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Key challenges of climate change adaptation in the building sector

This paper addresses the main challenges in climate resilience of the building sector, including climate adaptation schemes, energy efficiency, and mitigation approaches. These challenges are evaluated with regard to the state of the art, research interest, and regulatory issues, providing an assessment of the advances and defining research gaps in the literature review. The review shows that climate resilience mainly deals with larger systems, whereas the field is still developing at the building level. One of the main challenges identified is the institutional response. Many publications state that it is necessary to revise policies and develop legislation; however, this is sometimes hindered by uncertain climate change predictions. The EU legislation currently provides partial coverage of resource efficiency and climate mitigation in the building sector, while the national legislation is delayed. The current situation can impair the competitiveness of the national building sector, causing it to lag behind the goals set for achieving sustainability. From the cost perspective, immediate short-term actions are seen as more expensive, because delays can result in increased risks for major investments. The authorities are currently choosing between rapid and delayed actions, balancing the costs of early actions and the reciprocal costs of delay.

Keywords: buildings, climate change, climate resilience, economy, climate change adaptation

1 Introduction

The scientific evidence shows that the speed of climate change has significantly increased due to human activity (ARSO, 2018). Since the end of the nineteenth century, the air temperature on Earth has risen by 0.8 °C, and in the past twenty-five years it has been rising by 0.2 °C per decade (UKCP, 2009; WMO, 2018). At the current level of preventive measures, by the end of the century, the global average temperature will have risen by more than 4 °C relative to the pre-industrial era (UNEP, 2018) and a similar rise will take place in Slovenia (Bertalanič et al., 2018). This will have a severe impact on the built environment. Even if some previously set mitigation measures are applied, the global average temperature will rise by more than 3 °C relative to the pre-industrial era (UNEP, 2018), resulting in new requirements and use patterns in buildings. Global warming already influences the built environment by challenging building energy demand and energy supply systems (Olonscheck et al., 2011; Wang et al., 2014; Pérez-Andreu et al., 2018). Ocean warming results in higher surface water temperatures, a rising sea level, changed patterns of sea currents (WMO, 2017; MOP, 2018), and flooding of densely populated coastal regions (UNEP, 2018). Since the 1950s, changes have also been observed in the frequency of extreme weather events, contributing to significant damages in the built environment (IPCC, 2012; 2014; Dolinar, 2014; ARSO, 2018; Bertalanič et al., 2018). At the local level, the effects of urban heat islands further increase ambient temperatures and cause overheating (Wandl & van der Hoeven, 2018; Kaplan, 2019). It is therefore essential to take more intensive action on climate change mitigation and adaptation of the built environment, or else it will not be possible to limit these effects to a manageable level in the coming decades.

As a result of population growth, the increasing volume of residential buildings is a high-priority area in climate change mitigation due to its large share of CO_2 emissions, significant energy saving opportunities, and rising expectations regarding occupant comfort (Andrić et al., 2019; Dino et al., 2019). The results of measures introduced in previous years are to some extent already visible. In the EU the building sector has contributed most to absolute reductions of emissions. Although the majority of member states are currently not on track regarding the 2030 targets, they all plan to achieve largest decreases of emissions in the building sector. The reasons for such an approach are the market availability of suitable technologies for reducing energy use and the integration of renewables (EEA, 2019). This means that the sustainability measures in the building sector will continue in the future.

This article assesses climate change adaptation approaches in the built environment that many researchers believe have great potential for reducing greenhouse gas emissions. The most important areas of dealing with climate change impacts and mitigation strategies are climate change governance adaptation approaches, the improvement of resilience in urban areas, and mitigation approaches at the building level. The holistic approach is important, based on cross-disciplinary and complex decision-making, accentuating the fact that at present these decisions are often carried out within the framework of the influence of the involved stakeholders and the requirements that need to be addressed (Kristl et al., 2019). City planners and decision-makers need to clarify and communicate their approaches to the problem, intervention methods, available resources, and possible decision-making procedures (Gohari et al., 2020). The study was carried out as a systematic literature review, dealing with three main subjects of climate adaptation in the building sector: governance measures, adaptation of urban areas, and buildings. In the article's state-of-the-art section, research interest and regulatory issues are considered, providing a valuation of the advances and defining research gaps and trends in various aspects. An overview of the main challenges provides a good starting point for further investigation in this area.

