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Sustainable and affordable housing in Nairobi, Kenya

An analysis of challenges and opportunities from the perspective of key actors

TOYAH EGLIN

Supervisor: Joseph Mulligan
Examiner: Henrik Ernstson

MSc Sustainable Urban Planning and Design (AL250X)
Department of Sustainable Development, Environmental Science and Engineering (SEED)
School of Architecture and Built Environment
KTH Royal Institute of Technology

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Abstract

The global urban population is projected to grow rapidly in the coming years, leading to an increase in housing demand that is not always met with adequate supply of quality housing. In the low-and middle-income context of Kenya, this gap has led to the proliferation of sub-standard housing implementations, with significant social and environmental impacts. However, attention is rarely paid to sustainable housing design practices in Kenya, understood here as climate responsive and socially integrated adaptations, despite their proven capacity in other developing countries for reducing environmental impacts while making housing more affordable. The city of Nairobi presents potential for alternative trajectories of development in the construction industry as one of the fastest growing urban areas in the region with unique climatic conditions that are underutilised and understudied in the building sector. This thesis explores, through the perspectives of local actors, the potentials and challenges of implementing affordable housing in Nairobi by using sustainable, locally based strategies. This was achieved through desktop research, semi-structured interviews with key actors from across government, academia, and industry backgrounds, as well as a field visit to a development site. The collected data was then analysed qualitatively through a thematic content analysis and triangulated to extract relevant learnings. The key findings of this research are that there is a lot of potential in Nairobi for locally adapted housing strategies to respond to affordable housing issues and provide low-cost and high-quality alternatives due to its climatic conditions and socio-cultural traditions. Yet there are some structural challenges in terms of policy framing and local perceptions of sustainability that limit the implementation of such practices in the Nairobi housing sector. This thesis adds to the critical discussion of adequate affordable housing by providing a holistic view of the differing or overlapping perspectives in the field, deriving potentials of the local context, and providing an understanding that could help guide the housing industry in the direction of resilient and inclusive housing opportunities. The study suggests the need for further research into the implementation of sustainable and affordable housing in the context of Nairobi, as well as the wider regional context.

Keywords: affordable housing, sustainable buildings, local implementations, bioclimatic adaptations.

Sammanfattning

Den globala stadsbefolkningen förväntas växa snabbt under de kommande åren, vilket leder till en ökad efterfrågan på bostäder som inte alltid möts av ett tillräckligt utbud av kvalitetsbostäder. Bland Kenyas låg- och medelinkomsttagare, har denna klyfta mellan efterfrågan och utbud av bostäder lett till att informella bosättningar och bostäder av undermålig kvalitet har blivit allt vanligare. Detta har en betydande inverkan på miljön, men ändå ägnas sällan uppmärksamhet åt hållbara bostadsmetoder i Kenya, trots att de har visat sig kunna minska miljöpåverkan i andra utvecklingsländer samtidigt som de löser problem med överkomliga priser. Staden Nairobi har potential för alternativ utveckling inom byggbranschen, eftersom denär ett av de snabbast växande stadsområdena i regionen, en viktig knutpunkt för handel, transport, kommunikation och innovation, och har unika klimatförhållanden som är underutnyttjade och understuderade inom byggsektorn. Mer lokalt anpassade bioklimatiska och klimatsmarta byggnadsstrategier kan spela en grundläggande roll när det gäller att tillgodose efterfrågan på lämpliga bostäder till överkomliga priser i Kenya, bland annat genom att anpassa de byggda formerna till det lokala sammanhanget. I den här artikeln undersöks möjligheterna och utmaningarna med att skapa överkomliga priser i Nairobi med hjälp av hållbara, lokalt förankrade strategier, från perspektivet av lokala nyckelaktörer inom byggbranschen. Detta uppnåddes genom skrivbordsforskning, semistrukturerade intervjuer och ett fältbesök på en byggarbetsplats, vars uppgifter sedan triangulerades för att få fram relevanta uppgifter. De viktigaste resultaten av denna forskning är att det finns en stor potential i Nairobi för lokalt anpassade bostadsstrategier att lösa problemen med bostäder till överkomliga priser och tillhandahålla billiga och högkvalitativa alternativ givet klimatförhållandena och de sociokulturella traditionerna. Det finns dock vissa strukturella utmaningar som begränsar genomförandet av sådana lösningar och som måste åtgärdas för att de ska bli relevanta och motståndskraftiga inom bostadssektorn i Nairobi. Denna avhandling bidrar till litteraturen genom att ge en helhetsbild av de olika eller överlappande perspektiven på området, genom att härleda potentialer från den lokala kontexten och genom att ge en förståelse som förhoppningsvis kommer att hjälpa vägleda bostadsbranschen i riktning mot motståndskraftiga och inkluderande bostadsmöjligheter. Den ämnar även att bjuda in till ytterligare forskning om genomförandet av hållbara och prisvärda bostäder i Nairobi och i ett bredare regionalt sammanhang, samt uppmanar till ett nytt sätt att betrakta stadsutvecklingen, trots de problem som finns när det gäller att genomföra den på ett hållbart sätt.

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List of Acronyms

AHP	Affordable Housing Programme
CAHF	Centre for Affordable Housing Finance
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
IFC	International Finance Corporation (World Bank Group)
JICA	Japan International Cooperation Agency
KNBS	Kenya National Bureau of Statistics
NHC	National Housing Corporation
NCC	Nairobi City Council
Urban ARK	Urban Africa: Risk Knowledge

1. Introduction

Globally, the urban population is projected to grow from 3.6 billion in 2011 to 6.3 billion in 2050, with the majority of this growth happening in developing countries (Adabre et al, 2020; Gan et al., 2017, UN-Habitat, 2012). In Africa specifically, urban residents are expected to grow from 11.2% to 20.2% of the total population in those same years (Addy et al., 2022). This will inevitably lead to an increase in housing demand in urban areas, which is already apparent today. However, the current housing sector is struggling to cope with this increasing demand, with the deficit of adequate housing being a global problem (Adetooto et al., 2020; Moghayedi et al., 2021). In developing countries, this issue is apparent, with a growing number of urban residents moving to sub-standard housing due to the lack of affordable housing supply geared towards lower and middle-income households (Adabre et al, 2020). In Kenya, this has led to the proliferation of informal settlements around large urban areas, as people cannot find adequate housing within the city (Gachanja et al., 2023). Indeed, this expanding gap between housing demand and supply, in these contexts especially, has been found to push the housing sector towards "less efficient and more expensive solutions, and new city dwellers towards informal (and often illegal) independent construction of dwellings" (Wallbaum et al., 2012, p.354), Accommodating the lower income households and improving their quality of life is a central challenge in the urbanisation process of developing countries (Gan et al., 2017).

These constructions, as well as the increasing world urban population, have a significant and non-negligible impact on the environment. Today, the building sector accounts for approximately 30% of global carbon emissions and environmental pollutions, as well as 30-50% of the global energy use. In Africa, it is 54% of the primary energy that is consumed by this sector, while in Kenya specifically, this number is approximately 47%, with the residential sector accounting for the majority of this usage (Edge & IFC, 2021; Manzano-Agugliaro et al., 2015; UN-Habitat, 2016b). According to the International Energy Agency (IEA), 40% of the current building energy consumption comes from heating, ventilation, and air conditioning (HVAC) systems, and this figure is estimated to increase in coming years as the effects of climate change intensify (Manzano-Agugliaro et al., 2015; Pajek & Košir, 2016). As such, the African context presents a great potential for alternative development in the construction industry in the effort of climate change mitigation (Addy et al., 2022; County Government of Nairobi, 2018).

However, attention is rarely paid to sustainable housing practices in developing countries, despite their proven capacity for reducing environmental impacts while addressing challenges of affordability (Adabre et al., 2020; Ardda et al., 2018; Widera, 2014, 2021). Sustainable housing practices encompass considerations of environmental, social, and economic factors in their implementation (Mulliner et al., 2013). Moreover, decisions concerning suitable sustainable design strategies are frequently made without studying situational and contextual factors and without taking local practices into account (Yahya & Hassanpour, 2022). Haidar & Bahammam (2021) and Košir (2019) argue that contemporary architecture is often disassociated from the specific context in which it is located, leading to increased energy demands and performance issues. Manzano-Agugliaro et al. (2015), UN-Habitat (2012, 2016a) and Yahya & Hassanpour (2022) add that this is especially noticeable in developing countries, where a large part of the built form is based on

more western architecture that was imported through different means, including colonisation and globalisation. The result of this is that the buildings are usually not adapted to the local climate and require a more intensive use of artificial lighting and HVAC systems to make them comfortable. Designing buildings with an understanding of the local potentials and challenges in terms of climate, resources and conditions would provide energy saving potentials, emission and pollution reductions, and overall cost savings (Aghimien et al., 2020; Grosso, 2021; Haidar & Bahammam, 2021; Khambadkone & Jain, 2017; Košir, 2019; Manzano-Agugliaro et al., 2015; Olgyay, 1963; Pajek & Košir, 2016; UN-Habitat, 2012, 2016a; Yahya & Hassanpour, 2022). This is where bioclimatic and climate responsive design comes in as an alternative design paradigm with a lot of potential, yet in the context of Nairobi, it would require a more in-depth understanding of the situational and contextual potentials to be able to make full use of it (Adabre et al., 2020; Manzano-Agugliaro et al., 2015; Yahya & Hassanpour, 2022).

Subsequently, more locally adapted and climate responsive construction strategies could play a big role helping to meet the demand of adequate affordable housing in a more sustainable way in developing countries and Kenya in particular, if the bioclimatic potential of the specific context is explored and studied. This is what this thesis aims to consider, by interrogating the perspectives of actors in the housing industry of Nairobi and seeking to understand the bioclimatic potentials provided by the city.

2. Literature Review

The provision of affordable housing is a central issue to sustainable urban development in Kenya and globally, and this thesis explores the potentials that bioclimatic building strategies present to respond to it, specifically in the context of Nairobi. An extensive literature review has been conducted to better understand how affordability can be understood, and how it is defined and framed in the Nairobi context. Additionally, the literature on bioclimatic and climate responsive design strategies in the construction industry is explored to provide understanding of the potentials and challenges in its implementation generally. Gaps in the literature have been identified and extracted below.

2.1 Affordable housing

Affordable housing definitions

The notion of affordable housing is defined and understood in various ways in the literature. In a general sense, Gan et al. (2017) define it as housing that is made available for specific households with incomes that would not allow them to acquire appropriate housing in the general market, while Adabre et al. (2020) and Adabre & Chan (2018) sustain that the aim of affordable housing is to enhance housing affordability of low-income earners without incurring any cost burdens. Gan et al. (2017) and Wallbaum et al. (2012) add the dimension of time to the definition, saying that an affordable house should be able to be acquired within a certain period of time, implying a longer-term investment and consideration, which separates it from definitions of relief shelter. Moghayedi et al. (2021) argue that its definition varies based on contexts and personal opinions and is as such

highly subjective. They further explain that affordable housing can exist in different forms, including social, public or community housing, and is often based on a subsidy from the government. The most common way of quantitatively defining affordable housing internationally states that this housing type should not cost more than 30% of the household's income (Adabre et al., 2020; Adetooto et al., 2022; Haidar & Bahammam, 2021; Moghayedi et al., 2021; Mulliner et al., 2013). However, in current literature, this definition has increasingly been criticized, as using a ratio of housing price to household income tends to be normative and ignore wider social and environmental considerations (Adabre & Chan, 2018; Haidar & Bahammam, 2021; Mulliner et al., 2013). Other definitions include Wallbaum et al. (2012)'s claim that affordable housing is housing that costs less than 200 USD/m^2 to construct, or the measure of "shelter poverty" which also considers a household's ability to cover nonhousing costs (Adabre & Chan, 2018; Mulliner et al., 2013). Definitions of affordable housing often differ from definitions such as social housing, or informal settlement upgrading, which refer to different context and methods of approach (Moghayedi et al., 2021). Yet the social and environmental considerations are also not accounted for in these. Indeed, Mulliner et al. (2013) and Adabre & Chan (2018) argue that wider contextual factors cannot be ignored when looking at affordability as its definition goes beyond solely economic viability, and should consider factors such as quality, location, and access to services, as well as the longer-term affordability capacity of the household.

The exclusion of these factors when defining affordability can lead to more costs being engendered by the household overtime, such as increased energy bills, healthcare, and transportation costs (Gan et al., 2017). Most low-income earners have been found to value other influencing criteria apart from cost affordability in their decision-making process for housing, however there is often an information asymmetry between what they want from affordable housing, and what the developers provide, leading to unmet expectations and additional costs (Adabre et Chan, 2018; Adabre et al., 2020). Awanyo et al. (2014) support that involvement of the user in the design, construction and management of the house leads to the best affordable housing outcomes as it roots it in the households needs. Hence, many studies support that affordable housing programs should look beyond just economic viability and consider social, economic, and environmental sustainability factors (Adabre et al., 2020; Arrda et al., 2018; Gan et al., 2017; Moghayedi et al., 2021; Mulliner et al., 2013). Indeed, sustainable housing is defined as housing that is inclusive and affordable for all, while providing adequate access to services and opportunities, all while limiting the impact of the construction on the environment (Haidar & Bahammam, 2021; Moghayedi et al., 2021). Gan et al. (2017) and Adetooto et al. (2022) define sustainable affordable housing as it as "housing that satisfies the requirements and expectations of the current generation without jeopardising future generations' capacity to satisfy their own housing needs and demands" (p.3 in Adetooto et al., 2022). Mulliner et al. (2013) add that the aim of housing provision should not just be provision of shelter but should also aim at building communities. As such, sustainability, a wider term that here is understood as including environmental, social, and economic sustainability, presents itself as a potential basis for affordable housing as these concepts share some of the same goals, including but not limited to, reducing water and energy consumption, more efficient resource use, increasing building durability, quality of life as well as other considerations of social and economic factors (Gan et al., 2017; Haidar & Bahammam, 2021).

