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REFLECTIONS ON CLIMATE CHANGE CHALLENGES IN FAMILY HOUSE DESIGN

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Abstract:

Climate change is increasingly influencing how residential spaces are designed and used. While much attention has been given to dense urban environments, single-family homes in suburban and rural areas remain largely absent from mainstream climate strategies, despite their significant environmental footprint. This paper introduces a conceptual framework for climate-resilient housing, built around four key strategies: adaptation, mitigation, prevention, and compensation. It takes into account not only technical performance but also the spatial, ecological and social dimensions of housing. The study applies a qualitative and interpretive research approach, combining typological building analysis, environmental performance data, and literature on sustainable planning. To explore how the framework might be implemented in practice, three European case studies are used: Vauban in Freiburg, BedZED in London, and Aspern Die Seestadt in Vienna. Each of these offers a distinct model of sustainable housing development and provides a valuable basis for comparative analysis. By connecting local housing typologies with broader environmental systems, the framework contributes to a more integrated understanding of how single-family homes can actively support climate resilience. The findings offer a foundation for developing more adaptive, resource-conscious and socially inclusive approaches to residential design.

***Key words*: climate change, single-family housing, sustainability, adaptation.**

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1. INTRODUCTION

This article addresses the challenges of climate change in the design of single-family homes. This theme is fundamental for human development, namely housing. As humankind has evolved, so has housing, from caves converted to living spaces to the permanent houses we see today. Since the time of cave dwelling until today, accommodation and residential functions have been inextricably linked.

The primary function of a shelter was and is protection from the elements. At the same time, it enables community life and forms the core of society. Over time, people have added more features to their dwellings within the built environment. The dominant European view is that history "always begins with hunters, then passes to a stage of pastoralism, then to agriculture, and only then finally to the contemporary stage of urban commercial civilization" (Graeber and Wengrow, 2021, p. 60). Consequently, housing represents a status symbol associated with property since "cash income, political power, calorie intake, house size, number and quality of personal possessions" (Graeber and Wengrow, 2021, p. 74) define social status today. In particular, the protective function is becoming increasingly important nowadays, since climate change poses a threat in many ways, as illustrated in Figure 1.

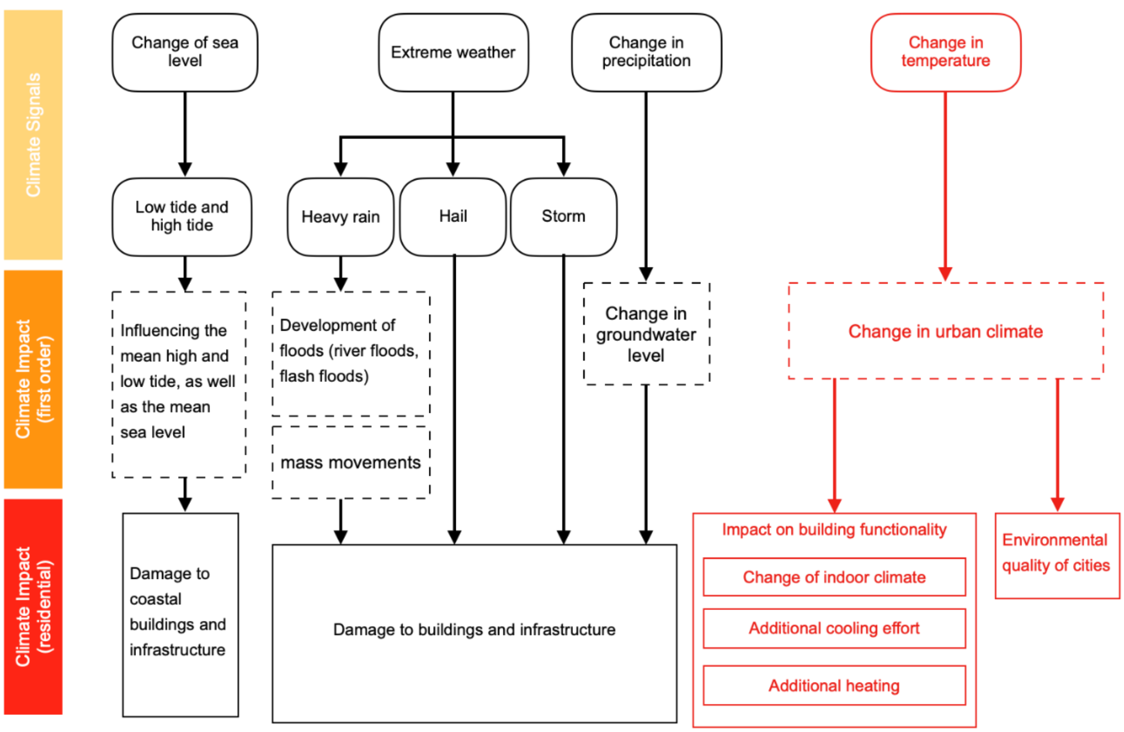

Figure 1: Climate signals and climate impact on buildings
(Source: Author's design, based on adelphi / PRC / EURAC et al. (2015, p. 419))

Germany has recorded an average of 5,000 heat deaths per year in the last five years. Between 2018 and 2023, the numbers vary between an estimated 8,300 deaths in 2018 and an estimated 1,900 deaths in 2021 (Winklmayr and an der Heiden, 2022). Figure 2 shows that in 2018 there were many weeks with an average temperature of more than 20°.

