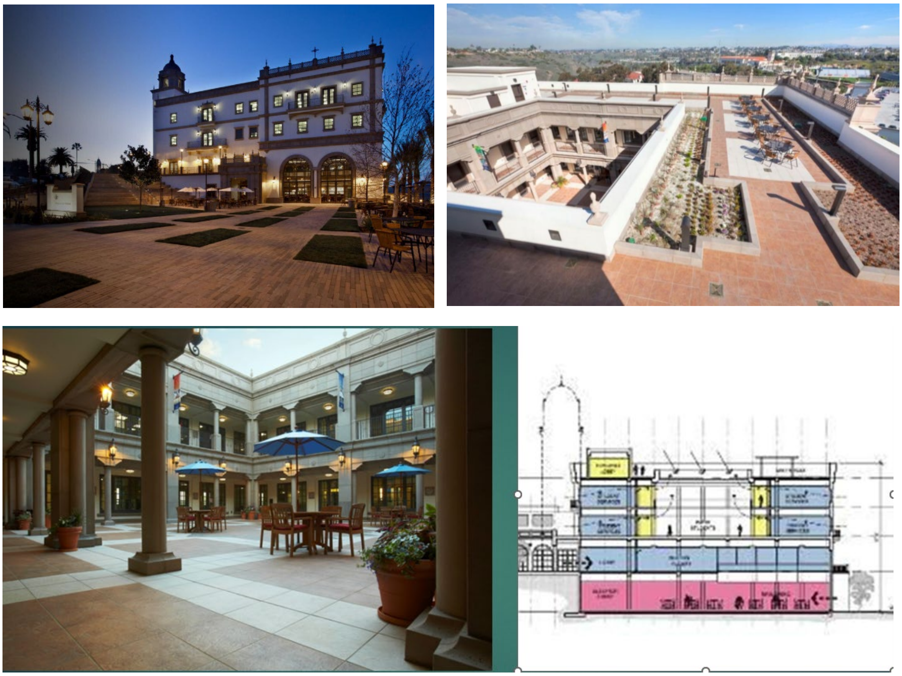
## 13.10. Current examples of implementation

We are now seeing successful projects emerge which incorporate the goals of the circular economy. Below are three examples of projects by my office, Kevin Hom Architect PC. Each project solution demonstrates responds to the three principles of the circular economy as outlined by the Eleanor MacArthur Foundation.

*The University of San Diego*

A Catholic college built in the early part of the 20th century in San Diego, California, modelled after the University of Salamanca in Spain.

*Fig. 13.3a/b/c/d – University of San Diego Student Center.*



*Source: Kevin Hom Architect PC.*

The project was the development of a new university centre; the program included dining facilities, offices, meeting rooms, and outdoor spaces. The project site was composed of the original building designed in the 1950s and an existing surface parking lot. The project solution was to renovate the existing building to build an extension over the parking lot. Noteworthy was the ability of the project to recycle the original building, and to incorporate cultural environmental solutions, which were part of the Spanish architecture vernacular to minimize the use of mechanical systems for air conditioning. The design eliminates the urban heat island caused by the black asphalt of the parking lot, now replaced by the green roof of the new extension. The project was ultimately awarded a gold award by LEED.

*Fordham University at Lincoln Center in New York City*

The Fordham University campus at Lincoln Center was developed in the 1950s as part of an urban renewal project in the City of New York, which included the Cultural Center of Lincoln Center.

The project goal was to design a new Business School, expansion of the University library and a retrofitted student centre within the existing campus plan.

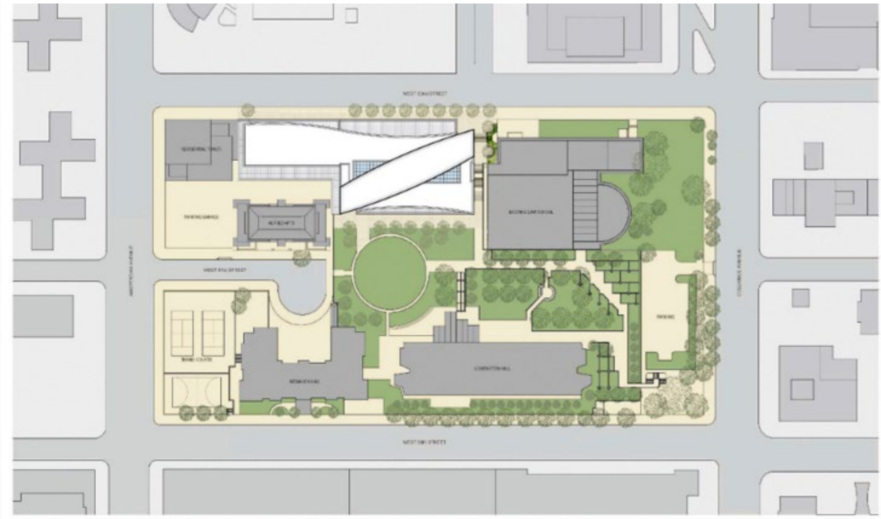
The critical decision was whether to demolish the existing structures and build a new facility or to retrofit existing structures. It was decided to retrofit an existing structure and reconfigure existing adjacent spaces. The final solution advanced the goals of the CE philosophy.

- Results include recycling the original building materials,
- Reduction of construction waste shorting of the construction process
- Existing buildings and adjacent spaces were recycled and converted into a new Business School and new University Library
- The building facade was replaced, creating a more energy-efficient structure
- New technology was utilized to upgrade the mechanical systems production

*Fig. 13.4a/b – Retrofitted Fordham University Library / Original University Library. Fordham University at Lincoln Center.*

*Source: Kevin Hom Architect PC.*

*Fig. 13.5 – Graduate School of Business Fordham University. Before After Retrofitting.*



*Source: Kevin Hom Architect PC.*

## *Tidewater community college University centre*

The Tidewater Community College Campus sits on the estuary system of coastal Virginia. Classified as wetland, the site is subject to coastal flooding.

*Fig. 13.6 – Tide Water Community College, Tidewater Virginia.*

*Source: Kevin Hom Architect PC.*

The original campus master plan called for a series of buildings built around a water retention pond, and the circulation for the campus was a series of parking lots which ringed the campus perimeter. The project was to construct a new University Center; the program included: classrooms, athletic facilities, dining and retail.

*Fig. 13.7 – The new building for the Tide Water Community College, Tidewater Virginia.*

*Source: Kevin Hom Architect PC.*

In addition to building the new building, the agenda for this project included the management of rainwater and coastal flooding and reorganizing the site circulation to encourage pedestrian circulation rather than auto use. The design solution was to build the building on top of the water retention pond, thereby minimizing the amount of surface area that is lost for water retention and reinforcing the natural estuary environment. The building was designed to be a central circulation hub which would foster pedestrian circulation and minimize the use of the cars to circulate from one parking area to another. These measures with the energy efficient sustainable building design promoted CE criteria.

## 13.11. Conclusion

Addressing the existential crisis of climate change and the waste and mismanagement of the environment and its resources is a global priority. The past practices of the built environment sector have contributed to this crisis. The stakeholders who represent this industrial economic sector need to revise their policies and methodologies to put in place economically feasible solutions with positive outcomes which will neutralize these global existential threats. There is no one path or one set of rules that will achieve this. The philosophy of the circular economy outlines the broad principles/concerns which address this crisis and advocates for a level of cooperation which will successfully implement policies that will address this existential threat.

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# 14. Design support tools for circularity-driven renovation projects

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*Never demolish, never remove, or replace. Always add, transform, and reuse*, is the leitmotiv of the 2021 Pritzker Prize Anne Lacaton and Jean-Paul Vassal. Rather, extend the lifecycle of buildings, make clever use of what exists, enhance their performance, and prepare them to face future challenges. In this sense, building renovation is the most sustainable and circular kind of intervention that can be undertaken in the built environment.

However, simply reusing existing buildings is no longer enough by itself. As circularity gained traction in many sectors, also in construction, key players have been called to perform sustainable renovation projects in the long term. This means considering the impact from the entire life cycle of added materials and components rather than only focusing on lowering the operational energy of existing buildings. Otherwise, the final energy and carbon balance of the renovation might be unfair.

Given the high degree of complexity of the retrofitting process, which includes environmental, social, logistical, technical, and economic issues, designers would benefit from a comprehensive assessment of as built and an effective forecast of the effects of design choices on the building and its broader context.

To this end, several design-supports tools have been developed, the most promising and forward-looking, including sustainability and circularity of resources as guiding principles.

## 14.1. Building renovation as circular action

In 2018 Constructions accounted globally for about 36% of final energy use and 39% of carbon emissions (GlobalABC/IEA/UNEP, 2020). This was mainly due to the operational stage of buildings, which is related to space and water heating, cooking, cooling, and lighting systems. However, it is estimated that about 11% of the global sector's carbon emissions are due to embodied carbon, which are emissions related to the whole life cycle of buildings' materials and components. Furthermore, the sector is accounted for over 50% of all extract materials and 40% of materials sent to landfills yearly. Even if new buildings are increasingly aiming for net zero carbon, zero energy or even positive energy, they are few in comparison to the existing stock. Therefore, because buildings have a long lifespan and a considerable part of the overall building stock in developed countries will still exist in 2050, it follows that the construction industry must address climate change and resource depletion mostly by enhancing what is already in place (McKinsey & Company, 2009; Lucon et al., 2014).