Many studies have recently explored the concept of sustainable affordable housing (SAH) and sought to define it, arguing that sustainability and affordability should be tackled and addressed together as they overlap in many ways (Adabre et al., 2020; Adetooto et al., 2022; Arman et al., 2009; Haidar & Bahammam, 2021; Moghayedi et al., 2021; Mulliner et al., 2013). Yet today, it is not a common practice in housing construction to address affordable housing deficit by using sustainable solutions due to the misconception that sustainable design strategies and technologies are expensive and solely geared towards high-end developments (Addy et al., 2022; Gan et al., 2017). It is true that a number of sustainable housing projects cannot be considered affordable due to some of their implementation strategies and target markets, and that in lower- and middle-income contexts, especially in developing countries, the priorities of people are different. Nonetheless, as Adabre & Chan (2018) and Moghayedi et al. (2021) say, not everything that is affordable is sustainable, and vice-versa, so it is important to bridge the gap between the two concepts and explore where they intersect to be able to extract the benefits from both. Incorporating sustainable strategies into affordable housing programs can have various benefits if implemented correctly, as mentioned earlier. Cost savings can be made on resource use, and reduction of energy and water consumption (Adabre et al., 2020; Aghimien et al., 2020; Haidar & Bahammam, 2021; Mulliner et al., 2013). Usually, the economic advantages are especially noticeable when looking at the life cycle of the building, and the affordability in the longer term, owing to better quality housing, minimizing the cost of maintenance and upkeep (Gan et al., 2017; Haidar & Bahammam, 2021). Locally adapted sustainable strategies that take into account the location of the construction usually make use of local materials, workforce and knowledge, limiting the environmental and financial cost of importing these (Addy et al., 2022; Arrda et al., 2018; Haidar & Bahammam, 2021; Wallbaum et al., 2012). Sustainable affordable housing also considers elements necessary for a decent quality of life, which are not necessarily quantifiable economically, but are fundamental and cannot be ignored. As such, it puts the user at the forefront and aims to understand locally variable needs better.

In the case of developing countries, this context specificity is just as important, and understanding the local needs within a country is a vital starting point (Arrda et al., 2018; Haidar & Bahammam, 2021; Moghayedi et al., 2021). Priorities in the construction of sustainable and affordable buildings are different than in more developed countries, yet sustainability issues are often overlooked in this context, although many of these countries present a huge potential for sustainable growth and change (Arrda et al., 2018; Gan et al., 2017). Haidar & Bahammam (2021) state that, according to the UN, only 13% of the cities around the world have affordable housing, and that cities in less developed countries have been found to be less affordable than cities in more developed countries (based on the price to income ratio). The reasons for this include rising housing costs, an increasing mismatch between demand and supply of affordable homes, unregulated construction frameworks, resource costs, as well as socio-cultural and political factors (Addy et al., 2022; Gan et al., 2017; Haidar et Bahammam, 2021). In line with the importance of contextualising the construction mentioned earlier by Moghayedi et al. (2021) and other authors, Ofori (2018) argues that the methods and practices of the construction industry in developing countries cannot be entirely based on learnings from other contexts as they are not adapted to the local environment, and that there is a need to "decolonise" research and practices by acknowledging the difference in each context and making use of them. As such, there is a gap in the research in situating affordable and sustainable

construction practices in the context of developing countries. There are a few studies exploring the intersection of affordability and sustainability conducted in places like South Africa and Ghana (Adabre et al., 2020; Adetooto et al., 2022; Arrda et al.,2018), but very few consider the Kenyan context specifically.

Affordable housing in the Nairobi context

The definition of affordability in the housing sector in Nairobi generally follows more universal interpretations of the term, including the income-cost ratio definition that states that affordable housing should not cost more than 30% of a household's income (CAHF, 2020; Government of Kenya, 2018; Gachanja et al., 2023). The Centre for Affordable Housing Finance in Africa (CAHF) states that affordability in the Nairobi housing industry is affected by factors such as inadequate frameworks, lacking housing supply, high costs of land and construction, as well as limited access to financing options. In a more general sense, it is likewise defined as a household's ability to pay for adequate and decent housing without experiencing financial burdens or compromising their ability to meet their basic needs (County Government of Nairobi, 2014; Gachanja et al., 2023; NCC & JICA, 2014).

In 2018, the Kenyan government set up an Affordable Housing Program (AHP) that aims to supply 250,000 affordable units per year to respond to the high demand in Kenya with an overarching target of providing affordable housing to all citizens by 2030 (Housing and Urban Ministry, 2017; Government of Kenya 2018). Furthermore, a National Housing Corporation (NHC) whose aim is to provide affordable housing to the local low- and middle-income population was set up in the 1950s. The NHC defines affordable housing in more quantitative terms, asserting that it should cost between KES 600,000 and KES 3 million (approximately €4,000 to €20,000), and is targeting households with a monthly income of KES 50,000 to KES 150,000 (approximately €300 to €1000) (Housing and Urban Ministry, 2017; Government of Kenya 2018). One of the Kenyan government's quantitative definitions sets a lower threshold of affordability by defining is as being accessible to households with a monthly income of KES 50,000 (~€300) or less per month, and with a maximum mortgage repayment period of 25 years (Gachanja et al., 2023; Government of Kenya, 2018; NCC & JICA, 2014). The definitions vary in the literature, and these figures serve as a reference to understand what affordability is understood as in the Kenyan context.

Despite some of the efforts by the national and county government to address affordability issues in Nairobi and Kenya more generally, their low levels of fulfilment means that it still remains a major challenge for the low- and middle-income population bracket to access decent and affordable housing in the capital city, as they face high housing costs and inadequate housing conditions (Gachanja et al., 2023, UN-Habitat, 2016b). This difficulty of access also has historical parallels linked to it. Indeed, the housing sector in Kenya has suffered many historical transitions, and affordability has been a challenge in the country for years, mostly linked to the import of building standards during the colonisation of the country. The British Empire occupied Kenya as a colony from the late 1800s until the country's independence in 1963 and was particularly attractive to the settlers due to its numerous natural resources and favourable climate (Home, 2012). This led to a change in the urban form, as well as the introduction of more westernised housing forms and construction standards, that have been found to not be adapted to the local climate, and often rely on the import of foreign materials (Macoloo, 1994; Widera, 2014). Socially, this also led

to a certain loss of cultural identity in the built environment as well as processes of segregation, leading to the exclusion of black Africans from accessing housing in the city for a long time (Home, 2012; Ogot & Ogot, 2020). Macoloo (1994) explains that many of the urban areas in Kenya were colonial creations and that the African population was viewed as only temporarily in these urban spaces, as they were expected to eventually return to rural areas and leave the cities for the colonial settlers.

Another identified challenge previously mentioned is the unprecedented population growth that Nairobi is experiencing. Indeed, Nairobi has one of the highest urban population growth rates in Africa (4.1%), which has led to an imbalance between the rate of urban population growth and infrastructure provision (County Government of Nairobi, 2018). This has caused a housing deficit in Nairobi that has pushed many residents to lower quality housing and informal settlements, the number of residents of which is estimated to double in the next 15 years (Edge & IFC, 2021; Government of Kenya, 2018). This is also caused by low levels of investment into affordable housing (Addy et al., 2022; County Government of Nairobi, 2018; Gachanja et al., 2023).

Furthermore, the way the city has been structured, in its infrastructure and service provision as well as in its activities, is very homocentric, with the highest demand for housing being near the business centre and work areas, adding more pressure on the urban core (County Government of Nairobi, 2018; Gachanja et al., 2023). In the CIDP (County Integrated Development Plan, 2018-2022) this increased pressure was identified as being at the source of a variety of environmental degradations, which are stated to be aggravated by the uncontrolled and unplanned settlements, the inefficient energy use, and the poor management of solid waste (County Government of Nairobi, 2018). In the plan, climate change impacts on the city were identified and include "change in water levels, lack of enough rainfall, increasing temperature, erratic weather patterns, food insecurity and increase in cost of food commodities" (p.26). The Nairobi County government has engaged itself to address these effects of climate change on the built environment and shown interest in enhancing its capacity to respond to emerging issues, however sustainable building implementation remain scarce, especially in the affordable housing sector (County Government of Nairobi, 2018; Edge & IFC, 2021; Gachanja et al., 2023; NCC & JICA, 2014). The Urban Economic Growth study (Gachanja et al., 2023) states that the current building codes are outdated and do not take into consideration the notions of resilience and sustainability, to provide planning for adequate building structures that can respond to worsening climatic and social conditions in the long term. The study suggested the need to revise the building code in this regard, while also localising the action plans, as these were considered to be too general and lacking contextual consideration.

When seeking to localise and contextualise construction frameworks and considerations, there are possible strategies. When combined with an environmental and social sustainability perspective, this links it to climate responsive and bioclimatic design and architecture.

2.2 Bioclimatic adaptations

The impact that the building sector currently has in terms of emissions, resource use and environmental impacts is considerable, thus working towards a more sustainable and resilient

sector can be instrumental in reducing environmental impacts overall. As previously mentioned, Haidar & Bahammam (2021), Košir (2019) and Widera (2015) claim that contemporary architecture frequently lacks a connection to the particular environment in which it is situated, which results in higher energy needs and performance problems. This is particularly evident in developing countries, where a significant portion of the built form is based on more western architecture that was imported through various channels, including colonization and globalization (Manzano-Agugliaro et al., 2015; UN-Habitat, 2012, 2016b; Yahya & Hassanpour, 2022). Because of this, buildings are frequently not climate-adapted, necessitating a greater reliance on artificial lighting and HVAC systems to maintain comfort. The impacts that the building sector currently have are projected to grow as climate change intensifies these needs (Manzano-Agugliaro et al., 2015; Pajek & Košir, 2016). Indeed, projections of Nairobi's future climate show a significant increase in average temperatures by the 2040s, with even higher levels expected for the end of the century. Additionally, the frequency of extreme heat events as well as the intensity of rainfalls are projected to increase in the future (Urban ARK, 2017). Buildings constructed and designed with a rooted understanding of the local potentials and challenges in terms of climate, resources and conditions would provide energy saving potentials, emission and pollution reductions, and overall cost savings (Aghimien et al., 2020; Grosso, 2021; Haidar & Bahammam, 2021; Khambadkone & Jain, 2017; Košir, 2019; Manzano-Agugliaro et al., 2015; Olgyay, 1963; Pajek & Košir, 2016; UN-Habitat, 2016b; Yahya & Hassanpour, 2022). This is where bioclimatic design, also called climate responsive design, comes in as an alternative building design paradigm (Manzano-Agugliaro et al., 2015; Yahya & Hassanpour, 2022).

Definitions

Bioclimatic building design refers to a type of building adaptation that considers and makes use of the local climate in which the building is located (Košir, 2019). The local conditions and resources are understood and used to enhance the building performance, usually emphasising resource and energy efficiency by using passive and semi passive strategies based on the specific context in which it finds itself (Aghimien et al., 2020; Pajek & Košir, 2016, Yahya & Hassanpour, 2022). These passive solutions are usually preferred as they directly play a role in the operational energy performance of the building, reducing energy use and improving levels of indoor comfort, however, the use of active mechanical elements is also possible (Košir, 2019). The bioclimatic building adaptations usually focus on the provision of natural lighting and ventilation, improving air quality, and enhancing indoor thermal comfort, improving waste management and the overall reduction of energy use in the building. This is for example achieved through work on the building envelope, natural ventilation and lighting possibilities, choice of materials, orientation of the building, shading, use of vegetation, etc… depending on the context, based on whether you are trying to gain or lose heat (Košir, 2019; Manzano-Agugliaro et al., 2015; Olgyay, 1963; UN-Habitat, 2016).

Moreover, researchers in the field add the dimension of social and cultural integration as an important consideration of bioclimatic design (Aghimien et al., 2020; Grosso, 2021; Haidar & Bahammam, 2021; Khambadkone & Jain, 2017; Košir, 2019; Manzano-Agugliaro et al., 2015; Olgyay, 1963; Pajek & Košir, 2016, Yahya & Hassanpour, 2022). Indeed, many authors argue that when seeking to understand the local conditions in which the building is set, attention has to be paid to the wider context, which might include social, cultural, economic, political, and historical

factors. These factors can be used to positively enhance the building performance or might help to better understand the conditions in which it is being built. Aghimien et al. (2020) and Pajek & Košir (2016) explain that this also allows for bioclimatic designs to place the focus on the occupant's needs and expectations at a local level, as well as considering local materials, knowledge and building techniques, providing services as well as functionality. As such the building aims to be holistically integrated into the local fabric and context, without shutting out the natural world but rather making use of it (Widera, 2014).

Elements of adaptation

In order to implement bioclimatic design strategies, the local climate has to be studied to understand the requirements for indoor comfort as well as the design potentials provided by the local conditions. Khambadkone & Jain (2017), Košir (2019) and Manzano-Agugliaro et al. (2015) mention some of the most common tools used for this type of practice, including analysis of climate profiles and characteristics as well as psychometric charts, as understanding the local climatic conditions of the building location is vital for choosing the appropriate design strategies for improving the building performance. When using the Givoni diagram, or psychometric chart, the climatic conditions are used to position the local context on the graph, from which the bioclimatic potential and necessary building adaptations to reach the comfort zone can be extracted. The notion of comfort zone is a generally defined term, but this definition can vary depending on the local perceptions and habits too, so should be adapted as well (Khambadkone & Jain, 2017). The elements included in this process are summarized in Appendix A below, to provide a better understanding of how climate responsive designs are approached and conceived in the literature.

Lots of research and design strategies have been developed for more western or developed contexts and climates, exploring the variety of adaptations that can be implemented in various micro-climates. More recently, developing contexts have stared to be considered, exploring how bioclimatic adaptations can help reduce energy use and enhance indoor comfort and building performance by making use of local climate characteristics and adapting the built form to the local conditions, with many of the traditional design methodologies having been replaced in developing countries by processes of globalised urbanisation and colonialism (Adabre et al., 2020; Adetooto et al., 2022; Ardda et al., 2018; Khambadkone & Jain, 2017; UN-Habitat, 2012, 2016; Widera, 2014). However, many of these studies focus on more extreme climates, and the more temperate climates in developing areas, such as is the case of Nairobi, are very much understudied in the literature. Indeed, although it presents some similarities with temperate climates elsewhere, Nairobi's equatorial location brings variations that should be considered, added to its socio-political context, that also plays a role in the potentials and challenges of the building sector (Moghayedi et al., 2021).

Definition over time and link to vernacularism

The terms "bioclimatic adaptation" or "bioclimatic design" as linked to buildings first appeared in the 1950s in Victor Ologyay's publishings and were then defined and popularised by his book 'Design with climate, bioclimatic approach to architectural regionalism' (1963). In his work, he highlights the importance of adapting human shelter to the climate in which it finds itself and develops a method to do so based on climate analysis and architecture application. He created the

first form of the bioclimatic chart using relative humidity and dry bulb temperature to ascertain the optimal thermal comfort zone, which was then further refined by Givoni (1969) and Szokolay (1980), who are considered major proponents in the field (Grosso, 2021; Khambadkone & Jain, 2017; Košir, 2019). The notion of bioclimatic design appeared thereafter in numerous studies on environmentally and climatically adapted architecture, however, in their definitions, these authors mention that the notion of bioclimatic architecture is not a newly invented one (Aghimien et al., 2020; Košir, 2019; Manzano-Agugliaro et al., 2015; Ologyay, 1963; Widera, 2014).