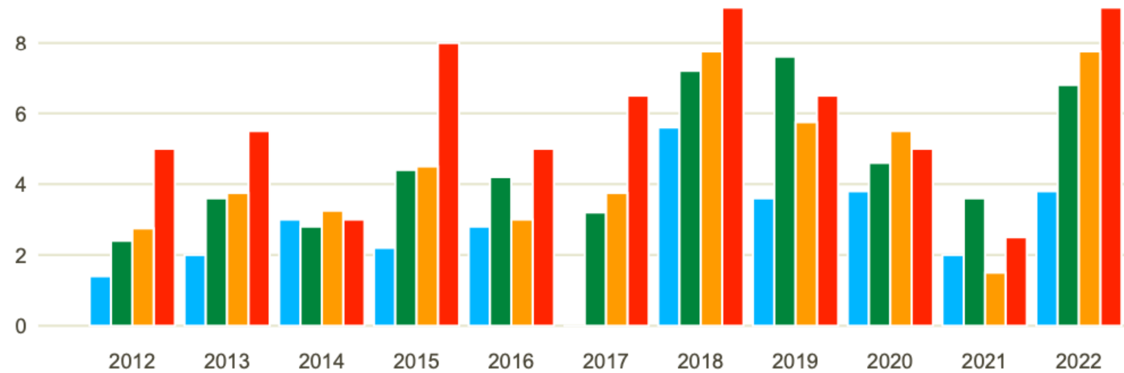

Figure 2: Hot weeks per year in Germany's north (blue), east (green), west (orange) and south (red) (Source: Winklmayr and an der Heiden (2022, p. 5))

In 2021, it was significantly less. Therefore, the connection between heat and the number of deaths is obvious and implies that living space is becoming less and less protective against heat (Winklmayr and an der Heiden, 2022). According to Läpple (2022), hardly any other area of the economy or society has such a large ecological footprint as the construction industry. The industry relies on fossil energy sources and uses many non-renewable resources.

While much of the focus in climate policy and research has been directed toward dense urban areas, a large part of the population resides in suburban and semi-rural single-family homes – spaces that remain underrepresented in current transformation efforts.

This gap is problematic, both in environmental and strategic terms. Single-family homes consume more land, energy and materials per capita than multi-family housing, and they are often built using outdated construction methods with limited integration into climate policy frameworks. Yet, these homes also offer significant potential: through direct ownership, long-term use and the flexibility to adapt or retrofit, they can become key sites of climate action – if approached with the right strategies.

Contrary to the widespread perception that the Paris Agreement of 2015 marked the beginning of international climate awareness, earlier milestones such as the Kyoto Protocol (UNFCCC, 1997) and the Copenhagen Summit (UNFCCC, 2009) laid essential foundations. They emphasized the role of the building sector in climate mitigation, a message later reinforced by the IPCC's 2014 assessment, which highlighted residential buildings as central to global decarbonization efforts.

Despite this, current policies often prioritize high-density urban development, leaving low-density residential areas largely unexplored. To address this, researchers have developed building typologies that allow for a more systematic understanding of energy use and renovation potential in these settings. The National Typology of Residential Buildings in Serbia (Jovanović Popović and Ignjatović, 2013) and related studies like Novikova *et al*. (2015) demonstrate how typological classification can serve as a foundation for climate-focused design and retrofitting strategies.

On a global level, reports by UN-Habitat (2009, 2011, 2016) have called for more inclusive and climate-responsive housing policies. These documents stress the importance of linking environmental goals with social equity, spatial justice and long-term resilience – not only in cities, but in all types of human settlements.
In response to these challenges and opportunities, this paper introduces a conceptual framework for climate-resilient single-family housing. The model integrates four strategic components – adaptation, mitigation, prevention and compensation – and proposes an approach that is both technically robust and socially grounded. To test its applicability, the study looks at three real-world examples: Vauban (Freiburg), BedZED (London) and Aspern Die Seestadt (Vienna). These case studies provide insight into how sustainability can be embedded in residential design, governance and everyday life – paving the way toward more inclusive, resilient and climate-conscious living environments.