In this context, renovation emerges as a key strategy as contributing to both reducing energy demand from existing buildings and boosting the circularity of resources (Gobbo, 2021; Preservation Green Lab, 2011). The first relates to enhancing energy performances of already existing buildings, thus reducing their operational energy up to 75% (Lucon et al., 2014). This entails, for instance, insulating envelopes and upgrading systems to limit unwanted heat exchanges, either out- or inwards. The latter relates with reusing buildings and structures, so reducing the amount of new materials to add, or at least recycling materials, and construction and demolition waste (Campioli et al., 2018). This would prevent new resources from being extracted, processed, and moved, thus new environmental impacts from being generated. Not to mention that reuse instead of demolition and reconstruction entail benefits other than environmental: if any, it allows to retain cultural values of the building, the sense of place, as well as memories and personal associations of inhabitants and local communities. For these reasons, in order to reach the ambitious energy and carbon saving targets set worldwide, policymakers are supporting the massive and effective renovation of existing assets. In Europe [EU] the Renovation Wave is the main strategy to this end (COM (2020) 662 final). Launched by the European Commission in 2019 under the wide umbrella of the EU Green Deal, the strategy is grounded on the fact that more than 220 million buildings in Europe date back before 2001 and are highly energy demanding. For instance, in the southwestern EU average energy demand for heating is 100-200 kWh/m$^2$y, compared to the standard for new efficient buildings, around 15 kWh/m$^2$y (Harvey, 2013). Older buildings are much less efficient at retaining warmth, and as a result, more than 75% of the EU's building stock leaks significant energy (BPIE, 2011; IEA, 2020). To address this issue, the EU aims to support energy renovation for around 35 million buildings by 2030, by means of significant incentives and investments, in addition to encouraging national governments, private investors, architects, designers, and local communities to get involved. In this context, however, renovation is no longer related with energy efficiency only. It should now be reframed according to the concept of circularity, as the sustainable use of natural resources, reduction of waste and measurement of resource efficiency has also become essential challenges, especially in times of dependence on supply. So, as a forerunner, the EU has launched a new Circular Economy Action Plan in 2020, where a specific Strategy for a Sustainably Built Environment is planned to be included soon (COM 2020 - 98 final). This Strategy will promote circularity principles in the built environment by:

- supporting recycled materials through a new Construction Product Regulation;
- promoting measures to improve the durability and adaptability of built assets, such as the use of construction digital logbooks;
- using the EU framework Level(s) to integrate life cycle assessment in public procurement as a pilot action;
- considering a revision of material recovery targets set in EU legislation for construction and demolition waste and its material-specific fractions;
- promoting initiatives to reduce soil sealing, and rehabilitate abandoned or contaminated brownfields.

## 14.2. Circular principles in renovation projects

This vision that integrates circular principles into renovation strategies is quite recent in the sector. For several decades indeed, "green buildings" were thought to be enough to cope with the environmental crisis. Policymakers, designers, and clients themselves have focused on reducing building's operational energy alone until it was pointed out that it was not enough to lessen the sector's environmental impact (Pomponi and Moncaster, 2017). Refurbishment does not always produce positive environmental balances because the potential loss of matter and embodied energy in the dismantled elements and the lack of control of the environmental quality of added materials and components risk producing an impact greater than demolition and new construction (Munarim and Ghisi, 2016; Berg and Fuglseth, 2018).

So far, indeed, plenty of thermal insulation panels have been installed thinking at conductivity index only, as well as thousands of photovoltaic panels have been set up considering only peak kilowatts for the first years. What will happen now that the first installations are approaching the end of their expected lifespan? Will these be simply disposed and replaced with most performing ones? Or do they have a residual value that deserves to be exploited further?

All stakeholders from the building sector are encouraged to reflect on this, on what happens beyond construction or renovation works. Even if there are no universal responses, the promising trajectory is to enlarge the perspective and go beyond the local and short-term effects of constructions.

A circular built environment should have fewer virgin resources, and most new building materials are reused, salvaged, biobased, or recycled; buildings are meant to be restored and upgraded rather than demolished, and they are used more intensively (by more people utilising more services), and lastly, when buildings reach the end of their useful life, as much material as possible is salvaged and recycled (USGBC, 2019).

Some useful principles can be implemented to this end, above all the 3R principles that are also supported by the EU Green Deal (COM 2019 - 640 final). This is, in the preferable order: reduce, reuse, and recycle. This translates into operative strategies and procedures that are developing at all levels and stages in the construction chain, from site to building materials, from the production of components to the demolition stage.

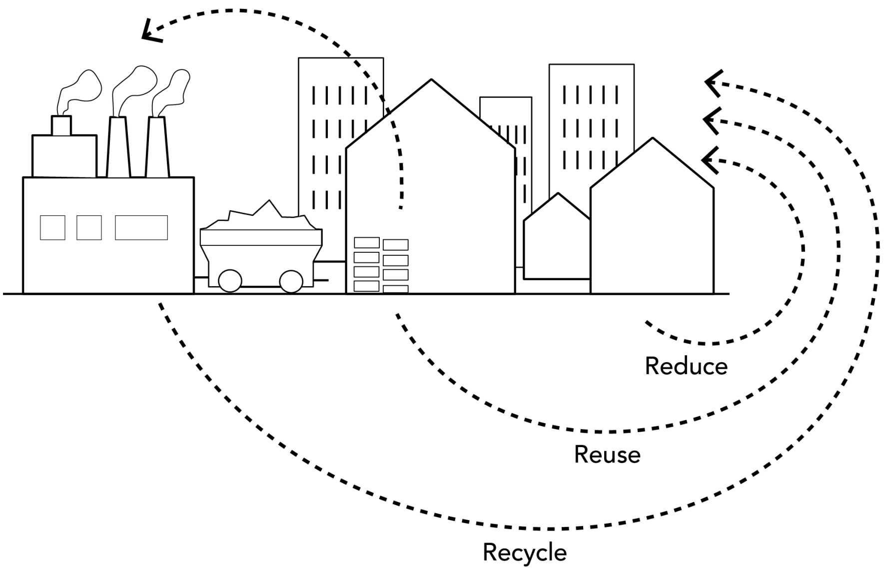
*Reduce the amount of waste you produce*. It deals with the idea of extending as much as possible the service life of buildings and materials to exploit their embodied energy, reduce the use of primary resources and the production of construction and demolition waste.

Therefore, it is important to implement effective and speedy procedures to assess the residual value of buildings, components and materials and their suitability for retrofitting (Scolaro and Marchi, 2019), as well as upgrading systems whenever possible.

*Reuse items as much as you can.* That means implementing effective strategies to use available materials and components on-site or in other buildings. Innovative trends in this field are platforms and experiences related to the Urban Mining concept, which extends landfill mining to the process of reclaiming compounds and elements from any kind of anthropogenic stocks, including buildings (Cossu and Williams, 2015). Noteworthy to this end is the Harvest map, an open-source platform whose aim is to exploit the end-of-life materials and sustain new construction, in line with the principles of small-scale circular economy (*Harvest Map* website; Jongert et al., 2007)

*Recycle items wherever possible*. Great effort has been put into implementing a recycling production chain for the construction sector, even in co-operation with other industries (Neves et al., 2020). This mainly deals with the industrial symbiosis practice that was firstly implemented in Kalundborg in Denmark (1972) and consists of resource sharing and waste valorisation among different supply chains to limit environmental impacts and encourage the economic decoupling of the production sector.

*Fig. 14.1 – Circular principles in renovating the built environment.*




*Source: Elaborated by the author and Licia Felicioni.*

These 3R principles must comply with the overall effort of reducing energy demand and carbon emissions for the entire construction chain (sustainable principles) (USGBC, 2014). Thus, preferring low-impact materials, such as local materials with short transportation tracks, or natural ones with low energy needed for extraction and processing, or materials that are designed to last (i.e., durable).

Lastly, another concept tightly related with circularity is gaining traction in the built environment, namely resilience. In fact, building codes and regulations often target occupants' safety, which is obviously of utmost importance, but do not care about the ability of a building to quickly recover damages to the building structure, systems, and components in the event of an earthquake or environmental catastrophe (resilient attitude) (ARUP, 2014). As a result, buildings' repair and restoration might be time-consuming, costly and in general terms, not convenient. Resilience-driven approaches are instead leading to a new vision of the building itself, which should be designed to last and adapt to new natural or human events.

It is thus important to consider prolonging the lifecycle of constructions to be resilient, sustainable, and circular, assuming both a short and medium-to-long term perspective. To sum up, operative strategies deal with maintaining as much material as possible, limiting integrations and replacements, recycling the dismantled building components, and choosing materials according to their environmental profile and their durability.

## 14.3. Implementing circular thinking in renovation projects

Although the economic and technical feasibility of building rehabilitation has been largely proven, as well as potential societal and environmental benefits, renovation rates remain low (Artola et al., 2016). Not to mention the application of circular principles.

In fact, building owners and potential investors face several obstacles in renovating their buildings. Along with difficulty in accessing funding – which has been partially covered by exceptional incentives in the last years (e.g., Super bonus in Italy), one of the most frequently mentioned barriers is the lack of information about where to begin and how to make the right steps (Fabbri et al., 2016).

On the one hand, technical interventions to renovate existing buildings are quite well established. Energy retrofit is mainly based on envelope thermal insulation; windows replacement; systems upgrading and integration with additional ones based on renewable energy sources; installation of shading systems for glazing. Adaptation of buildings to different users' needs or new functions is mostly achieved by means of cost-effective, reversible, and flexible systems, like dry wall for internal partitions, installation of self-bearing structures for elevators, emergency stairs, and additional lodges.

On the other, a coherent approach capable of making specific interventions working together is lacking. In addition, considerations about environmental implications are difficult to embed in the process and be understood by clients.

*Fig. 14.2 – Find the differences: the typical transformation of multi-family buildings in less than 50 years. More than ten differences emerge clearly, such as the glazing closing loggias, and many more have been performed inside.*

*Source: Elaborated by the author and Ambra Lombardi, based on ACER Archive.*

Refurbishment is indeed featured by a high degree of complexity that depends on the specific features of the building and its transformation during decades.