2 Study design

The systematic literature review (Punch, 2014) is structured as a gradual process in which the individual components are combined into a whole. At first, the separate fields of governance measures, urban areas, and buildings are studied, after which they are cross-combined with sustainability and climate mitigation approaches. This method allows the literature to be assessed from various viewpoints and enables an evaluation of problems that are not widely considered and could remain unnoticed. To include as much relevant information as possible, a range of various sources were searched to detect studies associated with climate change–related topics and buildings. The literature search encompassed various literature types (books, articles, studies, project reports, guidelines, statistical data, directives, standards, regulations, etc.) and research fields, such as climate adaptation strategies (strategic documents, regulations), energy efficiency in a changing climate (methods and calculations), and climate resilience and financial burden (influences on systems and buildings).

An article search was carried out of various scientific databases (e.g., Science Direct, WorldWideScience, and Emerald) for peer-reviewed publications from 2000 to 2020 written in English, with the keywords "climate change", "climate change strategy", "climate adaptation", "climate mitigation", and "climate resilience" combined with "building", "urban", "city", "real estate", "energy use", "energy retrofitting", "energy efficiency", "heating", "cooling", "management", and "financial". Examples

Table 1: Number of hits and relevant studies for selected combined search terms

Search term	Database	Hits	Title + kw	Abstract	Article
Climate change Urban	Science Direct	78,938	321	16	8
	WorldWideScience	1,430	370	18	9
	Emerald	5,289	26	4	2
Climate mitigation City	Science Direct	30,034	76	7	3
	WorldWideScience	897	128	6	3
	Emerald	2,088	52	0	0
Climate adaptation Building	Science Direct	23,638	116	8	7
	WorldWideScience	1,394	151	5	5
	Emerald	1,862	2	0	0
Climate resilience Energy	Science Direct	13,545	5	5	5
	WorldWideScience	1,013	25	7	6
	Emerald	1,354	0	0	0
Climate change strategy Policy	Science Direct	78,268	117	5	3
	WorldWideScience	1,038	87	4	2
	Emerald	13,922	27	2	2

of the basic keyword combinations used in the search and their relevant results are presented in Table 1. "Search term" describes what word combination was used to perform the search, "Database" is the database used for the search, "Hits" reveals how many results the search produced, "Title + kw" shows how many of the hits that were reviewed comprised titles and keywords relevant to this review, "Abstract" refers to how many of the abstracts fitted this review's mandate, and "Article" describes the number of general articles whose content is relevant to this review. To find legal and standardization references, various internet engines were run. Also, other relevant web sources were manually searched for project information and legal documents.

In the initial search the amount of hits was generally quite high (Table 1). Where possible the database search was set to search for articles according to relevance and publishing year. However, when the search advanced by using the selected keyword combinations, it was more difficult to find an appropriate number of articles with high relevance, especially in the fields of climate resilience/energy and climate adaptation/building. This was quite surprising, since the number of articles on energy use in buildings and similar topics is quite high in the literature. In this stage forward snowballing (Wohlin, 2014) was used in some cases to find the most recent publications. The selected articles were scanned for relevant keywords or terms. Many keyword combinations resulted in a considerable number of hits; however, in most cases only few initial pages gave relevant results. Furthermore, some databases produced very similar results, which diminished the need to use all the databases continually. The articles were culled and filtered based on the articles' title, keywords, abstract, or title content relevance. The final selection was based on the research topics stated in the introduction. The search resulted in a substantial quantity of studies and other publications from which more than 200 were selected for consideration. After examining their relevance and applicability, the culling process resulted in more than eighty sources that were used in the review. The selected articles were discussed from the perspective of three approaches to climate change adaptation: governance measures, urban areas, and buildings.