2. METHODOLOGY AND MATERIALS

This paper sets out to close a gap between theory and practice in the context of climate-resilient single-family housing. While much of the current research focuses on urban settings, this study shifts the perspective toward suburban and rural homes. These areas are often defined by private ownership, individual renovation decisions and more dispersed spatial structures. Although they are frequently overlooked in climate policy, they play a crucial role in shaping sustainable futures. Their diversity and flexibility offer unique opportunities to rethink housing strategies in a more inclusive and context-sensitive way.
The research follows a qualitative and interpretive approach. Rather than testing a specific hypothesis, it builds a conceptual framework based on a combination of sources. These include typological studies of residential buildings, such as those developed in Serbia, which provide structured insights into building stock characteristics. Further input comes from studies conducted in countries similar to Germany, where environmental standards and innovative housing strategies have already been implemented. In addition, the framework incorporates environmental performance data and academic literature on climate adaptation, mitigation and housing policy. Together, these resources offer a basis for understanding how homes function not just as technical systems, but as social and environmental spaces shaped by daily life, infrastructure and policy.
To explore how this framework can be applied in practice, the next research phase will focus on three case studies in Europe. These have been selected because they represent different approaches to sustainable housing and vary in terms of climate, scale and governance. Vauban in Freiburg is a neighborhood built on the principles of car-free living, strong community involvement, and passive energy design. BedZED in London is an early example of large-scale sustainable housing, integrating renewable energy, green construction and closed loop waste systems. Aspern Die Seestadt in Vienna shows how climate goals can be embedded in a large state-led urban expansion, combining energy positive buildings, efficient public transport and mixed-use development. By analyzing these projects, the study will test how the proposed framework – adaptation, mitigation, prevention and compensation – can respond to real life conditions and inform future policy and design in a range of European contexts.
The framework is structured around four dimensions. Adaptation focuses on how buildings respond to climate related stress, for example through natural ventilation, shading or

materials that regulate temperature. Mitigation looks at ways to reduce the environmental footprint of homes, using strategies such as renewable energy systems, compact layouts or smart technologies. Prevention involves designing with the future in mind, including circular material use, long-term durability, and planning for maintenance and change. Compensation addresses the wider impact of housing by integrating ecological functions, enhancing social inclusion and contributing to the broader environmental balance.

Since this is a conceptual study, no empirical fieldwork has been conducted yet. Instead, the aim is to lay a foundation for future application and testing. By linking international climate frameworks with practical design knowledge and regional housing typologies, this research contributes to a more comprehensive understanding of how single-family homes can become part of a sustainable and resilient built environment.

3. CONSEQUENCES AND CHALLENGES OF CLIMATE CHANGE ON DWELLING FUNCTION AND STRUCTURAL DEVELOPMENT

Before delving into the consequences and challenges of climate change on the dwelling function and physical structure of residential buildings, it is crucial to emphasize that these should not only be viewed as problems, but also as opportunities. Particularly in the context of residential function, the impacts of climate change can serve as catalysts for innovative housing concepts. The challenge lies not just in recognizing problems but also in identifying opportunities for adaptation and shaping a more sustainable future.

3.1 Definition of Residential Function and Structure

However, the first goal of climate-friendly construction is protecting people; the second goal is the long-term use of local resources. Due to the limited availability of building materials, construction technology with a high degree of efficiency in terms of durability and energy is required. Comfort functions complement the protective function, although the comfort aspect is not provided in autochthonous construction (Häupl, 2017).

Central terms in the discussion about climate-friendly buildings are the living function and the structure of living. For architecture, the concept of function is linked to action and the part-whole relationship (Poerschke, 2014). The part-whole relationship is evident in the rules of proportion and the variability that activity represents. These components defining the concept of function are also reflected in the natural sciences and the Latin origin of the term (Poerschke, 2014). Sociological approaches, such as the question of purpose and system, have led to discussions about the functional understanding of architecture. As cities and buildings serve a function but also a purpose, design serves the purpose of artistic expression and sustainability. Climate protection must be a priority. In order to distinguish function from purpose, the function should therefore be understood as an overarching construct (Poerschke, 2014).

In architecture, the structure of living refers to the inner order, the mental context underlying the arrangement, and the interaction of a building’s components (Schneider, 2019). Therefore, structural development means changing these orders and arrangements to enable different interactions and connections.

In the context of climate-resilient housing design, the integration of dwelling processes within the home and the adaptation of the physical structure of buildings are two pivotal

aspects. These two dimensions are interwoven and form the foundation for creating homes that not only accommodate residents' needs and activities but also withstand the challenges posed by a changing climate. In the following sections, we will delve into the intricate relationship between these aspects, exploring how they interact to forge resilient living environments.
To visually illustrate this dual focus, consider the following schematic representation (Figure 3):