In general terms, major issues can be grouped in the following categories:

- *Technical issues*, which relate with the difficulty of collecting suitable data on construction features, assessing residual performances of structures and components, and evaluating compatibility between new and old materials.
- *Logistic issues*, which mainly relate to the interference of the renovation project with occupancy of the building, both in terms of time of the intervention and its intensity (whether occupants can stay in or not during operations). This, for example, may drive owners who have no other options to relocate for small upgrades based solely on outside insulation and not well-performed windows replacement. In addition, existing components might be difficult to be moved elsewhere.
- *Socioeconomic issues*, which for instance, pertain the investment capacity of the owner, or the type of ownership of the building. Renovation of multi-property buildings can be particularly challenging as it is difficult to find agreement among several owners with different spending capacities, needs, and time constraints, so affecting materials and design choices.

This is just to mention a few conflicts that might occur in a renovation project and add complexity to the process itself. But there are many others indeed, some of which are already known, while others will occur in the future according to upcoming challenges for the environment and society.

What emerges is that the renovation project deals with several complex topics different in nature and scale and that, even more than in new constructions, need to be carefully considered in relation with the specific context in which one is operating. It is a difficult task for designers to adapt buildings built in a different sociocultural context to new challenges and needs while, equally important, giving them the degree of flexibility that will ensure their suitability for many years to come, most likely facing new, unanticipated, and uncertain challenges.

### *14.3.1. Complexity and multicriteria assessment*

The complexity that a design team should manage to perform an effective, circular, future-proof renovation project has clearly emerged. It derives that despite the extensive knowledge of technologies and interventions that can be implemented to renovate, retrofit, refurbish an existing building, designers alone often fail to consider all the issues properly. They would rather benefit from a design-support tool to manage all the interrelated topics.

Figure 14.3 conceptualizes the problem, from the knowledge of technical intervention to the need for structured and effective design support tools.

*Fig. 14.3 – Conceptualization of the problem, from technical intervention, and procedural gaps to assessment and predictive tools.*


*Source: Elaborated by the author and Licia Felicioni.*

Today designers can benefit from the guidance of several tools developed to this end. Most of them are based on multi-criteria analysis, that is, investigating different topics in a coherent manner by means of the same tool. Even if this operation might raise some concerns, especially related with the fact of combining "apples and oranges" (Jesinghaus, 2000), many of these tools are very helpful and well-established.

These generally evaluate different aspects of the project through specific indicators ranging from site condition to water management, from energy performances to waste management. Starting from the structured, guided assessment of "as built" in order to get a quick but comprehensive picture of the starting point, the design team is then guided to select the most effective design strategies to reach overall the best possible configuration for the object, that is "the best compromise" (Marchi et al., 2021). For this reason, the implementation process is often iterative. Assessment and simulation of the project's effects are thus recognized as keys to a successful intervention.

### *14.3.2. Green Building Rating Systems for sustainable and circular design*

Green Building Rating Systems (GBRSs) are probably among the most famous and valuable multi-criteria tools to assess and guide the whole design process to be greener. These tools support the consistent evaluation of a vast range of green building requirements, among which low energy consumption, efficient water management, good indoor environmental quality, sustainable location, and use of natural materials. The relative performances of the object (whether it is a new construction or an existing building) are weighted using a balancing process specific to each GBRSs and are combined into a single score/judgment that shortly communicates the building's overall level of sustainability. In this, they are useful not only in supporting the design team to evaluate all the relevant aspects of the building together, but also in guiding them to map important synergies among the building elements and function, hence enhancing the overall performance of the project.

Among the most spread worldwide: *Leadership in Energy and Environmental Design* (LEED, U.S.A.), *British Building Research Establishment Environmental Assessment Method* (BREEAM, UK), *Deutsche Gesellschaft für Nachhaltiges Bauen - DGNB System* (abbreviation in German for the German Sustainable Building Council) (*BREEAM* website; *DGNB System Version 2020 International* website; *LEED* website; Say & Wood, 2008). Noteworthy is also the *SB Method* and its national applications, such as *Verde* (ES), *SBTool PT* (PT), *SBTool CZ* (CZ) and *Protocollo ITACA* (IT) (*iiSBE Italia* website).

Many of these protocols embed circular thinking principles in the evaluation. For instance, they include credits that reward project teams who support the rehabilitation of brownfields, and minimize and optimize the use of buildings, building products and materials throughout the project life cycle, from construction and demolition waste management planning to product selection and ongoing sustainable purchasing. The most common tool to measure how materials and resources are used by the team is Life Cycle Assessment, but often speedy methods are provided in credits' specifications.

Moreover, several GBRSs have schemes dedicated or adaptable to renovation projects, which means that specific credits for the evaluation of existing building constraints and features are included. These generally have the same structure of new construction, but few credits are applied, as well as less strict gauges. Table 14.1 illustrates schemes dedicated to renovation in two of the most diffused GBRSs worldwide, as well as specific credits related with resource circularity.

*Tab. 14.1 – GBRSs, renovation and resource circularity.*

| **LEED (USGBC, 2019)** |
|---|
| *Schemes for renovation*<br>• New Construction and Major Renovation<br>• Operations & Maintenance<br>• Core & Shell |
| *Credits for circularity*<br>• High Priority Site and Equitable Development (LT)<br>• Outdoor and Indoor Water Use Reduction (WE)<br>• Enhanced Commissioning (EA)<br>• Optimize Energy Performance (EA)<br>• Building Life-Cycle Impact Reduction (MR)<br>• Environmental Product Declarations (MR)<br>• Sourcing of Raw Materials (MR)<br>• Material Ingredients (MR)<br>• Design for Flexibility (MR)<br>• Construction and Demolition Waste Management (MR) |
| **BREEAM (BREEAM, 2021)** |
| *Schemes for renovation*<br>• Refurbishment<br>• Fit Out<br>• Water Sub-metering; Leak detection; Leak prevention; Efficient |

*Credits for circularity*

- Building LCA (Mat 01)
- Sustainable procurement (Mat 03)
- Designing for durability & resilience (Mat 05)
- Materials efficiency (Mat 06)
- Recycled aggregates / Recycled and sustainable aggregates (Wst
- Life cycle cost and service life planning (Man 02)
- Monitoring of construction site impacts (Man 03)
- Reduction of operational energy use (Ene 01)
- Energy Sub-metering (Ene 03)
- Water Sub-metering and Efficient equipment (Wat 02)
- Construc. resource efficiency and Diversion from landfill (Wst 01)
- Recycled and sustainable aggregates (Wst 02)
- Adaptability (Wst 06)

## 14.4. Positive trends and prospects

Assessment and design-support tools that have been developed so far certainly have limitations. As much as they are “multi-criteria”, some aspects are neglected in favour of simplicity and user-friendliness. Their scope is indeed to make a complex problem easier to grasp.

However, in the last few years, big steps forward have been made to fill these gaps. Green Building Councils worldwide have tried to make GBRSs more comprehensive and balanced: the introduction of circular thinking and Life Cycle Assessment tools are certainly among the most relevant innovations in this regard. Furthermore, there is such a multitude of these tools that designers and clients might be confused. Some unifying tentative is now approaching, such as Level(s) by the European Union consisting of a transparent and robust framework of indicators that can be used by policymakers and stakeholders across the EU, and intended to be included in GBRSs (Cordero et al., 2019). Level(s) as well includes several circularity measures to boost effective and sustainable renovations.

Despite the differences in available tools and methods, what is interesting to note is that great effort is being spent in many fields to support designers and other relevant actors to renovate the built stock in a holistic, sustainable, resilient, and cost-effective way. Therefore, social, environmental, and economic measures are increasingly embedded and integrated into design-support tools, aiming at a better future.

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# *15. Is circularity a measure of complexity in architecture?*

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*The greenest building is the one that is already built.*
(Elefante, 2012)

Various globally faced social, economic, political, and environmental crises unescapably led us to "change" on all scales and in every aspect and in all forms of the environment, natural or built. Change is inevitable, but how it happens and its suddenness determines its impact and severity.

Absorbing change brings to forefronts studies on sustainability and resilience, which are addressed by several disciplines as one of the main subject matters in their broadest sense. In parallel to these discussions, it is widely accepted the necessity to switch from a linear economy to a circular economy in order to use resources efficiently and reduce waste, emphasizing the importance of re-valuing/recycling and upgrading.

Discussions on the circular economy cannot be isolated from discussions on sustainability. The number of studies on these matters is exponentially increasing, and one of the common denominators of them is the focus on the built environment and natural environment as a complex system together.

As the current discussions and research show, the sustainability concept coexists with the concept of resilience.

## 15.1. Sustainability and resilience concepts in socio-ecological studies

Resilience is a multifaceted, complex concept that has different connotations in regard to context and field and is mostly associated with sustainability. Although these two concepts mostly coexist and sometimes are used interchangeably, they are actually different (Bocchini et al., 2014; Achour et al., 2015; Lew et al., 2016; Marchese et al., 2018). Sustainability has become a central issue starting from the late 1980s, and with Brundtland Report in 1987 (Brundtland, 1987), it has become a norm for development. Resilience, on the other hand, is a more descriptive concept providing a framework to understand the change in the environment in the quest for balance between nature and humans.

The resilience concept that emerged from ecology studies is closely related to system theory. One of the highly acknowledged definitions is first proposed by Holling in 1973 (Holling, 1973) as *the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and persist*. From an ecological systems point of view, Holling discussed resilience as *dynamic behavior apart from equilibrium*, stability as *persistence of a system in (nearly) equilibrium*, and adaptive capacity *response to human-induced alterations* of an ecological system (Gunderson, 2000), Carpenter (Carpenter et al., 2001) described as *the degree to which the system is capable of learning and adaptation* then by Gunderson, Holling, Pritchard, and Peterson put forward the distinction between engineering and ecological resilience in 2002 (Holling and Gunderson, 2002). The former can be defined as the system's ability/capacity to return to global equilibrium following a perturbation in a precise way; the latter is more involved in systems' ability/capacity to adapt to change and multiple states of equilibrium.