Indeed, the design paradigm focusing of climate adaptability and local conditions is a practice that can be traced back to the origins of human settlements, whereby archaic architectural forms usually tended to be adapted to the local climate and conditions, and a result of years of development of traditional building techniques as well as cultural inputs, known as vernacular architecture (Ologyay, 1963; Yahya & Hassanpour, 2022; Widera, 2014). Vernacular architecture can be defined as a type of traditional architecture that is adapted to the physical and social needs of its inhabitants, while being rooted in the local context and making use of the surrounding conditions in order to provide an adequate indoor environment (Grosso, 2021; Košir, 2019; Pajek & Košir, 2016; Widera, 2014). It is based on the usage of local materials and knowledge, with a strong emphasis on the creation and upkeep of cultural identity and entities (Aghimien et al., 2020; Košir, 2019; Manzano-Agugliaro et al., 2015, Ologyay, 1963; Szokolay, 1980). In many places, these traditional building forms and elements were often replaced over time due to numerous factors including dissemination of more standardised building forms linked to globalisation and colonisation, technological advancements, and urbanisation (Grosso, 2021; Yahya & Hassanpour, 2022; Widera, 2014). In Kenya, the urban built environment was impacted by the colonial presence, that excluded local people and practices from the urban centres in favour for westernised standards, leading to a shift in perception that traditional practices were rudimentary and should be replaced (Ardda et al., 2018; Kimari & Ernstson, 2020; Widera, 2014). These traditional practices can still be found in more rural parts of the country, and a lot of the consideration for local culture and materials has been lost within urban areas.

As such, bioclimatic architecture is often inspired by elements of vernacularism, learning from local traditions and past construction and design methods, as are often seen to be better suited to the local climate. However, as Widera (2014) and Manzano-Agugliaro et al. (2015) state, the difference is that bioclimatic design is based on a more detailed and in-depth analysis of the climatic and environmental characteristics of the location, as well as allowing for the possibility of including more technological solutions in the building design. Furthermore, bioclimatic designs also tend to look forward in time, considering the potential impacts of climate change on the local environment and emphasising the resilience of the building, as such adapting it to the contemporary climatic conditions, but also preparing for any future variations (Košir, 2019; Yahya & Hassanpour, 2022).

Most of the studies linking vernacularism learnings to bioclimatic design focus on western contexts. As previously mentioned, when looking at developing countries, it is usually in more extreme climates, which includes mostly hot-humid or arid contexts. Research into adaptations for more temperate climes focuses in majority on developed countries, where there is a higher seasonal

variation of temperature as well as sunlight, leaving a gap on studying the climates in an equatorial context and associated potential adaptation strategies. There has been some work in Kenya done on analysing the climatic potentials for buildings, like Macoloo (1994) mentioning already years ago the importance of considering the local conditions and climatic suitability of building materials and the UN-Habitat (2016) writing a report on architectural bioclimatic design strategies for East Africa. While the Government of Kenya has not developed any works on climate responsive adaptations in buildings, it has called for solutions to address sustainability issues in the building sector. However, these scarce resources usually remain very broad and not very localised, with little action actually taken or link to the potential that they might present for the affordable housing sector to meet the increasing demand from low- and middle-income populations. Not much research has been done to understand the challenges and potentials that these strategies might have for understanding and responding to the affordability needs of the local Nairobi population, in the long term. This is where my thesis comes in, aiming to fill this gap in the research by providing a holistic view of the current perceptions of sustainable and affordable housing challenges and opportunities in Nairobi.

In this thesis, the terms bioclimatic or climate responsive designs and adaptations are used, but can be understood interchangeably with locally adapted design, sustainable design strategies, and climate adapted design.

3. Aim and Problem Statement

Problem statement

This study recognizes two interlinked challenges of sustainable urban development that exist in Nairobi at the moment that have been identified through the literature review. The first problem is rooted in the housing context of the city. The supply of adequate affordable housing is not sufficient to meet the demand of the rapidly growing population. The houses that are being supplied are themselves often unregulated in their construction and their maintenance, not affordable in the long run, or of inadequate quality.

The second problem has to do with challenges of environmental sustainability. Indeed, the building sector is a big contributor to emissions and environmental degradations, globally and in Nairobi. In the situation where the construction and maintenance of buildings is poorly regulated, this worsens its impacts and makes the building itself less resilient in the long term. With climate change, more extreme climatic events will occur (floods, droughts, heatwaves) for which buildings need to be adapted to provide adequate shelter and provision of services to its inhabitants.

As such, there is a need for inclusive and affordable housing solutions that are also resilient in the long term and adapted to the local context, now and in the future. It was found that very little research linking the two problems has been conducted in the context of Nairobi. My thesis aims to fill this research gap by exploring the interaction between these two issues within the Nairobi context through the perspectives of local actors and learnings from the literature. Other challenges linked to affordable housing exist in this region, such as access to adequate land for its implementation, lack of social housing policies, low enforcement of standards, and prevalence of

corruption in the approval process, amongst others. These are important drivers in the local housing sector that have a non-negligible influence, and their role is acknowledged. However, within the scope of this study, it is the linkages between sustainability and affordability in the built environment that is considered as it was found to be understudied in the given context and could provide potentials for responding to the other issues. And affordable housing is considered for the low- and middle-income population bracket and does not consider informal settlement upgrading progams or social housing.

Aims of the study

The overall aims of the study are:

1. Provide a deeper understanding of the potential of bioclimatic adapted building strategies in Nairobi's affordable housing sector.
2. Gather insights from key actors to better understand the current challenges and opportunities, collating them to draw out elements of divergence or convergence in the sector.
3. Develop a comprehensive understanding of the challenges and opportunities associated with sustainable affordable housing in Nairobi, based on the perspectives of different stakeholders.

In order to achieve that, I ask the following research questions:

Research questions

1. Is sustainable climate-responsive construction relevant and important to Nairobi's affordable housing sector?
2. In the opinion of actors in the field, what are the main challenges to implementing sustainable affordable housing strategies in Nairobi, and how can they be addressed?
3. How do different key actors in the affordable housing sector in Nairobi perceive bioclimatic design strategies and their potential to improve affordability and sustainability?

4. Methodology

In order to answer the research questions and fulfil the aim of this study, this study made use of a range of qualitative methodologies. The goal is here to provide a multi-disciplinary and diverse perspective on the stated problem by using multiple sources of data. In order to inform the results, data was gathered from a desktop review, from key actors in the sector through semi-structured interviews, and from a site visit to a sustainable and affordable housing development construction site in Nairobi. This data was then translated and analysed using an inductive thematic content analysis approach. As the project is based in Nairobi, Kenya, I start by situating the study.

a. Study area

The selected study area is Nairobi, Kenya's capital city (Fig. 1). Nairobi City County is one of the 47 counties in Kenya, and is bordered by the counties of Kiambu, Kajiado and Machakos (Gachanja et al., 2023; Otiso, 2012). The city currently has a population of over 4 million people,

making up more than 30% of Kenya's urban population and is the largest urban area in the country (CCEE et al., 2018; Gachanja et al., 2023; KNBS, 2019). Nairobi is experiencing one of the highest annual rates of population growth and urbanization in Africa (County Government of Nairobi, 2018; UN-Habitat, 2016b). However, many of the growing urban population is being absorbed into informal settlements of low quality of infrastructure and service provision, with 36% of Nairobi's population living in these informal settlements in 2019 according to the Kenya National Bureau of Statistics, and this number expected to double in the coming 15 years (Gachanja et al., 2023; KNBS, 2019).

In 2018, Kenya was the ninth biggest economy in Africa based on IMF rankings and has been classed as a "lower-middle income country" by the Work Bank (CCEE et al., 2018). It plays an important role as an east African regional hub for trade, transportation, communication, finance, non-governmental organizations, and tourism (CCEE et al., 2018; Gachanja et al., 2023; Otiso, 2012; NCC & JICA, 2014; UN-Habitat, 2016b).

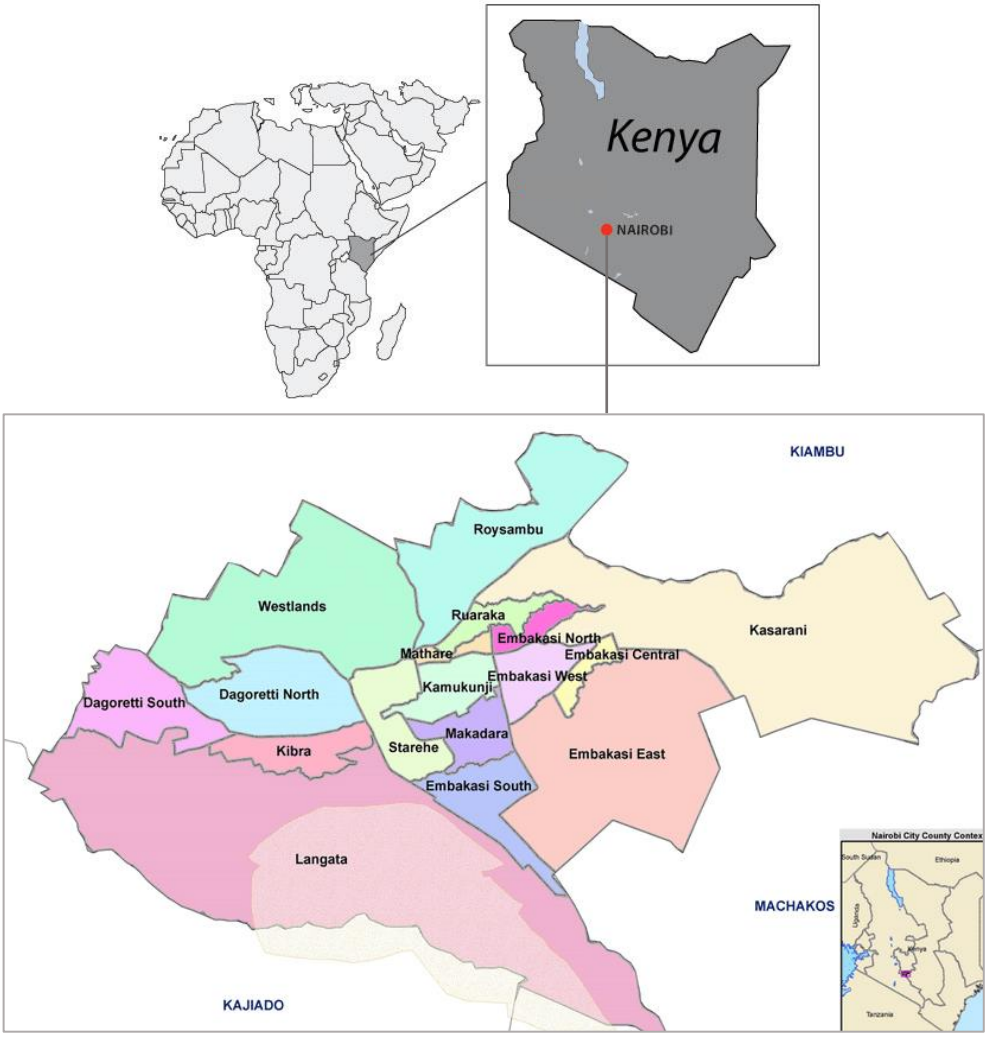

Figure 1: Situating maps of the study area of Nairobi, Kenya (CDC, 2019 & Kiplagat et al., 2020 respectively)

Nairobi is located near the equator and at an altitude of approximately 1,650m, resulting in a mild temperate climate. Weather and climate characteristics are further detailed as part of the data collection and analysis.

This particular study area was chosen firstly due to personal ties that offered contextual knowledge and access and provided valuable insight into the multifaceted challenges and untapped opportunities inherent within the specified region. However, Kenya, and more specifically its capital Nairobi, plays a significant role as a rapidly growing regional hub and as a low- and middle-income country in the African context, as its unique urban fabric and history offers a distinct set of challenges and opportunities for affordable and sustainable housing that remains as yet understudied. By selecting Nairobi as the study area, I strive to remain objective in my research, and aim to contribute to the understanding of sustainable and affordable housing practices within the specific context of a rapidly growing African city, providing valuable insights that have a strong relevance and learning potentials for urban areas in Kenya and other developing countries.

b. Data collection

This study is based on three types of data sources that we will expand on below. These include desk-based research, key informant interviews, and a site visit to one of the project sites.

Desk-based research

Climatic data was gathered from multiple sources via desk-based research to determine the significant climate characteristics of Nairobi. The aim of establishing the city's climatic profile is to further the understanding of the local challenges and opportunities and examine the implications of the required adaptations needed to provide adequate indoor comfort levels to inhabitants through its bioclimatic potential. EPW data files for Nairobi were gathered based on EnergyPlus weather statistics and analysed through Excel and the CBE Clima tool (Betti et al., 2022). The dataset from the Jomo Kenyatta International Airport weather files was chosen as it is one of the most comprehensive and complete. Data was also gathered from other sources to provide multiple sources and check validity, and were triangulated (UN-Habitat, 2016a; Urban Ark, 2017; WeatherSpark, n.d.).

Semi-structured key informant interviews

The main source of data for this study was gathered through a series of semi-structured interviews with different stakeholders from the housing development field in Nairobi, with the aim of getting their professional perspectives and insights on the current situation. This supplied qualitative data, both from public and private actors, that will later be used in addition to the data gathered through the desktop review to provide a comprehensive overview of the identified issues (MacCallum et al., 2019). Our sample includes experienced practitioners and researchers from the fields of affordable or sustainable housing, urban design and planning and policy making, as well as private developers and government representatives. Table 1 below presents an overview of the participants interviewed.

Table 1: Participants interviewed and their provided field of expertise.

ID	Gender	Main Discipline	Context/Field	Contact
P1	F	Affordable housing projects	Industry & Academic	Online
P2	M	Alternative building materials and technology, bioclimatic and vernacular architecture, affordable housing design	Academic	In-person
P3	F	Affordable housing in Nairobi	National Government	In-person
P4	F	Sustainable affordable housing projects, certifications	Industry	Online
P5	M	Affordable housing, cultural heritage	Industry & Academic	In-person
P6	M	Affordable housing in Nairobi	Academic	In-person
P7	F	Sustainable affordable housing projects, certifications	Industry	In-person

Semi structured interviews are based on predetermined information and questions but remain flexible by allowing the discussion to flow more naturally based on the inputs from the participants as they emerge. It is the researcher's job however to keep the topic on track and not diverge too far (MacCallum et al., 2019; Santo-Tomás Muro et al., 2020). Using the predefined questions as guides rather than a rigid structure is particularly useful to provide in-depth insight into issues and practices from different stakeholders' perspectives, revealing the complexities in the given research area (Amaratunga et al., 2002; Cheah et al., 2021; MacCallum et al., 2019; McIntosh & Morse, 2005). Cheah et al. (2021) and MacCallum et al. (2019) agree that the aim of using interviews in qualitative research is not to establish a singular truth or facts, but rather with getting a better understanding of the perspectives in the field and understanding of the issues at hand, which is particularly relevant in this study.