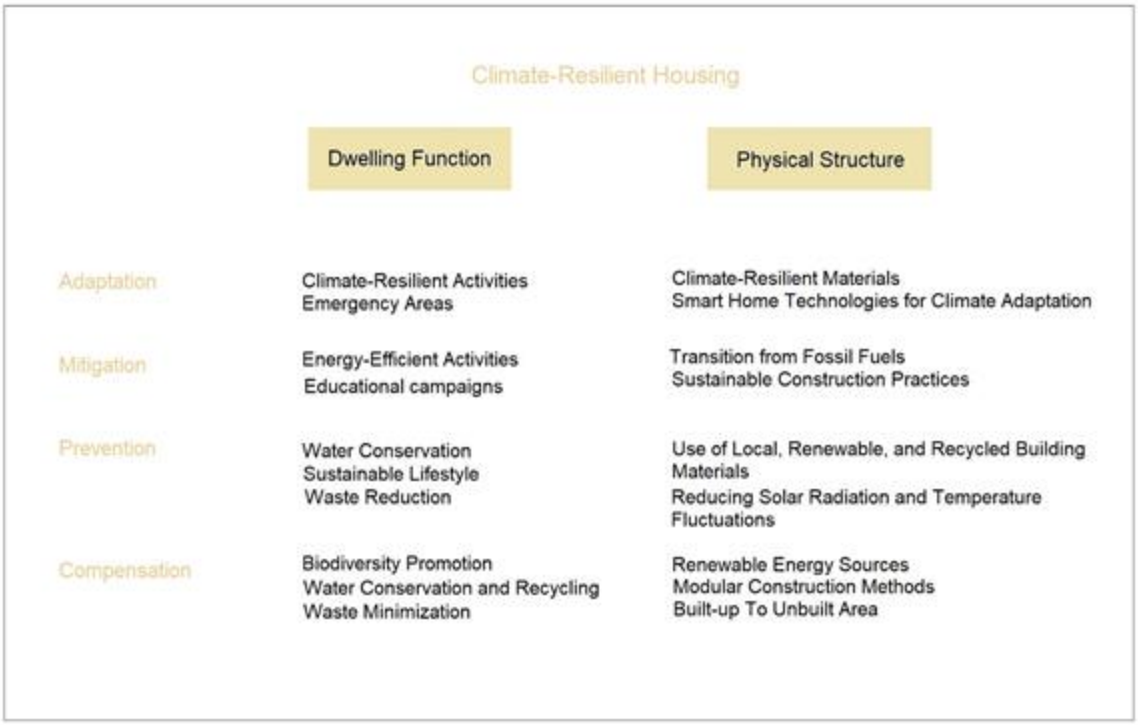

Figure 3: Climate-Resilient Housing
(Source: Author)

This figure showcases the synergistic relationship between the processes within the house and the aspects of building structures, highlighting their interconnectedness in achieving climate resilience. It serves as a guiding framework for the subsequent exploration of these two critical aspects in our climate-resilient housing design approach.

3.2 Consequences and Challenges for the Residential Function

Climate change is the greatest global challenge of our generation. Very many sectors are affected, including housing. Against this backdrop, housing faces many challenges and consequences that require strategies for adaptation or mitigation, since houses are not only places to live, but above all they provide comfort, security and community.
A direct consequence of climate change is the increase in extreme weather events, for example hurricanes, floods and forest fires. These frequent events cause a great deal of damage to residential buildings and often result in people being displaced from their homes, or even loss of life (IPCC, 2012). Heavy rain events also pose a hazard to residential buildings

as they can lead to flooding, which can cause severe damage to buildings. They can also affect infrastructure, which can result in power outages, telecommunications failure, or restriction of transport infrastructure. These occurrences can be quite harmful and affect the quality of life on many levels (Reicher and Söfker-Rieniets, 2022). Figure 1, presented above, provides an overview of the consequences.

Rising temperatures are also a terrible consequence of climate change. This turns houses into unbearable saunas, posing a particular danger to vulnerable groups, particularly the elderly and those with disabilities (ARD alpha, 2023).

At the same time, energy demand also increases as a result of increased temperatures, putting a strain on energy resources and impacting household energy consumption.

3.3 Consequences and Challenges for the Physical Residential Environment

The effects of climate change extend beyond residential functions to impact the physical environment of buildings. Melting polar ice contributes to rising sea levels, causing potential damage to coastal buildings and infrastructure. Heavy rain can cause river flooding and flash floods. In addition, there is also a risk of mass movements associated with hillside locations, which can cause significant damage or destruction to buildings (adelphi / PRC / EURAC, 2015).

Another consequence of climate change is the increase in solid winds. Heavy storms primarily damage the roofs and windows of buildings, but residential functions are also affected by the destruction of infrastructure, such as, overhead lines (adelphi / PRC / EURAC, 2015).

Increased temperatures lead to the warming of urban environments. The waste heat from buildings significantly impacts: the urban climate and air quality in cities; pollutant emissions; the building materials used; and the high proportion of sealed surfaces (adelphi / PRC / EURAC, 2015). Especially in densely populated areas, there is an interaction between buildings and the temperature change (more heat waves), which leads to a risk of overheating (Reicher and Söfker-Rieniets, 2022).

Among the identified consequences are changes in thermal behavior within urban areas, limited air exchange caused by surface properties, and the emergence of heat islands. This constellation endangers the health of the urban population (Reicher and Söfker-Rieniets, 2022). It is, therefore, crucial to mitigate the impact of climate change in urban areas.

The investigations into previous damage events in the Dresden region have made it clear that the consequences of climate extremes are already leading to considerable and hardly quantifiable damage to buildings. Irrespective of the changes to be expected due to climate change in the two impacts considered, flooding and heavy rain, it can be stated that the affected buildings are often not prepared for these impacts. Cases of damage, but also amounts of damage, are constantly increasing and, thus, confirm the hypothesis of a building structure that is susceptible to the impacts described (Nikolowski, 2014).