Over the past years, the resilience concept has spread into several fields, from ecology to computer science, from psychology to urban planning, engineering, economy, and more. There are several studies showing how resilience thinking affects current research fields. It is even seen that this concept has begun to precede the discussions on sustainability under the impact of sudden changes that we face globally (Fraccascia et al., 2018) Duchek defines resilience as a meta-capability that can be understood in three stages: anticipation, coping, and adaptation (Duchek, 2020). This definition shows why resilience has become a core concept in various fields and how it is related to sustainability studies, risk management, and more.

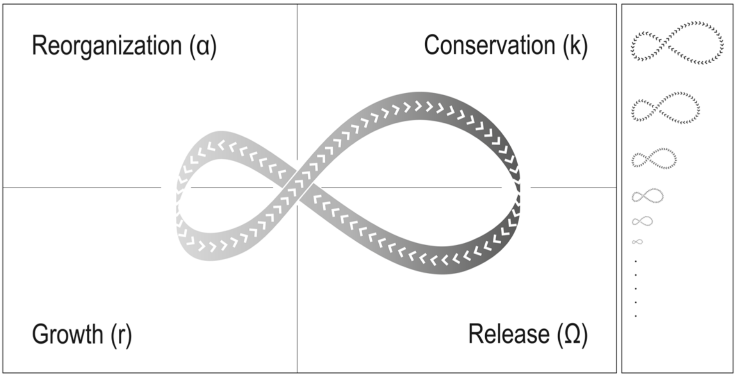
Sustainability and resilience concepts are both concerning the environment, natural or built. While sustainability stresses more "conservation and mitigation", resilience focuses on "adaptation to change" (Lew et al., 2016). Built as the term covers man-made everything for supporting mankind physically, economically, socially, and environmentally. Hollnager, in his study, approaches these two concepts by questioning the term environment in regard to resilience, signifying as a property of a system (Hollnagel, 2014). In his study referring to Mumford, *a system cannot be considered without including its relation to its environment (or to a general environment)* and acknowledging resilience as *the central unifying concept*.

As globalization intensifies and all the human and natural capitals are depleting, the complexity of interactions across scales in the social-ecological environment increases, forcing paradigmatic changes in economies, production/consumption cultures, and praxis as well as social systems. Changes are more drastic than before, which necessitates more extended approaches for achieving sustainability goals. Such complexity gave way to an important model which has roots in ecology: panarchy.

Panarchy as a conceptual framework in ecology studies was first proposed by Gunderson in 1995 (Gunderson and Holling, 1995), then by Gunderson and Holling in 2002 (Gunderson and Holling, 2002). In their seminal book, they state their purpose as *to understand the source and role of change in systems-particularly the kinds of changes that are transforming, in systems that are adaptive* concerning economic, ecological, social, and evolutionary changes in any scale and at any pace.

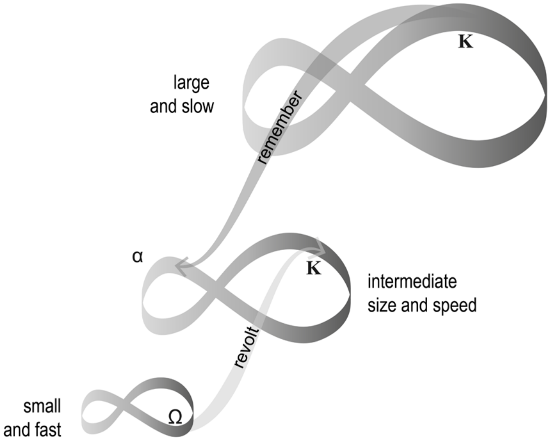
The essence of the concept is to delve into the interplay between c*hange and persistence, between the predictable and unpredictable* observed in systems. They grounded their theory based on observations on changes first in ecosystems and then subsequent changes in societies and economies. Panarchy theory's basic assumptions on ecosystems *change is neither continuous or gradual, nor always chaotic, but episodic; spatial attributes are neither uniform nor scale invariant over all scales; ecosystems do not have a single equilibrium with homeostatic controls to remain near it, rather in multiple equilibria; and policies and management that apply fixed rules for achieving constant yields independent of scale, causes systems that increasingly lose resilience* lead the concept of adaptive change and eventually adaptive cycles. An adaptive cycle for a given scale depicting the behavior of a complex system consists of four phases: growth (r), conservation (k), release (Ω), and reorganization (α), as shown in Figure 15.1. The growth phase is the accumulation/exploitation of resources, followed by conservation is the increase in connectivity and rigidity in the system, which actually result in loss of resilience and collapse of the system. The release is the rapid phase unleashing all the energy accumulated in K phase, and finally, reorganization is the rapid re-assembly of system components (Gunderson and Holling, 2002).

*Fig. 15.1 – Panarchy's adaptive cycles.*




*Source: Elaborated by the authors, based on Gunderson and Holling (2002).*

*Fig. 15.2 – Panarchical Connections.*




*Source: Elaborated by the authors, based on Gunderson et al. (2002).*

Panarchy theory aims to explain such cross-scale dynamic relations either discrete in time or nested; in other words, it recognizes both processes that infiltrate up from lower to higher scales. In the panarchy model, nested adaptive cycles in different scales of time, space, and speed overlap and reinforce each other, and their interconnectedness in different hierarchical scales determines the degree of resilience. Nash points out that *disturbances at one scale can be absorbed by other scales in the system* in relation to their resilience (Nash et al., 2014). In short, panarchy theory focus on the interaction of systems on different scales and their cyclic adaptations through stability and de-stability periods or change and persistence. Following the first proposal of the theory, it has been more and more linked to resilience as the measure of adaptive cycling and sustainability in a broader perspective to explain complex system dynamics not only for ecosystems but systems showing such cross-scale relations as economies, governance, law, conservation, organizations, planning and more.

## 15.2. Sustainability, circularity, and resilience

The era in that we live is acknowledged as the Anthropocene, wherein our activities have radically modified all the systems. In recent years, changes are speeding up and becoming more abrupt, both natural and built environments are declining, and even some of the critical thresholds are already crossed. Concerning all the ecological problems, the number of social and political turmoil, the most recent COVID-19 pandemic, the economic crisis on a global scale, depletion of energy resources, etc., show that to manage such crises, new strategies and action plans are necessary. One of the new approaches is transformative governance which is "rooted in ecological theories to explain cross-scale dynamics in complex systems, as well as social theories of change, innovation, and technological transformation" (Chaffin, et al., 2016). In this approach, unlike building resilience in adaptive governance, an active shift to a more desirable regime/state is targeted by altering the system structures and processes. Chaffin et al. in explaining adaptive/transformative governance, refer to resilience and panarchy in the framework of environmental governance. They use these concepts to explain changes in socio-ecological systems (SES) like gradual or incremental change, which is slow and predictable, adaptive change due to shifts in systems, and abrupt and transformative change (Chaffin, et al., 2016).

Transformation is deliberate and always includes human factor and societally initiated processes which also force us to reconsider the concept of resilience in its broadest sense. Folke and friends propose resilience thinking in the framework of dynamics and development of complex social–ecological systems (Folke et al., 2010). They define resilience as *the capacity of a*

*SES to continually change and adapt yet remain within critical thresholds* and adaptability as a part of resilience responding *to changing external drivers and internal processes allowing for development within the current stability domain, along the current trajectory*. In their work, they also provide a glossary for the term resilience for SES, where adaptive cycles of panarchy and transformability are interrelated (Folke et al., 2010).

*Table 15.1 – Examples of types of complex adaptive systems and variables that may be conducive to a cross-scale resilience analysis adopted from Sundstrom et.al. (2014) (Sundstrom et al., 2014).*

| **Systems** | **Variable** | **Functional Attribute** |
|---|---|---|
| Social-ecological/ Urban Systems | Population Size | Emergency services<br>Production<br>Transportation Options<br>Employment diversification and evenness<br>Energy Grid<br>Food Network<br>Types of open Spaces<br>Ecosystem services |
| Socio-cultural Systems | Population Size Government size/type | Cultural Diversity<br>Educational opportunities (e.g., years of schooling)<br>Socio-economic diversity<br>Political upheaval<br>Size of governed area |
| Economic Systems | GDP<br>Size classes of industry<br>Types within an economy<br>GINI coefficient<br>Stock market indexes | Industry types (product diversity, export diversity)<br>Natural Resource Dependence<br>Employment (qualifications, redundancy)<br>Standard-of-living measures<br>Market sectors |
| Socio-historical Systems | Population Size | Access to environmental sources<br>Social connectivity within and across scales<br>Types of governance |

Later, Sundstrom et al. explained the cross-scale resilience model first in general, and then they applied the model to various complex adaptive dynamic systems (CAS), including socio-ecological urban models, as given in the table below (Sundstrom et al., 2014).

In this study, we believe that architecture, one of the major actors in built environment with its cross-scale relations with social-ecological systems, is also a complex adaptive system (CAS) for which resilience is a very critical and sometimes controversial issue. CAS for architecture can be modelled starting from building scale as well. Even a simple building can epitomize the systems and their relations, making visible the interaction in cross-scales, serving to extend discussions on transformation that is observed in social-economic systems (SES). The fact that the construction industry is an important actor that consumes a large amount of natural resources, on the one hand, and its significant contribution to the economy, on the other hand, has emerged as a paradox in recent years. The rapidly increasing world population and the correspondingly increasing need for housing also highlight this ambiguity even more. As a result of all these, the concept of sustainability is being discussed more, and these discussions are accompanied by the change of economic models and the transformation of social-economic systems (SES).

## 15.3. Panarchy, circular economy, life cycle assessment and built environment

Transformation in SES eventually brings a change in economies and economic models. The shift from a linear economy to a circular one is the direct consequence of such transformation as a response to ecological-social crisis or, in other words, an adaptation to the current global crisis. Kennedy, in his study, defines the circular economy as *an alternate way of organizing industrial systems, seeking to ensure that social-ecological systems stay within limits favorable to human life by reducing the exploitation of raw materials and decreasing industrial emissions and waste* (Kennedy and Linnenluecke, 2022). Circular economy is not only eliminating waste, pollution, re-value materials but also it is underpinning the regeneration of nature (Ellen MacArthur Foundation, n.d.). Gladek furthers the definition of circular economy (Gladek, 2019). She explains the key features of CE as its pillars *(1) materials are cycled at continuous high value, (2) all energy is based on renewable sources, (3) biodiversity is supported and enhanced through human activity, (4) human society and culture are preserved, (5) the health and wellbeing of* *humans and other species are structurally supported, (6) human activities maximize generation of societal value, (7) water resources are extracted and cycled sustainably*.