However, when conducting semi-structed interviews, certain precautions have to be taken to limit the bias of the process, as well as making it clear that the perspectives gathered are inherently biased themselves and should be considered as subjective knowledge (McIntosh & Morse, 2005). From the researcher's side, it is important not to influence respondents' responses with my own inputs, and to remain objective in the discussions (Mathers et al., 2000). As such, the ethics and transparent positioning of the study have to be made clear, as well as insuring the informed consent and respect of confidentiality of the participants (MacCallum et al., 2019).

Based on the literature review and defined research questions and aims, an interview guide was developed, and includes the prepared questions on which the interviews were based (see Appendix B). Due to the semi-structured nature of the interviews, these questions served more as a reference from which the discussions evolved, with different potential axes to develop on allowing for flexibility in the discussions based on the answers of the participants. Questions were slightly adapted to each participant sector, as they are from different professional fields and backgrounds, and can provide different types of information to build on. However, the overarching themes and foundations of the questions were the same.

The interviews happened for the most part in person during my field visit to Kenya. The respondents that could not meet me face-to-face were interviewed online. Interviews were recorded by microphone and lasted between 45 to 90 minutes. Consent for the interviews was

explicitly accorded, with all the details and scope of the study explained in a transparent and appropriate manner so that the interviewee was fully aware of how their input would be used, with the guarantee that the recordings will not be published.

As mentioned previously, the sample of interviewees includes a range of different perspectives, but I acknowledge that it is not representative of the whole situation and sector. I did not for example, interview community actors, or people who live in the studied housings. This could provide more insight into the subject, but I was not able to access those actors within the scope of this research.

Site Visit

In addition to the interviews, a field visit was conducted to one of the development sites of a sustainable affordable housing project in Nairobi. The field visit lasted approximately one hour, during which impressions were gathered, and questions about the project were answered by the project manager. This site visit is referred to in Table 3 and in the data analysis as S1. This was an opportunity to get a hands-on perspective of the implementation of one of the only sustainable and affordable housing projects in the area, gaining more insight into the challenges and opportunities in the application of these concepts, and gathering data linked to design and construction strategies.

c. Data analysis

All interviews were transcribed verbatim and were then analysed using a thematic content analysis approach. In general, there are two main groups of methods to approach qualitative analysis: inductive and deductive methods. Deductive methods make us of predetermined codes and categories defined before the data is considered, and map connections in the data to these predefined groups (MacCallum et al., 2019; van Renswouwe et al., 2022). On the other hand, inductive methods are driven by the data, and commonalities are identified during the process of coding itself. It is an iterative approach, and its aim is to extract patterns from the data and keep the possibility of new findings more open (Green et al., 2007; MacCallum et al., 2019). Inductive methods can also be influenced by theory and the literature review, but do not serve as the first set of categories. Thematic content analysis is a commonly used inductive analysis methodology as is systematic way of identifying concepts that can then be categorized into themes, while allowing to understand where the participants differ or align in their perspectives (Amaratunga et al., 2002; Mathers et al., 2000). It aims to make sense and understanding the meaning of the respondents' accounts, as opposed to other methods that might consider the manner in which the respondent answers or the act of data creation itself (Welsh, 2002). As such, this method of data analysis is being used as the aim is to extract learnings from the respondents that might not have been found in the wider literature and is then more suited to be driven by the data, rather than firring the data to predetermined categories. However, the basis of the interview questions remains rooted in the literature, theory, and research questions, and so still play a role in the data analysis.

In this study, the thematic content analysis was performed using the qualitative data analysis software NVivo 14 as a starting point. This is a tool that allows for more systematic and consistent data coding and storage. It has been found to add rigour and accuracy to the analysis process, making the research more reliable (MacCallum et al., 2019; Santo-Tomás Muro et al., 2020; Welsh,

2002). However, the researcher is still the one performing the analysis and coding procedure. While this adds to the potential bias in the analysis, Welsh (2002) and Santo-Tomás Muro et al. (2020) argues that manual input and analysis, for example in the identification of themes, or for the interrogation of the work overall is still an extremely valid source of data translation and cannot all be done through a software. Thus, once the initial coding was performed in NVivo, the data was then transferred to a spreadsheet to manually finalize the classification of wider categories and themes.

The process of the thematic content analysis performed in this study included the initial coding of all transcripts and in an iterative manner, going back and recategorizing certain codes as the data analysis continued. Recurring patterns in these codes where then identified and were then grouped into categories. These categories were refined and recoded before themselves being grouped into wider themes and categories. These were based on learnings from the literature, as well as informed by the main interview themes, as the questions asked to the participants were themselves based on the literature and the research questions, driving the direction of the respondents' answers to a certain extent.

However, when using and analysing interview data, the possibility of introducing bias and error is none-negligible. Error and bias can appear at numerous stages of the process – on both sides (Du Toit et al., 2017; Mathers et al, 2000; McIntosh & Morse, 2015). One of the key elements to keep in mind is that when analysing and translating interview data, the researcher is presenting the participants' perspectives, and should not present or accept this as fact (MacCallum et al., 2019). Furthermore, bias exists as well from the side of the researcher during the data collection and analysis as the interviewee, as their opinion and mindset affect the framing of the study to different extents and should be limited as much as possible by favouring objectivity and impartiality (Dunn, 2005; Green et al., 2007; MacCallum et al., 2019; Welsh, 2002). The inductive method mentioned above aims to limit this by being data driven, opening up the research possibilities to new findings that the research might not have been aware more, thus making the study richer (Amaratunga et al., 2002; Cheah et al., 2021; MacCallum et al., 2019; McIntosh & Morse, 2015; Santo-Tomás Muro et al., 2020).

Many of the limitations of this study relate to issues of scale. Indeed, the processes considered here are not isolated, but rather part of a larger dynamic network of interactions. Due to time and resource constraints, certain temporal, geographical and thematic scopes were defined, but it is acknowledged that the results might not be representative of a wider system of processes and elements, and the results might vary if considered at different scales. Additionally, it is recognised that there are many more factors that can be considered when looking affordability and sustainability in the housing sector, as previously touched upon. As such, one of the risks with this type of study is that it might consider certain processes as independent from the larger urban framework and is not representative enough of the different challenges and interactions within it (MacCallum et al., 2019).

5. Results

5.1 Nairobi Climate Profile

a. Summary of key characteristics

In this section, a summary of the results of the desktop research are presented, providing a basic holistic understanding of Nairobi's climate profile and the characteristics that are either challenges or potentials for the implementation for the development of sustainable and affordable housing. Table 2 below presents the monthly averages of different climatic data in Nairobi as extracted from the different data sets mentioned above. The details of the climate analysis can be found in Appendix C, while this section examines the implications of the climate characteristics of Nairobi have in terms of bioclimatic potential.

The Nairobi climate generally falls into the Cfb category on the Köppen-Geiger climatic classification chart., which are characterised by subtropical highland climates and temperate oceanic climates. Table 2 in the Results section presents the monthly averages of different climatic data in Nairobi as extracted from the different data sets gathered during the data collection of this study.

Table 2: Summary table of monthly averages climatic factors in Nairobi.

Month	Dry bulb temperature (°C)	Relative humidity (%)	Rainfall (mm)	Wind Speed (m/s)	Global Horizontal Solar Radiation (Wh/m²)
Jan	20	70	40	4.7	285.1
Feb	21	69	40	4.6	289.1
Mar	21	62	70	4.7	272.5
Apr	20	75	160	4.1	236.0
May	19	81	110	3.5	217.6
Jun	18	73	30	3.1	201.1
Jul	17	71	10	3.2	197.0
Aug	17	74	10	3.6	219.9
Sep	19	65	20	4.1	250.1
Oct	20	68	40	4.7	256.5
Nov	19	76	110	4.8	230.2
Dec	19	75	70	4.8	247.2

b. Bioclimatic potentials

This localised climate analysis and investigation of its associated implications is important, as Nairobi is generally described as falling within the Cfb climatic category in the Köppen-Geiger classification (see Appendix 3). However, its actual climatic characteristics do not fall entirely within the definition of this category, as it remains quite broad and mostly based on western contexts (Košir, 2019; Widera, 2014). Below, figures 2 and 3 respectively show the psychometric

chart of Nairobi with associated recommended passive design strategies and the UTCI (Universal Thermal Climate Index) that presents the thermal heat stress per month in Nairobi respectively. Figure 2 was extracted from the UN-Habitat (2016a) report that seeks to understand the design potentials and recommendation for East Africa based on local climates. Here we can see that a good portion of the points fall within the comfort zone, while the rest mainly fall just below the comfort zone level, implying a need for little heating - which is in line with the seasonal variations in temperature that we have seen above.

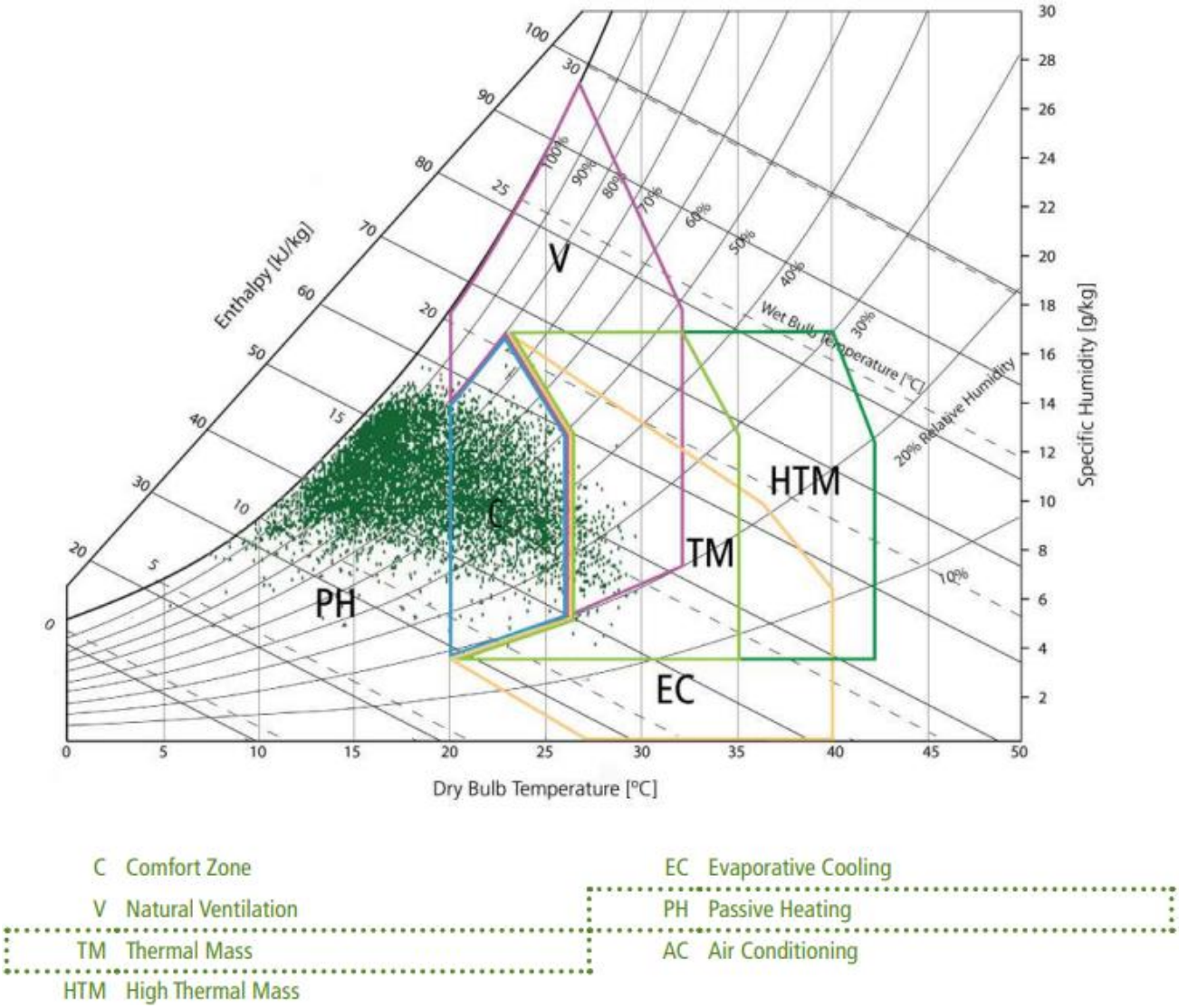

Figure 2: Psychometric chart of Nairobi with associated passive design strategies.

On the other hand, the UTCI graphs in Figure 3 show the overall thermal stress distribution in Nairobi, in line with the findings from the psychometric chart above, showing most months having a majority of percentage of time where there is no thermal stress, with otherwise periods where moderate amounts of cooling or heating are needed.