3 Review of climate change adaptation approaches

3.1 Governance measures

Authorities play a key role in adaptation processes. These further influence various stakeholders from national institutions to local players, NGOs, consulting companies, researchers, and insurance companies (Torabi et al., 2018). The system functions on the basis of the strategic and regulatory documents implemented in the decision-making process. In this context, one of the most important international agreements with a global impact is the Paris Agreement (UN, 2015b). An overview on climate change vulnerability and adaptation readiness in the 192 UN countries, by Sarkodie et al. (2019), shows that the developed countries have integrated climate adaptation plans and policies into their developmental agendas and are less vulnerable to climate change due to strong economic, governance, and social adaptation readiness. The developed countries have to commit assistance to developing countries and international assistance is needed to strengthen their resilience.

At the EU level the strategy for adapting to climate change (European Commission, 2013a) has been oriented toward further guidelines for governing bodies, civil society, the private sector and individuals working in environmental protection in order to ensure the full activation of ecosystem-based adaptation approaches. After the adoption of the Paris Agreement, the European Council stated that "the Agreement remains a cornerstone of global efforts to effectively manage climate change and is no longer negotiable" (European Council, 2017: 6). The EU also played a prominent role in the process that led to the adoption of the 2030 Agenda for Sustainable Development (UN, 2015a). A joint statement was adopted (European Commission, Council & Parliament, 2017), establishing a common framework for the development policies and implementation of the 2030 Agenda. The latest document in this line is the European Green Deal (European Commission, 2019) which sets out how to make Europe the first climate-neutral continent by 2050. The growing recognition of the impact of urban areas on climate adaptation and mitigation strategies has initiated several policy schemes (Pasimeni et al., 2019). The European Parliament has made a commitment to reach carbon neutrality by 2050 (European Commission, 2018) and directed the EU countries to prepare national energy and climate plans and climate policies. In Slovenia, the original version of the climate plan (Vlada Republike Slovenije, 2019) was criticized for its lack of ambition (C 4424 final, 2019; Zgonik, 2019) but in the final version the government strengthened the commitment and the goals were set more boldly (Vlada Republike Slovenije, 2020). The Slovenian government has also adopted the Ordinance on the Climate Change Funding (Odlok, 2020). At the local level, the Covenant of Mayors for Climate and Energy (Internet 1) connects cities committed to reaching the EU's climate and energy targets.

Various forecasts suggest that the price of insisting on an existing pattern of performance will be much higher than a timely and sufficiently comprehensive response. The Stern Review (Stern, 2007) suggested that the overall costs and risks of climate change would be equivalent to losing at least 5% of global annual GDP. The current forecasts have not considerably changed. In central and southern Europe, including Slovenia, the economic losses at the current rate of climate adaptation are projected to exceed 4% of annual GDP in the last third of the twenty-first century (Internet 2). The rapid decarbonization of the energy system and the reduced consumption of natural resources requires 1 to 2% of annual GDP (Internet 2; IPCC, 2018). Such evaluation is approximate, considering the uncertainty of the various factors in play, which include but are not limited to climate evolution, frequency of extreme weather events, and variation in energy prices. In any case, the result of a 1% of GDP investment in reducing emissions for a few decades will still have a positive effect regardless of the science being right or wrong.

The "no regrets strategies" (UNEP & UNFCCC, 2001: 50) can minimize the costs of climate change and represent a meaningful action, economically and environmentally. They can be an opportunity to remove market imperfections and create new benefits through greater industrial competitiveness in energy efficiency. According to several authors, carbon footprint is the most effective measure to mitigate climate change (Nordhaus, 2017; Freire-González, 2018). The carbon tax, which is expected to rise steeply over the years, should be enacted in the context of a green tax reform. Even though the carbon pricing serves several important purposes, the global commitment requires acknowledging the vital role of instruments other than carbon pricing (Tvinnereim & Mehling, 2018).

At the building level, the most important climate change mitigation measure is increased energy efficiency of the existing building stock. The economic assessments of energy retrofitting measures are traditionally based on the investment rate and the reduction of energy costs. Apart from the institutional level (European Commission, 2012) future financial benefits of mitigating climate change are seldom considered in the evaluation of the retrofitting investments at the project level. Nydahl et al. (2019) emphasize that the evaluation of various energy retrofitting measures may become financially sound investments if the reduced future costs of mitigated life cycle greenhouse gas emissions are included in the analysis. They can be based on standards (e.g., oSIST prEN 17472, 2020) or schemes, such as the Level(s) tool (Dodd et al., 2017). For this reason, the investment processes should encourage a balance between financial success of the business and social success and welfare of residents in the community (Boge et al., 2018, Salaj et al., 2018). In addition, more reliable models that evolve from investing only in the building to also investing in social security and regional development are needed (Temeljotov et al., 2011).