In December 2015, the acceptance of legislation on transition to circular economy by the European Committee can be accepted as another milestone in transforming SES (European Commission, 2015). In this transition period, the involvement of LCA in the preparation of action plans was given importance and highlighted by the Committee. All the studies on the transition to CE, new legislations, directives, and new governance models show that if a circular economy is targeted, a holistic system approach is necessary. Since CE is not solely an economic model but it is rather a fundamental change in socio-ecologic systems. In this regard, understanding circular economy within the framework of complex systems, their resilience, and their interactions/dependencies on different scales can facilitate to develop novel strategies to achieve well-being of societies and environment as well as sustaining/improving the relation between natural and built environment.

While keeping the delicate balance between nature and built environment, how circular economy can be rationalized/operationalized, the four cycles of panarchy, exploitation (r), organizational consolidation (K), creative destruction or "release" (Ω), and re- or de-structuring (α) can be used. Rich proposes panarchy and adaptive cycles as a model for the historic built-environment and explores the potentials of future-proof concept as a guide to determine how a historic building will survive and continue to serve (Rich, 2019). Rich uses this term as a substitute of resilience and defines as *the process of anticipating the future and developing methods of minimizing the negative effects while taking advantage of the positive effects of shocks and stresses due to future events*. Future-proofing provides strategies for *appropriate and sensitive* interventions in historic buildings/environments. These strategies are; "(1) Prevent decay, (2) Stimulate flexibility and adaptability, (3) Extend service life, (4) Fortify, (5) Increase redundancy, (6) Reduce obsolescence, (7) Plan Ahead, (8) Diversify, (9) Be local and healthy, (10) Consider life cycle benefits, (11) Take advantage of cultural heritage policy documents, (12) Promote understanding, (13) Use it" (Rich, 2019). It should be noted that future-proofing is not aiming to prolong the life of buildings or products for forever, but it rather explores flexibility/adaptability of them to changing conditions. Future-proofing (or resiliency) strategies require a holistic approach to determine what, how, and to which extent interventions must be done. In this regard, the panarchy model and its adaptive cycles provide a valuable framework to picture-out the possible impact on different scales, as exemplified in several studies from ecology to law (Ruhl, 2012), and their number is increasing significantly in parallel with developments in construction industry, from economy to conservation. As can be seen, future-proofing (or resiliency) strategies are not only well overlapping with life-cycle assessment/management processes but also meet the requirements of circular economy. Life cycle assessment (LCA) is defined by EPA as *a process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities* (European Environmental Agency, n.d.). LCA, as a method mostly focuses on material and energy flows in the life cycle of a product, a service, or a building to assess the regional and global impact. LCA can be applied partially (cradle to gate) or concerning the whole life cycle (cradle to grave). In this approach, determining the system boundary, which is defined as *the demarcations on the technological system and nature, delimitations of the geographical area and time horizon considered, boundaries between production and production of capital goods and boundaries between the life cycle of the product studied and related life cycles of other products* is not an easy task yet it assures the accuracy of assessment (Tillman et al., 1994; Li, Zhang et al., 2014).

Today there are various software that are employed in LCA in the assessment of residential buildings (Islam, Jollands, and Setunge, 2015), and their number is increasing significantly in parallel with developments in the construction industry. Although LCA is a valuable asset in planning and designing, yet its accuracy is highly dependent on inventory data quality, and most of these tools are using region-specific data like raw materials, climate, available energy resources etc. which are mostly not compatible with other regions, making hard to achieve high accuracy and thus decision making.

LCA stages, according to EN 15804 are shown below. This systematic representation, according to standards, gives a clear picture of a life cycle of an artefact, and yet it is not enough to scrutinize the cross-scale relations and complexities inherent in the systems. Moreover, system boundaries cannot be defined by scientific or technologic options only, but as Schlör et al. indicate, *The characterized boundaries are not only defined by possible technological options, but also by the social frame of the chosen sustainability strategy. The boundaries depend not only on scientific restrictions and technological options but also on social restrictions and the chosen sustainability strategy and its degree of freedom of choice for people, derived from social conceptions about intra- and intergenerational justice* (Schlör et al., 2015). LCA has been employed more and more in product design and in buildings to assess the environmental impact as a part of the CE framework. On the other hand, some LCA studies have shown that the promotion of extensive *re-use, recycling and recovery* in material and energy production and consumption may have some adverse effects on socio-ecological system or not always favourable from an environmental point of view (Haupt and Zschokke, 2017). Haupt and Zschokke, in that study summarizing the discussions on LCA and CE points out that the essence of transforming the economies into circular one is *to assess systemic changes* and the benefits (as well as adverse effects) of such closed-loop models should be explored more regarding the environment in the broadest sense in all scales.

*Tab. 15.2 – Life Cycle Stages according to EN 15804.*

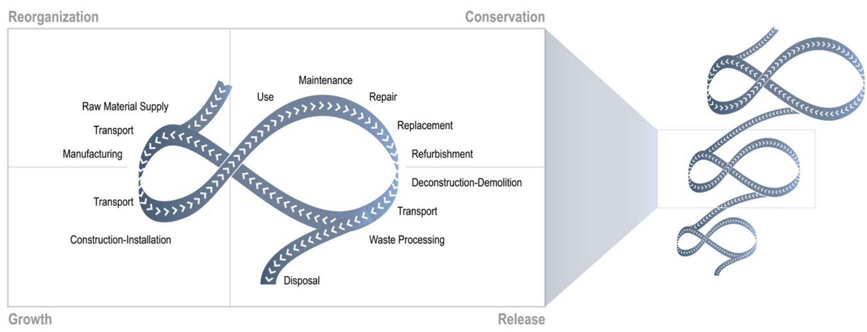
| **Building life cycle information** | | | | | | | | | | | | | | | **Supplementary information beyond the building life cycle** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | | | Construction process | | Use stage | | | | | End of life | | | | | |
| Raw Material supply | Transport | Manufacturing | Transport | Construction- installation process | Use | Maintenance | Repair | Replacement | Refurbishment | De-construction | Transport | Waste Processing | Disposal | Reuse – Recovery – Recycling potential |

The system approach and re-thinking of resilience either in engineering or in nature and understanding can contribute to developing new strategies both preserving the balance between ecology and society but also economies and development of new action plans which should help to decide on 'resilience of what and to which extend'.

## 15.4. Conclusion

There is a global change that ecological-sociological systems should cope with. Transforming our systems in all scales compels a new and extensive perspective. Circular economy has been encompassed as a new philosophy bringing paradigmatic shifts in production and consumption. Resilience thinking and adaptive cycles proposed by Holling have found wide acceptance in various fields, so does in socio-ecological studies and eventually in CE and life cycle thinking LCT and life cycle assessment LCA. In searching for correspondence between LCA stages and panarchy cycles, the following mapping can be proposed as follow. The "Product Stage", including the (A1) raw material extraction and processing, processing of secondary material input, (A2) transport to the manufacturer, and (A3) manufacturing as it is presented in ISO EN15804, is reflected to the reorganization phase (α) of panarchy cycle indicating rapid re-assembly of components either with the introduction of new material into the system or as a continuation of release phase. Then, the second phase related to the act of construction (A4), including the transportation and construction-installation processes (A5), is determined as a part of the growth (r) phase of the cycle. The "Use Stage" is projected into the conservation (k) phase with the following steps: (B1) Use, (B2) Maintenance, (B3) Repair, (B4) Replacement, and (B5) Refurbishment. Finally, the release phase (Ω) is matched with "End of Life" stage, where the energy of the system will be released after deconstruction either by disposal or by recycling.

*Fig. 15.3 – Projection of Panarchy Model onto the phases of life cycle of a system.*




*Source: Elaborated by the authors.*

On the other hand, the evaluation of LCA through the lenses of panarchy cycles, as explained above, reveals that the very compartmented stages of LCA do not suffice to reflect the complex nature of circularity. Panarchy model is derived from ecological resilience, not deterministic but more normative, as a conceptual model that helps to recognize changes in different scales, temporal, spatial, or social. The four cycles of panarchy, growth or exploitation, conservation, release or creative destruction, and reorganization show system response and its resilience to predictable or unpredictable changes. Panarchy model helps to understand the paradoxical relations in life cycles, such as persistence versus change, flexible versus efficient, resilient versus transformational, and connected versus adaptable (Gunderson, 2000; Holling and Gunderson, 2002). Panarchy cycles are not hierarchical, fixed, or sequential; they are nested and interacting. Hence resilience is not a fixed feature, but it is dynamic and changing. Projection of panarchy model onto phases of life-cycle assessment methods of a system (a simple product or a building) shows how critical to determine the system boundaries and to consider the resilience in different scales and contexts. The complexity and nested nature of interactions of systems in an environment actually make it very hard to confine them into well-separated modules.

This complexity also shows that the 3R's of circular economy (re-use, recycling, and recovery) should also be planned considering the delicate and sensitive balance in socio-ecological systems. Transforming economies to a circular model actually means transforming the environment as a whole. It should always be remembered that natural and built environments are interconnected systems, and any intervention to one of them will affect the other on cross scales.