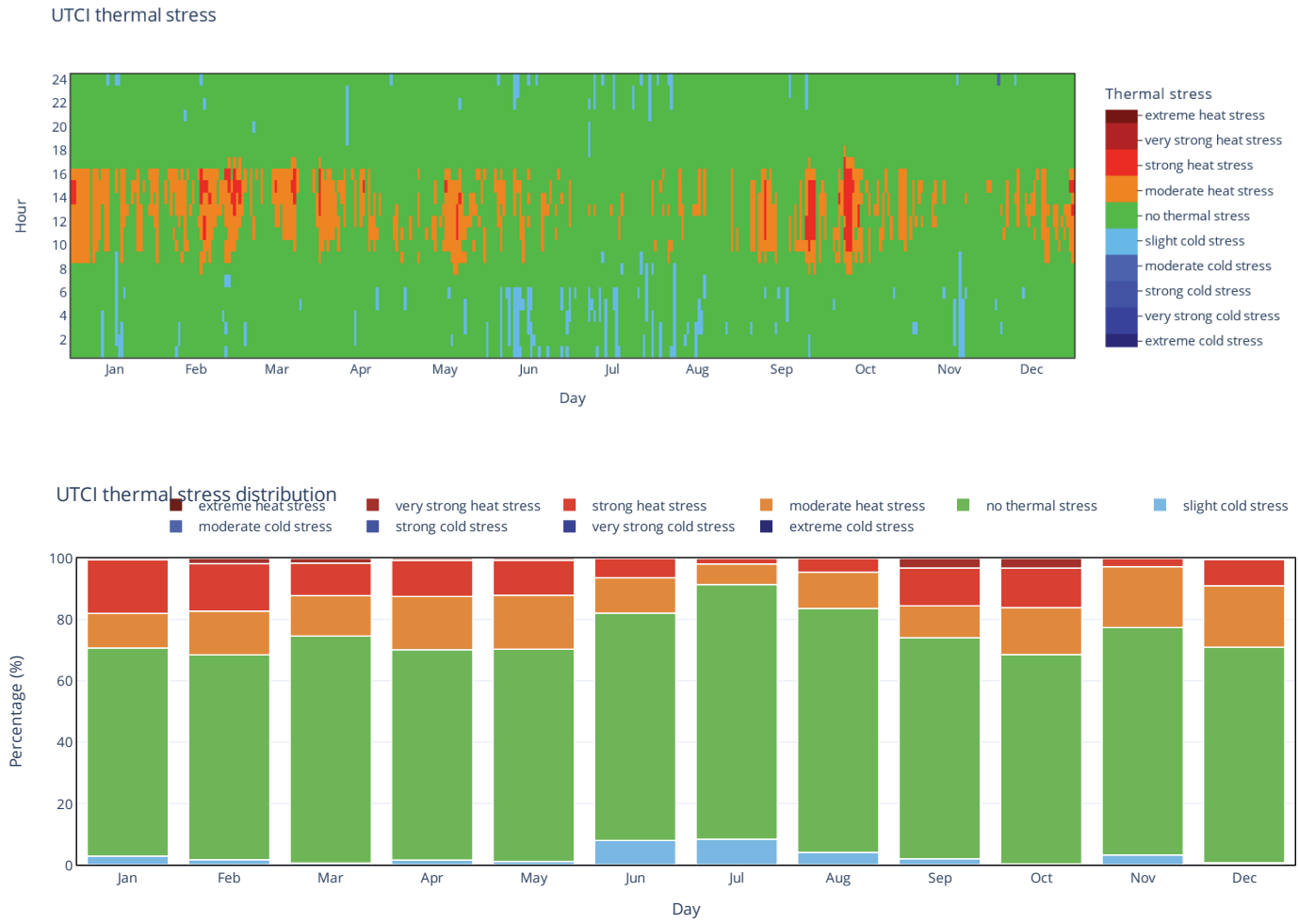

Figure 3: UTCI overall thermal stress distribution graphs of Nairobi

The most influential and best suited building design strategies to respond to these needs for passive heating in the coldest months and passive cooling during the warmest can be extracted from the learnings from these figures, in addition to the inputs from the literature (Košir, 2019; Manzano-Agugliaro et al., 2015; UN-Habitat, 2016). In the hotter periods, the indoor comfort level can be maintained by allowing for natural ventilation, appropriate sun shading devices, use of vegetation for cooling and shading effects. In the colder periods, the orientation of the building and its thermal mass play a central role. Orienting the building to the east and west favours natural lighting and ventilation, minimizing heat gains during the warm periods if appropriately shaded and allowing for solar radiation to enter during the colder ones. More compact forms and medium weight structures are suited to make use of solar gains for passive heating, which retains and accumulates heat, that can then be released during colder periods and at night.

5.2 Insights from key actors in the Nairobi housing industry

In this section, I present the results as extracted from the thematic content analysis summarised in Table 3. As a result of the analysis, a total of 13 themes grouped in 5 sections were defined with their respective sub-categories. The input elements gather the synthesis of the initial coding from what the participants said, to provide a better understanding of the categories. First, definitions of affordability and sustainability in the Kenyan context as understood by the participants are presented. Second, contextual factors are presented that help better understand the local conditions. Then, I focus on the different practical elements of sustainable and affordable housing that were identified by the interviewees as being necessary to consider in Nairobi. Fourth, the identified processes and wider sustainable systems are presented. Finally, I indicate the challenges that were put forward and identified in the interview process for the implementation of sustainable affordable housing in the Nairobi context.

Table 3: Summary of the results of the coding of the interviews as grouped into categories and themes.

General structure	Themes	Categories	Input elements	ID
Definitions	**Affordability**	Different definitions based on sector and actor	Any project that is <4 million Kenyan shillings for the developer. Depends very much on payment plan - if you have to give it up front, it´s expensive, but if you have a payment plan of 3-5 years, it´s very affordable	P4
			Rent should be affordable to people who make ~1 dollar per day	P3
			Depends on the cost of end user finance and the cost of construction (borne by the developer) - affordability criteria should specify these costs and the payment plans	P4
			"The best way for developers to improve affordability is to partner with end user finance providers" (either for mortgage, a tenant purchase scheme, pension funds, saccos people with long-term finance that can offer 10- 20 year payment plans that then also don't compromise on their ability to deliver at scale)	P4
			Includes the political, the social, the economical, and can happen at different scales	P1
				P3
				P6
			Affordable units = 50,000Ksh per square meter of gross net	P6
		Split in the categories in Kenya	Affordable housing, social housing, informal housing/settlements	P4
				P1
				P2
		Context dependent	Important to consider the users and their needs	P3
				P2
			Different ways of living and practices affect what people look for in affordability	P2
	Sustainability	Social aspects	Sustainability can be understood through social and cultural factors	P6
			It provides people with decent homes - links to quality (i.e., reduced crime and access to services)	P3
			Human centred, responds to community and user needs	P2
		Environmental aspects	Reduces use of resources and helps environment stay healthy	P4
				P3
		Economic aspects	Framing of sustainability in Kenya is usually based on monetary terms	P4
			Need for balance & respect between both economy and environment	P2
			SDGs are too global, need more work at community ward level	P5

		Must be locally defined	Requires localised and contextual understanding	P2
		Improves quality	Serves as a measure of quality	P4
				P2
		Role in achieving affordability	Direct measures of costs savings in terms of water, energy, sewage, exhuming...	P4
			Benefits overlap between the two, they are easy to combine and compatible	
		Benefits in the long run/Ability to last	Reduces user cost in the long run	P4
			Difference between green, eco and sustainable buildings is long term thinking	P2
			Brings foresight and has little need for maintenance	P2
Context	**Identified issues**	Housing supply/demand	Increasing demand for affordable housing	P2
			Difficulty in meeting government requirements	P6
			Fast population growth, but then move to slums when there is no adequate affordable housing	P2
				P3
		Unregulated & unstandardised constructions	Lack of foresight in constructions	P2
				P6
			Unregulated sector	P4
			Standards have disappeared and been forgotten	P2
			Building code not adapted and at broader national level	P2
			People doing as they wish, no balance between the demand and the type of housing appearing	P2
		Maladapted buildings	Westernised and maladjusted buildings	P1
			Uncomfortable indoor temperatures now more than before due to building form	P2
			Lots of imports lead to a loss of local identity	P2
			Standards changed, used to be better adapted to climate	P2
		Social issues	Wider social system is unbalanced	P2
			Political issues bring instability (election times, demonstrations...)	P4
			Quality of life decreasing	P1
				P3
				P4
		Environmental issues	Intensifying climatic events, hard to predict and plan	P2
			Current practices are harmful to the environment	P2
			Environmental factors are not considered	P2
		Lack of motivation	No push for people to try new things in the industry	P4
			High construction costs are off putting for developers	P6
				P4
	Differing priorities	Basic amenities for "survival"	Environmental considerations are not a priority	P6
				P3
				P4
			Food, clothing, shelter, education needs	P4
				P5
		Fluctuating incomes	Requirements changing month to month because incomes are not stable	P1
		Traditional & cultural practices	Traditional and social practices in ways of using common spaces (cooking methods, meeting and exchanging...) and people want access to this	P1
			Different preferences - people willing to compromise on certain things (like proximity) to get access to others (more space, closer to social amenities...)	P2
	Potentials	Natural raw materials	Identity and strong traditions of using local materials	P2
		Vegetation	Climate is perfect for growing native plants	P2

		Climate	Climate has a lot of potentials - should make more use of solar energy, rainwater harvesting, boreholes, daylight, as well as wet and dry seasons	P2
				P3
		Traditions	Building standards from the past, they were better adapted	P2
Elements	**Design and construction**	Contextualisation	Situational awareness of human development, and understanding that environment is changing so needs to keep updated local information	P2
			Need to understand social context, practices, priorities, and challenges	P1
			Need to understand climatic context and profiles	P2
		Daylight	Natural lighting should be favoured - potential in Nairobi for it	P4
				P2
				P3
				S1
			Contextual design adaptations to maximize daylight while considering safety	P4
				P7
				S1
		Orientation	Building orientation, considering the sun (east & west facing facade openings) and access to green spaces	P4
				S1
				P2
		Heat gain/loss (thermal massing)	Colour of the walls to reflect light and minimize heat gain	P4
			Thermal massing is an important factor	P1
		Materials	Types of local environmentally friendly construction materials with potential include adobe bricks, prefabricated materials, masonry, recycled plastic pavers	P5
				P4
				P1
			Make use of Alternative Building Materials & Technologies (ABM&T) - which can be defined as materials that are either alternative, appropriate, or emerging	P4
				P2
			Materials should be sourced locally "Buy Kenyan, build Kenyan"	P1
				P3
				P2
			Benefits of local materials include ties to cultural identity, reduced resource use and environmental impact, lowers cost of materials...	P2
				P3
			Give pride to and showcase natural raw and local material	P2
				S1
			Lots of imports, have to discourage it	P2
				P3
		Shading	Sun shading implementations are easier because there is less seasonal variation	P4
				P2
		Typologies	Natural raw materials and their use have endured changes over time	P2
			Importance of densification and doing it right	P6
				P1
			Uniformalise general typologies to enhance affordability - but mix these standardised typologies to cater to different needs (incremental housing as a potential example for this)	P1
				P2
				P3
				P7
				S1
			Focus on passive design	P2
		Vegetation	Nairobi climate as an opportunity since it's favourable for growth	P2
			Little to no maintenance needed with native plants	P2
			Ecosystem services provision from vegetation	P2
			Better urban environment & systems with access to green spaces	P2

				P4
			Need for balance and foresight, replacing what is removed from natural areas	P2
		Ventilation	Potential for natural and passive ventilation	P4
				P2
		Aesthetics	Cheap design elements by making use of exposed natural materials	S1
				P2
	Infrastructure and services	Access to services	Building new urban nodes by providing more localised access to services, decentralising them	P4
				P7
				S1
			Still connecting urban fabric and these services nodes to maintain environmental resources and not create disconnected urban jungles	P2
				S1
				P4
			Sharing access and provision of services across counties	P2
				P3
			Social considerations: access to services linked to cultural and traditional perspectives	P2
				P1
			Emergency services	P3
			Water - through rainwater harvesting to make use of heavy rains during the season; as well as boreholes	P2
		Access to services	Transport also needs to be provided and connected	P2
				P5
			Proximity to schools, hospitals, work	P2
				P4
		Maintenance	Long term maintenance is facilitated through sustainable design	P2
			Breaking it down into smaller maintenance units makes it easier to manager	P6
			Should be maintained by owners	P3
		Performance	Role of sustainability indicators in achieving sustainability is most to serve as guidelines	P2
				P4
		Plot size/Number of units	Smaller plots (50x100 or less) are what a large number of people are using to build on - cannot deny that fact	P6
				P4
			Alternative project options considering affordability and sustainability usually prefer larger plot sizes due to the economies of scale. It is easier to provide services for a larger plot than for many small ones	P4
				P3
				S1
				P7
	Comfort and health	Dignified living	Access to resources and services beyond just the basic ones for survival (access to green and open spaces, place for kids to play, adequate amount of space...)	P4
				P7
				S1
				P2
				P3
			Possibility of involvement & participation of people living there	P3
		Open space	Defining requirements, 10-30% of open space to be provided	P6
				P4
			Access to open green space is an important consideration	S1
			Cultural and social needs linked to it, like outdoor cooking on the ground floor	P1
		Safety	Safety risks, crime is a big concern in Nairobi	P6
				P3
			Changes over time in urban form, not as many delimitations some years ago	P5
				P7

			Innovative design adaptations to consider safety while allowing for other things, like daylighting	P4 S1
	Social and cultural	Participation & inclusivity	Gender roles and empowerment of women and young people in the construction industry	P3
			Role of women in construction is being changed	P4 P7 S1
			Encouraging local labour	P3
		Identity	Role of local people: they cannot be excluded from consideration and can provide cultural input and local workforce	P3
			Understand cultural context, issues, and potentials	P5 P2
			Housing identity has been lost and should be recovered, use local materials and indigenous knowledge to do so	P2 P3 P5
		Location	New urban nodes bring new expectations: outside of town but still well connected, understanding that not everyone wants to live in Nairobi itself either	P4 P5 P2 P7 S1 P3
			Land prices are higher in the CBD, but with not much space. People want to be closer though so have to find a balance	P4
		Human centred design//culture centred design	Prioritising user experience	P4 P2 P3
			Sustainable design places community, user, and indigenous culture at the centre of the design	P2 P5
Sustainable systems/ processes	**Designing for wider sustainability**	Scalability	"Economies of scale" are very important to sustainability and for the conclusion of the project	P3 P4
			More sustainable and affordable to go bigger with the plots	P4
			Increasing project site size over time	P4
			Long term investments and planning, no profits at first	P4
			Build in phases to make it easier and mixed with urban fabric	P4
			Maintaining affordability through sustainability, by keeping the price down over time but the quality high	P4
		Replicability	International examples: Replicable in the local context, possibly scalable in the region	P1
			Standardised process makes it cheaper and replicable	S1 P4 P7
		Learning opportunities	International and neighbouring examples and practices can be learned from	P2 P1 P3 P5 P6
		Integration with wider urban network	Access to resources & services has to be thought at a wider scale to not make it uneven and badly planned	P5 P3 S1

				P4
				P7
			Think of the urban fabric design also at the street level and by involving people	P6
			Wider urban fabric connections in terms of regional connections, considerations, and sharing potentials	P6
				P2
				P3
	Engaging actors and stakeholders	Actors/stakeholders	Government, private and corporate developers, users & all their different interests	P6
				P2
				P3
		Participation	Users and their experience at the forefront of the design	P2
			Enhance public participation	P5
				P3
			Enhance community involvement	P3
			Understand and adapt to local needs	P3
				P1
		Local workforce	Creating local job opportunities, community involvement	P3
	Aligning policy and regulations	Policy & regulations	Necessary guidelines should be clear and define minimum amenities required for decent living and supporting of natural embedded constructions	P6
				P2
				P4
			Improve zoning laws, they used to be much better	P2
				P3
			Contextualisation by adapting codes and regulations to local areas, favouring county implementations and documents rather than only national ones	P2
			Maintaining affordability while providing quality requires not only infrastructure but also strong policy frameworks	P1
		Regional considerations	Wider collaborations with neighbouring counties and urban nodes to favour decentralization	P5
				P2
			Regional integration and sharing of resources and knowledge when appropriate	P3
				P2
		Tenancy	Pushing for private ownership	P3
			Rental laws are important to define	P1
		Process	Responsibilities of different actors have to be made clear - foundations to be provided by local county government	P3
				P1
				P2
			Opportunity for alternative development, cannot go through same process of industrialization as developed countries	P2
				P3
				P6
				P5
		Strategy document	Vision 2030	P3
				P2
Challenges	**Practical implementation**	Lack of resources	Limited end user finance options and unfriendly to people buying the units	P4
			County owns more land in Nairobi than in other counties but does not have the resources to build or maintain it	P3
			Lack of financial resources	P3
				P1
			Gaps in the policies/government regulations	P1
			Lack of data can be paralyzing in research in this field	P6
		Lack of foresight	No forward thinking in construction and natural maintenance	P2

			Lack of maintenance plans or procedures	P2
			No guidelines provided on how to develop housing on different sized plots	P6
			Not understanding people's needs, and a lot of favouring of quick profits over long term considerations	P6
			No upgrading of infrastructure inside of town or integration to wider service network outside of town	P2
		Long term investment/long term of returns/slow returns	Steep learning curve to get to know the designs and construction techniques	P4
				P7
			People are not "brave enough" to try affordable and sustainable housing	P4
			Takes time for it to be profitable	P4
		Risk of gentrification	People cannot always afford it anymore when upgrading happens	P1
				P3
		Multitude of actors	Differing interests when many people are implicated, still relies on client approval	P4
				P2
				S1
				P6
				P7
				P3
	Socio-cultural context	Unprecedented / uncontrolled growth	Challenge of meeting increasing demand properly	P2
				P6
		Established mindset	Local perception of sustainability is not always good or seen as relevant to the local needs	P6
			Established practices make it harder for people to accept new strategies or ways of doing things	P4
				P2
				P3
			Lack of motivation to try affordable and sustainable housing	P4
			Gaps in civic education lead to lesser involvement of people, they don't care	P3
		Political context	Government corruption	P4
			Government mindset	P2
				P4
			Political interference and interests	P3
			Gaps in policies/government regulations	P1
		Gender issues	Main buyers are men	P3
			Construction is a male dominated field	P3
			Women have to be empowered in the processes, as well as young people	P3

Some points of tension were identified, where the perspectives of the different participants were contradicting. Other points were found to be corroborating between the different actors. These provide the basis of the discussion of this study, as well as the overall learnings extracted from the data analysis, and a summary of these points can be found in Table 4 below. These points were derived from the data analysis either as elements in the same category and sub-category with contradicting perspectives on the same subject, or as the elements that were most recurringly mentioned and upheld by the participants.