The information presented above shows that climate change mitigation will probably result in lower energy consumption, overall greater savings, and a change in established consumer preferences (IPCC, 2014). The changes will also affect the amount of income that users or individual households spend for building heating and cooling. Clarke et al. (2018) note that many studies on socioeconomic and energy system changes address the statistical economic relationship between climate variables and energy consumption. They argue that such a general approach based on information from past periods has limitations regarding the changing energy systems in future periods. Particularly challenging is the calculation of the impact of energy consumption on the share of household income spent. According to Olonscheck et al. (2011), the net global use of energy resources will increase by 0.1% if the temperature rises by 2 °C. If users try to maintain the same level of thermal comfort, they will spend an additional share of their income on energy (Clarke et al., 2018). Aiming toward energy independence by having control over energy consumption can have a highly positive impact on such economies. It guarantees that energy consumers are less dependent on a volatile market in the context of scarce fossil resources. Furthermore, the geopolitical benefit is significant in a world where the suppliers of petroleum hydrocarbons are heavily polarized on the political stage.

3.2 Urban areas

Generally, the effects of urban climate change are reflected as climatic events that affect the fundamentals of urban systems (population, built environment, and infrastructure). The consequences can be physical (e.g., damage to objects) and/or socio-economic (e.g., loss of income, health effects; Wandl & van der Hoeven, 2018). The past extreme weather events have above all exposed the vulnerability of major urban areas with a large population and complex infrastructure. Although resilience to climate change can be linked to the core priorities of city authorities, such as economic growth and social well-being, adaptation processes in most urban areas are evolving extremely slowly (Carter et al., 2015).

Resistance to climate change is a key concept, but in the context of cities this is a complex process including a number of various factors (Torabi et al., 2018). Given the intertwining nature of urban systems, it is difficult to accurately determine the effects of climate change on certain sectors and systems, because the consequences are often more extensive than immediately comprehended (Carter et al., 2015). According to Rastandeh (2015), the analyses of alternative future scenarios offer a good starting point to study probable influences of mitigation strategies on the future development in the changing conditions. This approach can be a crucial political instrument for including climate change in decision-making. However, more methods and technologies are needed to transform these presumptions into realistic development patterns. For example, Truong et al. (2018) propose a new model for selecting investments in climate adaptation, which takes into account the unreliability of climate change forecasts. The authors note that this framework significantly increases the value of investment adjustments compared to previous practices. In particular, it is important to take into account the proper sequence of investments in order to maintain the flexibility of investment in the uncertain climate change conditions. Furthermore, in their comprehensive study Mata et al. (2019) calculate the variations in the energy-saving potentials and costs for a series of energy-saving features in five climate change scenarios and compare the obtained uncertainty due to climate change to other uncertainties, such as the boundaries for emission inventories and energy system development. They find that the financial effectiveness of the retrofitting measures is often founded on the relationship between annualized investments and energy-saving potentials. Future climate conditions have a less decisive role. Measures that primarily affect heating energy need are more robust than changes in electricity use. The strategies for building retrofitting should focus on prioritizing energy savings and mobilizing investments that may not be profitable based on the current techno-economic standpoint.

Deep and rapid decarbonization of the building sector requires energy demand reductions and the integration of renewable energy sources (EPBD 844, 2018). As already mentioned above, energy retrofitting of buildings is an efficient and cost-effective approach. Bunten & Kahn (2017), however, believe that the durability of real estate capital can hamper the climate change adaptation process. In this type of scenario, Dafermos et al. (2018) provide an assessment of the consequences of climate change on financial stability using an analysis of the value of financial assets and the financial position of companies and banks. The simulations are carried out using the global data from 2016 to 2120. They find that climate change, due to the destruction of capital and the consequent reduction in profits is likely to gradually exacerbate companies' liquidity, which can lead to a higher level of defaults and thus have a negative impact on both the financial and non-financial sectors. The damage caused by the consequences of climate change can lead to the migration of capital, which may result in a gradual decline in share prices of the affected companies. Financial instability as a result of climate change can have a negative impact on lending. Furthermore, the economic and social aspects of short-term approaches to the issue may result in growing problems in the future (Champagne & Aktas, 2016).