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# *16. Improving the efficacy of circularity in the building sector to cope with climate change: shared actions among operators*

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## 16.1. Circular economy concept and its relation with climate change

In recent decades, the World's linear economy has been oriented toward the circular economy (CE) to reduce environmental impacts based on the preservation of natural resources and to avoid waste through principles such as reuse, recycling, and recovery (OECD, 2012; EEA, 2016; Deloitte, 2021). At the European level, the introduction of "The Circular Economy Package" (EC, 2015) and the subsequent reinforcement "Circular Economy Action Plan for a Cleaner and More Competitive Europe" (EC, 2020), have designated the building sector as a "priority area" towards the CE transition. This sector indeed is attributed to 9% of the Gross Domestic Product (GDP) in the European Union (EU) economy; however, it is responsible for a large resource consumption of about 50% of all material extracted in the EU and causes more than 35% of the total EU waste, and consequent greenhouse gases (GHG) emissions and associated climate change impacts, during the life cycle of a building process. Therefore, climate change mitigation actions should consider this sector in the major roles (Norouzi et al., 2021). In effect, even though global $CO_2$ emissions from building operations declined 10 % due to the Covid-19 pandemic, the construction sector in 2020 is still attributed to 36 % of global energy demand and 37 % of energy-related $CO_2$

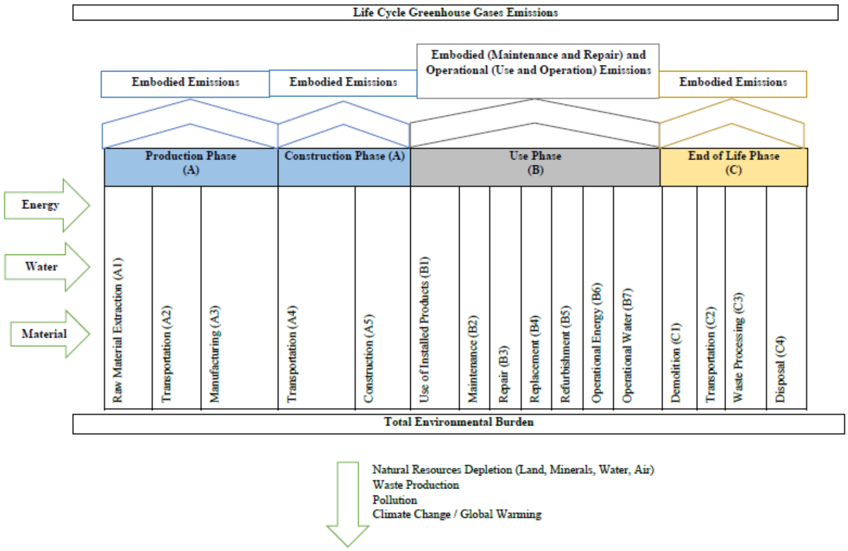
emissions (UNEP, 2021). The political and scientific debate concerning global climate change has focalised on the construction sector for over twenty years, and the CE approach has been introduced to make this sector more sustainable by reducing environmental impacts (Núñez-Cacho et al., 2018). There have been several attempts to foster the CE implementation in the construction sector and in the scientific community focusing on three main topics: 1) waste management, regarded in most of the studies (Osmani and Villoria-Sàez, 2019; Munaro et al., 2020) with a special focus on recycling (Pan et al., 2020), especially at the material scale applications (Caldas et al., 2021), emphasizing the importance of traceability systems of materials and information (Koutamanis, 2020); 2) design for reversible building concept, investigated by the researchers to obtain flexible, adaptable, and disassemble buildings (Akinade et al., 2020; Dams et al., 2021) with the utilization of Building Information Modelling (BIM) and Material Passport (MP) digitalization tools; 3) business and stakeholders networking and green deal along the value chain of the construction sector, to encourage platforms to link collaborative process and networks among different stakeholders (Leising et al., 2018; Konietzko et al., 2019; Hossain et al., 2020). However, effective implementation of the CE in the construction sector is still in its infancy stage due to the barriers that emerge from the limited current policies and practices scarcely shared among stakeholders and mostly focusing on waste minimization and recycling. Likewise, the latest call of the European Community on the Horizon program - Integrated solutions for circularity in buildings and the construction sector - confirms the need for an integrated and shared approach among stakeholders for effective implementation of circularity through innovative policies and coordinated practices (GlobalABC, IEA, and UNEP, 2020), to cope the climate change related to the environmental impacts due to the whole life cycle of a building.

## 16.2. Climate change within the building life cycle

The principal environmental impacts of the construction sector are associated with the enormous use of natural resources, energy, water, and land, involved in the life cycle of a building process, and thus, GHG emissions (Figure 16.1). The production phase, especially for low-energy buildings, contributes a large share of the total life cycle impacts, depending on climate, energy supply, and lifespan (Stephan et al., 2013). This phase is attributed to a large amount of resource depletion, as approximately 50% of all extracted materials being manufactured into construction materials and products

(Koroneos and Dompros, 2007; Ngwepe and Aigbavboa, 2015), and a large amount of mostly fuel-based energy consumption as 15-60% of total life cycle consumption of a building process (Gibberd, 2014), and 11% of the global GHG emissions (UNEP, 2020).

*Fig.16.1 – Environmental impacts associated with the life cycle of a building.*




*Source: Elaborated by the authors, based on (Li, 2021), Figure 1, p. 4.*

While the construction phase is associated with mainly fossil fuel and electricity-based energy (2-9% of the total life cycle energy consumption of a building), water and land utilization result in further GHG emissions (Gustavsson, Dodoo and Sathre, 2015). On the other hand, the use phase, which is divided into the use and operation stage, and the maintenance and repair stage, generally contributes the greatest share of life cycle primary energy and GHG emissions, mainly from the use and operation stage, which globally accounts for around 25-40 % of total final energy consumption (OECD, 2003). The end-of-life phase, finally, results in embodied GHG emissions attributed to 0.2-0.3%, and energy consumption of 1-3% of the total life cycle impact (Gustavsson et al., 2015). The impacts of GHG emissions - carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$) - cause chlorine to destroy stratospheric ozone, but as is now known, $CO_2$ is the primary cause of climate change. According to life cycle assessment (LCA) metrics, in terms of Global Warming Potential (GWP), $CO_2$ equivalent emissions over the entire life cycle of a standard building contribute about 20-30% to climate change in the production phase; 5-10% for the construction phase, over 50% for the use phase, 8-10% for the end-of-life phase, and negative 5-10% for benefits and loads across the system boundary (Birgisdóttir and Rasmussen, 2016). Given its environmental impacts, the construction sector could play an important role in the transition to the CE on the European scale (EC, 2014b). However, several environmental, economic, social, technical, political, and organizational barriers are still present in the effective implementation of the CE in this field.

Environmental barriers emerge from human health and safety risks due to the existence of lead, asbestos, or contaminated materials (Charef et al., 2021), while economic barriers are mainly related to high initial investment and equipment costs, lack of market volume and incentives for circular products, and low price of virgin materials compared to circular materials (WBCSD, 2018).

Social barriers instead are related to issues of culture, trust, beliefs, and societal upbringings, such as status quo bias, comfort with being and operating in a known and trusted linear system, and limited attention, awareness, and interest in circularity (Ottosen et al., 2021).

Technical barriers are related to the low quality and unreliability of reclaimed materials, the complexity of a building process with a long-life cycle longer than that of industrial products, while political barriers are associated with the lack of adequate standards and guidelines, lack of recertification, legal guarantees, and lack of economic incentives and government support (Yu et al., 2021).

Finally, organizational barriers emerge from the high fragmentation and project-based characteristic of the construction sector, in particular the lack of stakeholders' willingness to collaborate and to integrate knowledge and competencies within all building's life cycle (Górecki et al., 2019).

The interdisciplinary nature of the CE is further complicated with respect to the construction industry, which itself is fragmented and characterized by a wide variety of phases and operators with very different backgrounds and skills. Along the building process, manufacturers, designers, consultants, end-users/owners, contractors, maintainers, and demolishers only temporarily work together according to codes and canons of their specific knowledge: this causes a lack of communication among supply chain actors, who do not possess a short- and long-term view of the environmental impacts due to their activities (Giorgi et al., 2022; Tirado et al., 2022). Hence, strengthening collaboration and mutual awareness among stakeholders could be essential to improve the effectiveness of the transition to the circular approach in the construction sector. So, considering that more shared "circular" actions are more likely to be implemented in favour of the CE approach in the building sector, this study aims to identify possible "circular" actions, shared between stakeholders, to implement circularity and then cope with climate change. This could contribute to build up possible common strategies shared between operators to cross the actual barriers that emerged and build up future operational scenarios.

## 16.3. Key stakeholders and circular actions

The proposal, according to various authors (Giorgi et al., 2022; Tirado et al., 2022), is based on the initial assumption that the implementation of circularity in the construction sector is possible only through the active involvement of operators in the sector and a shared approach among them. Starting from this, the aim is to define which "circular actions" recurring in the various phases of the construction process, are common to the different operators or groups of operators involved.

Furthermore, considering that more shared actions are more likely to be implemented, the recurrence of the "circular actions" with respect to the actors involved, could be the prerequisite for effectively implementing circularity in the sector, because it also means defining a common field of work, making everyone responsible for his active role towards the circularity of the sector. Therefore, through a critical literature review, the operators are identified and thus "circular actions" are selected within the scientific literature only from the Web of Science and SCOPUS, using some keywords identifying the relationship between climate change and the construction sector. The selection criteria concerned only circular economy actions undertaken against climate change at the materials and building level, referring to the production, construction, use, and end-of-life phases.

### *16.3.1. Key stakeholders*

The construction sector is more complex than other industries, and it involves different operators in several processes and sub-processes in which they are numerous, and work only temporarily together by taking on key roles depending on the building process they are in Feige et al. (2011).