4. STRATEGIC RESPONSES TO CLIMATE CHALLENGES IN HOUSING

Housing is increasingly confronted with the complex and far-reaching consequences of climate change. From extreme weather events and heavy rainfall to rising sea levels and prolonged heatwaves, the environmental pressures on residential spaces are growing

rapidly. These developments pose serious risks not only to buildings themselves, but also to the health, comfort, and safety of their occupants.
To ensure that housing remains functional, livable, and sustainable under changing climatic conditions, a strategic and integrated approach is essential. This chapter introduces a four-dimensional response framework based on adaptation, mitigation, prevention, and compensation. Together, these strategies form a holistic foundation for climate-resilient housing development and renovation.
Rather than treating buildings as isolated technical objects, this framework understands them as embedded in wider socio-ecological systems. It takes into account not only structural and material aspects, but also spatial, behavioral, and institutional factors.

4.1 Adaptation

Adaptation entails adapting to the expected or actual consequences of climate change, in order to mitigate damage or capitalize on advantageous opportunities.

4.1.1 Adaptation in Dwelling Functions

In order to be able to cope with the dangers of climate change, residential construction needs resilience. A crucial aspect of climate-resilient housing is the functional adaptation of dwellings to the previously mentioned challenges of climate change. One consideration could be to reinforce different areas within homes with climate-resilient materials and designate them as safe (Riegel *et al*., 2013). Smart home technologies can be used to monitor and adapt the indoor climate to ensure comfort and energy efficiency (Das Haus Online, 2018).
In this regard, multi-purpose rooms with appropriate ventilation and insulation can serve as emergency shelters. Attention must be paid to accessibility so as not to neglect residents with mobility problems (Gupta *et al*., 2021).
To achieve this, homeowners and builders need to redesign their housing structure. Resistant building materials that improve insulation must be used. Energy-efficient appliances must also be used, for example by using renewable energy sources. Promoting decentralized renewable systems, like solar panels, can empower homeowners to adapt independently.

4.1.2 Adaptation in the Physical Environment

To adapt residential buildings to the challenges of climate change, the built environment must be conceived as a flexible, energy-conscious, and ecologically integrated system. Climate-resilient architecture considers not only the operational performance of buildings, but also the environmental impact of construction materials and design choices over the entire lifecycle.
Passive design strategies tailored to local climatic and geographical conditions offer effective ways to regulate indoor temperatures without excessive energy use (Flores-Larsen *et al*., 2019). Planning processes should promote modularity and adaptability, enabling future renovations and functional adjustments (Vogt, 2021).
A fundamental goal is the reduction of fossil fuel dependence through the use of renewable, low-impact, and recyclable materials. At the urban scale, strategies such as unsealing

surfaces, increasing vegetation, and implementing rainwater retention systems support natural cooling processes and biodiversity (Rahla *et al*., 2021; Reicher and Söfker-Rieniets, 2022).
Building-integrated photovoltaics (BIPV) can contribute to decentralized energy production while complementing architectural design. Green facades, rooftop vegetation, and shading elements like trees improve evaporation and provide thermal protection, making buildings more robust against heat stress.

4.2 Mitigation

Mitigation involves endeavors directed at lessening or averting the release of greenhouse gases, thereby reducing the scope and repercussions of climate change. It encompasses initiatives that tackle the fundamental causes of climate change.

4.2.1 Mitigation in Dwelling Functions

To mitigate some of the climate change, housing can play its part by reducing the carbon emissions emitted from the construction and ongoing operation of residential buildings. A few approaches can be used to do this, including:
Smart home automation can reduce energy consumption while maintaining comfort by optimizing heating, cooling and lighting (Das Haus Online, 2018). Composting and recycling can reduce a household's CO_2 footprint by maintaining sustainable practices (BDE e. V., 2020).
Strong regulatory frameworks and incentive-based funding for energy-efficient retrofits are essential to drive wide adoption. Government intervention in the form of policies and regulations can spur positive change by pointing to the construction of environmentally friendly houses and the promotion of public transport. Importantly, public awareness and sensitization to the impacts of climate change on housing can help individuals take action to mitigate them. Educational initiatives should also target tradespeople and builders to embed sustainability early in the construction process.

4.2.2 Mitigation in the Physical Environment

Minimizing the consumption of fossil fuels or renouncing fossil fuels entirely will make a decisive contribution to climate protection. Solar thermal and geothermal energy for heat generation and photovoltaic technologies for electricity generation are currently available as direct methods used in building. Other energy-saving methods, such as heat recovery from wastewater and room air, are also available (Reicher and Söfker-Rieniets, 2022).
However, construction activity also leads to an increase in greenhouse gas emissions of 20-25% for buildings renovated according to the current efficiency regulations and up to 50% for buildings considered particularly energy efficient. Another measure to save energy is the insulation of building envelopes (Reicher and Söfker-Rieniets, 2022).
Ivanova *et al.* (2020) examined changes in consumer behavior towards low-carbon alternatives. Regarding residential construction, the authors found that containment was most effective when renewable electricity was purchased or produced. Such behavior resulted in an average of 1.5 and 1.3 tCO_2eq/capita (Ivanova *et al.,* 2020).