Matko et al. (2016) also find that introduction of methods that allow for risk assessment influences the reduction of damages due to extreme weather events. A good example of such an approach is a study by Pasimeni et al. (2019), which analyses the synergy between adaptation and mitigation actions at the urban level in Italy and Spain (urban adaptation and health, transport, infrastructure, and energy). Urban management measures were classified as soft (focused on environmental information), grey (focused on buildings), and green (focused on nature-based solutions). The overall comparative analysis shows that in large and medium-sized Italian cities, mainly soft (52%) and green (28%) adaptation measures have been integrated into local energy, environmental, and climate mitigation planning. This is in line with the EU Communication (European Commission, 2013b), which states that green approaches are one of the most widely used, economically sustainable, and effective tools to combat the effects of climate change. Certain problems can be mitigated or adapted to climate change using green infrastructure (e.g., use of biodiversity and different ecosystems) which are being increasingly implemented (Ravnikar & Goličnik Marušić, 2019); however, further measures at the level of buildings should also be employed.

Adaptations (green infrastructure) affect health (cleaner air, better water quality, fewer diseases), social contacts (strengthening the sense of community, avoiding the feeling of exclusion), allow for physical, psychological, emotional and socio-economic benefits, link urban and rural areas, create an attractive environment for living and working, and strengthen regional and urban development (European Commission, 2013b). Indicators for the design effectiveness and local climate resilience can be used to monitor the degree of adaptation. As an example of such an approach, a project of eight Asian cities can be mentioned, in which a common conceptual framework was set up, within which the individual cities carried out the local alignment process (Tyler et al., 2016). The adaptation processes should be as multidimensional and synergic as the cities themselves, with mitigation strategies integrated into the very core of city planning and management (Carter et al., 2015).

3.3 Buildings

This review of the relationship between climate change and the built environment shows that the building sector represents a significant potential for climate change mitigation and reaching the sustainability goals (Andrić et al., 2019; Kristl, 2019). However, a building adapted to climate change is still not a well-defined term (Grynning et al., 2017). Currently, the literature reviewed is not comprehensive and mostly relates to general legislative levels and planning strategies. The findings are to some extent generic and are therefore not applicable to actual situations. Also, the specific impacts of climate change on buildings are somewhat difficult to assess, because they depend on local anomalies. Very useful is the study by Antonopoulos et al. (2019), which finds that the impact of urban micro-climates on energy use depends on local temperature variation and microthermal anomalies as well as urban and social differences. This corresponds to the results of a review on building energy use, which finds that urban heat islands can increase cooling loads by 19% and decrease heating loads by 18.7% (Li et al., 2019). It can be noted that the available studies mainly address the impacts of climate change on energy consumption in buildings, greenhouse gas emissions, and thermal comfort (Kershaw et al., 2011; Olonscheck et al., 2011; de Wilde & Coley, 2012; Esteves, 2014; Wang & Chen, 2014). In most cases they demonstrate that the future shifts in energy use will be substantial and that the historical weather data are not adequate for accurate assessment of buildings' energy performance (Farah et al., 2019). For instance, a study by Dolinar et al. (2010) examining a low-energy building located in two typical climates in Slovenia, pre-Alpine and Mediterranean, predicts a temperature increase of 1 to 3 °C and a solar radiation increase of 3 to 6%. In the pre-Alpine region the heating energy use would be reduced by 6 to 25%. In the coastal region, the change would not be significant. This information is instructive, because a favourable configuration of the building would enable a significant reduction in heating energy consumption. However, the cooling requirements would increase by about six times in the pre-Alpine region and around twofold in the coastal region, compared to the current situation.