The representative number of key stakeholders is, therefore, a subjective issue defined differently by authors. According to WBCSD (2018), there is a total of 14 key stakeholders involved, namely: developers, architects, advisors, and engineers, suppliers, and venders, building companies, wholesale, real estate investors, users, facility members, specialised construction and installation companies, owners, deconstruction and demolition companies, waste treatment companies, financial institutions and banks, and regulators and legislators. Larsen et al. (2022) define the number of key stakeholders as 20 of which 13 (designers, consultants, contracts, producers, suppliers, end-user/consumers, buildings workers, architects, engineers, building owners, demolition experts, developers, and local community) of them directly involved at least one of the phases in the life cycle, and other 7 (present society, policymakers, non-governmental organizations, internal and external clients, public/media, and future society) not directly involved. In accordance with several authors (Freeman, 1984; Wallbaum et al., 2010), this study has considered 18 key stakeholders (Table 16.1): 12 internal, strategic stakeholders; 5 external, normative stakeholders, and 1 both external and internal stakeholder. The internal, strategic stakeholders are allocated to one or more life cycle phases of a building, while the external, normative ones are not directly involved in the process, but can still influence it with regulatory or mandatory decisions.

*Tab. 16.1 – The key stakeholders and their involved life cycle phases.*

| **Internal, Strategic Stakeholders** | |
|---|---|
| **Key Stakeholders** | **Life Cycle Phase** |
| Designers/Planners | Design Phase, Construction Installation Stage (Construction Phase), Repair, Replacement, and Refurbishment Stages (Use Phase) |
| Architects, Engineers | Design Phase, Construction Installation Stage (Construction Phase), Repair, Replacement, and Refurbishment Stages (Use Phase) |
| Banks/Financial Institutions | Design Phase |
| Consultants/Advisors | Design Phase |
| Investors/Developers/Contractors | Design Phase, Construction Installation Stage (Construction Phase), Repair, Replacement, and Refurbishment Stages (Use Phase), Demolition/Deconstruction, Waste Processing, and Disposal Stages (End-of-Life Phase) |
| Owners | Design Phase, Construction Installation Stage (Construction Phase), Use, Maintenance, Repair, Replacement, and Refurbishment Stages (Use Phase), Demolition/Deconstruction Stage (End-of-Life Phase) |

| | |
|---|---|
| Suppliers/Venders | Raw Material Supply (Production Phase), Construction Installation Stage (Construction Phase), Repair, Replacement, and Refurbishment Stages (Use Phase), Demolition/Deconstruction, Waste Processing, and Disposal Stages (End-of-Life Phase) |
| Manufacturers/Producers | Manufacturing (Production Phase), Construction Installation Stage (Construction Phase), Repair, Replacement, and Refurbishment Stages (Use Phase), Demolition/Deconstruction, Waste Processing, and Disposal Stages (End-of-Life Phase) |
| Construction/Building Companies | Construction Installation Stage (Construction Phase), Repair, Replacement, and Refurbishment Stages (Use Phase) |
| End Users/Consumers | Use, Maintenance, Repair, Replacement, and Refurbishment Stages (Use Phase), Demolition/Deconstruction Stage (End-of-Life Phase) |
| Demolition/Deconstruction Companies | Demolition/Deconstruction Stage (End-of-Life Phase) |
| Waste Treatment Companies | Waste Processing and Disposal Stages (End-of-Life Phase) |

**Both External and Internal Stakeholders**

| **Key Stakeholders** | **Life Cycle Phase** |
|---|---|
| Public Authorities/Policy Makers | All Building Life Cycle Phases |

**External, Normative Stakeholders**

| **Key Stakeholders** | **Life Cycle Phase** |
|---|---|
| Non-governmental Organizations and Civil Society | All Building Life Cycle Phases |
| Researchers / Experts | All Building Life Cycle Phases |
| Future Generations and Society | All Building Life Cycle Phases |
| Public / Media | All Building Life Cycle Phases |
| Environment | All Building Life Cycle Phases |

For this proposal, we have considered only the internal operators assigning them to the phases in which they are involved, excluding transportation related to manufacturing, construction, and end-of-life, energy and water operational phases, and the potential for recovery, reuse, and recycling beyond end-of-life, since the latter is affected by the choices made in the previous phases. The degree of efficacy was measured by the recurrence of operators in each phase of the life cycle of a building process according to formula (1) in Figure 15.2. As covering the life cycle, from the design phase to the disposal, the degree of efficacy reaches its maximum value of 1, with the summation of the identified degree of efficacy values for each stage according to formula (2) in Figure 15.2. Therefore, the degree of efficacy was identified, within a range from 0 to 1, based on the recurrence of operators within the phases of a building process.

*Fig. 15.2 – Formulas for the degree of efficacy based on the number of stakeholders, and for the degree of efficacy based on the recurrence in the life cycle phases of a building process.*

$$R_{ST} = \frac{\textit{Number of Key Stakeholders involved in the Life Cycle Stage}}{\textit{Maximum Number of Stakeholder Throughout the Life Cycle}} \quad (1)$$

$R_{ST}$= Degree of efficacy based on the number of operators

$$(R_{ST})_T = \sum_i^n R \quad (2)$$

$(R_{ST})_T$= Degree of efficacy based on the recurrence of operators in the life cycle phases of a building process
i= The first phase considered in the life cycle process
n=The last phase considered in the life cycle process

*Source: Elaborated by the authors.*

### *16.3.2. Circular actions*

The identification and selection of "circular actions" were conducted through a critical literature review, selecting 21 circular actions related to strategic approaches such as low input production of materials and energy (Hammond and Jones, 2008); design of reversible building and construction systems (Antonini et al., 2020); design for standardization (Minunno et al., 2018); design for end-of-life recycling (O'Grady et al., 2021); reuse of building products and components (Assefa and Ambler, 2017); and open and closed-loop recycling (Andersen et al., 2020).

The actions (1), (6), (7), (8), (10), and (13) have been attributed to the design (preconstruction) phase, namely: design out waste, design in modularity, design for adaptability and flexibility, design for disassembly, design for standardisation, and design for recycling.

The actions (2), (3), (4), (14), (15), and (16) have been attributed to the production phase, namely: use of less materials, use of less hazardous materials, use of secondary materials, reverse logistics, eco-design, and take-back schemes.

The actions (5), (9), (11), and (12) have been assigned to the end-of-life phase, namely: reuse of products and components, selective demolition and deconstruction, closed-loop recycling, and open-loop recycling. The circular actions (17), (18), and (19) are referred to the construction phase, respectively, to the off-site construction, procurement of used materials, and procurement of recycled materials, while the actions (20) and (21) are referred to waste minimisation and maintenance minimisation strategies addressed to the use phase.

Table 16.2 shows the 21 circular actions broken down to the entire building life cycle and the excluded phases (coloured in grey) because they do not directly correspond to a stakeholder among the key ones considered above and because they depend on decisions assumed in the previous phases, as already specified.

*Tab. 16.2 – Life cycle process of the identified circular actions.*

| Circular Actions | Design Phase | Raw Material Supply | Transportation | Manufacturing | Transportation | Construction | Use | Maintenance | Repair | Replacement | Refurbishment | Operational Energy | Operational Water | Deconstruction | Transportation | Waste Processing | Disposal | Recovery, Reuse and Recycle potential |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | X | X | X | X | | | | | | | | | | | | | | |
| (2) | X | X | X | X | X | X | X | | | X | | X | | X | X | X | X | |
| (3) | X | X | X | X | X | X | | | | | | X | | | | | X | |
| (4) | X | X | X | X | X | X | X | | | X | | X | | X | X | X | X | |
| (5) | X | X | X | X | | | | | | | | | | X | X | X | X | X |
| (6) | X | X | X | X | | | | | | | | | | | | | | |
| (7) | X | X | X | X | | | | | | | | | | | | | | |
| (8) | X | X | X | X | | | | | | | | | | | | | | |
| (9) | X | X | X | X | X | X | | X | | X | X | X | | X | X | X | X | X |
| (10) | X | X | X | X | | | | | | | | | | | | | | |
| (11) | X | X | X | X | | | | | | | | | | | | X | X | X |
| (12) | X | X | X | X | | | | | | | | | | | | X | X | X |
| (13) | X | X | X | X | | | | | | | | | | | | X | X | X |
| (14) | X | X | X | X | | | | | | | | | | | | X | X | X |
| (15) | X | X | X | X | | | | | | | | | | | | X | X | X |
| (16) | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X |
| (17) | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X |
| (18) | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X |
| (19) | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X |
| (20) | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X |
| (21) | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X |

*Source: Elaborated by the authors.*

The degree of effectiveness of circular actions was calculated according to Figure 16.3. In terms of recurrence in each life cycle phase based on the maximum number of circular actions; the value was obtained in the range of 0 to 1, with a sum of the degree of effectiveness values identified for each life cycle phase by using the formula (4) in Figure 16.3. The degree of efficacy based on the recurrence of the shared circular actions in the life cycle process was then attributed to each one of the identified circular actions.

*Fig. 16.3 – Formulas for the degree of efficacy based on the number of shared actions and for the degree of efficacy based on the recurrence in the life cycle phases of a building process*

$$R_{SA}=\frac{\textit{Number of Shared Circular Actions Present in the Life Cycle Stage}}{\textit{Maximum Number of Shared Actions Throughout the Life Cycle}} \quad (3)$$

$R_{SA}$= Degree of efficacy based on the number of shared circular actions

$$(R_{SA})_T=\sum_i^n R \quad (4)$$

$(R_{SA})_T$= Degree of efficacy based on the recurrence of shared circular actions in the life cycle phases of a building process
i= The first phase considered in the life cycle process
n=The last phase considered in the life cycle process

*Source: Elaborated by the authors.*

## 16.4. Circular actions shared among the key stakeholders

The methodology has offered to find the degree of efficacy of both the key stakeholders (Table 16.3) and the shared "circular actions" (Table 16.4), based on their recurrence in the life cycle phases of the building process. In the design phase, all the 21 shared "circular actions" are performed by 12 operators; in the production phase, divided into the raw material supply and the manufacturing stage, the 21 "circular actions" are shared between 7 operators; while in the construction phase only 10 "circular actions" are performed by 12 operators.

The use and the maintenance stage include 8 and 7 shared circular actions, respectively and 8 operators in each one of these. In the following three stages (repair, replacement, and refurbishment) of the use phase, there are 6, 9, and 1 shared circular action, and 14 stakeholders are involved in each one of these stages.