However, the ability to mitigate the effects of climate change depends on the energy source. Multiple contextual factors need to be considered, such as the type of electricity used to produce renewable technologies, the location, as it affects the amount of energy produced in the usage phase, and the use and maintenance of the new technologies.
There are other options related to space heating and infrastructure. These options include refurbishment and renovation, the installation of heat pumps and renewable heating systems. These options have an average reduction potential of 0.9, 0.8, or 0.7 tCO2eq/capita. Converting buildings to passive house standards also offers a scalable path to mitigation, though it requires significant investment and planning.

4.3 Prevention/Avoidance

Prevention or avoidance concerning climate change encompasses actions taken to prevent or alleviate the incidence of unfavorable climate-related effects. This involves proactive practices and strategies to minimize the risk of harm related to climate impacts.

4.3.1 Prevention in Dwelling Functions

Preventing climate impacts on the functional aspects of housing can only be achieved if sustainability and resource efficiency are at the forefront. Practices and technologies must be used to reduce the carbon footprint in daily life within a dwelling. Residents need to make sustainable lifestyle choices so that they can contribute to a climate resilient living environment. This includes, among other things, reducing energy consumption in the home by being more conscious of it. Lights and appliances should be turned off when not in use. Heating and cooling systems should also be optimized (Schöner Wohnen, 2011).
Climate-conscious living also involves using water sparingly. Care should be taken to ensure that leaks are repaired quickly or that water-saving taps are used. These things can lead to a significant overall reduction in water consumption and thus counteract the water scarcity that comes with the effects of climate change (Das Haus Online, 2019).
Waste reduction can also lead to prevention of climate impacts. Residents should adopt practices such as reducing, reusing, recycling and composting waste. In this way, households can minimize waste and contribute to a better environment (BDE e. V., 2020).

4.3.2 Prevention in the Physical Environment

Sustainable building materials play a key role in climate protection. Alongside CO_2 storage, avoiding waste and promoting recyclability help reduce environmental harm (Reicher and Söfker-Rieniets, 2022).
Bell (2019) critiques "green" buildings that still consume large amounts of energy and space. Instead of building new homes, existing structures should be preserved and improved – by avoiding demolitions, reusing vacant stock, and maximizing renovation potential.
To mitigate heat stress, passive strategies like reducing sun-exposed window areas, using light-colored surfaces, and installing shading (e.g. trees or overhangs) are essential (Häupl, 2017). Building orientation and compactness also influence heat gain, with east-west alignment and high-density offering advantages (Hausladen *et al*., 2012).

Circular economy principles – such as recycling materials and designing for disassembly – help conserve resources (Rahla *et al*., 2021). Urban mining and reused concrete reduce emissions and minimize the need for new raw materials (Vogt, 2021).
Reducing embedded energy requires locally sourced, renewable, and low-impact materials. Prefabricated, modular construction can also lower waste and energy use. Wood is particularly valuable as a carbon sink when used responsibly (Hafner, 2022). Green building also means avoiding harmful chemicals to protect biodiversity (Reicher and Söfker-Rieniets, 2022).

4.4 Compensation

Compensation entails measures or strategies to counteract, balance, or rectify environmental or societal impacts arising from climate change or associated activities.

4.4.1 Compensation in Dwelling Functions

Compensation measures in the context of housing construction aim to give something back to the environment and communities that are affected by it. This is more than just protecting residents from climate-related risks. Housing here becomes an agent of positive change by taking a proactive stance towards environmental protection (Stiftung WWF Deutschland, 2022).
Within a property, one can adopt several environmentally friendly practices that can promote nature and species conservation. For example, one can make one's garden or balcony very nature-friendly by planting native flowers or even a tree to attract insects and birds to promote biodiversity. Birdhouses and feeders can also be installed by residents to feed birds, especially in the winter months (Tagesschau, 2023). Rainwater collection systems and greywater reuse are effective compensation strategies, especially in regions facing water stress.

4.4.2 Compensation in the Physical Environment

Compensation strategies applied to the physical environment of housing seek to preserve and restore ecosystems that may be damaged during a construction phase.
Renewable energy in particular plays a very important role in compensating for environmental impacts by minimizing the use of fossil fuels and harmful emissions. These energy sources produce clean energy by using natural processes that do not release greenhouse gases or harmful waste. Renewable energy refers to the use of solar energy, wind energy and hydropower. This can make an important contribution to offsetting the effects of climate change, and can create a more sustainable energy future (BMZ, 2022).
Another factor for environmental protection and urban planning is the ratio of built-up to unbuilt area (Umweltbundesamt, 2022). To give more land back to the environment, paved areas must be unsealed and converted into green spaces. This can be achieved by building gardens, parks, roof gardens and vertical gardens. People thus have the opportunity to feel a little closer to nature (Verbraucherzentrale NRW, 2023).
Reusing vacant buildings and materials not only saves resources, but also compensates for past environmental degradation.