Many other studies also predict that the share of energy consumption for heating and cooling in relation to the current situation can significantly change. Thus potential change in the energy mix, notably a significant reduction of traditional heating energy sources, is likely to occur (Clarke et al., 2018). One recent study predicts that annual heating energy will decrease by 21 to 22% and annual cooling energy will increase by 29 to 31%. Combined heating and cooling energy will decrease by 4 to 5% compared to current energy use (Farah et al., 2019). Moreover, the temperature extremes will have a significant impact on building performance. The preliminary results based on energy simulations show that noticeable overheating will occur in the future, which will have a strong effect on cooling energy use and/or occupant comfort (Dino & Akgül, 2019). It is estimated that the relative variation in peak load for cooling demand under near-future extreme conditions may be up to 28.5% higher than in typical conditions (Moazami et al., 2019a, 2019b). The energy robustness of buildings thus cannot be assessed solely based on typical future conditions.

Several studies also indicate substantial differences between cooler and warmer climates. Although the decreasing rate of heating hours in cooler climates is almost negligible, the decreasing rate in warmer climates may be significant (0.8% and 43% of heating hours respectively in 2050 compared to 2010, for the medium weather scenario (Andrić et al., 2017). This means that the heating energy demand may decrease and overheating may intensify, especially in buildings planned for today's moderate climates (Košir et al., 2018). This aligns with findings by Weng (2017) dealing with thermal comfort in UK residential buildings, using climate scenarios for 2030, 2050, and 2080. By 2050, building overheating can be prevented by intensive ventilation and, later, night ventilation can be used. However, passive cooling has limitations, and by 2080 a combination of shading and artificial cooling will have to be used. In northern Europe, adaptation to climate change relates primarily to better moisture resistance due to the expected increase in precipitation and slight rise in temperatures (Lisø et al., 2017).

This means that it is predominantly necessary to address typical building-physics issues, such as waterproofing and water vapour diffusion through the building envelope (Grynning et al., 2017). In the context of climate change, the paradigm of well-insulated buildings in temperate climates certainly needs some reconsideration. In warmer climates the heating energy consumption will probably significantly decrease, whereas the demand for cooling and the risk of overheating will significantly increase in all scenarios. Strategies like natural and mechanical ventilation will have a limited impact, whereas thermal insulation and reduction of infiltration will have larger impact on energy demand (Pérez-Andreu et al., 2018). Furthermore, Bruno et al. (2017) stress that well-insulated buildings in warmer climates are likely to overheat throughout the year and suggest a thorough examination of the building's geometry and the concept of the building envelope. It is also important to shade openings and employ night ventilation (Blecich et al., 2016), as well as carefully study the solar exposure of the building envelope (Košir et al., 2014).

Some stakeholders are already reviewing various adaptation options, such as finding alternative locations and adjusting maintenance of the current building stock. However, these measures are not sufficiently comprehensive in order to effectively mitigate all the consequences of climate change (Bunten & Kahn, 2017), such as the heat island effect and urban population resilience. Above all, it is necessary to ensure that the new buildings will not be affected by the negative impacts and burdens caused by the changed weather patterns, and that it will be possible to easily repair the damage caused by extreme weather events (Champagne & Aktas, 2016). Regarding existing buildings, appropriate and climate-adapted building management and maintenance measures, including plans for the improvement and upgrading of the existing systems, must be developed (Grynning et al., 2017). Furthermore, some authors feel that it is necessary to immediately initiate the preparation of measures to mitigate the effects of climate change, and that these should be multidisciplinary with integrated engineering and socio-environmental aspects (Pisello et al., 2017). The support of decision-making aimed at reducing risk and climate vulnerability in the built environment has to be universal, consisting of national building acts, national and international standards, certification schemes, and design guidelines (Lisø et al., 2017).

4 Discussion

The effects of climate change are numerous and reflect on the natural and built environment. Because buildings and infrastructure have a long lifespan, they are exposed to the climate not only during the time of their construction, but also to climate change over their subsequent decades of service. In this regard, the buildings that are currently being designed and also the existing buildings have to be taken into consideration. The review shows that the three areas considered (regulatory measures, urban environment, and buildings) have significant potential for climate change mitigation. They can also be considered as three levels of actions that can potentially be taken, but they must be the result of a concerted strategy, or they will not have the desired effect. Despite numerous significant developments, there are not many comprehensive studies dealing with the selected questions. Especially, three key challenges can be defined: the lack of specific climate adaptation strategies, energy use predictions in the changing climatic conditions, and resilience to climate change with a special focus on the financial burden.