Table 4: Summary of the main consensus and contention points as extracted from the data analysis.

Main points of consensus	Main points of contention
• Creation of new urban nodes is needed	• Optimal plot and development site size
• Climatic potentials of Nairobi for efficient and locally adapted building adaptations	• Sharing of knowledge between sectors and availability of data on best construction practices
• Benefits of using sustainable construction practices	• Motivation to implement sustainability in affordable housing from government and industry actors
• Need for updated construction frameworks and guidelines on affordable and resilient building	• Definitions of affordability and its present role in Nairobi and the construction industry
• Housing demand is currently unmet by supply	• Differing interests of actors in the field in the development of affordable housing and uptake of sustainable strategies
• Need for local empowerment – women, young people, local workforce	

6. Discussion

In the analysis of the data, different relationships emerged of contrasting and overlapping perspectives. These recurring patterns are vital to understand the role that sustainable design strategies can play in the affordable housing market in Nairobi, and what potentials and challenges are identified by the interpolation of key actor perspectives, either by what was explicitly said, or by exploring the contrasts in their discourses.

6.1 Project sizing

Indeed, one main topic of contention is the size of the plots on which affordable housing developments should be built. During the interviews, it became apparent that there are varying perspectives and standpoints on this element, and this can be attributed mostly to a divergence between theory and practice, or aspirations and reality. The interviewed developers mainly argued that larger plot sizes, with a minimum of 3-8 acres and 300-500 units approximately, are preferable in order to reach affordability and sustainability goals (P3, P4, P7). This is because of what they called the "economies of scale" (P2, P4, P6), suggesting that the larger the development, the easier it is to provide access to services without compromising the environmental integrity of the site and surroundings, and allowing for cost savings, while also providing potential for dignified living. This approach has indeed been studied in the literature and found to enhance sustainability and affordability, especially on the developers' side (Gan et al., 2017; Ofori, 2019; UNEP, 2021; Widera, 2021). However, the implementation of larger sized developments implies certain demands that are not necessarily easy to meet, such as the availability of space in attractive central areas, and the connection and integration of these plots to the wider urban fabric if they are out of town. In Nairobi, the fact remains that most people are currently building affordable housing on smaller plots, mostly 50x100m or even 40x80m (County Government of Nairobi, 2018; NCC &

JICA, 2014). This is due to regulations that were in place before the Physical Planning Act of 1999, which allowed larger plots to be subdivided multiple times without strict rules (P6). Then, it was because these smaller plots were meant for individual homes, yet it was soon found to be financially profitable for the land owners to densify them by maximizing the units built in this limited space (County Government of Nairobi, 2018; Macoloo, 1994; P6). This means compromising on air quality, natural lighting, ventilation and general comfort and wellbeing (P4, P6).

Many of the participants agreed that the issue here is that these constructions are very unregulated, and lead to affordable homes that are of very low quality and short-term durability. But since it is still the most common practice, it cannot be ignored and has to be addressed, either by providing solutions for these plot sizes, or incentivising the people constructing to do it differently. Another issue, as was brought up by a couple of interviewees, is that in the larger projects, there is usually one responsible developer, limiting the variety and diversity of involved actors. This can make the management process and the provisioning of services more efficient, however it can also lead to the exclusion of a multitude of actors and monopolies being created in the construction sector of Nairobi. Sources add that this might lead to the uniformalisation of the built environment, which does not contribute to the creation of a vibrant and diverse urban fabric (Ardda et al., 2018; Gan et al., 2017; Mulliner et al. 2013; Ofori, 2019). A potential recourse to this is the process of incremental housing, or developments organised in phases, subdividing larger projects into smaller ones, with the important element of involving multiple people (Ardda et al., 2018; Widera, 2014; P4). These people can be numerous developers, consultants, building experts from various fields, but should definitely include the perspectives of the end user and community. This would help anchor the projects in the local context and responds to people's actual needs while respecting the social and cultural implementation, also engaging people to promote their commitment and connection to the projects (Arman et al., 2009; Gan et al., 2017). This has to be considered properly and could require further research into the challenges and potentials of such processes.

6.2 Creation of new urban nodes

The main alternative strategy put forward by the participants is the creation of new urban nodes outside of the central Nairobi area and their provision of localised access to services (P2, P3, P4, P4, P6, P7). This would have the effect of decentralizing services and infrastructure in Nairobi, which was identified in the literature as one of the challenges in the city (County Government of Nairobi, 2018; Gachanja et al., 2023). The integration of design adaptations to the streetscape, by understanding the role and importance of social practices in the local context should also be considered. In order for this to be accomplished in a resilient and appropriate manner, the interviewees' shared opinion is that there needs to be solid and clear frameworks, regulations, and guidelines, as well as incentives in place to promote proper engagement. In many of their perspectives, one of the most important factors to consider here is the connection and integration of these new urban nodes to the wider urban fabric, so as not to create disconnected and uncoordinated "urban jungles" (P4). Indeed, as previously mentioned, Adabre & Chan (2018), Haidar & Bahammam (2021) and Mulliner et al., (2013) argue that affordability cannot be understood purely in terms of economic viability but should also consider wider contextual factors (such as location, quality of space, access to transport services, etc). This would allow for the

provision of adequate housing services based on economic, environmental, and social sustainability considerations, ensuring that the quality of affordable housing can be sustained over time and not devolve into the typologies and processes that eventually make up informal settlements today. It is vital that these urban nodes be framed properly as to not become unregulated and low-quality sites. This would require a solid foundation in the construction sector on which to build upon, as well as a shift in the local mindsets and perceptions of affordable and sustainable housing.

6.3 Policy framework & local perceptions of sustainability

This foundation of which sustainable and affordable housing can be implemented relies not only on infrastructural adaptations, but also requires adequate policy framing and shifts in the mentalities (Haidar & Bahammam, 2021; Mulliner et al., 2013). The policies and regulations that will guide the implementation of sustainable and affordable housing has to come from the county and national governments in the opinion of most interviewed stakeholders. From a couple of the interviews, it was clear that there is a general lack of motivation or drive to try new methods of constructing affordable housing from the building industry, linked to the scepticism towards sustainable practices as well as to the prioritisation of more short-term economic benefits rather than long term resilience (Ardda et al., 2018; Widera, 14). Indeed, many actors in the field view sustainable strategies for enhancing the affordability of housing as a gamble, as the financial return is only profitable in the long term and requires an investment at the start of the projects (P3, P4, P6). This is linked to the lack of foresight that other participants mentioned as being prevalent in the country (P2, P5). As such, the framework of sustainable and affordable housing constructions provided by the government should also serve to reassure other industry actors and normalize these projects, to enhance the interest in their execution. Some of the participants involved in such projects expressed their hope that they would be able to help set new adequate standards, to show the potentials of such developments (P1, P2, P4, P6). The need for a maintenance framework and regulations post-construction is also linked to the lack of foresight in the industry and could help with the durability and long-term resilience of these housing projects. Many interviewed actors also see the need for the county government to update the current codes and regulations, to keep them up to date with current conditions, and localise the considerations more (P1, P2, P3, P4, P6). One suggested way forward is also the creation of cross-county relationships, in terms of sharing of knowledge, resources, and materials, especially when the climatic conditions are found to be similar between neighbouring counties and regions (P2, P3, P5).

As of now, it is clear that one of the main challenges in the housing industry in Nairobi is that the different actors are operating in silos, with not much discussion happening between them. Indeed, it was made evident in the interview process that there is little communication and exchange between the different stakeholders in the field, leading to inconsistencies, miscommunications, and gaps in the affordable housing implementations. Enhancing exchanges throughout the housing and construction sector and favouring transparency could also help with data collection and use. Many of the studies or programs that touch upon subjects related to this were either abandoned or are not being considered in the building sectors, such as the UN-Habitat (2016) bioclimatic report that is not disseminated. P6 mentioned that the lack of readily available data makes the execution and application of projects difficult, as much of the data in Kenya is not recorded and a lot is transmitted

orally, especially traditionally – one of the motivations for using interviews in this research to get hands-on perspectives. This would help for scalability and replicability to a certain extent. Since the sustainable and affordable building strategies studied in this thesis focus on local contextualisation, the replicability of such projects is difficult. However, the process through which these construction adaptations are thought of and implemented are definitely replicable to the wider region, pushing for local promotion of identity, materials, and knowledge, learning from the local climates that are often misunderstood or generalised, and involving the people in the construction process of sustainable and affordable housing (Haidar & Bahammam, 2021; Wallbaum et al., 2012; Widera, 2014).

The local mindset plays a very big part in the implementation of resilient, inclusive, and sustainable affordable housing (Ardda et al., 2018). Indeed, throughout the interviews, the participants made it apparent that scepticism and uncertainty towards notions of sustainability are prevalent in the general population of Nairobi, especially in the low- and middle-income context as well as in government agencies. Indeed, the participants emphasized the fact that in the affordable housing context, the priorities of people were more focused on day-to-day survival and provision of basic amenities rather than wider sustainable notions, as these are often attributed to more western ideals and standpoints and not considered relevant to the local population by many and are thus often dismissed. Widera (2014) and Ardda et al. (2018) examine this, underlining the importance of taking these differing priorities into consideration and not diminishing them or trying to solve it from an "outsider" perspective. As such, there is a need for a shift in the mindsets and the way that sustainable strategies are perceived, destigmatising the notion, and going beyond the term "sustainability" itself, which today has a lot of different associated definitions and connotations, towards an understanding of the value and potentials that locally adapted and climate responsive sustainable strategies can provide for local needs and improved quality of life. In this sense, P4, as well as the authors Gan et al. (2017) and Manzano-Agugliaro et al. (2015), put forward the role that sustainability can have for achieving affordability targets, and projects should aim to answer the affordability and sustainability issues in one go.

6.4 Nairobi climatic potentials

Moreover, based on the learnings extracted from the data analysis, it has been found that Nairobi presents a number of potentials for sustainable and affordable housing, that is inclusive and resilient in the long-term. Based on the climate characteristics identified through the desk research, general recommendations of the best building adaptations can be extracted, when triangulated with what was found in the literature about bioclimatic adaptations, and what was explained by certain interview participants about their construction implementations. Firstly, the climate characteristics exhibited in the city make it favourable to bioclimatic building adaptions. Indeed, the city's bioclimatic potential, as exhibited in Figure 2, is such that most of the year the comfort level can be reached with minimal complex implementations, and during some periods of the year, require either passive heating or natural ventilations, both adaptations that are within reach due to the yearly climate in Nairobi, making it cheaper to implement and upkeep. By having a temperate climate with fewer seasonal variations, the implementation of affordable housing designs that allow to save energy consumption and other service provision costs is facilitated (Haidar & Bahammam, 2021; Khambadkone & Jain, 2017; Pajek & Košir, 2016). What is needed is the

knowledge of how to implement it, and the drive to do so, and just as P2 and P4, as well as Adetooto et al. (2022) suggest, these implementations can be quite simple and do not necessarily require a lot of resources or technologies, incurring cost savings. An understanding of the local context of the building site, with its potentials but also its challenges is the most important factor, understanding that the solar potential and low diurnal variations for example, are a great opportunity (P2; Košir, 2019). Elements of vernacularism and traditional building practices should be re-examined and learned from. Indeed, P2 and P5 argued that the traditional houses that used to be more prevalent around Nairobi were better adapted to the climate and required little-to-no mechanical technologies to make the indoor environment adequately comfortable. As such, exploring traditions and cultural practices can be an important way of learning to adapt the building to the local climate while exploring the local history (Aghimien et al., 2020; Grosso, 2021; Košir, 2019; Manzano-Agugliaro et al., 2015; Pajek & Košir, 2016; Widera, 2014). It is a process of contextualising the indoor building environments into the wider local fabric, reducing the separations and barriers between the two, and improving the comfort of the users through this. However, provisions and considerations of the intensifying climatic events have to be analysed to make the homes resilient in the long term and not impact their quality or cost overall. The most influential building adaptation recommendations that were extracted by combining findings from the literature and data analysis were to meet the seasonal heating demand through solar heat gain and adapting the thermal mass. East-west oriented buildings to favour natural lighting and ventilation is recommended, while medium weight structures are suited to the Nairobi climate to make use of passive solar gains for passive heating (Košir, 2019; Manzano-Agugliaro et al., 2015; UN-Habitat, 2016, P4). One aspect that would require more research here and that was found to be lacking in the literature, is the possible adaptation strategies to the seasonal variations between wet and dry periods of the year, looking at how the building design can be adapted to harmonize these different periods, and use the potential and opportunities of one part of the year to respond to the challenges of the other.