4.5 Innovative Approaches to Sustainable Living Environments

When it comes to sustainable and climate-resilient housing, especially in the context of single-family homes, new ideas are emerging that go beyond technical upgrades and energy-saving checklists. These approaches look at the home as a whole – Its structure, materials, environment and the way people actually live in it. They aim to create adaptable, regenerative spaces that respond to both climate and lifestyle changes.

One promising starting point is the use of building typologies. By grouping homes based on their shape, age, usage and climate zone, planners and researchers can develop solutions that match the specific needs of different housing types. This allows for practical and scalable improvements across regions. The TABULA project, for example, showed how this typology approach can be used to guide targeted renovation and energy strategies across Europe (Loga *et al*., 2012).

Another area of innovation lies in combining passive design strategies with smart technologies. Instead of relying entirely on high-tech systems, many sustainable homes use simple, proven principles like orientation for daylight, cross-ventilation and thermal mass to improve comfort and reduce energy needs. These are increasingly supported by responsive systems that adapt to weather and user behavior – helping buildings stay efficient without being overcomplicated (Pomponi and Moncaster, 2016).

Smart home systems themselves are also becoming more human-friendly. Rather than creating fully automated environments that can feel impersonal or even frustrating, designers are working on hybrid models. These systems learn from how people use their homes, but still allow manual control. The goal is to help residents understand and influence their energy use, without overwhelming them with technology (Wilson *et al*., 2014).

Material cycles and resource use are also being rethought. Circular building principles are gaining momentum, especially in housing. These include modular design, reused and recyclable materials, and buildings that can be adapted or even disassembled over time. Such practices reduce environmental impact over the building's life span and encourage long-term thinking (Geissdoerfer *et al*., 2017; Pomponi and Moncaster, 2017).

Sustainability in housing now increasingly includes nature itself. Green roofs, rain gardens, and native planting are being integrated into the design from the start – not as extras, but as essential parts of how homes interact with their surroundings. This brings ecological value directly onto residential plots, creating small but meaningful habitats and helping to manage water and heat locally.

Finally, housing needs to adapt to people's lives just as much as to climate conditions. Flexible layouts, movable walls and rooms that can serve multiple purposes allow a home to evolve with its occupants. Whether it is working from home, caring for family members or aging in place, these spaces are designed to stay functional over time. Adaptability like this is increasingly seen as a marker of long-term building quality (Pinder *et al*., 2017; Gann *et al*., 2003).

Altogether, these approaches reflect a growing awareness that sustainable housing is not just about saving energy—it is about making homes more responsive, more inclusive and more deeply connected to the environment and the people who live in them.

5. CLIMATE-FRIENDLY LIVING AS PART OF SUSTAINABLE LIVING DESIGN

Ivanova *et al.* (2020) agree that the size of the building is the most important factor in determining the energy consumption of a house. Therefore, reducing the size of buildings will also significantly reduce housing-related emissions and energy use. However, the authors warn that "there are significant structural (e.g., lack of adequate alternatives), psychological (e.g., attachment), and security (e.g., loss of property) barriers associated with downsizing" (Ivanova *et al.* 2020, p. 10).

The results for less living space and co-housing (including reducing living space with less heating and construction, living with others, and renting out guest rooms to other people) can lead to CO_2 reductions of up to 1.0 tCO2eq/capita. The average is 0.3 tCO_2 eq/cap (Ivanova *et al.* 2020). Moreover, the link between the physical structure of buildings and the quality of life of the occupants is clear. Climate-resilient housing therefore seeks not only to provide protection from extreme weather events, but also to improve the overall living experience, comfort and health (Ruíz and Mack-Vergara, 2023).

According to Satterthwaite *et al.* (2020), even informal settlements require extensive modernization since only basic modernization does little to build resilience, but extensive modernization that significantly improves resilience can be expensive. Bültmann-Hinz (2021) also warns that renovations are associated with considerable investments and, thus, costs that are not always offset by corresponding energy savings. In the absence of this adaptation, the response to heat stress, such as air conditioning, accelerates climate change, leading to a vicious cycle of higher energy consumption and greenhouse gas emissions (Matthies *et al.,* 2008).

Since the advantage of achieving climate protection goals in the building sector benefits society, society should also bear part of the costs. To solve the tenant-landlord dilemma in a targeted manner, state subsidies, whether tax-related or otherwise, could be an opportunity to increase the incentives and acceptance for energy-related refurbishments and, thus, advance the energy transition (Bültmann-Hinz, 2020).

In addition, there are limits to the adjustments. A building can only be operated passively as long as sufficient indoor conditions can be guaranteed both in summer and winter (Kovats *et al*., 2014). The climate inside a building is an essential aspect of well-being and health. This observation means that energy consumption can only be reduced to the extent that human well-being and health allow (Kovats *et al.,* 2014). The indoor climate can also be influenced by natural surfaces that regulate humidity and temperature (Reicher and Söfker-Rieniets, 2022).