One of the important challenges is institutional response. Many studies claim that development of policies and legislation are necessary but are sometimes hindered by inaccurate climate change predictions. This reflects in an uneven level of readiness. Although many developed countries include climate change challenges in their strategic developmental documents, the existing infrastructure and building regulations are adapted to the earlier climate patterns, whereas estimation methodologies for longer future periods of time are still being developed. Insufficient information about the consequences of climate change and the associated unreliability of the forecasts makes adaptation measures difficult to choose.

At the urban level the high complexity presents an important challenge, which makes adaptation only one of the problems that planners and decision-makers encounter daily. For this reason, the adaptation processes often advance extremely slowly. Such a situation reduces the competitiveness of the sector and increases lagging behind the goals of achieving sustainability. Often nature-based solutions are suggested as a suitable strategy for introducing adaptation and mitigation schemes. Nevertheless, some strategic documents that form the basis for further development of environmental policies have already been prepared; still, it is essential to increase the extent of research in order to create a suitably large pool of information that various stakeholders can use to prepare adaptation strategies.

At the building level, there are no clear guidelines for climate adaptation yet, though standards for the sustainable evaluation of buildings are being developed and the common EU framework of core sustainability indicators was developed. Furthermore, strong research activity has been set out by the European Commission (2020), supporting the development of climate modelling, methods, and standards, improvement of understanding the economics of climate change, and development of technological options and strategies to improve air quality and reduce the carbon footprint of European cities and create climate change networks. Combined, these activities have a strong potential of firmer guideline positioning in the future. At the level of new buildings, for example, guidelines with a clear objective for nZEB in early 2021 (EPBD 31, 2010) have already been defined, and in the field of the existing buildings accelerated investment in energy retrofitting is supported (EPBD 844, 2018). These measures already show results. However, the field of climate resilience at the building level is still evolving. The evidence shows that in the developed countries, where many of the buildings were built before 1980, attention should be further focused on creating adequate guidelines for renovating the existing building stock, adapted to future climatic conditions. Future building services may depend on a significantly different energy mix than that of today, as global temperature increase and local temperature anomalies can significantly affect energy use. In developing countries with rapid urban growth, the focus should be on strategies and policy development.

In the financial field, immediate actions are seen as more expensive, but delaying could result in increased risks and therefore larger long-term costs. It is estimated that the overall costs and risks of climate change will be much higher than the cost of action towards reducing greenhouse gas emissions (Stern, 2007). As a result, the state of the economy at home and abroad, as well as international trade flows may be affected (IPCC, 2014; NIJZ, 2016; WMO, 2018). This adds to the increasing amount of income that users or individual households will have to allocate to energy expenses and should encourage authorities to gradually introduce changes in planning as well as in evaluation processes. The future financial benefits of limiting climate change are rarely included in the evaluation of retrofitting investments. The choice faced by the authorities between a rapid or a delayed action must be guided by the balance between economic costs of early actions (such as the risk of retiring some still usable capital stocks prematurely) and the reciprocal costs of delay. Delaying involves the risk of locking in today's model of high-emissions capital equipment for decades. If the need to reduce emissions rapidly becomes an absolute priority, prematurely retiring those investments would be at a large cost. Acting early would allow an increased long-term flexibility of approaching the stabilization of atmospheric concentrations of greenhouse gases.

5 Conclusion

The systems will have to globally adapt to climate change, circular production processes, ageing population, urbanization, immigration, and vulnerable infrastructure. This means that the upcoming strategies for raising the competitiveness of the building sector will have to include new environmental, economic, and social approaches, which also constitute the three main pillars of sustainability. Although concrete climate change mitigation measures are increasingly favoured by professionals, the general public is in favour of adaptation processes only in general terms. Climate change will inevitably affect people's current lifestyle and quality of life. It is also becoming increasingly clear that significant financial investments will be required in individual areas. For this reason, awareness raising and informational campaigns on the impact of climate change on life, society, and adaptation strategies should be stepped up. Climate neutrality can be achieved only by transforming the existing sociotechnical structures, including energy and urban systems (EEA, 2019). This information is crucial for preparing concrete measures to address the upcoming climate change challenges in the built environment.

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