Another main climatic opportunity presented by the city of Nairobi is its potential for vegetative growth. Nairobi is colloquially known as the “Green City in the Sun” due to its abundant greenery which can grow easily in the favourable local climate, as demonstrated in the climatic profile description (Ogot & Ogot, 2020). However, during the interviews, it came up that in the opinion of certain interviewees, current construction practices tend to lack foresight in the way that vegetation, such as trees, is thought about and is often cleared without consideration of its ecosystemic benefits (P1, P2, P7). Hence, the need to respect and learn about the native vegetation, as well as local raw materials, is identified, with the aim of understanding their potential and ability to improve the urban housing quality, provide basic amenities, and reduce environmental impacts, without incurring additional maintenance or import costs. In architectural terms, this conscious integration of nature into the built environment is sometimes referred to as biophilic design, the purpose of which is to increase people’s contact with nature within urban areas and create more sustainable environments. The benefits of this are numerous and include the improvement of mental and physical health of the building’s occupant, a healthier urban environment, enhancement of cultural identity, as well as the provision of shade, reduction of air and sound pollution and decreasing the building’s energy consumption by promoting passive cooling mechanisms (Widera, 2014; Yahya & Hassanpour, 2022). However, this integration has to be done thoughtfully and

carefully, as non-adapted vegetative elements might incur more costs and require more maintenance. It is also important to stay away from notions that any vegetation is beneficial to add to the building site, and rather understand the functioning of the native local flora that is better adapted. The need to understand the local context in ecological and climatic terms makes "adapted" biophilic design closely related with the principles of bioclimatic and climate responsive adaptations, for example through the selection of natural elements that are either native to the area or adapted to its climate, and the role that cultural significance should have, or through the implementation of relevant natural ventilation and daylight systems (Yahya & Hassanpour, 2022).

As was mentioned previously, the city of Nairobi is experiencing high rates of population growth and urbanization. This should be seen as an opportunity to build and plan for the long term with new paradigms that focus of the local needs and potentials, rather than continuing with certain inadequate current practices, that are often a result of colonial or globalised imports (Addy et al., 2022; Ardda et al.,2018; Macoloo, 1994; Widera, 2014).

6.5 Limitations of the Study and Future Work

This study is focused in its scope due to its time and resource limitations. However, it highlights the potential for further work on the subject of sustainable and affordable housing developments in Nairobi, as it is a complex issue requiring a multitude of considerations in its implementation. One element that would be important to consider is the gathering of insights and perspectives of the people to whom this housing typology is targeted and including more factors of environmental justice in the research. This was not possible to accomplish within the scope of this study, but including a variety of stakeholders involved in the development of adequate affordable housing is vital. Furthermore, studies looking at actual implementations and performing assessments on them as well as on theoretical modelling could provide insights and best practices or mistakes to learn from and provide a practical investigation of this issue. Finally, a cost analysis would also be beneficial to examine in quantifiable terms the benefits that sustainable and bioclimatic adaptations can have over the building's life cycle in Nairobi, possibly making the argument for their development stronger in this context.

7. Conclusions

This study aimed at investigating the potentials and challenges of sustainable and affordable housing in Nairobi through the perspectives of key industry actors as well as a climate analysis. This was done using various methods which include desk research, a set of semi-structured interviews with key actors, as well as a field visit to one of the development sites. Through the qualitative analysis of the data, the implementation of locally adapted building strategies was found to be a potentially relevant option in the context of the current affordable housing quality and supply issues of the studied area. Indeed, Nairobi is seeing a significant urban population growth that is expected to keep growing in coming years, however, the housing sector is struggling to cope with this increasing demand, especially in the low- and middle-income context.

The city presents various opportunities for sustainable and affordable housing that focus on bioclimatic building adaptations. Indeed, through the interviews and desk research, it was found that using local materials, knowledge and workforce can have significant cost saving effects that do not require a compromise on the quality of the housing. This type of building strategy was said to lead to reduced environmental impacts, which despite not being seen as a priority by most people in low- and middle-income situations in Nairobi, allows for the improvement of the general quality of life and of housing, without incurring significant costs or gentrification processes. It also favours the promotion of cultural identities and practices, respecting the local traditions, resources, and people, and exploring elements of vernacularism. By going beyond simple economic viability as a marker of affordability, the users' needs and right to decent standards of life are taken into consideration. Furthermore, it was argued that Nairobi's climate and location displays great potential for more passive and integrated designs, contextualising building practices more and dissociating them from harmful global trends.

Yet, through the discussions with the key local actors, it was reaffirmed that the priorities of most people in this context are not in sustainable approaches and changes, but rather in meeting daily needs and getting access to basic amenities. This is also linked to the prevalent perception of sustainability in the area, which is seen as a foreign notion, towards which many are suspicious or dismissive. However, in recent years, some changes in this mindset have happened, with many participants being strong advocates for the benefits that sustainable strategies can provide, and trying to show how affordability and sustainability goals are often interlinked. Otherwise, the main challenge in the implementation of sustainable and affordable housing as perceived by the participants of this study is the lack of structural foundations in terms of policy, regulations, guidelines, and funding opportunities. Furthermore, the definition of affordability also seems to vary depending on the actor, as developers, users, government departments, and consultants do not view it in the same way, and the term usually means something different for each. There is very little communication between the actors in the different sectors, and comprehensive data is not readily available. This leads the housing construction practices being unregulated and haphazardly done, increasing their environmental, social, and economic impacts in the long term with no foresight of the future implications and needs.

As such, through this study, it was found that there is strong potential for using climate responsive and sustainable building adaptations to respond to affordable housing needs. However, the political and social framework in which they would be implemented requires significant change in order for it to be successful, in a resilient and inclusive manner. Nairobi is an area experiencing much growth, and as such work has to be done to implement the infrastructure and services systems properly from the start, instead of having to change it later on. It is vital to learn from the local context and potentials, disassociating and decolonizing practices from unfitting norms that are imported from abroad, and adapting the suitable learnings to the local context. This would require additional locally situated research on the Nairobi climate profile, the local materials that can be used, and redefining sustainability and affordability in this region, as there is little work done in this direction presently. This thesis is an attempt at providing a holistic view of the current perspectives in the affordable housing construction sector in Nairobi, investigating where the

stakeholders' views differ or overlap in their understanding of the opportunities and challenges in the implementation of more sustainable and resilient affordable housing practices, and providing a basis on which further work and research can be done in this regard.

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9. Appendices

9.1 APPENDIX A – ELEMENTS OF BIOCLIMATIC ADAPTATION

This section serves to provide a better understanding of bioclimatic adaptations and their process. It serves as a complement to the literature examined in section 2.2 of this study and is aims at giving better detail to the concept.

In order to implement bioclimatic design strategies, a thorough understanding of the local climatic characteristics is required. Khambadkone & Jain (2017), Košir (2019) and Manzano-Agugliaro et al. (2015) specify that a first step can be the identification of the climate classification type in which the building location falls, which can help identify general climate characteristics and provide points of comparison with other places that might have a similar context (Košir, 2019; Szokolay, 1980). The Köppen-Geiger climate classification system is one of the most commonly used ones, and presents five main types of climates, with various subtypes, based on the globe's main biomes, as well as temperature and precipitation (Košir, 2019). Figure 4 below shows their spatial distribution in Kenya, with Nairobi and its surroundings displaying a complex mix of climate types, but is usually attributed to the Cfb and Csb categories.

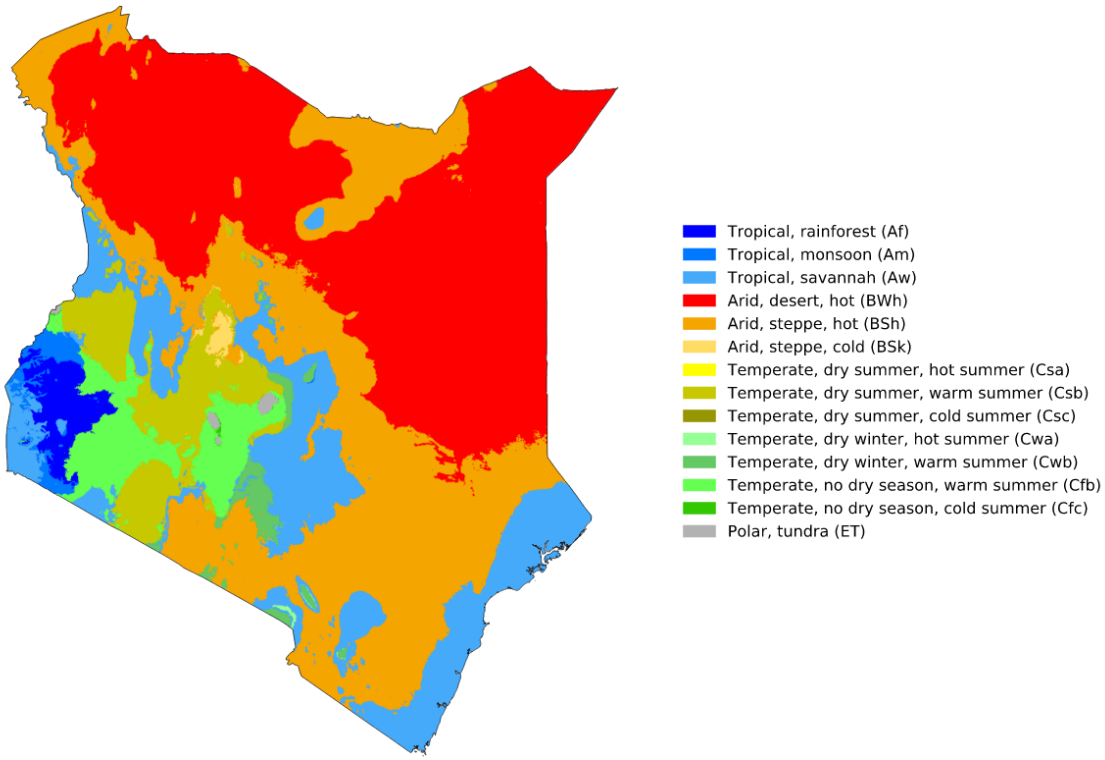


Figure 4: Köppen-Geiger classification map for Kenya (1980-2016). (Source: Beck et al., 2018)

Based on this, a more detailed analysis of the building location's climatic characteristics and profile can be done to extract relevant information. Different authors (Košir, 2019; Ologyay, 1963; Pajek & Košir, 2016; Wallbaum et al., 2012) highlight the most influential climatic factors in the building design process. These include:

- Air temperature (dry bulb temperature)
- Relative humidity of the air
- Air movement (wind)
- Solar radiation received
- Daylight length
- Diurnal and annual variations in temperature
- Precipitation
- Cloud cover
- HDD/CDD

Once the conditions in which the building is located are understood, a psychometric chart, also called the Givoni diagram (Figure 5 below), can be used to assess the requirements to reach the comfort zone. The notion of comfort zone is a generally defined term, but this definition can vary depending on the local perceptions and habits too, so should be adapted as well (Khambadkone & Jain, 2017). The psychometric chart makes use of the relative humidity and dry-bulb temperature of a place to estimate the potential adaptations required to reach optimal thermal comfort levels. These tools are the most commonly described in the literature as a basis on which bioclimatic design strategies can be developed and conceived.

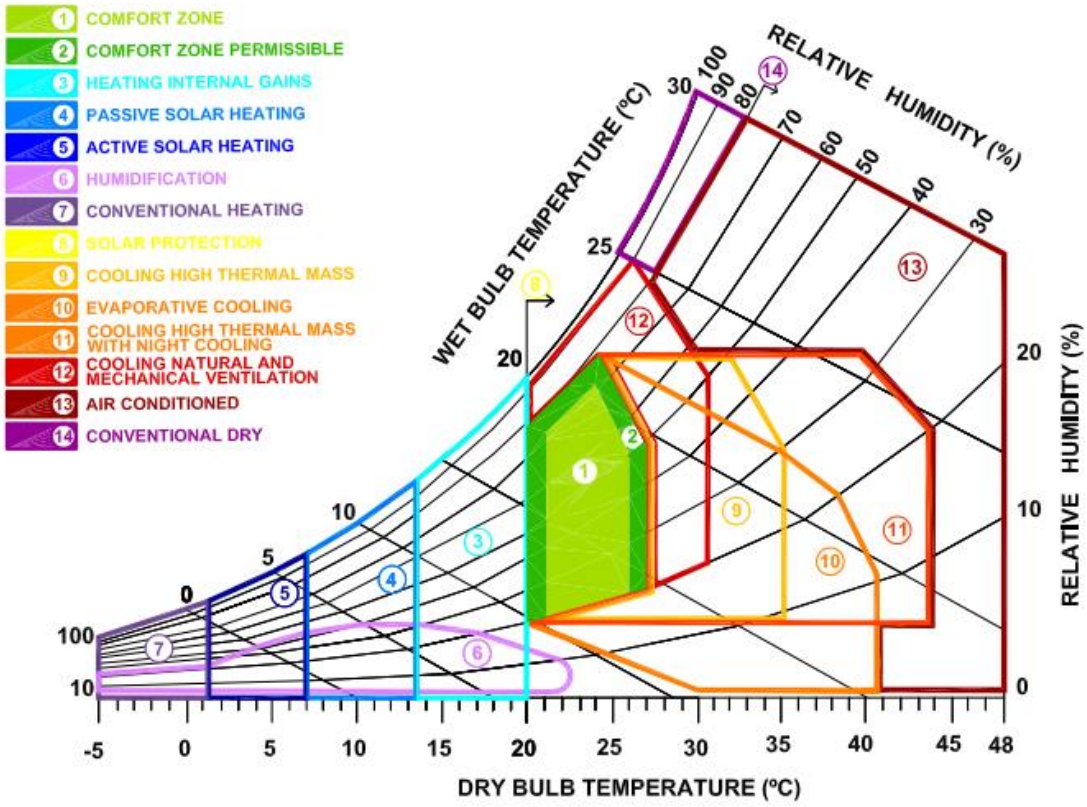


Figure 5: Psychometric chart with associated interpretation of bioclimatic design strategies (Košir, 2019).

Adaptations and design strategies usually focus on the following elements: choice of building materials, orientation of the building and placement and size of the openings along the façades (in

order to maximize natural ventilation, lighting and heat gain or dissipation), sun shading devices (to control solar radiation and associated heat gain), thermal mass, building forms, building envelope, colour, and material of external surfaces (linked to received solar radiation) (Košir, 2019; UN-Habitat, 2016).

9.2 APPENDIX B – INTERVIEW GUIDE

This section describes the interview guide that was used during the data collection phase of this study. The interviews were conducted either in person or online via Zoom and lasted on average 45 to 90 minutes. Each interview was recorded with the consent of the participant to facilitate data collection and analysis and to allow for a natural flow in the discussion.