In the end-of-life phase, 10 shared circular actions are taken care of by 12 operators in the deconstruction/demolition stage; while the waste processing includes 15 shared circular actions between 10 operators, and 16 shared circular actions by 10 operators are involved in the disposal stage. In the light of the aforementioned findings, the degree of efficacy value ($R_{ST}$), which is based on the number of stakeholders in each life cycle stage, demonstrated the highest value (0.11) in the repair, replacement, and refurbishment stages, while the lowest values (0.05) were presented by the raw material supply and manufacturing stages. On the other hand, the degree of efficacy value ($R_{SA}$) of shared "circular actions", showed the highest value in the design and production phases (raw material supply and manufacturing stages), while the lowest value was presented in the refurbishment stage of the use phase.

Based on the degree of recurrence attributed to the number of stakeholders and circular actions in each stage of the life cycle process, it was possible to indirectly identify in which stages of the process "circular actions" appear most effective (Table 16.5).

*Tab. 16.3 - Recurrence of key stakeholders and the degree of efficacy values in the life cycle stages.*

| Life Cycle Phase | Key Stakeholders | Degree of Efficacy ($R_{ST}$) |
|---|---|---|
| **Design Phase** | 12 | 0,09 |
| **Production Phase** | | |
| Raw Material Supply Stage | 7 | 0,05 |
| Transportation Stage | 0 | 0 |
| Manufacturing Stage | 7 | 0,05 |
| **Construction Phase** | | |
| Transportation Stage | 0 | 0 |
| Construction Installation Process Stage | 12 | 0,09 |
| **Use Phase** | | |
| Use Stage | 8 | 0,06 |
| Maintenance Stage | 8 | 0,06 |
| Repair Stage | 14 | 0,11 |
| Replacement Stage | 14 | 0,11 |
| Refurbishment Stage | 14 | 0,11 |
| Operational Energy | 0 | 0 |
| Operational Water | 0 | 0 |
| **End of Life Phase** | | |
| Deconstruction/Demolition Stage | 12 | 0,09 |
| Transportation Stage | 0 | 0 |
| Waste Processing Stage | 10 | 0,08 |
| Disposal Stage | 10 | 0,08 |
| **Benefits and Loads Beyond the System Boundary** | | |
| Recovery, Reuse, and Recycle Potential | 0 | 0 |
| **Total Value** | | **1,00** |

*Source: Elaborated by the authors.*

*Tab. 16.4 – Recurrence of shared circular actions and the degree of efficacy values in the life cycle stages.*

| Life Cycle Phase | Shared Circular Actions | Degree of Efficacy ($R_{SA}$) |
|---|---|---|
| **Design Phase** | 21 | 0,15 |
| **Production Phase** | | |
| Raw Material Supply Stage | 21 | 0,15 |
| Transportation Stage | 21 | 0 |
| Manufacturing Stage | 21 | 0,15 |
| **Construction Phase** | | |
| Transportation Stage | 10 | 0 |
| Construction Installation Process Stage | 10 | 0,07 |
| **Use Phase** | | |
| Use Stage | 8 | 0,06 |
| Maintenance Stage | 7 | 0,05 |
| Repair Stage | 6 | 0,04 |
| Replacement Stage | 9 | 0,06 |
| Refurbishment Stage | 1 | 0,01 |
| Operational Energy | 4 | 0 |
| Operational Water | 0 | 0 |
| **End of Life Phase** | | |
| Deconstruction/Demolition Stage | 10 | 0,07 |
| Transportation Stage | 10 | 0 |
| Waste Processing Stage | 15 | 0,10 |
| Disposal Stage | 16 | 0,11 |
| **Benefits and Loads Beyond the System Boundary** | | |
| Recovery, Reuse, and Recycle Potential | 13 | 0 |
| **Total Value** | | **1,00** |

*Source: Elaborated by the authors.*

The cradle-to-gate considered circular actions, such as (1), (6), (7), (8), and (10), demonstrated the lowest values for both the degree of efficacy values as 0.20 for $(R_{ST})_T$ and 0.45 for $(R_{SA})_T$, while the "circular actions" with the cradle to cradle or the cradle to grave approach demonstrated an increasing rate as the "circular action" is shared between more operators and in more life cycle stages. The highest values were obtained in the (16)-(21) as 0.89 for $(R_{ST})_T$ and 0.99 for $(R_{SA})_T$.

Moving from the design phase to the end-of-life phase, more and more stakeholders are involved in the process, called upon to share more and more "circular actions": this could encourage both a greater exchange of information and knowledge among operators and an increase in mutual awareness and therefore also in the possibility of effectively implementing circular actions in the construction sector.

*Tab. 16.5 – Degree of the efficacy of the identified actions*

| Circular Actions | Design Phase | Raw Material Supply | Transportation | Manufacturing | Transportation | Construction | Use | Maintenance | Repair | Replacement | Refurbishment | Operational Energy | Operational Water | Deconstruction | Transportation | Waste Processing | Disposal | Recovery, Reuse and Recycle potential | Degree of Efficacy $(0< (R_{ST})_T <1)$ | Degree of Efficacy $(0< (R_{SA})_T <1)$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **(1)** | X | X | X | X | | | | | | | | | | | | | | | **0,20** | **0,45** |
| **(2)** | X | X | X | X | X | X | X | | | X | | X | | X | X | X | X | | **0,72** | **0,92** |
| **(3)** | X | X | X | X | X | X | | | | | | X | | | | | X | | **0,38** | **0,63** |
| **(4)** | X | X | X | X | X | X | X | | | X | | X | | X | X | X | X | | **0,60** | **0,92** |
| **(5)** | X | X | X | X | | | | | | | | | | X | X | X | X | X | **0,61** | **0,73** |
| **(6)** | X | X | X | X | | | | | | | | | | | | | | | **0,20** | **0,45** |
| **(7)** | X | X | X | X | | | | | | | | | | | | | | | **0,20** | **0,45** |
| **(8)** | X | X | X | X | | | | | | | | | | | | | | | **0,20** | **0,45** |
| **(9)** | X | X | X | X | X | X | | X | | X | X | X | | X | X | X | X | X | **0,83** | **0,92** |
| **(10)** | X | X | X | X | | | | | | | | | | | | | | | **0,20** | **0,45** |
| **(11)** | X | X | X | X | | | | | | | | | | | | X | X | X | **0,36** | **0,66** |
| **(12)** | X | X | X | X | | | | | | | | | | | | X | X | X | **0,36** | **0,66** |
| **(13)** | X | X | X | X | | | | | | | | | | | | X | X | X | **0,36** | **0,66** |
| **(14)** | X | X | X | X | | | | | | | | | | | | X | X | X | **0,36** | **0,66** |
| **(15)** | X | X | X | X | | | | | | | | | | | | X | X | X | **0,36** | **0,66** |
| **(16)** | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X | **0,89** | **0,99** |
| **(17)** | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X | **0,89** | **0,99** |
| **(18)** | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X | **0,89** | **0,99** |
| **(19)** | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X | **0,89** | **0,99** |
| **(20)** | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X | **0,89** | **0,99** |
| **(21)** | X | X | X | X | X | X | X | X | X | X | | | | X | X | X | X | X | **0,89** | **0,99** |

*Source: Elaborated by the authors.*

## 16.5. Remarks and future considerations

The current CE implementation in the building sector still lacks adequate communication and collaboration between operators, since the complexity of the process and the variety of the operators with diverse occupations, missions, and skills, hence the effective implementation of the CE in the construction sector requires a strong network between stakeholders across the entire value chain, connecting all phases of a building's life cycle. Moreover, considering that more shared "circular actions" are more likely to be implemented in favour of the circular economy approach, this study tried to establish a degree of efficacy of the shared circular actions based on their recurrence in the life cycle process phases and the greater number of involved operators.

This study proposed a methodological approach to attribute a degree of effectiveness to both operators and "circular actions", based on their recurrence along the process, as a condition to build a common and shared field of work, to define strategies to implement the circular economy in the construction sector.

The work of field should be set to encourage the operators and be available to all of them so that they can create business relationships, share information, and work collaboratively. In this sense, the CE implementation in the construction sector could increase as the actions are shared between more operators covering more life cycle stages, from design to end-of-life, and thus the environmental impact and consequent climate change associated could be faced in a more effective way.

The methodology has been elaborated based on "generic" circular actions extracted from the literature of the sector, but to clearly define a potential shared field of work, it will be necessary to identify the specific actions through an accurate analysis of what really happens on the field within the different phases of the construction process and which operators are really involved and conscious of their role. From the results that could emerge, it will be possible to effectively delineate specific and effective "circular actions" to implement circularity in the construction sector based on an active stakeholder's involvement in each life cycle stage.

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Cities are facing unprecedented challenges driven by different forces. On the one hand the ever-increasing effects of climate change are impacting on the urban microclimate and environmental balance, on the other one social, political and economic issues are influencing the living conditions, the accessibility to primary services and resources, as well as growth opportunities for the younger generations.

The rise of a social awareness regarding these topics suggests how relevant scientific-based evidence could be and calls for additional efforts to bridge the gap between science and society, in order to stimulate a collective responsibility and due actions.

The complex interaction among these factors inspired a forward-looking reflection not only on key drivers of change but also on possible future trends for research assuming an interdisciplinary and multiscale perspective. The book collects several experiences from different contributors working in many contexts and countries, but sharing the same projection to the future. Four key priorities are addressed: the resilience to climate-related events and impacts, the energy issue with reference to both the advances at building level and the role of end users, the capacity to adapting components and systems to emerging needs, and the adoption of assessment and simulation tools for improving the design capacity within a circular system perspective.

The book provides therefore insights, experiences, approaches to deal with current and especially with future transition processes which are expected to shape the cities of tomorrow. Thus, its ambition is not to provide definitive answers but to become a starting point for exploring promising research pathways for the next generation cities.

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