In a situation where renewable energy sources cannot completely replace fossil fuels, even strategies to promote energy-efficient and environmentally friendly technologies have a significant disadvantage, the so-called rebound effect. As demand from the public continues to increase, reliance on traditional energy sources is becoming increasingly unsustainable, especially as indoor comfort becomes more important in people's daily lives. Therefore, in the short to medium term, only smart technologies can effectively meet the challenge of maintaining a quality indoor microclimate through home automation and control systems at a reasonable cost (Ryzhov *et al*. 2019). If we recognize these principles and the link between climate resilience and quality of life, we can build a future where homes can offer more than mere shelters.

6. DISCUSSION

The growing urgency of climate change requires a shift in how we understand and design single-family homes, particularly in suburban and peri-urban areas where these housing types dominate. While cities have become the focus of climate innovation, it is precisely in these lower-density zones – where energy consumption, land use, and individual ownership converge – that untapped potential for climate action lies. This paper proposes an integrative framework for climate-resilient housing based on four pillars: adaptation, mitigation, prevention, and compensation. The following discussion explores both the strengths and limitations of this approach, offering a balanced view of its practical relevance.

One of the framework's key advantages is its holistic nature. Rather than focusing solely on energy or materials, it combines technical design strategies with ecological thinking, behavioral insights, and attention to everyday living needs. By connecting building performance to human comfort, social inclusion, and long-term environmental responsibility, the model offers a broader vision of what sustainable housing can be. It not only asks how homes are built, but also how they are used, shared, and maintained.

Another strength lies in its adaptability. Drawing on building typologies – defined by characteristics such as construction period, climate zone, and usage – the framework enables context-specific strategies. This is especially valuable in retrofitting older housing stock, where standardized solutions often fall short. A typological approach makes it possible to plan interventions that are both technically effective and socially appropriate.

At the same time, several challenges must be acknowledged. First, many of the proposed strategies require financial resources that are not available to all households. Technologies such as smart home systems, solar panels, or high-performance insulation can offer long-term savings but remain costly in the short term. This raises questions of equity: who can afford climate resilience, and who is left behind?

Second, there are cultural and spatial tensions. Compact, modular designs may be environmentally sound but run counter to widespread preferences for large, individualized homes. Likewise, strategies such as green roofs, shared gardens, or water reuse systems require more than design – they demand ongoing care, cooperation, and sometimes a shift in values. In privately owned, self-managed housing, such collective approaches may not be easily adopted.

Third, even well-intentioned technical solutions can create unintended consequences if not properly integrated. Over-insulation, for example, can lead to poor indoor air quality without adequate ventilation. Smart systems might reduce energy use but increase dependency or alienate users unfamiliar with digital interfaces. Climate resilience, therefore, is not just about design quality – it is about usability, education, and support structures.

To evaluate the real-world applicability of the framework, three exemplary case studies will serve as the next research phase: Vauban in Freiburg, BedZED in London, and Aspern Die Seestadt in Vienna. These three developments illustrate different approaches to sustainable housing. Vauban shows how community-driven planning and passive house standards can transform urban life. BedZED provides early lessons on ecological building, particularly around the interaction between technology and user behavior. Aspern demonstrates how sustainability can be embedded at scale through state-led urban expansion and integrated infrastructure.

Together, these case studies provide a valuable testing ground for the framework. They allow us to examine how climate strategies function in practice – under different climatic, cultural, and political conditions – and where adjustments are needed to make them more effective and inclusive.
Finally, this discussion draws attention to a structural imbalance in current climate policy: while most funding and attention is directed toward inner-city transformation, a large share of emissions and resource use comes from low-density residential areas. If we are serious about a just and effective transition, we must place the single-family home at the center of our thinking – not as an obstacle, but as an opportunity for change.

7. CONCLUSION

Single family homes are often left out of the spotlight when it comes to climate policy. Yet they make up a large part of how people actually live, especially in suburban and rural areas, and their environmental impact is anything but small. This paper has shown that these homes deserve a more central place in the conversation about sustainable living.
The framework presented here is built around four key ideas: adaptation, mitigation, prevention and compensation. It offers a way to rethink how single-family homes can respond to the challenges of climate change. The approach brings together technical strategies and human needs, showing that good design can and should work with local conditions, everyday life and long-term sustainability in mind.
Of course, real change is not just about having good ideas. It also depends on whether those ideas can be implemented in practice, whether they are affordable, and whether they are supported by the right policies. That is why the next step will focus on three real-world examples: Vauban in Freiburg, BedZED in London and Aspern Die Seestadt in Vienna. Each of these places takes a different approach, and together they offer valuable insights into what works, what does not, and where more learning is needed.
In the end, this research invites a shift in how we think about the home. Not just as a private space or a place to live, but as something more – a setting that can support a more sustainable, fair and resilient future, starting from where people already are.

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