The interviews followed a semi-structured format, based on the questions below. These questions were formulated based on the linkages between the research questions and the information gathered in the review of the literature. They served as a basis on which the discussion could be built and expanded on and did not constitute a strict order and requirement. The interviews were slightly adapted based on the expertise of the person spoken to, but with the same ultimate goal of getting their input and perspective on affordable sustainable housing in Nairobi or beyond, and how strategies for locally adapted designs that are inclusive and affordable.

Interview questions

CONSULTANTS//PRIVATE DEVELOPERS//GOVERNMENTAL RESPRESENTATIVES

1. How would you define affordability in the Nairobi housing context?
2. What role does sustainability play in the field of housing developments today?
3. What would you say is the most cost-efficient building design strategy that you have found?
4. What would you say is the most impactful sustainable building design strategy in terms of affordability that you have found?
5. Why and how did you choose these specific implementations?
6. What climatic characteristics are the most important in your design choices? In terms of being a challenge but also possibly an opportunity
7. What is your target market when developing affordable housing?
8. What would you say is the most impactful sustainable building design strategy in the local Nairobi context?
9. Do you think this type of construction model is replicable and scalable?
10. What were the major challenges experienced in the implementation of sustainable affordable housing?
11. What were some of the possible strategies that were left out (orientation, passive lighting design, passive ventilations, energy savings, water consumption, HVAC), and why?
12. What are your most notable recommendations to achieve sustainability targets?
13. What sustainability targets are you aiming for?
14. How does the aim of keeping it affordable hinder or enable the realisation of these targets?
15. Can sustainability be affordable? In what way are you pushing this forward and enabling it?
16. How can quality be maintained while providing affordability?
17. What part do locally sourced materials play in affordable housing design in Nairobi?
18. How do you make use of performance indicators in your work?

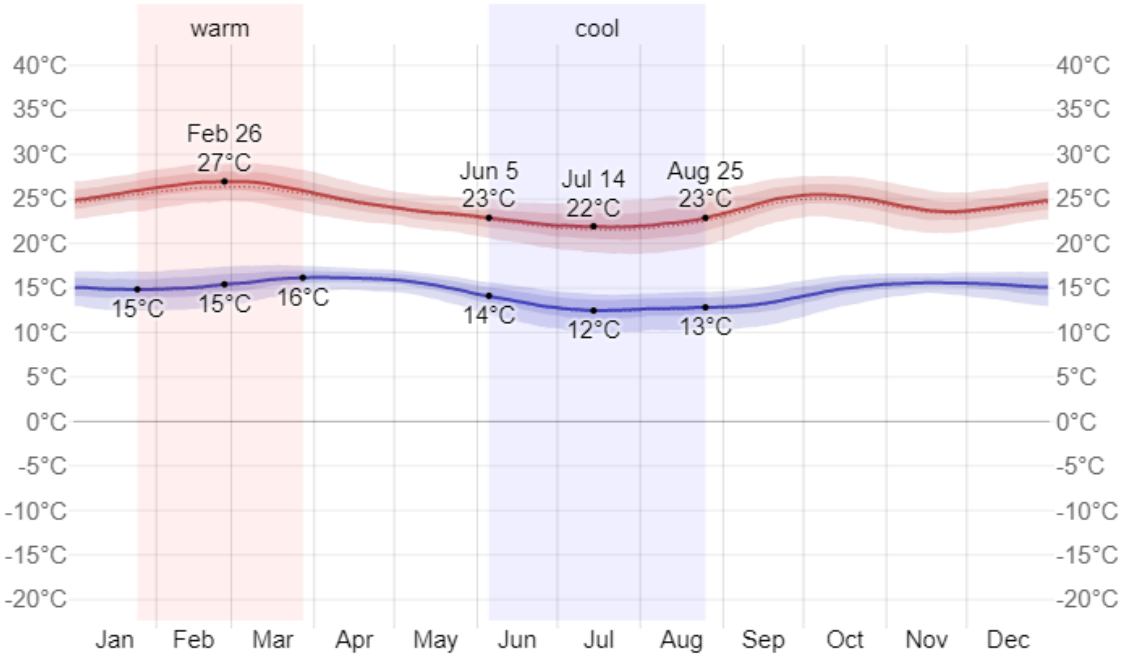
INTERNATIONAL PRACTITIONERS

19. How is affordable housing defined in the context you are working in?
20. Towards what market are your developments geared?
21. What role does sustainability play in your housing developments/projects?
22. What (infrastructural) strategies have you found to reach the intersection of sustainability and affordability in housing?
    a. What role does locally adapted (bioclimatic) design play in your work?
    b. How is the local environment, climate and knowledge included in your work?
23. Do you use any indicators or certification schemes to help measure the performance of your buildings?
24. How replicable do you think this model is, to the area, the region and beyond?

9.3 APPENDIX C – DETAILED CLIMATE CHARACTERISTICS

This section presents a more detailed overview of the research done on the climate profile analysis of Nairobi. The Nairobi climate generally falls into the Cfb category on the Köppen-Geiger climatic classification chart., which are characterised by subtropical highland climates and temperate oceanic climates. Table 2 in the Results section presents the monthly averages of different climatic data in Nairobi as extracted from the different data sets gathered during the data collection of this study.

In general, Nairobi has an annual average temperature of 19°C, with March being the hottest month, and July being the coldest. Table 2 shows the monthly average temperatures with data recorded from 1970-2021, while Figure 6 below shows the maximum and minimum temperatures throughout the year. The temperature usually varies form 11°C to 28°C. Figure 7 displays the hourly average temperatures over the whole year with an associated coloured characterisation of each temperature range.



Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	26°C	27°C	26°C	25°C	23°C	22°C	22°C	23°C	25°C	25°C	24°C	24°C
Temp.	20°C	21°C	21°C	20°C	19°C	18°C	17°C	17°C	19°C	20°C	19°C	19°C
Low	15°C	15°C	16°C	16°C	15°C	13°C	13°C	13°C	13°C	15°C	16°C	15°C

Figure 6: Average high and low monthly temperatures in Nairobi (WeatherSpark, n.d.)

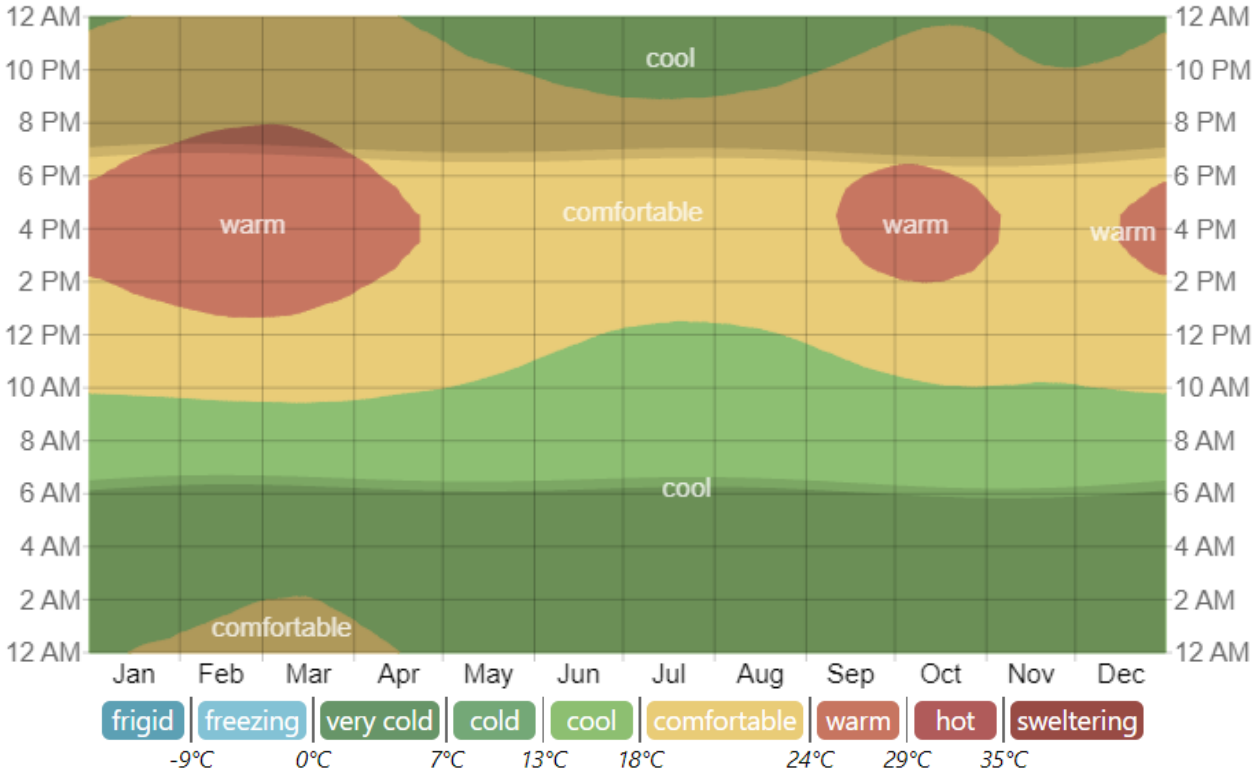


Figure 7: Characterization of average hourly temperature per month in Nairobi (WeatherSpark, n.d.)

The relative humidity was found to be above 60% during the whole year. Nairobi received approximately 600mm of rainfall per year. The longer rainy season covers the months of March to May and the shorter one lasts from November to December, while the dry season is usually in June to October. Figure 8 below shows the average daily chance of precipitation in Nairobi throughout the year, highlighting the different peaks and dips.

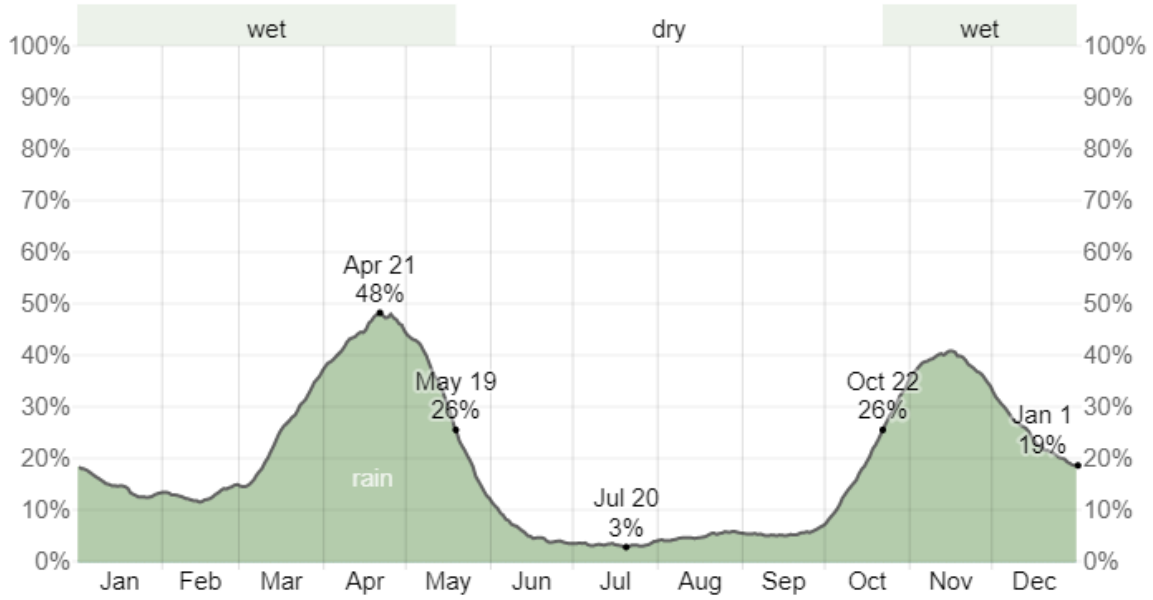


Figure 8: Annual average daily chance of precipitation in Nairobi, in % (Betti et al., 2022)

The predominant wind direction is East and North-East with an average wind speed of 4.2 m/s. Figure 9 below shows the annual wind rose of Nairobi, highlighting the main direction and average wind speeds. Finally, Nairobi has relatively constant daylight hours throughout the year with approximately 12h of daylight per day.

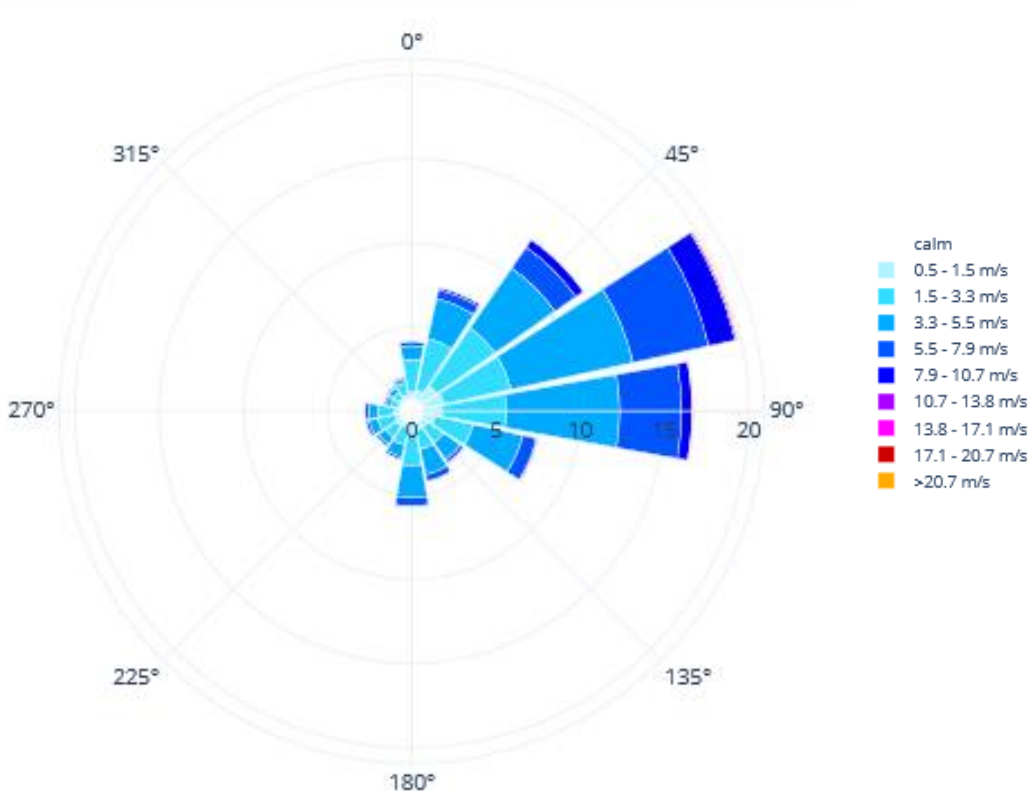


Figure 9: Nairobi wind rose (Betti et al., 2022)